Dairy Nutrition
Pakistan

Edited by
Peter H. Robinson and U. Krishnamoorthy

Project Director
P. E. Vijay Anand

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Handbook of Dairy Nutrition Pakistan

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Foreword

The agriculture economy of Pakistan is relying heavily on the livestock sub-sector which has a contribution of 51.8% to agriculture value added and 11.3% to national GDP, during 2008-9. The growth in the livestock sub-sector was 3.7% which is quite surpass than other development sectors of economy during the current financial year. The dairy industry of Pakistan was most neglected area during the last few decades but now the focus of both public and private sector is growing due to increasing gap between supply and demand with increasing population growth. The current scenario demands to put more efforts in the development of dairy industry.

With the mission, the ASA-IM/Pakistan is helping different stakeholders of poultry, livestock and dairy industry by providing them scientific platforms to disseminate knowledge and transfer of technology through different educational activities like seminars, workshop, training programs cum study tours in USA and other counties, not limited to publication of technical bulletins and books. The salient intellectual attempts made by ASA-IM were "Manual of Feed Microscopy and Quality Control", Handbook on Poultry Diseases" and "Handbook of Poultry Nutrition".

The current project of ASA-IM is to bring out "Handbook of Dairy Nutrition" to aim at dairy nutrition in order to improve dairy feeding practices of Pakistan. The ASA-IM/Pakistan leaves no stone unturned while planning this handbook to address the prevailing issues and bottleneck pertaining to feed and nutrition of dairy animals.

Prof. Dr. Muhammad Abdullah, Dean, Faculty of Animal Production and Technology, University of Veterinary Animal Sciences, Lahore was entrusted the role of the Lead Author to work with association of the Chief Editor, Dr. Peter H. Robinson, Cooperative Extension Specialist, Department of Animal Sciences, University of California, U.S.A. and the country project coordinator to strengthen the contents for the successful completion of Hand Book of Dairy Nutrition (Pakistan Chapter).

The ASA-IM, Pakistan wishes to express thanks to the chief editor, lead author from Pakistan, co-authors from Pakistan, both federal and provincial livestock departments, concerned academia, local dairy associations and dairy farmers in the successful completion of this handbook.

The ASA-Pakistan is confident that different components of dairy industry will be benefited from this handbook and play their vital role in bringing "White Revolution" in Pakistan.

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Preface

Growth in the dairy industry, of late has been very significant in the Asia Subcontinent. Pakistan is the fifth largest milk producer in the world and countries like Bangladesh, Nepal and Sri Lanka are fast catching up with milk production in order to become self sufficient. A significant change forthcoming is the commercialization of dairy and there is increasing thrust for dairy development by respective Governments in these countries. Entrepreneurs are investing in good animal breeds and are keen on total animal care covering aspects like health, nutrition and reproduction. Favourable economic improvements are also accelerating dairy development. Milk as a commodity will be heavily in demand in these regions for nutrition to the growing populations.

This project of developing four handbooks on dairy nutrition is undertaken by the American Soybean Association – International Marketing (ASA-IM), for Bangladesh, Nepal, Pakistan and Sri Lanka. It is aimed at providing overall guidance to improve milk production in the regions with special emphasis to nutrition as this aspect is one of the major factors that can drive growth in the dairy industry. Among a variety of feed stuffs that are used for dairy feeds, the handbooks have focused on soy products as a dependable and consistent source of protein and energy for dairy feeds in the modern era.

The handbooks are prestigious outcomes of elaborate field and desk work of the editors, country authors and personnel of the ASA-IM-Asia Subcontinent. They are designed to improve knowledge and technology base for most people engaged in the dairy industry. It is also hoped that the different handbooks will serve as cross-reference material for countries in the region to facilitate learning from each others experiences. As a result of this project, we look forward to specific improvements in nutrition, increased usage of quality ingredients and scientifically formulated balanced feeds in the dairy industry and will be open to take this forward.

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CHAPTER I A

Brief History and Current Status of Dairy Industry in Pakistan

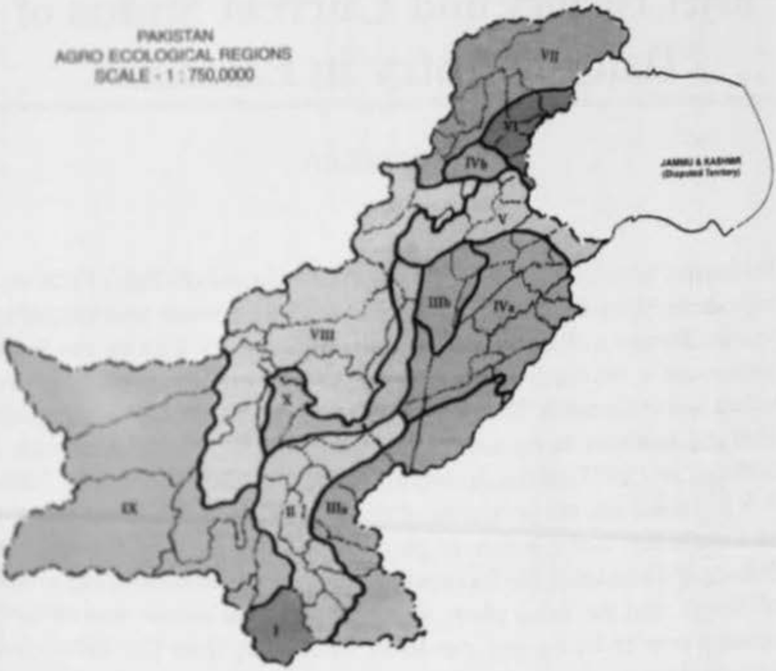
(M. Abdullah)

Pakistan lies between 23.35 to 37.05 north latitude and 60.50 to 77.50 east longitude touching the Hindukush Mountains in the north and extending from the Pamirs to the Arabian Sea. It is bound by Iran in the west, Afghanistan in the north-west, India in the east and south-east and the Arabian Sea in the south. There is a common border with China alongside Gilgit and Baltistan in the north. Pakistan covers 796,095 km^2 with a population of 156.77 million according to the population census of 2006-07. It is divided into the provinces of Sindh, Punjab, North West Frontier and Balochistan, and consists of physical regions such as the western offshoots of Himalayas, the Balochistan Plateau, the Potohar Plateau and Salt Range, and the Indus plain, which is the most fertile and densely populated area of the country due to its sustenance from the Indus river and its tributaries.

Climate and Cropping Systems

The total land area of Pakistan, including Azad Kashmir, is 88 million ha, of which about 60% (45.2 million ha) is rangelands. These rangelands receive less than 200 mm rainfall, are located on rocky soils, deserts and rough topography, and partly support 93.5 million livestock during the summer. The main agricultural, and dairying, lands are in the great plains of the valley of the Indus and its tributaries (Figure 1), Punjab, Sindh and, to a lesser extent, the North West Frontier Province (NWFP). There is about 16 M hectares of irrigated land and about 5 million hectares of rainfed (barani) land.

Figure 1. Map of Pakistan



Pakistan has four distinct seasons being a cold winter from December to February, a spring season from March to May, a hot summer from May to August (hot and rainy) and an autumn beginning from late September until frost at the onset of winter. Most of the rangelands of Pakistan are in arid and semi-arid zones characterized by low precipitation, extreme temperatures, low humidity and seasonal drought. The northern areas of Pakistan are located out of the monsoon rain shadow. Pakistan is divided into 10 major Agro-ecological zones (Table 1).

[I=Indus Delta; II=Southern irrigated plain; III–A=Sandy desert, III–B=Sandy desert; IV–A=Northern irrigated plains; IV–B=Northern irrigated plain; V=Barani (rainfed) areas, VI=Wet mountains; VII=Northern dry mountains; VIII=Western dry mountains; IX=Dry western plateau; X=Sulaiman Piedmont]

Table 1. Characteristics of the agro-ecological zones (AEZ's) in Pakistan

AEZ	Climate	Temperature (°C)		Rainfall (mm)		Major crops	Animal grazing
		Summer (max)	Winter (min)	S	W		
I	Arid tropical	34–45	5–20	75	5	Rice, pulses, sugarcane, berseem, banana	Summer best grazing season, autumn poorest
II	Arid subtropical continental	30–50	0–12	55	0	Cotton, wheat, sugarcane, rice, sorghum, berseem	Summer best grazing season
III A	Arid subtropical	39–45	2–7	46	0	Guar, millet, wheat mainly	Land use grazing season
III B	Arid to semi-arid, subtropical continental	40–46	1–5	71	18	Gram, wheat, cotton, sugar-cane, guar	Land use mostly grazing
IV A	Semi-arid (eastern part) to arid (south-west) and subtropical continental	39–46	2–6	100	22	Wheat, sugar-cane, melons, oilseeds, cotton, maize, berseem, citrus, mango	Grazing available
IV B	Semi-arid and subtropical continental	36–44	1–5	32	29	Sugar-cane, maize, tobacco, wheat, berseem, sugar-beet, gram, groundnut	Grazing available
V	Humid, hot summers and cold winters (in foothills), semi-arid (south-west)	38–45	0–6	200	36	Wheat, millet, maize, rice, oilseeds, pulses, fodder	Good grazing in summer, poor in winter

AEZ	Climate	Temperature (°C)		Rainfall (mm)		Major crops	Animal grazing
		Summer (max)	Winter (min)	S	W		
VI	Humid, mild summers and cold winters (east), subhumid mediterranean	35–44	0–4	236	116	Maize, rice, wheat, apples, fodder	Land use mostly forest or grazing
VII	Snow-covered high mountains, mild summers and very cold winters	30–35	–13–1	20	75	Maize, wheat, rice, fruit orchards	Land use mainly pasture, alpine pastures in summer
VIII	Semi-arid highland	30–44	–10–8	95	35	Wheat, maize, fruit orchards	Land use mostly grazing, alpine pasture in summer in same district
IX	Arid desert	33–44	–4 to15	4	37	Wheat, sorghum, millet, melons, orchard fruits	Land use mainly pasture, low carrying capacity
X	Arid and hot, subtropical continental	40–48	1–7	38	1.3	Wheat, sorghum, millet, gram	Land use mainly grazing, low carrying capacity pasture

Source: Social Sciences Division & Crop Sciences Division, Pakistan Agricultural Research Council (PARC)

Dairy Development Trends in Pakistan

A major structural transformation has occurred in the agricultural sector of Pakistan over the last two decades. While the share of agriculture in the gross national product (GDP) has declined from 30% in 1980 to 20% in 2006-07, the contribution of the livestock sub-sector to agricultural GDP increased from 26 to 49%. The dairy sub-sector had the most important role in this transformation, as milk production increased from 5.4 million tonnes in 1960 to 33.2 million tonnes in 2007 (Economic Survey of Pakistan, 2006-2007). The cattle and buffalo population, and the total milk production trend from 1906 to 2007 are in Table 2 and Figure 2 respectively. The buffalo population increased rapidly after 1980's, as did total milk production.

Table 2. Buffalo and cattle population in Pakistan 1960-2006 (millions)

	Buffalo	Cattle
1960	8.2	16.6
1970	8.9	14.5
1980	11.4	13.9
1990	17.7	12.5
2000	22.7	22.0
2002	24.0	22.9
2003	25.5	23.8
2004	26.3	24.2
2005	28.5	25.6
2006	27.3	30.0

Source : Agriculture Statistics of Pakistan

Although milk production increased approximately six-fold between 1960 and 2007, 85-90% of milk consumption in both rural and urban areas remained as raw unprocessed milk and as traditional milk products such as yoghurt, ghee/butter oil and butter. Raw milk is usually boiled at home prior to consumption. Most raw milk and traditional milk products are marketed by farmers in their own localities, and/or by informal traders in urban and rural areas. Consumer demand for processed milk has been increasing since the mid 1990's. Of the processed milk products, 50% is UHT milk, 40% powdered milk and 10% pasteurized milk, yoghurt, cheese and other milk products.

The trends in the dairy sector with respect to production, consumption, trade and marketing patterns have been directly and/or indirectly influenced by different policies, program and institutional initiatives taken since the 1960's. Some policy measures remained effective for specific years or periods, while others had a long term goals and confounded effects of short-term measures. Moreover, some policies were focused on specific geographical areas, such as Punjab and Sindh, the main dairy producing areas of the country, while others had an economy wide impact.

Livestock Reproduction and Breed Improvement

The Directorate of Breed Improvement, L&DD department, Punjab (established in 1972) provides breeding service through Semen Production Units at Qadirabad, District Sahiwal; Karaniwala, District Bahawalpur; Kallurkot, District Bhakkar, and Kherimurat, District Attock and 750 Artificial Insemination Centres throughout Punjab. The Semen Production Units provide semen to the Semen Bank at Lahore, from which it is distributed. Artificial Insemination (AI) Technicians are available at AI centers and sub-centers for provision of breeding service and treatment of venereal/genital diseases under supervision of Veterinary Officers. Artificial insemination services are provided for Rs. 30 per insemination for local cattle and buffalo, as well as for semen of locally maintained exotic breeds, and for Rs. 60 per insemination for progeny tested or imported semen at AI Centres.

Punjab livestock breeding policy

The Livestock & Dairy Development Department, Punjab, has formulated a comprehensive Livestock Breeding Policy, after a thorough debate involving all stakeholders with objectives to:

1. Improve milk production of buffaloes and local dairy cattle breeds by selection.
2. Reduce the age at first calving and calving interval of buffalo and dairy cattle.
3. Conserve recognized buffalo (Nili, Ravi & Nili-Ravi) and cattle (Sahiwal, Cholistani, Dhanni, Dajal and Rojhan) breeds as purebreds.
4. Manage the desired level of exotic blood in cross-bred cattle for optimum performance, 50% or less for small farmers and 50-75% otherwise.

5. Ensure availability of good quality indigenous animals for draught and beef.
6. Regulate the quality of the breeding services.

Progeny testing program

Selection of sires (bulls) plays a significant role in transmission of desirable characteristics to progeny. Selection may be based on the pedigree or the progeny of that bull, although the latter is considered more reliable, and is referred to as Progeny Testing. A comprehensive Progeny Testing Program has been underway since 1980 at the Livestock Production Research Institute, Bahadurnagar, in the home tracts of the indigenous breeds of buffalo (Nili Ravi) and cattle (Sahiwal), as well as at livestock farms in the public and private sectors. The program involves the following steps:

- Registration and identification of buffaloes / cattle
- Milk recording of registered animals
- Selection of bull sires
- Selection of bull dams
- Production of candidate bull calves
- Purchase and rearing of bull calves
- Selection of candidate bull calves
- Test mating of contesting bulls
- Collection and preservation of semen
- Evaluation of bulls

Status of Dairy Sector in Pakistan

Livestock are important component of Pakistan's resources since 30-35 million rural people are involved in livestock raising. Average household holdings are 2-3 cattle/buffalo, and 3-4 sheep/goats per family which contribute 35 to 40% of their income. According to the Census of 2006, the share of livestock in agricultural growth jumped from 25.3% in 1996 to 49.6% in 2006, and now amounts to 11.4% of overall GDP. Within the livestock sector, milk is the largest and most important commodity, with an estimated annual milk production in 2006-2007 of approximately 38.4

million tonnes, making Pakistan one of the world's top milk producers. This is about 28% of the value of the total agriculture sector. The country's production base is highly fragmented and dairy enterprises are dominated by the private sector, with the government playing a regulatory role. According to the Livestock Census of 2006, among the 8.4 million reported dairy households, 51% own a herd of just 1-4 animals.

Various regulatory measures to control milk prices, coupled with a continuous increase in input prices, affects farm profitability. This especially affects large dairy farmers with considerable investments. These factors have led to many well established large farmers pulling out of the dairy sector, and it has discouraged new investment in large scale dairy production and marketing.

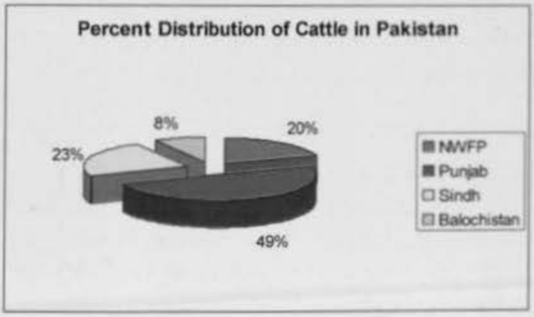
In contrast, small and subsistence farmers barely survive in this regulatory and economic environment. The primary reasons for their survival are use of family labor on the farm and access to free grazing, both factors that keep production costs relatively low. However, this is only an artificial calculation of costs since no price is put on family labor. Similarly, marketing costs are minimized through localized sales and use of unsophisticated equipment.

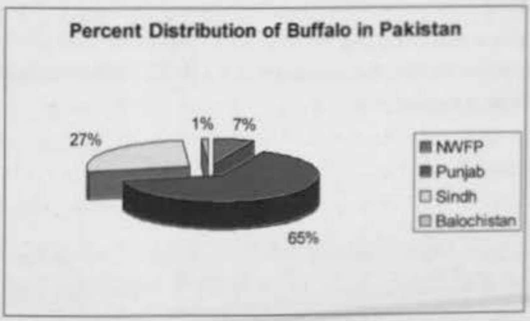
Approximately 80% of the milk is produced in rural areas, with peri-urban and urban areas accounting for another 15% and 5%, respectively. Only 3-5% of total production in the country is marketed through formal channels, with the remaining 97% produced and marketed in a raw form by informal agents in the marketing chain. Smallholder dairy producers are faced with daunting challenges in the areas of infrastructure, financial insecurity, quality assurance, price regulation, untrained manpower and seasonality. A fragmented farm base coupled with low productivity makes collection practices inefficient. Access to infrastructure, such as cold storage, is limited and leads to post harvest losses of up to 20% in some areas. The disparity between input and output prices has inverse affects on farm profitability, making these challenges a serious threat to development of the dairy industry in Pakistan. However the private corporate sector has recently demonstrated a keen interest by investing heavily in dairy processing. Government and donors have also been providing unprecedented assistance to the sector.

Dairy Animal Population and Geographical Distribution

The Livestock Census of 2006 revealed that there were 29.56 million cattle, 27.33 million buffaloes, 26.49 million sheep and 53.79 million goats in Pakistan. The province-wise distribution of animals is in Figure 2.

Figure 2. Provincial distribution of buffalo and cattle





Size of Dairy Herds

Despite milk being the most lucrative livestock product, milk production is the least commercialized enterprise in Pakistan. About 55 million landless/ small land holding farmers are responsible for the bulk of milk production in the country. According to the Livestock Census of 2006, among the 8.4 million reported dairying households, 51% own a herd size of just 1-4 animals. Table 3 shows percentage ownership by herd size.

Table 3. Herd Size by House Hold

Number of Animals	Percentage Ownership by HH (%)
01 TO 02	27.32
03 TO 04	23.73
05 TO 06	14.32
07 TO 10	13.68
11 TO 15	6.29
16 TO 20	2.65
21 TO 30	2.58
31 TO 50	2.71
51 AND ABOVE	6.72
TOTAL	100.00

Dairy Breeds

Buffalo

Buffaloes found in Indian/Pakistan subcontinent belong to the water buffalo group. Although raised for milk production, Pakistani buffalo are considered to be triple purpose domestic animals (i.e., milk, meat, draught). The two best-known buffalo breeds are:

Nili-Ravi

This breed emerged from frequent interbreeding of two distinct breeds (i.e., Nili and Ravi). The home tract of Nili-Ravi buffaloes includes Lahore, Sheikhupura, Faisalabad, Okara and Sahiwal districts of central Punjab and Multan, and parts of Bahawalpur and Bahwalnagar districts of southern Punjab. The best animals are found in the riverine tract of the Sutlej river, southwest of Pakpattan, Mailsi. It is the best buffalo breed in Pakistan and called the 'Black Gold of Pakistan'. Males attain maturity at the age of 30 months and females at 36 months. Milk yield is 1800-2500 liters with about 6.5% butterfat. Adult males weigh 550-650 kg while females weigh 350-450 kg. Growth rate of the animals when kept on fattening rations is about 800-1000 g/day. Age at first calving ranges from 40–52 months. Average gestation period, calving interval and lactation length are 310, 480 and 280 days respectively.

Figure 3. Nili-Ravi Buffalo

Kundi

The home tract of Kundi buffaloes includes all of Sindh province, especially on both sides of river Indus from Kashmore to Shah Bandar. Males attain maturity at the age of 30 months and females at 36 months. Milk yield is 1700-2200 liters with about 6% butterfat. Adult males weigh 500-600 kg while females weigh 300-400 kg.

Figure 4. Kundi Buffalo

Cattle

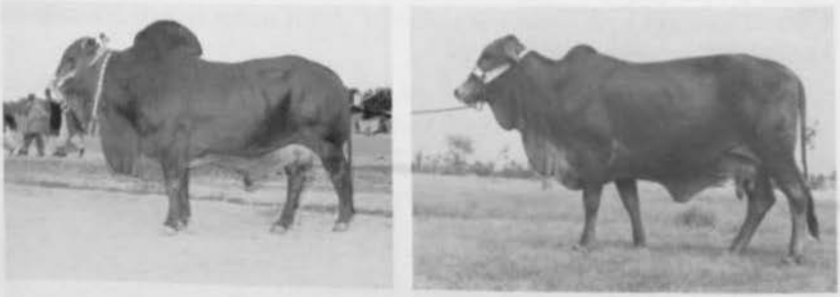
Pakistani cattle are classified into milk, dual purpose (i.e., milk and draught purpose) and draught breeds. However the majority of cattle (i.e., 60-70%) in Pakistan are nondescript animals without well defined type and production characteristics.

Milk Breeds

Sahiwal

The Sahiwal originated in the dry Punjab region which lies along the Indian-Pakistani border. They were once kept in large herds by professional herdsmen called "Junglies" However with the introduction of irrigation in the region, the herd size declined. It is a beautiful dairy breed of Pakistan which is well adapted to unfavorable conditions such as tick infestation, feed scarcity, heat and diseases. The home tract of Sahiwal cattle is the central and southern districts of Punjab province including Faisalabad, Okara, Sahiwal, Khanewal and Multan. Milk yield is 1500-2200 liters with about 4.5% butterfat. Adult males weigh 400-500 kg while females weigh 300-350 kg.

Figure 5. Sahiwal Cattle



Red Sindhi

The home tract of the Red Sindhi cattle includes Karachi, Thata, Dadu, Hyderabad districts of Sindh and Lasbella district of Baluchistan. Milk yield is 1500-2000 liters with about 4.0% butterfat. Adult males weigh 425-525 kg while females weigh 300-350 kg.

Figure 6. Red Sindhi Cattle

Cholistani

The habitat is the Cholistan tract desert area adjoining the colonized areas of Bahawalnagar, Bahawalpur and Rahimyar khan districts. Milk yield varies from 1200 to 1800 liters/lactation, with body weights of 450 to 500 and 350 to 400 kg in males and females respectively.

Figure 7. Cholistani Cattle

Dual-Purpose Breeds

A large population of dual purpose breeds also contributes significantly to total milk production. However most milk from these animals is consumed at subsistence level.

Kankrej

The home tract of Kankrej cattle includes Thrarker and Badin in Sindh extending to Gujrat in India. Adult males weigh 500-650 kg while females weigh 350-400 kg. They have medium sized udders and are fairly good milk producers.

Tharparker/Thari

The home tract of Thari cattle includes Tharparker in Sindh. Adult males weigh 400-500 kg while females weigh 300-380 kg. The udder is medium sized and strong and the cows are fairly good milk producers.

Figure 8. Tharparker/Thari Cattle

Crossbred Cattle

Commercial dairy farms raise a considerable number of crossbred animals for milk production. The prevailing crosses are Friesian and Jersey with Sahiwal and non-descript local animals. The F1 generations of these crosses are good milk producers with dominant physical traits of exotic cattle (i.e., without hump), well developed udders and black and white patches on the body or whole darker body.

Cattle crossbreeding policy was introduced in the early 1970's to take advantage of heterosis, by crossing indigenous cattle *(Bos indicus)* with imported semen of Holstein Friesian and Jersey *(Bos taurus)* breeds. These exotic breeds have evolved into highly superior cattle in terms of milk production, age at puberty, age at first calving, calving interval, conception rate and other traits of economic importance through at least 50 years of continuous selective breeding. The objective of crossbreeding policy was to boost milk production/animal in the wake of increasing demand for milk and milk products. Early results were encouraging and there was phenomenal improvement in milk production from 800 liters per lactation to 2342 liters on average in the F1 generation. This generation was 50:50 tropical and temperate cattle with good heat resistance, slightly higher vulnerability to local diseases such as FMD, but their ability to cope with external and internal parasites was minimal. In addition, due to their higher maintenance and production requirements farmers were not able to fully exploit their genetic potential to their economic advantage.

Exotic Breeds (Holstein Friesian, Jersey)

At present, the population of pure Holstein Friesian and Jersey cattle is nominal in Pakistan. There are only a few precedents of importing Holstein Friesian and other exotic breeds such as Jersey, Illawara and Shorthorn cattle in the public and private sectors. The purpose was to maintain nucleus herds of these exotic breeds, in order to produce progeny tested bulls, and for local crossbreeding, as well to study their adaptability and tolerance to heat and disease. These experiments were at the Quetta Dairy Farm, various military farms, Bhuneke farm, Nestle Dairy Farms and some private breeders.

This experience of importing and maintaining purebred dairy cattle for successful and profitable dairy farm entrepreneurship has had mixed results. Especially on public sector farms, there has been a complete failure to maintain productive potential and per lactation yield has dropped from 6868 ± 234 and 5894 ± 211 to 3061 ± 281 and 2274 ± 260 for Holstein Friesian and Jerseys in 2001. Similarly, problems of malnutrition, adaptability to the hot and humid environment, tick infestation and resistance to FMD and other contagious diseases played an important role in the failure of this strategy. However, under well maintained and environmentally controlled farming systems, their performance is acceptable. But this level of investment is not possible for the majority of dairy farmers and only multinational companies have the ability to establish commercially viable dairy farms with exotic breeds. However, this has a knock-on effect on market prices of milk, and its value added products, which is not matching Pakistan's general public spending power.

Figure 9. A purebred Holstein Friesian herd maintained in Pakistani conditions

Non-descript Cattle

The majority of cattle (i.e., 60-70%) in Pakistan are nondescript animals without well defined type and production characteristics. Average milk production ranges between 500 and 1000 liters per lactation with 2–3 year calving intervals. In addition to their low genetic potential in production, and poor reproductive traits, these cattle are not reared and fed according to their nutritional requirements and have to survive on subsistence feeding.

In the case of rural household dairying, these cattle are kept with limited commercial objectives, while traditional Gawalas (Gujjars) compensate for their low productivity through practices such as mixing water and other deleterious ingredients into the milk to improve its consistency and make it acceptable to consumers. With the rapid development of the dairy sector due to public sector support policies, and with more investors putting their money into the dairy business, the situation is improving and there is a realization for a need to conserve and improve pure dairy breeds, as well as import purebred exotic and crossbred animals.

Figure 10. Two strains of non-descript cattle of Pakistan

Milk Production Dynamics

Within the livestock sector, milk is the largest and most important commodity, and Pakistan is the fifth largest milk producer in the world. The share of buffaloes in total milk production was 64.7% followed by cows at 34.5% and goats at 0.8% in 2006. Annual milk production of cows increased from 9.4 billion liters in 1996 to 13.3 billion liters in 2006, an impressive increase of 42.4%. Gross annual milk production of buffaloes jumped from 18.9 billion liters in 1996 to 25.0 billion liters in 2006, a growth of 32.5%. Overall, milk production increased by 35.6% in 2006 over 1996. During 1996, the share of buffaloes milk was 66.9%, while it was 33.1% in cows. It is clear that buffaloes and cows are the major milk producing animals. According to a study on milk marketing conducted by the FAO in Pakistan in 2003, 80% of milk in the country is collectively produced by rural commercial and rural subsistence producers, peri-urban producers account for 15% , and urban producers contribute only 5%.

Per Capita Consumption of Milk

As a food item, all milk (both milk and milk equivalents) is second only to cereals in per capita consumption, which is currently 190 liters, or 520 ml milk per day. About 28% of milk produced is consumed in cities, 80% by children. Provincially, per capita consumption is 246 kg in Sindh, 132 kg in Punjab, 86 kg in NWFP, and 108 kg in Baluchistan. Per capita consumption of milk among the people of Pakistan is not optimal due to a gap between demand (7%) and supply (3-4%), and rising prices. The milk supply deficit peaks in summer when demand for milk based drinks is higher and milk production is lower due to lack of fodder.

Table 4. Annual milk production between 1986-1996 and 1996-2006

	Gross Annual Production ** (Billion Liters)			% Change	
	1986	1996	2006	1986&1996	1996&2006
Cows	7.07	9.36	13.33	32.4	42.4
Buffaloes	14.82	18.90	25.04	27.5	32.5
Total	21.89	28.26	38.37	29.1	35.6

Consumer Preferences

According to an FAO report, buffaloes are recognized as the "Black gold of Asia" with an average milk yield per lactation of 1800-2500 liters, and examples can be found of productions of 6,000 liters in 305 days. Each year, an adult buffalo produces 4-6 tonnes of wet manure plus additional urine as bio-fertilizer thereby reducing needs for chemical fertilizers, as well as providing essential soil humus.

Pakistan Dairy in the Global Context

In 2007, Pakistan produced 38.37 million tonnes of milk, which was 6% of world milk production. However Pakistan produces only 40-45% of the amount of the milk produced in India and the USA, the world's largest milk producing countries.

Over 70% of farms have less than 2 hectares and keep an average of 1-3 dairy animals per farm. A comparison of average milk yields among various countries shows that one New Zealand dairy animal produces as much milk as three dairy animals in Pakistan; while one American cow produces as much as seven Pakistani cows. This dramatic difference in productivity is due to a variety of factors including genetics and management technologies. Fortunately, many of these factors are known, suggesting great potential for development of the local dairy sector.

Table 5. Milk Production in kg/animal per lactation

	Cattle	Buffalo
Bangladesh	207	407
Bhutan	257	400
India	987	1,450
Nepal	415	850
Pakistan	1,195	1,909
Sri Lanka	627	496
Australia*	4,926	0
New Zealand*	3,947	0

*Sources: 1) FAO, 2004 and 2) *Mr. Collin's Report Feb, 2005*

Pakistan has a per capita milk production of about 230 kg per year, which is more than twice that of India and 70% that of the USA. Recent growth in per capita milk production has been driven by increases in animal numbers rather than milk yield.

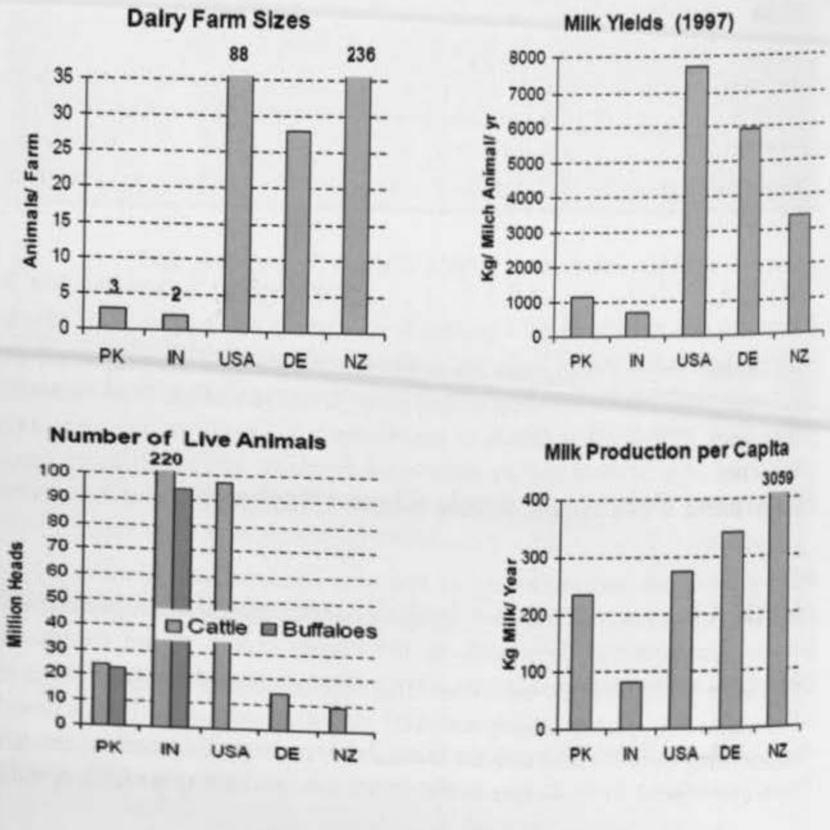
Raw and Processed Milk Flow Channels

Milk production and marketing in Pakistan is exclusively dominated by the informal private sector, consisting of various agents, each performing a specialized role at their node in the supply chain. These consist of producers, collectors, middlemen, processors, traders and consumers.

Only 40% of milk left after calf suckling, home consumption and indigenous home processing finds its way to the urban market, and up to 15% of milk is wasted due to unavailability of cooling and storage. It is estimated that only 3-5% of the urban market flows through formal processing channels, while the remaining 97% is consumed as raw milk or informally marketed through local milk men.

Village households sell part of their morning milk to either a milk center (the majority of centers are operated by a few large processing companies or milk traders) or milk men. Usually these households consume most of the evening milk in the form of various value added products such as butter oil (ghee), butter or yoghurt and traditional drinks such as lassie (prepared from fermented milk after removing cream). Surplus milk products are sold in the village or sold to sweet makers in cities.

Figure 11. Dairy comparisons by country in 1997



Raw Milk

The more commercially oriented rural farms (i.e., those with more than 3 dairy animals) sell their surplus milk to milkmen or deliver it to village milk collection points of commercial processing companies. In contrast, commercial urban or peri-urban farms sell their milk directly to consumers as the price that can be charged in the towns and cities is higher.

Processed Milk

Processing of milk is done by the formal sector. Of the different types of processed milk, pasteurized milk (both in loose form and plastic pouch packing) and UHT milk in tetra packs are by far the most popular products. Milk powder with different levels of fat is also produced. Yoghurt, butter, cheese and ice-cream represent a small proportion of processed dairy products.

The informal sector produces lassie (a drink from boiled and/or raw milk), which is very popular in summer and is used as a thirst quencher. In winter, the most common indigenous milk products are boiled milk and sweets produced by condensing liquid milk, which is called khoya. These products are produced by specialized milk shops in the cities and capture high prices.

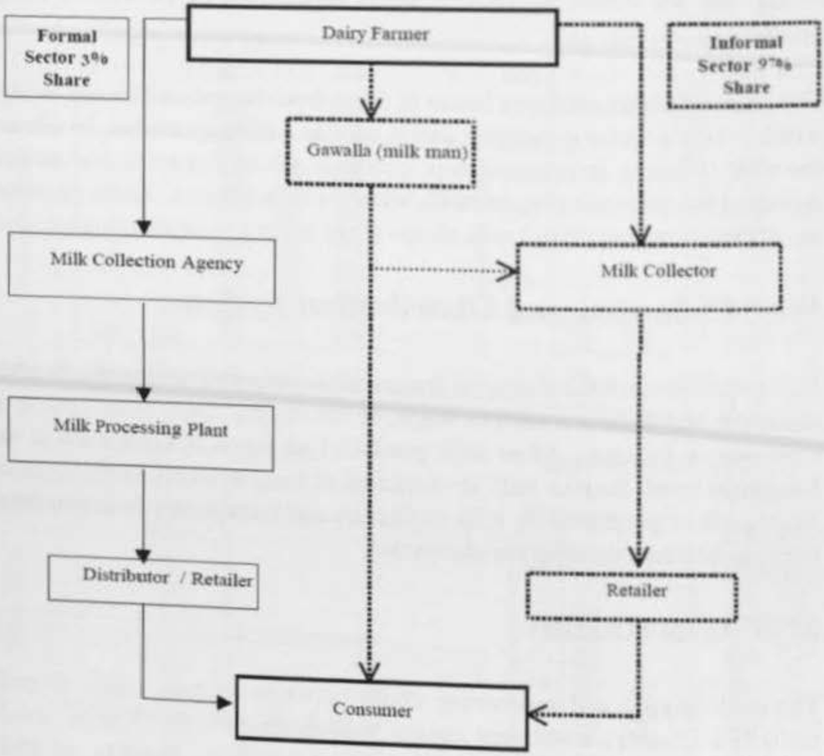
Milk Collection and Distribution System

Milk collection and distribution is fragmented compared to systems in other countries, and there is a need to improve the supply chain from farmer to consumer in Pakistan. Most milk produced on farms is consumed at the household level. Surplus milk is marketed at local markets in the form of liquid milk or purchased by milk collectors and transported to urban areas through different distribution channels.

Milk Man (Dodhi)

The milk supply and marketing chain involves players such as milk collectors (dodhis), traditional cream manufacturers and "Khoya" (milk concentrate for local sweets) makers and retailers. Dodhis, or milk collectors, play an important role in collection and the marketing chain in the dairy sector. The dhodhi community may number as many as a million. Small scale collectors collect about 200-400 kg of milk per day from various farms, often in remote areas. In small towns, they may directly market the milk but, in larger urban areas, they sell it to large collectors. Medium scale milk collectors collect 400-800 kg milk per day in a way similar to small milk collectors. This group may carry out door to door milk delivery and marketing in some nearby urban markets using various means of transportation. Large-scale milk collectors collect 1.5 to 3 tonnes of milk/day, often purchased from the small and medium scale collectors and act as middlemen between them and retail shopkeepers. Large scale milk adulteration is practiced mostly by this group of large scale milk collectors

Figure 12. Flow channels for milk in Pakistan



Milk Processing Industry

The kinds of technologies used in milk processing are pasteurization and sterilization, the principal type of which is ultra heat treated (UHT) treatment. In Pakistan, modern milk processing in the dairy sector started in the early 1960s, and by the mid-1970's there were 23 milk pasteurization and sterilization plants. With one exception, all of them are now closed due to low consumer acceptance, short shelf-life of the product and lack of trained manpower. The first UHT plant was built in Pakistan in 1977, and the success of this plant attracted many other investors such that, during 1983-87, 20 new plants were built. Current UHT capacity in the dairy industry is more than demand, and plants are operating below capacity. Growth in demand is not likely to keep pace with the production capacity for relatively high-priced UHT milk.

Processors remain a key driver of the dairy industry with constant reinvestments and diversification of product portfolios. Processors have a small share (i.e., 3-4% of total milk), whereas they invest the most and pay the highest taxes. The processed milk sector of Pakistan contributes 0.43% to GDP. The eight major dairies in the country are Nestlé, Nirala, Halla, Noon, Milac, Dairy Bell, Dairy Crest and Premier, and other smaller ones have also emerged. Nestle is the biggest processor in the sector, collecting over 1000 tonnes of milk daily, and intends to invest an additional US$480 million over the next five years. Similarly Haleeb, Noon Dairy, HALLA (Idare-e-Kisan), Dairy Crest, Nirala Dairy and Premier Dairies are continuously investing to upgrade their plants.

Table 6. Situation of milk processing

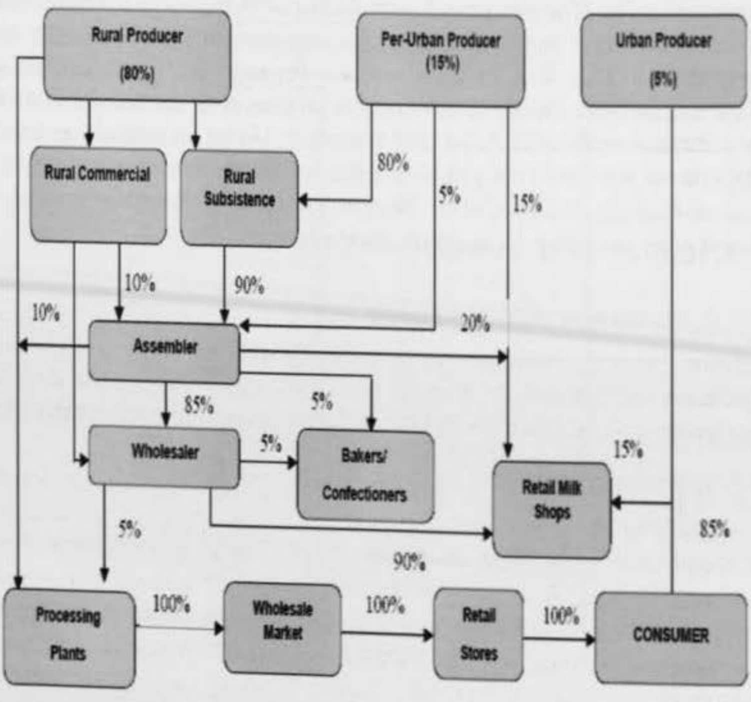
Operating milk plants	17
Closed milk plants	26
Milk production processed by milk plants	3%
Processing capacity per day:	
Milk production traded as raw milk:	0.65 million liters
	97%

(50% used as fresh or boiled milk 8% yoghurt (dahi) 42% used as khoya, sweet meals, ice cream, butter, rubri kheer, cheese and other milk based products).

Major Milk Products

Yoghurt is a fermented milk product obtained through controlled lactic acid fermentation of milk by S. thermophilus and L. bulgaricus. Lassi is a by-product obtained from yoghurt by indigenous methods. This product is used with or without sugar or salt depending upon consumer preference. Khoa is concentrated whole milk obtained by open pan condensing of cow or buffalo milk, or a mixture. Paneer is an acid and heat coagulated product prepared by the combined action of acid coagulation and heat treatment of buffalo or cow milk. The precipitation involves formation of large structural aggregates of proteins in which milk fat and other colloidal and soluble solids are entrained with whey. Cream may be defined as "that portion of milk which is rich in fat" or "when milk fat is concentrated into a fraction of the original milk". It is rich in fat and the fat soluble vitamins A, D, E and K.

Figure 13. Percentage Flow of Milk through Market Channels



Butter is the product obtained from the milk of a cow or buffalo, or from cream or curd, with or without addition of salt and annatto, or carotene for coloring, and should contain not less than 80% milk fat and not more than 1.5% salt on a cured weight basis. It must be free from other animal fats, waxes, vegetable oils and fats. Ice cream is a frozen dairy product made by blending and processing cream and other milk products, together with sugar and flavor, with or without stabilizer or color, and with incorporation of air during freezing. The product should contain not less than 10% milk fat, 3.5% protein and 36.0% total solids. Ghee is clarified fat derived solely from milk, or from desi butter, or from cream to which no coloring matter is added. It is the richest source of milk fat of all dairy products. When prepared by traditional methods, it is normally very low in fat soluble vitamins. Milk Powder is a dehydrated product made from dairy processed milk by removing water in evaporators and drying to a moisture content of **$\leq$ 5.0%**

Processed Fluid Milk

Pasteurized milk is formed by thermal inactivation of microorganisms at temperatures below 100°C to improve the hygienic quality of milk to achieve preservation. UHT Milk has a long shelf life, up to six months, at ambient storage conditions. In this method of heat processing, milk is heated to temperature of 137–140 °C for 30 seconds. All heat resistant spores are destroyed.

Conclusions and Suggestions

Statistics on the livestock sector are not properly collected and maintained. Accurate data on animal population, production, marketing and disease incidence should be collected and, based on this data, short and long term development plans should be prepared for development of the dairy sector.

Lack of proper marketing, and non-accessibility to markets, result in exploitation of farmers by middleman in various ways. It is difficult for small holder farmers owning one or two animals to organize their marketing. Thus, small-holder livestock farmers should be encouraged to organize into cooperatives, associations or public groups to facilitate requisite inputs to increase production and improve quality, as well as to market their surplus produce at advantageous prices. The prevailing marketing system is dominated by middlemen and needs capacity building of all stakeholders to develop a marketing network and marketing information system. In this regard, the private sector should be encouraged to strengthen the marketing network. To meet the projected increase in the domestic demand of milk, at least a 5-7% per annum growth rate is required.

A desirable strategy to be adopted is to reduce government's role through policy reforms and strengthened market liberalization. The appropriate role of government is to become the enabler of smoothly functioning markets through institutional and regulatory reforms that facilitate private sector activities and market efficiency. More consistency is required for sustainable livestock production. Government has a key role and responsibility in quality control and implementing internationally accepted regulations. This role has become more important in light of WTO agreements and regulations. The future of the Pakistan livestock sector depends on how well it can compete in the global market and, for that, quality control to comply with international standards are crucial.

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CHAPTER I B

Status of Dairy Production and Marketing

Milk Marketing System

(R.S.N. Janjua and Dr. A.H. Hashmi)

Marketing Structure

The livestock sector in Pakistan accounts for 52.2% of agricultural value added while the four major crops rice, wheat, cotton and sugar cane account for 34%. Livestock is 11% of GDP and affects the lives of 30-35 million people in rural areas. With an estimated 33 billion liters of milk produced annually from 50 million animals managed by about 8 million households, Pakistan is the 4th largest milk producing country in the world. It has a livestock and agriculture sector contributing over 10% to GDP, and a milk economy that is 27.7% of the total agricultural sector. It is a market that is expected to grow an additional 3 billion liters in the next few years at a growth rate faster than most sectors. This is a sector that can bring radical change to the country.

The annual milk production of 33.6 billion liters is shared between the rural economy (71%) and a much smaller urban share (29%). Only 3% of total production of milk is processed and marketed through formal channels. For the other 97%, a multi-layered distribution system of middlemen has evolved. The contribution of processed milk to real GDP in Pakistan was 0.43% in 2004-05. Despite only a small percentage (i.e., 3%) of milk processed, the (UHT) market is growing at a steady rate of 20% per year. Presently 97% of raw milk produced in the rural economy is not linked to the market mechanism. For this reason, the dairy sector in the rural economy is not making a contribution to the national economy that is in accordance with its potential. About 40% of surplus milk left from calves suckling, home consumption and indigenous home processing channels, finds its way to the urban markets and up to 15% milk is wasted due to unavailability of cooling and storage facilities. As a result, Pakistan is a net importer of milk and milk products. The quantity of milk produced and utilized through different channels are in Figure 1.

Indirect Marketing of Milk

The sale and purchase of milk is generally direct although, in some cases, commission agents also negotiate prices. They bargain with the seller to reduce the price while negotiating with the purchaser to obtain higher rates. Milk is usually sold in litres, kilograms or maund, and the agent charges Rs10 on the sale of every 40 litres.

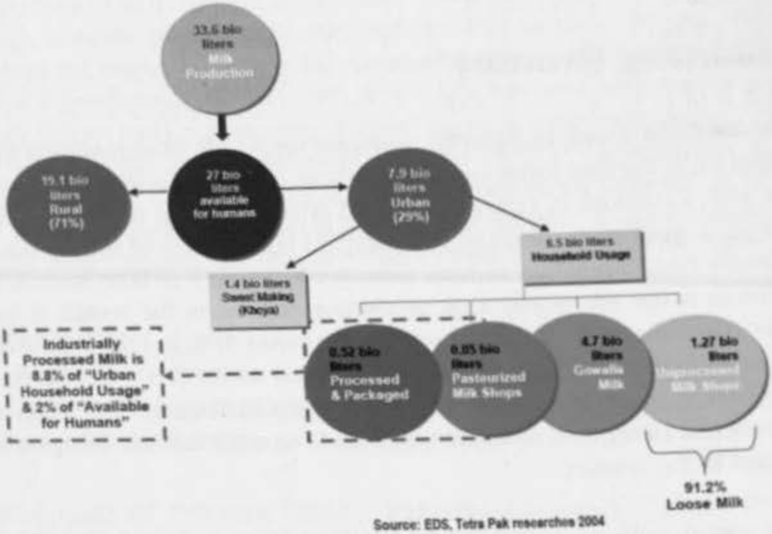


Figure 1. Milk production and utilization pattern in Pakistan

Direct Marketed Milk

Producers contact city buyers to sell milk. Terms and conditions are decided mutually and written agreements are rare. Once the agreement is finalized, the producer is bound to supply the agreed quantity and the buyer has to accept the agreed price.

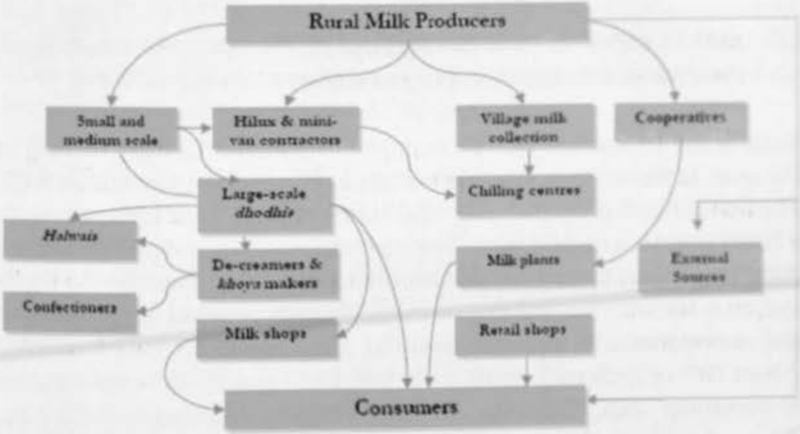
Milk Transportation

Milk is transported through pick-up truck, public transport and motorcycle in cases of long distances, and on bicycle and horse or donkey carts for short distances. The road link between rural and urban areas is not well established and distant producers, due to the high perishable nature of milk, are unable to bring it to urban markets. The milk collection and distribution system is illustrated in Figure 2.

Quality Assurance

Quality is the most neglected aspect of the system as there are no tests at any stage of the marketing chain. For example, many of those who handle milk are not conscious of hygiene and many shops in urban areas are exposed to dust and flies. Very few shops have refrigeration facilities and milk is of poor quality. Containers used in transportation are unhygienic because of the difficulty in cleaning them. Adulteration of milk is common.

Figure 2. Milk production and distribution system



Milk Product

About one-third of total milk production is consumed as fluid milk, and a similar quantity for ghee preparation, while the remainder is converted into butter, cream and indigenous milk products such as curd, Khoya and lassi. In Sindh, peri-urban dairy farms are the main source of fresh milk.

There are two marketing chains in the milk marketing structure in Pakistan, non-commercial and commercial. In non-commercial marketing, the producer sells surplus milk to Gawala (milkman), and the Gawala sells to Halwai (sweets shop) after de-creaming, or directly to consumers or retailers in urban areas. In commercial marketing, there are 5 marketing approaches for fresh milk produced.

1) the producer supplies milk directly to a milk processing company. This system provides the safest and the most hygienic milk to processors, and consumers get good quality milk.

2) producers sell to Dodhi (milk collectors) and the Dodhi sells this milk to a milk processor.

3) producers sell milk to Dodhi and Dodhi sells this milk to a mini contractor who sell all milk collected from Dodhies to milk processors.

4) includes a Hilux contractor added to the third system of commercial milk marketing. This Hilux contractor collects milk.

5) milk is collected by milk suppliers or big contractors from mini contractors and collected milk is supplied to milk processors.

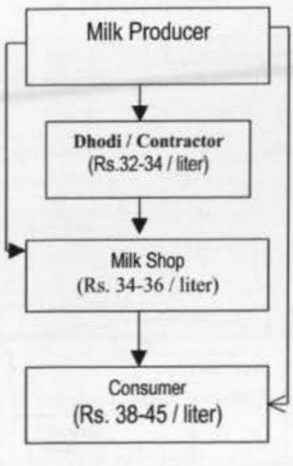
Karachi and Hyderabad are two examples of commercial dairy farming in Pakistan. In these cities, there are two marketing systems to sell fresh milk. The first is Bandi (Contract) and other is sale of milk in the open market. In a Bandi system, a middle man plays a pivotal role to negotiate between the commercial dairy farmer and the shopkeeper in the city. Normally the Bandi system is for one year, but due to drastic changes in prices of green fodder and concentrates, farmers are trying to adopt Bandi for only 6 months. About 10% of fresh milk produced in both cities is sold on the open market at prevailing rates. Normally, the Dairy Farmers Association decides the price of milk in the open market in negotiation with City District Governments.

NWFP and Baluchistan produce 12 and 2% of total milk production in Pakistan. In the NWFP, Peshawar city alone consumes 500,000 liters milk/day. About 50% of this milk comes from nearby districts such as Nowshehra, Charsada, Mardan and Swabi. There are about 800 dairy farms near Peshawar city, but they all are small and medium sized dairy farms ranging from 20-50 animals. Due to smuggling of milking animals to Afghanistan, a shortage of milk in the province has occurred and this has increased the price of animals. USAID has established some milk byproduct units in earthquake areas of District Mansehra that are producing yoghurt and ghee. Major milk producing districts of the NWFP are Nowshehra, Swabi, Charsada, Mardan, Harripur, Swat, Kohat and D.I. Khan. In FATA, the Bajore agency, Kurram agency, North/South Waziristan especially Wanna, and Malakand agency are areas with good potential for NWFP milk production.

Baluchistan is about 50% of Pakistan's area but, due to unavailability of water, a lot of its resources cannot be utilized. Pishin, Zhobe, Mastung are potential districts of Baluchistan. In Quetta city, milk comes from Pishin and Mastung and the rest of the milk comes from Sindh province near cities like Shikarpur, Dadu and Larkana.

Azad Jammu and Kashmir (AJK) is an area where dairy farming is still in its infancy. The plain districts of the AJK such as Bhimber, Kotli and Mirpur have fodder availability and these districts have 5-10 animals/herd . In Bagh and Poonch districts of the AJK, 2-5 buffaloes/herd is prevalent. Jhelum valley provides milk to Muzafarabad and, in all of Kashmir, about 10-15% of milk comes from their own dairy animals with the rest of the demand supplied through processed packed milk.

Figure 3. Supply Chain for Urban Marketing

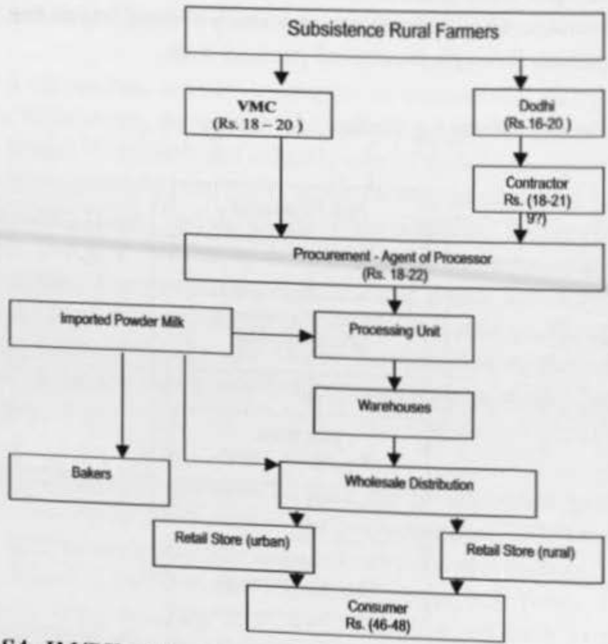


Source: ASA-IM/PK estimates

The Government of Pakistan has established two independent companies, Pakistan Dairy Development Company and Livestock and Dairy Development Board, to boost dairy and livestock sector in Pakistan. These two companies and provincial governments provide milk cooling tanks to dairy farmers to increase the bargaining power of dairy farmers to obtain better prices.

Non-commercial milk marketing systems have their own pricing mechanisms. Gawala try to get milk from milk producers at the lowest possible price and, after adulterating it, sell it to consumers or retailers at a higher price. There is no government rule or law to check the price of Gawala milk. In commercial marketing of milk, it is purchased based on its fat or solids not fat (SNF) percentage, with 6% fat and 9% SNF as yardsticks to measure price. The quality and safety of milk produced meets International standards for bacterial counts. However to provide safe and hygienic milk to consumers, use of total plate count (TPC) as a milk pricing mechanism is critical.

Figure 4. Milk pricing system (Milk Supply Chain for UHT Milk)



Source: ASA-IM/PK estimates

Human Consumption Patterns of Milk and its Products

In Pakistan, only 3-4% of total milk produced is processed and the rest is used as produced by the animal. About 20-25% milk is channeled to urban marketing systems to meet the needs of urban consumers in cities such as Karachi, Lahore and Rawalpindi.

By increasing the purchasing power of consumers, some milk left after processing is utilized in byproducts such as flavored milk, yoghurt, butter, ghee, cheese, ice cream, sweets, lasee sweet and salt (yoghurt and milk shake: Mostly consumed in Punjab and upper Sindh) and lasee plain (without cream used in Baluchistan and NWFP).

Per Capita Consumption of Milk

As a food item, all milk (both milk and milk equivalents) is second only to cereals in per capita consumption at 190 liters on a national basis, or 0.52 liter per day. About 28% of milk produced is consumed in cities, 80% of this by children. Provincially, per capita consumption is 246 kg in Sindh, 132 kg in Punjab, 86 kg in NWFP and 108 kg in Baluchistan.

Table 1.

PER CAPITA AVAILABILITY OF MILK
(July-June)

(000 tonnes)

	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
1. Production	19901	20453	21027	21625	22400	22899	23578	24000
2. 55% Consumed as Fresh Milk	10945	11249	11565	11894	12320	12594	12968	13200
3. Dry Milk Imported*	76	80	40	28	48	40	72	72
4. Net Availability	11021	11329	11605	11922	12368	12634	13040	13272
5. Per Capita availability (kgs/annum)	81.72	82.15	82.92	83.45	84.28	84.42	85.50	85.40

** = One tonne dry milk is equivalent to 4 tonnes of liquid milk.*

Source:- Planning & Development Division (Nutrition Section), Islamabad.

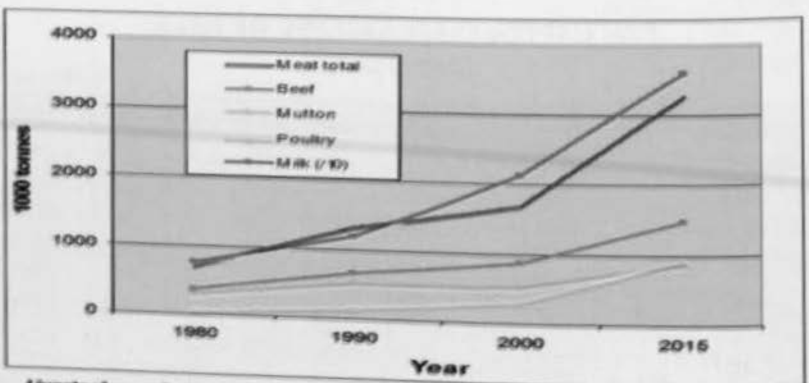
Future Projections

Demand for milk is increasing by 7% annually but supply is only increasing by 3-4% suggesting that, in spite of being the 5th largest milk producing country in the world, Pakistan will have to import milk for domestic consumption in the near future. However per capita availability of milk in Pakistan is high relative to that in developing countries. As the population of Pakistan grows, demand for milk and milk products will increase.

At this time, Pakistan spends about US$40 million on import of dry milk powder, and this cost will rise with the increase in population. The projected Pakistani demand for milk and dairy products in 2015, when the population of Pakistan will be 175 million, will be 40 billion liters of milk. Ghee, butter and other product needs will require more milk from existing livestock resources in Pakistan. There will be a need for increased milk yield per animal and use of better management practices to increase the supply of fresh milk.

Figure 5.

Livestock Products Consumption Growth in Pakistan
(FAO, 2002)



Livestock revolution driven by rapid rise in consumption of animal products

CHAPTER I C

Milk Production Systems

(M. Abdullah)

National Perspective

The Pakistan population has increased from 65 to 157 million over the past 3 decades and is forecast to increase to 234 million by 2025. Within the Pakistan economy, agriculture, including livestock, is the largest sector. Therefore rural development based around productivity gains in food and livestock production is important to achieve food security and alleviate poverty. However, traditional family succession practices are leading to fragmentation of land holdings leading to economically unviable farm units.

Estimated land availability has declined to about 0.15 ha per capita and is forecast to shrink to 0.06 ha over time. Similarly, per capita water availability has declined from 5,600 meters^3 to 1,200 meters^3 over recent decades, and may fall to what is considered a water-deficit level (i.e., <1,000 meters^3 per year) by 2010. Access to irrigation water from rivers or ground water is a major constraint to crop and livestock production in many rural communities.

The bulk of agricultural and livestock production comes from small household farms that are owned or tenanted with landless families who also rear livestock. The rate of increase in the Pakistani population, and the need to dramatically increase food production, means that competition for land and water resources will become more intense and the ecological sustainability of already fragile systems will be further challenged. Significant areas of range land, that comprise about 60% of the area of Pakistan, have already been exploited beyond short term repair.

The rapidity of these changes, and the lack of further arable land, means that increases in food crop and livestock production must come from productivity improvements, especially increased yields per unit of input. Notably, the highest densities of livestock in rural areas correspond with areas where the intensity of cropping and density of humans is greatest. Thus, interventions to increase farm milk output need to occur in a systems context.

Pakistan ranks as the 5th largest producer of milk in the world and dairy is by far the largest livestock sector, valued in 2002 at Rs 300 billion. However the supply of milk and meat does not match domestic demand. It is estimated that milk and/or dairy products currently provide more than half of animal protein available for each person daily. Further, nearly 30% of household expenditure on food items is on milk and dairy products. With projected population growth, the deficit between domestic supply and demand for milk is expected to grow from 3.5 to 55.5 million tonnes by 2020.

The rural population engaged in livestock production has been estimated at 30-35 million, and these farmers/households derive 30-40% of their income from livestock (Economic Survey of Pakistan, 2006-07). Statistics indicate that national milk production now exceeds 38 million tonnes, having increased from about 12 million tonnes in 1990. Given the nature and geographic spread of the production systems, and the collection and marketing systems, the accuracy of this data would not be expected to be high. One estimate indicates that a further 6 million tonnes of milk may be lost due to poor handling and management. Nevertheless milk production has been estimated to be increasing at >5% per annum. This sustained rate of increase is substantial, and has been achieved despite perceptions that farmer's knowledge and skills are generally low and that adoption of technology has been poor.

Buffaloes are the major milk producing animal, accounting for about 66% of all milk produced, and their numbers are increasing. They are concentrated in irrigation areas and along rivers, as are the human population. Nili Ravi and Kundi are the principal breeds and there is a strong cultural attachment to these breeds in Punjab and Sindh, respectively. While there are large numbers of high producing animals in research institutes and commercial herds, the genetic potential of buffaloes in rural areas is seen as a constraint to milk production. Buffaloes have a seasonal breeding cycle, with calving concentrated in autumn and early winter. This, together with the seasonal variation in fodder supply, means that peak milk production from buffaloes occurs from November to February, with abundant berseem fodder available in January/February. However milk production drops rapidly during summer (June/July), due to limitations in feed availability, high temperatures and the onset of late lactation. Milking herds are often comprised of buffalo and cattle, with cattle used to maintain continuity of production.

Cattle numbers are relatively static, possibly reflecting the increased mechanization of cropping systems. The major milk-producing breeds are Sahiwal (Punjab), Red Sindhi (Sindh) and Tharparker (a dual purpose breed). Lactation lengths in Sahiwal and Red Sindhi are 270 to over 400 days, and generally longer than in buffalo. Dairy cows are more productive than buffalo through the summer and are used by farmers to stabilize milk supply and maintain cash flow. Milk is produced in mixed crop-livestock farming systems, except in peri-urban dairies. There are four main systems of milk production from cows and buffaloes:

Rural Subsistence Smallholdings

This is a traditional system where milk is produced for the family at minimal cost. The average subsistence unit consists of three buffaloes. They are landless farmers and extra milk is usually sold in the vicinity. This type of production system is the most prevalent in arid zones and desert areas of Punjab, Sindh and Baluchistan. Pastoralists raise camels, donkey, sheep, goat and cattle. These people use indigenous breeds of livestock, which can survive and produce milk under the harsh climate of arid and semi-arid regions of the country. But under drought conditions their ability is reduced. Like in other extensive systems, diseases and parasitic infestation are prevalent. Other health problems are related to mineral and protein deficiency.

Rural Market-Oriented Smallholdings

Farmers in this system produce milk in excess of family requirements, which is sold to milk markets. These farmers have satisfactory access to milk markets and this system is the main source of milk in Pakistan. They are often termed agro-pastoral farms and are found where land resources are limited, population is increasing rapidly and there is a possibility of growing cash crops. Cattle and buffalo raised in this system are normally the indigenous ones. The herds migrate in seasons of low fodder availability and suckling is the practice of calf raising. Either men or women milk the animals, which is by hand. However, some pastoralists practice weaning after a specific period, while other small landholders allow calves to wean naturally. Production costs are higher in the pastoral system, but production per man day is far lower. As in other extensive systems, diseases and parasitic infestation are prevalent. Other health problems are related to mineral and protein deficiency.

Rural Commercial Farms

These are mixed crop-livestock farms, or specialized farms for breeding and milk production, containing more than 40 animals with 90% buffaloes and 10% cattle. These farms are usually better organized, but their contribution to total milk supply is small. Feeding is often haphazard and management is poor. Farmers don't understand the value of pasture and forage and, if so, don't cultivate sufficient land area. Health service availability is relatively better and occasionally farmers benefit from them. Milk is sold to a middleman (Dhodi), who sells it to the city market on the consumer's doorstep. Some milk collection centers in the Punjab and Sindh are collecting milk from these farmers (i.e., Halla, Milk Pak & Nestle Ltd). The major problem of these farmers is the small size of their land holdings.

Peri-Urban Commercial Dairy Farms

These farms are in the outskirts of all big cities. The largest farm is at the Landhi Cattle Colony, Karachi, where more than 200,000 milking animals are kept. Most herds in this category have 15-50 animals and more than 90% are buffaloes, mostly adult lactating females. Being a high cost system, only high milk potential animals are kept with high turnover.

There are small numbers of large scale private or government owned and military dairy farms. Military farms work to cater to the requirement of the military and they have their own processing plants for milk. In government farms, under the Directorate of Livestock Farms in each province, animals are kept for preservation of pure breeds of the respective area, improvement of germplasm of local breeds through selection, progeny testing such as the bull mother scheme for Nili-Ravi buffalo at LPRI (Bhadar Nagar Okara) and for experimental purposes. In these farms, modern husbandry practices, such as weaning calves at birth, and milking with machines, feeding of high energy concentrates, artificial insemination and veterinary care are practiced. In the private sector, after expulsion of dairy animals from big cities such as Karachi, Lahore and Faisalabad, cattle colonies were established by the government where dairy animals are only kept for commercial milk production. One of the famous dairy colonies of the country is the Landhi Cattle Colony, Karachi. In this colony, which is the biggest cattle colony of the country, modern dairying is prospering.

However, there are variations in how the systems operate among provinces. In Punjab, the three major livestock production systems are irrigated systems, Barani systems and desert systems, with buffalo and cattle production systems classified into rural-irrigated, rural Barani, progressive (commercial) and peri-urban. In Sindh, the systems are classified as settled (mixed or dairy farming) and migratory farming. The majority of buffalo and cattle are in rural subsistence farms, with most of the rest in rural market oriented farms. Over 70% of buffalo and cattle are in herds of less than 10 animals. Also, about 70% of households with large ruminants have herds of less than 5 animals, while a further 20-25% of households have 5-10 animals.

Many farmers rear large ruminants as well as sheep and goats, of which there are over 24 and 56 million, respectively, in Pakistan. The interdependencies and reasons for keeping a number of livestock species, needs to be understood at the household level when considering interventions to increase milk production. For example, why do the poorest, landless farmers keep large ruminants, when intuitively the risks and costs incurred in rearing small ruminants are much lower? Is it because they provide a daily source of food and income? Such questions need to be posed across wealth classes, as it is unlikely farmers will adopt existing technologies if they are not rational in a systems context.

Over 90% of buffalo and over 70% of cattle are in Punjab and Sindh provinces. There are four agro-ecological zones in Punjab, being Arid (Barani) - rain fed pastures, Thall – availability of canal water, Cholistan – desert systems and state land and river belts.

Punjab contains 58% of Pakistan's buffalo and 42% of the cattle. Milk is produced primarily in the irrigation areas and along rivers. Milk production varies widely within and between systems (Table 1). In larger commercial production systems, average production is probably higher than in peri-urban farms. Potential production of Nili Ravi buffalo and Sahiwal cows when they are well fed on locally available feeds in research centres is about 2,500 kg/lactation, respectively. Crossbreeding of Sahiwal with Holstein Friesian has produced adapted animals yielding 5,000 kg milk/ lactation.

Sindh contains 35% of Pakistan's buffalo and 30% of the cattle. The preferred dairy breeds are Kundi buffalo and Red Sindhi cows. Milk production levels in small holder systems are similar to the Punjab. While in Punjab, lower profits from crops, and the increasing demand for milk and meat are leading farmers to keep more stock in agricultural areas, in Sindh, the increasing intensity of cereal cropping in irrigated agricultural areas is displacing livestock onto more marginal lands.

There are a number of large buffalo colonies in peri-urban feedlot systems on the fringes of Karachi and other major cities. These peri-urban dairy colonies were established in 1980 under Government policy to depopulate livestock from metropolitan cities, while ensuring the growing demand for milk and milk products from the urban population. This has created employment opportunities for the poor, and a remunerative market outlet for producers.

There are about 1 million buffalo in dairy colonies around Karachi, where the domestic demand for milk is about 8 million litres per day. While average daily production is estimated to be about 8 kg milk per buffalo, there is a shortfall as high as 4 million litres per day, primarily due to seasonality of breeding and short lactations.

In the Landhi Cattle Colony, there are over 340,000 buffaloes in feedlots in an area with a 5 km radius. Individual feedlots in the colony may contain over 300 lactating animals, with animals owned by small holders and/or leased from larger owners and operated co-operatively. The larger herd owners may have 50-100 animals, which may in turn be leased to small holders. The features of this colony are:

- Milk production averages 2,400 L/lactation, compared with 1,200 L/ lactation in rural small holder systems.

- All feed is purchased from irrigated cropping regions and must be transported considerable distances daily, adding to feed costs. Escalating fuel prices will further erode profit margins for feedlots sourcing forage from distant crop growing areas.

- While straw is stored dry, there are issues with mycotoxins, exacerbated by poor storage, in concentrate feeds.

- Feedlot rations consist of harvested forages – chopped maize stover, forage sorghum and/or millet with chaffed cereal straw plus concentrates fed at up to 1 kg/3 kg milk or up to 8 kg/head/day.

- Feedlots do not keep dry animals or rear herd replacements. Animals are purchased at point of calving from breeders in Sindh and Punjab provinces.

- Many farmers use growth hormone to increase milk production, with feed offered not always increased to meet increased nutrient demand.

- Calves are sold and, without their suckling stimulus, hormones injections (oxytocin) are used for milk let-down. Low pregnancy and high abortion rates are associated with use of oxytocin.

- Injections of oxytocin and growth hormone interact negatively with feed nutrient supply and reproduction, and very few animals conceive during lactation.

- Productivity of feedlots is restricted because of very low reproductive rates and animals are sold at the end of lactation with >90% going to slaughter for meat consumption. A few animals are purchased by breeders from rural areas for mating and sale back to feedlots.

- This one-way traffic through feedlots is counter-productive to breeding programs to improve genetic potential of the Pakistan buffalo herd, and causes upward pressure on price of replacement animals, with average prices now Rs 70,000–100,000 for buffaloes at calving. Dry animals have a slaughter value of ~Rs 25,000, a substantial loss against returns from milk for a single lactation, but a high price for breeders.

- Transport of feed from rural crop farms to feedlots represents a net loss in soil fertility, which has to be replaced from purchased fertilizers, and creates an environmental problem at the feedlot with a concentration of nutrient rich manure, which could be returned to farms, possibly as back loads.

- Health and disease problems are exacerbated by massive inter-regional transport of animals adding to potential spread of diseases, such as foot and mouth disease, haemorrhagic septicaemia, brucellosis, TB, leptospirosis and others, together with higher incidence of management diseases, such as mastitis and metabolic disorders.

- Veterinary coverage is much better than in rural areas, but costs and effectiveness of vaccines are a problem.

- Hygiene during milk harvesting, storage and transport is an issue best addressed by regulation.

Farmer exit rates are very low, less than 2%/year, indicating the systems are profitable for the producers due to the high milk price. However in the long term a rethink is needed so that these systems meet food safety requirements, impact less on the environment and are acceptable in animal welfare terms. The production systems are currently complicated by poor hygiene, and serious environmental and welfare problems. It is likely that the demand for fodder by these dairy colonies has implications for agricultural systems in rural areas. For example, continual export of organic matter and nutrients in fodder places more pressure on agricultural land and might be the catalyst for changes in the farming systems. Understanding these interactions between the colonies and agricultural systems will be important if rural farmers can profit more from supply of fodder to the colonies than from crop and livestock production.

Constraints to Dairy Production

Low milk production per animal is due to a number of interacting factors. Increasing livestock numbers, large numbers of dry adult and younger replacements in herds, and poor reproductive performance with long inter-calving intervals all limit the amount of feed available for productive purposes. Cattle in small holder systems are predominantly indigenous breeds and frequently produce less than 1,000 kg/lactation, with lactation lengths between 200 and 260 days. Inter-calving intervals for cattle may exceed 450 days, and, because of seasonal breeding behaviour, buffaloes often fail to breed until they cease to lactate, resulting in extended dry periods.

Table 1. Indicative levels of milk production (kg/lactation) of buffalo and cattle in different production systems

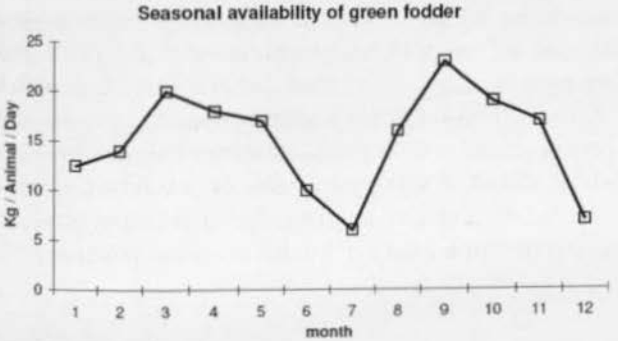
Production system	Buffalo	Cow
Commercial	2500	2500
Peri urban	2500	1800
Irrigated	2000	900
Arid (barani)	1200	450

In rural areas, feeding systems that recognize animal nutrient requirements for maintenance and production, and strategic use of feeds to achieve higher production compared with currently prevalent unscientific feeding, would substantially increase milk production.

There are large differences between the feeding systems and needs of small holder and peri-urban farmers. Grazing may provide 50-60% of the feed consumed by animals in small holder systems, whereas in peri-urban systems fodder crops may provide 50%, and straw 35%, of feed, respectively, with some supplemented concentrates. It is easier to manage nutrition where animals are stall fed compared to systems that involve grazing.

In general, critical feed shortages occur in May-July and November-January with declining quality (Figure 1). The major fodder crops in winter (rabi) are berseem clover, lucerne and oats, with some barley, rye and triticale. Main summer (karif) fodders are sorghums and sorghum hybrids, maize, millets, cowpea, guar and napier grass. Feed resources available at household level, and their allocation, is critical to productivity gains (i.e., more milk per unit of feed).

Figure 1. Seasonal availability of green fodder (Source NRC, Islamabad)



Government and University Research Institutes have developed forage production strategies to improve nutrition and minimize seasonal feed gaps for milk production. Forage crop yields achieved by research institutes are frequently 50-100% higher than that achieved by farmers, but adoption of improved practices has been low. Production differences partly relate to improved varieties, but probably also indicate lower inputs of resources, such as water, fertilizer and management by farmers.

Technologies have been demonstrated to improve the nutritive value of cereal straws with urea and molasses treatment, and for provision of quality conserved forage by harvesting crops for silage or hay, but again these have not been widely adopted.

Government attempts to provide concentrate mixes of consistent quality at near cost have had some impact near research or feed preparation centres, but penetration to the bulk of rural milk producers has been minuscule. The cost and quality of feed by-products available for production of formulated concentrate vary within and among years. Nutritional analyses of local feeds are available and have been used in ration formulation at a research level, but this information is not readily available to farmers. In addition, many farmers have limited knowledge of animal requirements or ration formulation for milk production. A second major constraint relates to animal health, with mortality rates as high as 20% in rural systems. Endemic diseases such as FMD, haemorrhagic septicaemia, brucellosis, as well as leptospirosis, clostridial diseases, mastitis, metabolic diseases and internal and external parasites all present challenges. While there are government supported vaccination programs, limited animal health coverage occurs with the average area covered by each veterinary officer being 248 km^2 (>55,000 animals) and the average area covered by each veterinary assistant 85 km^2 (>19,000 animals).

A further constraint is the low genetic potential of the animals. Cattle in small holder systems are predominantly indigenous breeds, while animals in peri-urban systems are of higher genetic merit (Table 1). Peak yields of 16-18 kg/day are achievable for buffalo and cross-bred cattle (indigenous x Holstein Friesian) in commercial/market oriented production systems, with average production of 7-9 kg/day. However, the price for high genetic merit buffalo (Rs70,000-150,000) and cattle is beyond the means of most rural households. Availability and transfer of research information on genetics and reproduction has been limited for small producers. Supply of semen and/or superior blood lines from animal breeding programs reach very few farmers. However, it would seem illogical to approach these constraints in rural small holder systems before the constraints in nutrition and health are addressed.

Milk production at the farm level is the weakest link in the Pakistan dairy industry, and failures can largely be attributed to a lack of commercial farms. The current process of collecting milk from a large number of subsistence farmers is time-consuming, costly and prone to adulteration. Main reasons for the underdeveloped dairy industry include:

Low genetic potential animals

Genetic potential of local breeds of cows and buffaloes is one of the major constraints to increased milk productivity, and establishment of medium to large scale commercial dairy farms has not been economically viable due to this constraint. No fruitful efforts have been made to improve breeding of cows and buffaloes towards being more efficient milk producing animals. Even the purity of local breeds has been endangered through indiscriminate unplanned cross breeding.

Improper feeding

A large number of animals are grazed on marginal lands. Stall feeding includes large amounts of wheat straw that has little nutritional value. Concentrate feed use is very limited. Dirty, non-potable and limited water is offered to heat stressed animals thereby negatively affecting their productivity. Milk yield per lactation is much lower than that in many other countries (Section 1A, Table 5). According to estimates, a 50-100% increase in milk yields are possible by adopting correct feeding programs.

Housing

Animal housing is a low priority area for farmers. A large number of farmers cannot afford any housing for their animals, which are left out in all weather.

Animal health

Lack of manure management and dirty water are the major sources of diseases and infections in animals. The Livestock Department is responsible for disease prevention and treatment of animals, but there is an acute shortage of funds to dealing with such diseases, which ultimately leads to decreased animal productivity.

Consequences of Not Developing the Dairy Industry

The milk deficit will continue to grow in urban areas, with consequent increases in unethical practices, such as adulteration of fresh milk. Adulterated milk increases social costs to public health. While the dairy industry can contribute to alleviating rural poverty, if it is not developed along commercial lines, rural poverty will accelerate the rate of rural to urban migration, putting unsustainable strains on cities. Increasing import of powdered milk will lead to problems in the balance of payments and trade deficit.

Production constraints

- Farmer knowledge and attitude: gender is important in who rears livestock, poor knowledge of forage production, animal nutrition, health and management, limited acceptance of better management practices.

- Farm resources and access to credit: access to land and water, as well as cost of pumping water, limited access to credit.

- Quality of buffalo and cattle: low genetic potential, poor selection and use of high potential animals, reproductive failure/long inter-calving intervals, culling and slaughtering of valuable animals, high mortality rates, susceptibility to heat stress.

- Animal health: vaccination including access to viable vaccines, poor access to veterinary services.

- Feed resources: insufficient feed to meet requirements, seasonality of supply, poor feeding strategies, competition for feed resources, seed availability and quality, poor agronomic practices, with limitations imposed by poor input (water, fertilizer) use, poor conservation practices, cost and quality of supplementary feeds.

- Lack of effective veterinary and extension services: skills and motivation of Government staff, extremely high ratio of households to service providers.

- Food safety: sanitary and hygienic conditions of production, harvest and transport.

- Marketing: the traditional supply chain and those developed by milk processors were said to disadvantage farmers.

- Infrastructure: inadequate infrastructure for handling, processing, storage and transportation of livestock products, particularly in remote areas.

- Government policy: at national, provincial and district level were unstable.

Estimates of the fodder/feed deficit at a national level suggest, for example, a 15-30% deficit in total digestible nutrient requirements for livestock. On average, livestock obtain about 50% of their nutrients from green fodder, 38% from crop residues with the rest from grazing vacant lands and cropping land post harvest, and cereal by-products and oil cake/meals. Such estimates highlight the limitations in digestible energy and protein supply at a national level, but ultimately understanding deficits in different agro-climatic zones and the resources available to individual households will be needed to sustainably increase milk production.

Between 1990 and 2005, there was a trend towards reduced areas of fodder crops, while production per ha has remained static. At the same time, the livestock population has increased, circumstances that suggest nutrient requirements for maintenance have increased, reducing availability for production. This critical constraint of insufficient feed consumed by dairy animals is widely recognized, as is the fact that it is aggravated by continuous increases in the milking animal population.

Future Aspects of the Livestock System and Suggestions for Improvement

Motivating farmers to provide proper shelter with appropriate drainage and ventilation for animal housing requires capacity building of farmers. Modernization of existing dairy shed and establishment of new modern and hygienic plants must be undertaken at the national level.

Superior fodder should be identified and propagated in the field. Year round fodder production systems should be devised, and legume/non-legume crop combinations can improve the feeding status of livestock. The strategy should be to improve productivity through better utilization of available feed, with improved forage and pasture. Increasing self-sufficiency on feed grain will be important in future livestock sector developmental programs. Yields of fodder, and its availability for longer periods, should also be increased by growing high yielding varieties of fodders, and by following suitable crop rotations. Similarly, rain-fed fodder and roughage yields can be significantly increased by following modern rain water harvesting techniques. Rangeland management needs multidisciplinary approaches such as classification, determination of stocking rate, deferred and rotational grazing, reseeding of rangelands, development of drinking water for livestock, Silvi-pastural management, forage conservation during lean periods, use of urea-molasses blocks, removal and burning of undesirable plant species, establishing demonstration farms, mobile extension units, credit and other similar services. Rations should be formulated to achieve better utilization of nutrients by animals. Feeding should be aimed at the physiological stage of animals, rather than feeding animals haphazardly.

Animals with high genetic potential for milk production are the cornerstone of any successful production strategy. Pakistan has a number of breeds having characteristics of high milk production that are well adapted to the local environment. There is a need for genetic evaluation and breed organization techniques. To improve yields per animal, there is a dire need to start national progeny testing schemes on a large scale by involving animal breeding and genetics experts.

In the animal health sector there is a need to ensure animal health coverage that is both prophylactic and curative. Provision of better animal disease diagnostic facilities and ensuring provision of required quantity of good quality vaccine in the field are needed. The increasing confluence of animals and human health problems, as well as the pressing issue of emerging diseases, require increased attention to livestock health. Climatic and environmental constraints that have limited a host of diseases to the equatorial latitudes are changing. Today, it is estimated that 55% of human diseases have animal origins. The government should establish well equipped laboratories in each district. Because the livestock sector is now moving from traditional "one man one buffalo" systems to "semi commercial" and "commercial" systems, there is a need for reliable diagnostic facilities at the District level.

Finally, there is a need for better articulation of poor producers' needs from service agencies, and reform of research and extension agencies to make them more client-led and poverty-focused. There is a danger that livestock production and processing will become dominated by integrated large-scale commercial operations, displacing small-scale livestock farmers to exacerbate rural poverty. At the smallholder-level, livestock are often the only means of asset accumulation and risk diversification that can prevent a slide into poverty by rural poor in marginal areas.

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CHAPTER II A

Dairy Feeding and Management Systems

Dairy Cattle

(M.E. Babar)

Livestock production is an integral part of Pakistan's rural socio-economy. While the size of a holding is a matter of prestige for well off rural families, for poor and landless farmers it serves as the backbone of their economic status. About 70% of dairy cattle operations in Pakistan are rural family subsistence farms operated by gawalas (dairying families) in the urban and peri-urban areas with little or no technical input. In addition, mixed dairy herds of buffalo (65%) and cattle (35%) are maintained because of seasonal variations in breeding patterns of the species. Most rural family subsistence herds range from 1–10, with an average size of 7, with dairy animals including cows and buffaloes. There are nearly 4.8 million small-scale rural units with less than 6 head and 0.6 million peri-urban units. Almost 80% of total milk supply is derived from 5.4 million mixed crop/livestock farms located mostly in irrigated areas. These farms keep buffalo primarily for milk production and indigenous cattle for dual purposes (Livestock Census, 2006).

More recently, hundreds of semi modern/progressive dairy/livestock units, in the public and private sectors, are being established all over the country. Their average holding size is 30–300, including crossbred and purebred cattle as well as buffaloes. Some of these farms are established for breeding purebred Sahiwal cattle, but others have a mixture of crossbred and Sahiwal cattle for crossbreeding whereas the rest are purely for milk production. The small holding size is an endemic constraint to transforming Pakistan's dairy industry into a commercially profitable entrepreneurship because of their limited resources, abilities and willingness to adopt new technologies to improve genetic merit and feed efficiency to support higher production.

Housing

Traditional to modern dairy housing

For 70% of rural dairy production, dairy housing continues to be the most neglected area. During extreme hot and humid weather, when green fodder and water availability is restricted for dairy animals, appropriate and convenient housing is the only alternative to assist the thermoregulatory system of animals by protecting them from direct exposure to heat, dehydration, energy needs to regulate body temperature, panting, restlessness and exposure to ecto-parasites. These factors are ultimately seen as low performing animals in terms of growth rate, milk production, reproductive efficiency and disease resistance. In addition, virtually no research into this area has been conducted to date to design economical and environmentally friendly housing systems in the different parts of the country. Pakistan, being a highly versatile geographic nation, has a variety of climates (Section 1A), which call for specialized dairy housing research programs to be established with a mandate to produce expertise specialized in designing suitable and standard housing structures for the provinces and areas of Pakistan, as well as for keeping indigenous, crossbred, exotic and mixed cattle and buffalo dairy farming operations. Erection of housing is by far the largest capital cost incurred to establish a dairy farm and there needs to be a balance between models that emphasize convenience versus productivity, and their cost effectiveness.

Principles of dairy cattle housing

Dairy housing needs to utilize locally developed and investigated expertise, as well as materials and methodologies that consider cost effectiveness of the product. Results of dairy housing research should be tested, and their blueprints must be widely distributed to relevant academic and research institutions, support NGO's, construction industries and farming communities. Resulting housing designs must strike a balance between economy, profitability and animal welfare issues, with the objective to provide protection from the rigors of extreme weather, be clean and comfortable, be cost effective and exclude predators and thieves.

Construction based upon these principles will ensure animal well being, which allows increased productive performance, while ensuring increased milk production, less labor need, high quality milk production, increased animal health and well being, low mortality, easy to implement modern husbandry practices, improved reproductive efficiency, higher feed efficiency, enhanced social and financial status of the farmers and a model for other farmers to follow.

Specifications for farm location

Topography	Somewhat leveled
Drainage	Good slope
Soil type	Sandy loam, fertile, neither too dry nor too moist
Elevation	Higher then surrounding
Sun light	Exposure of floor to sunlight
Protection	No direct draught
Market	In close proximity
Durability	Longer life
Labor	Skilled, reliable, cheaper, regular, plenty, honest and laborious
Accessibility	Near to main road
Surrounding	Safe and clean
Electricity	Enough and continuous supply
Others	Banking, postal, communication, school, shopping center
Facilities	Feed storage, hay stack manure pits

Types of Dairy Cattle Housing

Traditional system

About 70% of subsistence dairy farmers are extremely poor and their circumstances don't normally allow them to have organized housing arrangements for their animals. The majority are illiterate and not receptive to outreach advice to improve their farming practices. Educated young people are increasingly not staying in the dairy business and so the chances of adopting modern husbandry practices are also diminishing within the gawalas. The various types of housing under traditional conditions are:

Shelter-less open housing barns

In this arrangement, animals are tied to a wooden or steel peg fixed in the ground with a chain around a portable wooden manger for groups of about five animals. A few trees are often the only protection from sun and cold. Animals stand and rest on a muddy floor of dung and urine. Once a day these animals are let loose and driven to grazing areas. The calves are also accompanied by their dams and stay in close proximity to them, but are prevented from suckling. Thus key features of this system are:

- No sanitation and maximum chances of hoof and teat infection
- Unhygienic milk production because animals are covered with dry dung
- More prone to disease due to favorable conditions for the microbes to thrive
- Difficult to manage and more labor intensive
- No protection from extreme hot, cold and rainy weather
- Exposed to injury due to slippage and theft
- Clear violation of animal welfare principles
- Low production due to stressful living conditions
- No adequate and clean water supply

Figure 1. Traditional dairy farm setup in rural areas of Pakistan

Semi and fully covered housing system

Hundreds of small scale semi-modern dairy farms have buildings built partly according to technical specifications for an ideal dairy farm. These buildings contain most of the recommended facilities and comply with the per animal open, sheltered, feeding and watering space requirements. However they lack a complete set up for dairy production and animal welfare that can enhance profitability. Lack of financial resources, awareness, and insufficient technical inputs in construction of sheds and barns, are major constraints to constructing ideal dairy buildings. Recommended requirements for various age groups, feeding and watering space are in Tables 1 and 2.

Modern dairy cattle housing in Pakistan

With the involvement of corporate and multinational companies such as Nestle, fully automated and environmentally controlled dairy housing systems are being introduced. Some of these farms are already in operation with farm holdings in the 1000's of purebred Holstein Friesien, Jersey and/or crossbred cattle. At the same time, these companies have horizontal business arrangements for production, collection, processing, packing and marketing of dairy products.

Free stall housing

Contemporary modern dairy farms are now increasingly being erected with free stall systems. In this system of housing, all animals are free to move with individual feeding stalls separated by steel pipe barriers with feeding stalls in front of each animal. In this system, animals normally select their space due to social order within the group. All feeding, breeding, calving, AI, record keeping, office administration and labor management operations are completed separately according to recommended standards. Free stall housing may be designed in different arrangements such as single row or double row systems. Similarly the double row system has main categories of tail to tail /face out system and head to head/face in systems. A comparison of merits and weaknesses of the two systems are in Table 3.

Table 1. Space requirements for different age groups in a dairy farm

Animals	Covered area (sq f)	Open area (sq f)	Max animal/pen
Bull*	120	240	1
Cows	36	72	50
Down calver	120	120	1
Young calf	10-12	10-12	30
Older calf	20	40	30

Table 2. Feeding space requirements for dairy animals

Animals	Feeding Space (f)	L / 100 animals	Watering (L / 100 A)	Width (f)	Depth (f)	Height (f)
Cow / Buffalo	2-2.25	200-225	20-22	2	1-1.75	1.60
Calf	1.5	150-175	15-17	1.33	0.5	0.67

Figure 2. Semi modern and traditional-cum-semi modern farms (From Doodh Darya)

Figure 3. Views of a modern free stall dairy cattle housing system

Table 3. Comparative merits and demerits of tail to tail and face to face system

	Parameters	Double row system	
		Tail to tail	Face to face
1.	Feed distribution	Difficult	Easy
2.	Cleaning gutters	Easy	Difficult
3.	Supervision of milking	Easy	Difficult
4.	Possibility of stealing milk at milking time	Difficult	Easy
5.	Detection of injury at hind quarter	Easy	Difficult
6.	Look of animals at a glance	Easy	Difficult
7.	Fresh air and direct sunlight		
	(A) Milker at milking	Less	More
	(B) Animals	More	Less
8.	Floor space for barn	More	Less
9.	Cost of construction	More	Less
10.	Gutter exposed in sun rays and kept dry	Less	More
11.	Easier for cows to get into stalls	No	Yes
12.	Danger of spread of disease	Less	More
13.	Walls are splashed and kept dirty with dung & urine	No	Yes
14.	Back tracking of feed to trolley	Needed	Not required
15.	Safer for health of cows	Yes	No

Dairy Cattle Feeding

Low genetic potential is generally responsible for poor productive performance of dairy cattle in Pakistan. It is, however, also true that our cattle have never been fed to express their true performance potential. In this system, the thumb rule for dairy cattle feeding is to feed high producing animals more than their actual nutritional needs, whereas low production animals are barely fed to meet their maintenance and production requirements. This practice results in unnecessary wastage of valuable feed resources and it deprives the poor producers of the ability to express their potential performance.

There have been continuous outreach efforts launched by government and public sector research institutions to educate dairy farmers to adopt improved feeding, breeding and management practices in order to enhance the productivity of dairy animals. However, very little has been achieved from such initiatives due to a lack of dedication by the field workforce. Similarly, an equal lack of interest in adopting cost effective dairy practices has also played a role in the low success rate of development projects such as the 'World Bank 10 Districts' project in Punjab province. Organizations such as Pakistan Dairy Company, Dairy Development Board, SMEDA, Livestock Departments of the four provinces, the agricultural and veterinary institutions and NGO's in the dairy sector are providing consultancies, but the results of these efforts are yet to be realized.

Availability of Feeds and Fodders for Dairy Cattle Feeding

Being predominantly an agricultural land, Pakistani soil is fertile and fit for cultivating a vast variety of cereal crops, fodders, oil seeds, fruits and vegetables. Four clear seasonal variations are an added advantage which supports cultivating non-native crops. There has been some work to take maximum advantage of land in year round rotations by cropping fodders for livestock without disturbing the period for cultivating cereal and other cash crops.

In addition, cash crop residues such as wheat straw, rice straw and other dry roughages are abundantly available and can be utilized as dairy cattle feeds. Wheat straw treatment with urea and molasses was developed and introduced in the 1980's and 1990's to enhance its nutritional value. However, this technique is now little used due to its low comparative advantage and labor intensiveness. Cereal crops such as maize, sorghum and millet are also used as fodders, and these crops could be used for fodder preservation as silage. Another option is to produce compacted hay bales of leguminous crops when they are abundantly available in the winter and use them in times of inclement weather. An inventory of different fodder crops with their season of cultivation and nutritional parameters is in Table 4.

Table 4. Seasonal dry roughages and green fodders

Dry Roughages	Green Fodders		Fruit Residues
	Winter Fodders	Summer Fodders	
Wheat Straw	Barseem	Maize	Citrus peeling/juice residues
Rice Straw	Alfa Alfa (Lucerne)	Sorghum	Melon Peeling
Oat Straw	Oats	Millet	Expired Fruits
Maize/Sorghum Stubble	Rye Grass	Mott Grass	Expired Vegetables and Peelings
Sugarcane Baggass	Sugarcane tops	Sadabahar	Sugar beat pulp
Cotton Seed Hulls		Guar	
Corn Cobs			

Feeding Systems in Dairy Cattle Farming

The dairy industry varies from rural backyard subsistence farming to environmentally controlled production systems with highly mechanized facilities. Accordingly, feeding systems have been adopted that fit the scale of the enterprise. Apart from progressive and highly mechanized farm systems, dairy cattle feeding systems lack the ability to meet the nutritional requirements of dairy animals for maintenance and milk production. The foremost factors that account for the absence of scientific feeding systems for a great majority of dairies in the country include the economic capacity of small scale domestic farmers, lack of awareness and willingness to adopt scientific feeding methods, unavailability of ample feed resources during hot summers and extreme winters, absence of fodder preservation methods, lack of use of modern husbandry practices to cope with labor intensive activities and the absence of a support network in the form of outreach technical services and farmer cooperatives. Dairy cattle feeding can be categorized into the following systems:

Grazing system

This is most widely practiced in family subsistence or backyard systems having 1-2 animals. Young family members take the dairy animals out after morning milking and move them around different grazing areas on the periphery of the village until evening milking. Cows graze available grasses and stubbles in the harvested and open fields, and are kept in proximity to pond water for drinking. Sometimes they are also grazed in fodder fields cultivated by farmers for grazing or leased from other farmers. On return for evening milking, these animals may or may not be offered soaked leftover foods (Chan Bura) mixed with wheat straw. Apart from inherent low productivity coupled with poor nutrition, milk production is minimal (5–6 kg/day) with low reproductive performance.

Fodder plus concentrate

Traditional

This type of feeding system is most widely practiced by small to medium scale rural farmers and peri-urban traditional gawalas. Their holding size varies from 5–20 animals including cattle and buffaloes. Animals are fed a mixture of wheat bran, cottonseed cake and straw during morning and evening milking while, during late morning to early evening, they are fed seasonal fodders in cut and carry systems. Some progressive farmers use formulated rations instead of "Khal Banola and Choker". This feeding system meets the maintenance and milk production requirements of the animals which is reflected in higher milk production and better reproductive performance. However, under this system, there is more chance of malnourishment relative to the vitamins and minerals that are vitally important to maintain health, production and reproduction.

Commercially formulated concentrate mixture

With expansion of the dairy sector, a number of commercially formulated concentrate mixture are now available. Such mixtures are formulated by specialist dairy nutritionists relative to protein, energy, fat and micronutrient (vitamin and mineral) requirements. The quality, and results, of using these commercial mixtures are not consistent under all climatic and geographical conditions. However, some dairymen find them suitable because these are less labor intensive and convenient. For small scale farming, these commercial mixtures usually prove to be less cost effective.

Total mixed ration (TMR)

TMR are used in modern dairy farming systems, but use of TMR are very limited at present and have only been adopted where high producing exotic herds of cows, such as Holstein Friesien and/or Jerseys. At present, only a few brands are available in the market. TMR can also be prepared by using locally available feed ingredients.

Milking Dairy Cattle

Milking dairy animals are important relative to hygienic milk production, shelf life of milk and dairy health management. At present, about 90% of dairy farmers use hand milking practices under the traditional rural household, peri-urban gawala (dairying families) and semi-modern dairy farming systems. The most critical factors with hand milking are maintenance of milk hygiene to assure longer life of fresh and raw milk during transportation and its consumption due to public health concerns.

Under prevailing dairy cattle production systems, and due to poor hygiene, hind quarters and udders of cows are usually covered with dried dung and dirt sticking to the cows skin, open and filthy milking places and use of open mouth utensils which are not regularly and hygienically cleaned (and sometimes have deposits of fungus in crevices and the bottom of these utensils). Similarly milkmen hygiene are such as clothing, body cleanliness and individual practices are not satisfactory in many cases. For these reasons, significant amounts of milk are spoiled before reaching the consumer. The absence of pasteurization and chilling facilities further aggravate spoilage. Unhygienic hand milking practices also add to widespread problems of udder health, and the prevalence of mastitis.

Due to the establishment of large numbers of modern and environmentally controlled dairy farms, machine milking practices are gaining in popularity. Machine milking is only cost effective with large scale commercial dairy farming and only a few dairy farms with large numbers of high producing cows have adopted it. Milking machines are constructed so that sucking is interrupted by rhythmical motions (opening and closing) of the liner. Teat massage by appropriate liner movement ensures:

- High milk flow and healthy teat and udder
- The liner's action on the teat stimulates the cow for maximum milk yield
- No mechanical impact and stress on the teat extraction
- No changes in teat dimensions
- Uniform milking throughout the lactation therefore milk consistency
- Complete and fast milking with better milk recovery with massage
- Complete and fast milking with better milk recovery and teat massage
- Reduce dependability on hand milkers.
- Better utilization of labor

However, some of the disadvantages of machine milking include:

- High input and maintenance cost for small scale dairy farmers
- Intensive and highly technical system for a majority of layman farmers
- Use of faulty systems may cause harm to udder health of the animals

Dairy Cattle Breeding

Dairy cattle *(Bos indicus)* of Pakistan contributes 35–40% of total revenues generated by the industry. Sahiwal and Red Sindhi are the only designated pure milk breeds of cattle in the country. However, their population numbers, productive and reproductive performance statistics are not encouraging as both are rapidly declining in numbers and are now categorized as "under threat" breeds. Their genetic potential for growth, milk production and reproduction are very low and have not shown much improvement due to the absence of systematic, consistent breeding management and genetic improvement. Some efforts to develop AI services in the country have been undertaken to increase reproductive performance and genetic merit by using imported and indigenously produced semen from Bos taurus for crossbreeding purposes. However this has not proved to be a long term solution. Similarly, some efforts to produce progeny tested breeding bulls in Sahiwal and Red Sindhi cattle by the Livestock and Dairy Development departments of Punjab and Sindh governments were also undertaken, but they were under-funded and lacked continuity and not much has been achieved so far from these projects in terms of enhancing genetic worth of these breeds.

Breeding dairy livestock is also a management art as it involves application of principles of genetic selection for long term improvement. Cattle breeding can be discussed on "Short term" and "Long term" basis.

Short term breeding management

Breeding dairy livestock in a broader term, is generally understood to manage year-round reproductive performance of animals. This could well be termed as short term breeding strategy. All lactating cows and AI bulls are managed to achieve optimal performance in terms of different reproductive parameters. An inventory of the reproductive parameters for different classes of dairy cattle is in Table 5.

Achieving the highest degree of success in short term breeding is vital for a successful and profitable dairy enterprise. An efficient and competent short term breeding management regime ensures the highest degree of reproductive efficiency in a dairy herd. A sound and concerted management strategy, and professionally competent work force, are the essential components of achieving success in short term breeding objectives. Low reproductive efficiency is one of the major constraints to profitable dairy farming in Pakistan. Longer calving intervals, increased incidence of anestrous, delayed puberty, lack or unavailability of proven bulls, early embryonic deaths, reproductive disorders, correct record keeping, none (or minimal) application of modern reproductive techniques are endemic factors leading to poor reproductive performance of dairy cattle. The only way to improve reproductive performance of dairy cattle is to apply effective management tools at the farm level.

Table 5. Reproductive Parameters for different classes of dairy cattle

HEIFERS	LACTATING COWS	A.I BULLS
Age at puberty	Heat Detection	Age at puberty
Heat detection	Service period	Age at first service
Age at first service	Conception rate	Ejaculate volume
Conception rate	Non-return rate	Semen quality
Non-return rate	Calving interval	Cryo-preservation
Age at first calving	Dry period	No. of conceptions per 100 doses
	Fertility/Reproductive efficiency	Fecundity
	Reproductive health	Reproductive health

Artificial insemination is an important breeding technique that has made it possible for proven and superior bulls to sire thousands of cows. In fact AI is so potent and powerful that it has made it possible to use semen of proven bulls for crossbreeding around the globe. Although most dairy producers use AI in the developed world, its use in Pakistan is still low, albeit increasing.

Breed improvement by L and DD Punjab

The directorate of "Breed Improvement" was established in 1982 to enhance genetic merit of dairy livestock in Punjab. However their major emphasis has been promotion of AI services in the province. There has been a lack of long term breeding programs for genetic improvement through selective breeding programs. A brief list of projects provided by the Directorate of

Table 6. Projects Launched by the Directorate of Breed Improvement L & DD Punjab

S. No	Name of the Project
1	Pak Sahiwal A.I. Project
2	Strengthening the Artificial Insemination Services in Punjab
3	Bull Performance Testing Station for D.G Khan Division
4	Establishment of Artificial Insemination Centres in Punjab
5	Establishment of Artificial Insemination Centre in Soan Valley at Pail Noshera
6	Establishment of Semen Production Units in Punjab
7	Expansion of AI Centre at Qadirabad, Sahiwal
8	Establishment of Artificial Insemination Centres in Barani areas
9	Establishment of Semen Production Unit in Bahawalpur Division
10	Establishment of Semen Production Unit at Kallurkot
11	Enhancement of Artificial Insemination in the Punjab Province
12	Breed Improvement through Progeny Tested Bulls
13	Procurement of Young Bulls from the Breeders
14	Establishment of Semen Quality Control Unit at Lahore

Breed Improvement (Table 6) shows that the concept of breed improvement through AI services has been established.

Cattle breeding for genetic improvement

A long term breeding strategy involves producing genetically superior stock through application of effective breeding plans with different degrees of selection/culling intensities depending upon requirements of the breeding system. The most limiting factor to achieving significant improvement in the genetic potential of dairy cattle has been lack of consistency and continuity in breeding schemes that were initiated by the Department of Livestock and Dairy Development, Punjab and elsewhere. However some progeny testing efforts are underway. These include:

Progeny testing program in sahiwal cattle

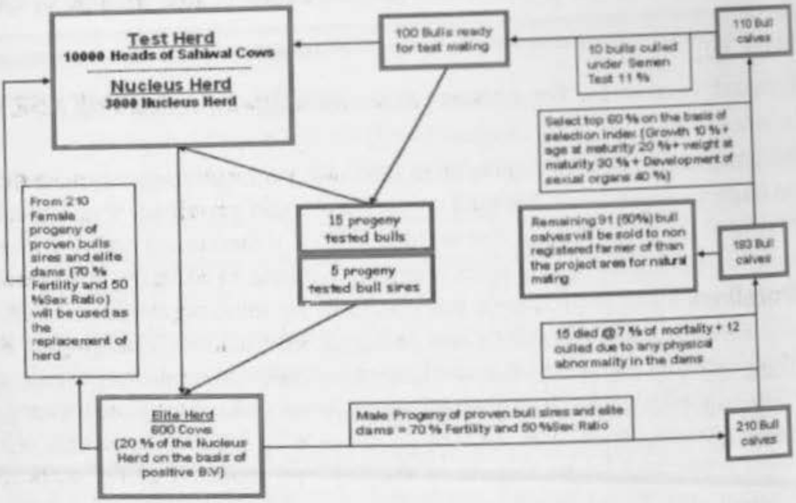
Started during 1979-80 at the Livestock Production Research Institute, Bahadarnagar, Okara. It was a launched on a very limited scale with a very small number of Sahiwal cows. The present status of this scheme is not known.

Research centre for the conservation of sahiwal cattle (RCCSC)

This project was originally initiated in 2003-04 to conserve and protect the remaining population of Sahiwal cattle in Punjab province. Population statistics of Sahiwal were at threshold levels of a threatened species. The centre is working on a long term breeding scheme to identify and select elite Sahiwal cows to produce a nucleus herd by selecting animals on the basis of individual performance and pedigree information. This project is also encouraging farmers to maintain purebred Sahiwal herds by providing technical knowledge, holding Sahiwal cattle shows and offering cash awards for milk production and type traits in 10 districts of Punjab. At present, the achievements and future targets of RCCSC as reported at its website www.rccsc.com.pk are listed as:

- Registration of 10000 (8000 private and 2000 Govt.) Sahiwal cows
- Recording of milk production performance
- Genetic evaluation of registered cows every year
- Amongst the progeny of high producing mothers, the top 50% will be identified as test bulls each year
- Selected bulls tested for semen quality, collection and storage at SPU Qadirabad
- Embryo transfer trials will be conducted

Figure 6. RCCSC'S breeding plan



- 5% of the progeny tested bulls will be selected as new generation bulls

Disease Control

Herd health management plays a pivotal role in a profitable dairy enterprise, and a number of factors account for maintaining herd health standards at the farm. Type of housing, hygiene standards at the farm, animals, herdsmen and dairy farm equipment, following standard management practices in feeding, breeding, milking and adhering to the strict schedule of prophylactic measures such as regular and timely year round vaccination of dairy cows and calves, and proficient and early veterinary coverage in cases of disease outbreak are some of the critical measures to maintain a healthy and thriving herd for a successful and economically rewarding dairy farming operation. The most prevalent diseases of cattle in Pakistan are:

Bacterial Diseases

Hemorrhagic septicemia (HS)

Caused by *Pasturella multocida*, it has a very high mortality rate. It is not a seasonal disease, but occurs when animals are in stress. Vaccinating animals, avoiding stress and proper isolation can prevent HS.

Black quarter

Is caused by *Colostridium chauvoi* normally between the ages of 3 months and 2 years. Incubation period of the pathogen is 1-5 days. The disease can be prevented by deep burying or burning the body and by vaccination between 4 and 12 months.

Brucellosis

In cattle the disease is caused by *Brucella abortus.* The disease is prevented by eliminating affected animals from the herd through regular testing. In some cases, Brucella strain-19 vaccination is effective.

Mastitis

The bacteria *Staphylococcus aureus*, *Streptococcus agalactia*, *Staphylococcus agalactia*, *E. Coli*, and *Staphylococci*, as well as viruses, fungus and poor management cause the disease. The disease can be prevented by regular screening of infected animals.

Anthrax

The causative organism is *Bacillus anthracis*. Animals can be vaccinated to prevent occurrence of disease and eradication of disease requires deep burying of dead animals.

Scours

Is caused by *E-Coli*, viruses and over feeding of milk in young calves. Colostrum feeding, avoiding over feeding and protection against inclement weather are preventives.

Navel ill

Occurs due to infection of the umbilicus of young calves from pathogens such as *Streptococci*, *Staphylococci*, *E Coli*, *Salmonella* and *Corynebacterium*. It can be avoided by proper cutting and disinfecting the navel cord at birth.

Viral Diseases (Foot and mouth disease (FMD))

Virus strains which cause disease are A, O, C, Asia 1, SAT1, SAT2 and SAT3. In Pakistan, A, O and Asia1 are prevalent. To prevent occurrence, vaccination is necessary.

Parasitic Diseases (Babesiosis)

It is a problem caused by *Babesiosis bovis* that spreads through ticks (Boophilus), and can be treated with injection of Imizole at 10cc/animal repeated after 48 h, Diaminazine at 50 cc with 5 cc Adrenalin, Acaprine 10 cc and Babson with 5 cc Acaprine.

Metabolic Disorders

Milk fever

Is caused due to drop of blood calcium after parturition from 10 mg/100cc to 5 mg/100cc or lower. Administration of calcium chloride at 150 g in 24 h and 2 h prior to calving and 10 h after parturition, feeding diets with 1:3.3 ratio of calcium to phosphorus, injecting Vitamin D 2-5 days prior to parturition and partial milking after parturition can prevent the disease. Treatment is administration of 500 cc of 20-25% calcium gluconate.

Fat cow syndrome

Fat cow syndrome occurs when excessive fat is mobilized from body reserves. It is exacerbated by feeding excessive energy during late lactation and/or the dry period. Not feeding excessive grain in late lactation and the dry period, feeding grass and hay ad libitum during the dry period, and proper body condition can prevent this syndrome.

Ketosis

It occurs during the first weeks after calving due to impaired carbohydrate and fatty acid metabolism due to a negative energy balance in high producing cows. There are two forms (i.e., wasting and acute form), with the wasting form characterized by anorexia, dislike for grains, preference for hay and reduction in milk production and body weight over several days. In acute case, ketone odor (i.e., fingernail polish remover) occurs in breath and milk. Symptoms include delirium, circling, head pushing, apparent blindness, wandering, vigorous licking of skin, constant chewing and convulsions.

Internal Parasites

Liver fluke

The characteristics of liver fluke infestations are weakness, off feed, jaundice in severe cases, swelling in joints. Avoid grazing cows and calves around stagnant water.

Round worms

Round worm infestation causes weakness, diarrhea, anemia and hair falling from the body coat. Fecal samples should be examined for roundworms. Dosing animals with anthelmintics at regular intervals can minimize roundworm infestation.

Ecto-Parasites

Fleas/ticks/maggots

Causes irritation on body coat, sometimes holes in skin, loss of hair from body coat. Cleanliness in sheds is critical and spraying animal houses with DDT can minimize fleas and ticks.

Dairy Industry of Pakistan - Future Projections

Despite constraints and shortcomings, current dairy production in Pakistan offers great potential, and a promising future, because of the diversity of naturally available dairy genetic resources. Even in its highly volatile and scattered state, the dairy industry still contributes substantial revenues to the national economy. The overall growth rate in the livestock sector during 2006 was 8% (Economic Survey of Pakistan, 2007-08), and the dairy industry has a major share. According to FAO's (2004) dairy statistics, per 1000 capita availability of milk was the highest (177.6 tonnes/year) of South Asia. This also reflects the present health and vigor of the dairy sector, and its enormous future potential. However, this needs a highly focused and concerted campaign to promote dairy cattle production in the country through provision of sustainable inputs. There is also a need for comprehensive understanding and insight of the past and present dairy sector to plan and implement future dairy cattle production strategies. For this purpose, a review of constraints, and the structure of the dairy sector, would help forecasts of the industry.

Dairy Sector - Constraints

- Lack of sustainable and consistent policies especially genetic improvement
- Inadequate applied research culture and facilities to develop indigenous technology and its transfer at farm gates.
- Insistence to stay with conventional breeding and management practices
- Scattered dairy structure with small holdings unsuitable for commercialization
- Predominantly manual operations prevent efficient dairy production
- Poor farmer adoption of the latest and cost effective production techniques
- Lack of dedicated outreach work force to bring about positive change in the sector
- Insufficient financial incentives and lack of essential infrastructure for dairy professionals to devote their expertise in the rural areas

- Excessive public sector red tape prevents fast progress in dairy development

- Absence of sound marketing channels that protect farmers interests

- Human population increases that result in human versus animal competition for grain causes the dairy industry to suffer poor nutrition and be unable to deliver its full potential

- Prevalence of common diseases due to lack of hygiene and poor management practices resulting in higher cost of production

- Due to the important role of buffalo, and its low productivity, there is lack of certainty over whether to have cows or buffaloes as the major dairy animal

There is a need to adopt clear cut and well defined strategies to develop the dairy sector in terms of implementation of national breeding policies, conserving and improving indigenous dairy cattle breeds, or to entirely replace them with crossbred cows, to continue the present situation, or to encourage corporate sector multinationals to decisively take over the dairy industry, without consideration of its implications to the rural economy and price structure, in order to protect consumers' rights. All these questions need to be addressed quickly to prevent market forces from making their own way to shape the future of Pakistan's dairy industry.

Cattle are important because they supplement seasonality of the buffalo lactation cycle to compensate for milk shortage, are a rich source of beef and milk, require less inputs to yield high fat milk, are more adaptable to local environmental conditions and dairy potential is higher. Despite these merits of cattle, there are limitations in dairy cattle production systems that prevent cows from being the main dairy animal. A declining population of pure dairy cattle, large nondescript draught cattle population (70%) with low dairy potentials, small herd size and scattered cattle populations prevent implementation of productivity enhancing breeding plans, consumer preference for buffalo milk which is high in fat and solids, poor nutrition due to the inability of farmers to feed cattle appropriately, inadequate disease control due to poor sanitary and management practices and inadequate AI provision from genetically superior sires to bring about permanent improvement in production potentials.

The future of dairy cattle production in Pakistan suggests either replacement of purebred native dairy breeds with crossbred and exotic cattle or conservation, utilization and improvement of native dairy breeds. To achieve the latter, it will be necessary to create a production oriented environment, keep records, select elite cows, provide in vitro production of progeny tested germplasm (and its use and preservation in gene banks), establish Open Nucleus Breeding Scheme at public sector cattle farms, develop technologies to produce alternate and inexpensive feed resources, improve milk collection, value added and marketing channels, promote cooperative dairy farming and credit facilities for small dairy producers and launch integrated national coordinated programs on cattle breeding, nutrition and health.

Growth Requirements of the Dairy Sector

The demand for milk and its products is expected to rise in Pakistan due to its fast population growth rate and increased per capita income. For the year 2010, the demand for dairy products is projected to be 36.9 million tonnes of fresh milk equivalent, whereas the production is estimated at about 34.3 million tones. This projected shortfall of 2.6 million tonnes would further burden the national economy through importation of dairy products. The only way to curb this trend is to take measures to bridge this gap, which would include long and short term measures such as:

Long term measures

- Augment genetic improvement of dairy cattle by combining conventional selective breeding techniques and mapping of quantitative trait loci (QTL) for milk production genes
- Innovative research in dairy nutrition to efficiently utilize agricultural by products due to global shortages of cereal grains
- Initiation of country wide epidemiological studies and disease management plans to improve veterinary coverage
- Proper dissemination of research findings to end users through a dedicated

and trained outreach work force

- Encouraging and financing public/private sector joint ventures for production and commercialization of dairy products

Short term measures

- Systematic and well planned crossbreeding of low producing cows with semen from genetically exotic bulls at a mass level.

- Improving milk collection and dairy market infrastructure by establishing and financing small dairy co-operatives to reduce milk spoilage during transportation.

- Establishing a public sector network of milk collection points in rural areas to ensure higher milk prices to producers and prevent private sector dairy processors from exploiting farmers.

- Establish dairy monitoring cells to protect the interests of consumers and milk producers, and to control malpractices in dairy marketing channels.

To meet the future demand for dairy products, the way forward is to promote commercial dairy production in the private and public sectors by providing financial/technical assistance and training to modernize the traditional urban/peri-urban and rural subsistence farmers by establishing small co-operative networks throughout the country, as well as attracting more investment to establish purely commercial dairy entrepreneurship. In order to make this happen, additional resources are urgently needed to develop the academic and research sectors in the dairy sciences of Pakistan.

CHAPTER II B

Dairy Feeding and Management Systems

Buffaloes

(M. Mushtaq, S. Shafiullah Khan)

In Pakistan, livestock production is primarily based on subsistence small holder farming. The majority of rural livestock farms follow crop-livestock mixed farming. More than 60% of buffalo and 56% of cattle are maintained in herds of less than six, and farm resource bases are highly variable. With the exception of some commercial dairies in peri-urban, and some rural areas, the predominant livestock production system of Pakistan is low-input . More than two thirds of livestock are maintained by small farmers who do not have enough resources to provide proper shelter, feed or disease protection. Thus many animals are unable to express their production potential.

Over the last fifty years, livestock production in Pakistan has undergone certain changes. At the time of independence from Britain, the economy was mainly dependent on agriculture, which was contributing more than 60% to national GDP, and more than 87% of people were earning their livelihood from agriculture or agriculture based industries. At that time, agriculture activities were almost entirely dependent on livestock. Indeed, large ruminants were used in every phase of crop production process including preparation of land, ploughing, increasing soil fertility, operating well based irrigation channels, harvesting of crops and post harvest handling, processing and transporting produce to nearby markets. In this system, which lasted until the mid 1970's, there remained a high demand for livestock numbers and little attention was paid to per animal productivity. In the absence of urban markets, most milk was consumed in rural areas.

Presently, more than 50% of the population of cattle and buffaloes maintained in Pakistan is in low-input production systems based on subsistence small holder farming systems. However this varies from province to province and species to species. About 34% of buffalo are maintained in a medium input production system, with high input production systems only operative in peri-urban or rural market oriented areas.

Herd size appears to be the major determinant of the type of buffalo production system in Pakistan. It indicates the availability of resources to the buffalo owner, as well as whether buffalo farming is the main or a subsidiary business in a mixed crop-livestock farm. The distribution of buffalo population by herd size in Pakistan, as reported in the Livestock Census of 1996, is in Table 1.

Table 1. Distribution of Herd Size in Buffalo

Herd Size	Percent Buffalo population	Cumulative (%)
1-2	18.1	18.1
3-4	24.5	42.6
5-6	17.4	60.0
7-10	19.6	79.6
11-15	10.2	89.8
16-20	4.2	94.0
21-30	2.9	96.9
31-350	1.6	98.5
More than 50	1.5	100.0

Buffalo Production Systems

Buffalo of Nili-Ravi and Kundi breeds are the major source of milk in Pakistan. Beef is a by-product of dairy buffalo farms, and buffalo beef constitutes nearly one half of the beef produced. In the early 1990's, buffalo produced more than 70% of total milk produced in Pakistan. Later, due to the increased number of crossbred dairy cattle, the share of buffalo milk in national milk production slightly decreased. According to the Livestock Census of 1986, buffalo milk constituted 66% of the total milk produced in Pakistan. Due to the absence of big urban markets, most milk was produced and consumed in the rural areas.

Rural small holders subsistence production systems

This production system covers the largest proportion of the buffalo population and, according to FAO (1987), more than 60% of buffalo are maintained under this system. The situation has changed over the years and currently 45-50% of buffalo are in this type of production system, where an average production unit is three buffaloes with 1-2 adults.

About 50 to 60% of the feed requirements are met from grazing. The remaining 40-50% of feed needs are met through feeding wheat straw and green fodders. Concentrates are seldom purchased. Average lactation yield per buffalo remains about 1200 liters and farmers try to ensure that at least one buffalo remains in production at all times. The members of the farmer's family will consume most of the milk produced.

Rural market-oriented smallholder production

Rural small farmers who have access to nearby markets practice this system, and for most of them market access is indirect through middlemen. About 30% of rural small holders are estimated to have an interest in producing milk for sale. However, over the last 15 years, this percentage has considerably increased because of establishment of a milk processing industry that provides milk collection services in rural milk pockets. Under this system, an average unit consists of 5-7 buffaloes, consisting of 3-4 adults and 1-2 heifers. Occasionally 1-2 male calves are kept, but buffalo bulls are rare. Lactating buffaloes are generally stall fed with green fodder, straws and concentrates. Dry buffaloes, heifers and male calves are almost exclusively grazed on waste land or crop stubbles. Under this system, average lactation yield ranges from 1,800 to 2,000 litres with a lactation length of more than 250 days. More than 50% of milk produced is either sold directly or through middlemen.

Rural commercial buffalo production

The development of commercial dairy farms started in Pakistan in the early 1980s. Currently, about one quarter of buffalo are in this type of production system. A typical rural buffalo farm running on commercial basis consists of more than 30 buffaloes, of which 60% are adult females. Approximately 40% of these adult females are in milk at any time of the year. These production units usually have animal sheds.

Fodder crops provide more than 50% of feed requirements, whereas straws provide about 35%. In this type of production system, the average lactation yield ranges from 2000-2400 liters per buffalo. Lactating buffaloes receive maximum attention in terms of feeding management and disease control. Dry animals however, are fed on cheap low quality feed ingredients and grazing is sometimes available. Female calves are kept as replacements but male calves are either sold or slaughtered at a very young age. More than 90% of the milk produced on these types of farms is sold.

Peri-urban milk production

Development of the peri-urban system began in response to growing urban demand for milk. Peri-urban milk production units are both large and small, with large production units located around major cities and smaller units established around towns and villages. Large peri-urban units have herds ranging from 20-50 head, almost all of which are adult females with more than 95% in production. Selected 3rd or 4th lactation animals, with calves, are kept over the lactation period of 250-300 days. Calves are generally slaughtered after the first week. Most dry animals are sold for slaughter, but a minority that get pregnant earlier are kept or returned to rural areas until they are ready to calve. Feeding varies with feed availability but usually includes wheat straw, chopped green fodder and concentrate, which is generally home mixed from wheat bran, cottonseed cake rice polishing or crushed wheat. Production average about 2,500 liters per lactation.

Urban milk production

Due to increasing urbanization over the last 2-3 decades, the large cities have expanded and the large peri-urban commercial dairy farms were converted into urban commercial dairy farms. The commercial cattle/buffalo colonies of Karachi are the oldest, and largest, peri-urban dairy colony of Pakistan which was converted into the largest urban milk production colony in the country. The colony is spread over 1500 acres where more than 200,000 dairy animals are maintained in about 2000 dairy farms.

More than 95% of dairy animals are buffaloes. About 70% of buffaloes maintained in the colony are purchased from Punjab, while the rest are brought form Sindh province. Feeding of lactating buffaloes, management of calves and breeding of dry buffaloes are practiced on the same lines as described for the peri-urban commercial dairy farm. Most dry animals are slaughtered in Karachi, but few are sent to rural areas of Sindh and other provinces for re-breeding and a new next lactation. Concentrate as well as fodder and roughages are purchased.

Current Feeding Practices for Buffaloes in Pakistan

Soon after birth, colostrum is fed to the newborn calf with no measured quantity or timing up to 4-7 days in urban, periurban and rural farms. From 7 days, whole milk is fed at 1-2 liters twice daily for female calves and ½ -1 liter twice daily for male calves, and continued up to 3-4 months. During this period only green fodder is fed with some wheat straw to males and females. After 3-4 months, female calves are fed ½ -1 liter of whole milk along with green fodder ad libitum while male calves are used only for let down of milk (i.e., suckling mother). Usually male calves are culled or sold to butchers.

Excessive feeding of milk and fodder leads to diarrhea, or death, and economic losses to the farmer. Due to potential death of the calf, farmers usually utilize oxytocin or a straw stuffed calf for milk let down.

There is no concept of early weaning of calves and feeding calf starter and milk replacer at any level. Use of cottonseed cake and wheat bran mixtures with dried bread is the conventional feeding practice for the buffaloes for let down of milk. Young female calves from 4 months to 1 year are fed green fodder, wheat straw and rice straw only, whereas male calves are sold to butchers without assessing their genetic worth in urban and peri-urban areas. In rural areas, male calves are kept for breeding and draught.

Feeding green fodder, wheat or rice straw and cottonseed cake is common for buffalo heifers in all three farming systems and this also occurs during pregnancy. However, urban farmers feed heifers an additional balanced ration along with wheat bran, mineral mixture and green fodder.

Total mixed ration (TMR) are used only on institutional farms. There is no concept of TMR or balancing ration in farm communities. In lactating buffaloes, feeding of cottonseed cake, wheat bran with green fodder and wheat straw is practiced in most rural areas, while a balanced ration is also fed in addition to conventional feeds in urban areas. Dry buffaloes are fed wheat/rice straw in rural areas while low producing buffaloes are sold to butchers and productive ones are fed green fodder and/or wheat/rice straw mixtures. Underfeeding of heifers results in delayed puberty, increased age at first calving, reduced fertility and increased calving interval, which ultimately leads to economic losses. Productive, reproductive and metabolic problems arise when buffalo breeders do not fed balanced rations with optimum nutrient levels.

Housing

Efficient management of animals is incomplete without a well planned and adequate housing. Improper planning in the arrangement of animal housing may result in additional labour charges and thus reduce the profit of the owner. During erection of a house for dairy animals, care should be taken to provide comfortable accommodation for individual animals. No less important is sanitation, durability and arrangements for production of clean milk under convenient and economic conditions.

Types of Management Systems

The most widely prevalent practice is to tie the buffaloes with rope on a katcha floor. It is quite easy to understand that unless animals are provided with good housing facilities, they will move too far in or out of the standing space, defecating all around and even causing trampling and wastage of feed by stepping into mangers. Animals can be exposed to extreme weather condition leading to poor health and low milk production.

Dairy animals may be successfully housed under a wide variety of conditions, ranking from close confinement to few restrictions except at milking time. However, two types of dairy barn are in general use, being loose housing barns in combination with some type of milking barn or parlor, and a conventional dairy barn.

Loose housing system

Loose housing is defined as a system where animals are kept loose except while milking and when physically examined. This system is the most economical because the cost of construction is significantly lower than in conventional types, it is possible to expand with few changes, it facilitates easy detection of animals in heat, animals feel free and are more profitable with even minimum grazing, animals get exercise which is important for health and production, and better management can be provided.

Conventional dairy barn

A conventional dairy barn is comparatively costly and is becoming less popular, although in this system animals are more protected from adverse climate conditions. The barns generally needed for proper housing of different classes of dairy stock on the farm include buffalo houses or sheds, calving boxes, isolation boxes, sheds for young stock and bulls, and bullock sheds. Buffalo sheds can be arranged in a single row if the number of buffalos are small (i.e., <10) or in a double row if the herd is large. Ordinarily, not more than 80-100 buffaloes should be placed in one building. In double row housing, the shed should be arranged such that the buffaloes face out (tail to tail) or face in (head to head).

Advantages of tail to tail system

Under average conditions, 125-150 man hours of labour are required per buffalo per year. Time and motion studies showed that 15% of expended time is spent in front of the buffalo, 25% in other parts of the barn and the milk house, and 60% behind the buffaloes. In cleaning and milking, the wide middle alley is a great advantage. There is a lesser change of spread of disease from animal to animal, and buffaloes can always get fresh air from outside. Any sort of minor disease, or any change in the hind quarters of an animal, can be detected quickly.

Advantages of face to face system

Buffaloes make a better showing for visitors when heads are together, the buffaloes feel easier to get into these stalls, the sun shines into the gutter where they are needed most, feeding of buffaloes is easier, and both rows can be fed without back tracking.

Milking

Buffaloes have been used for milk production for centuries. They have not been subjected to the same breed-upgrading as cattle of the western world. However, the buffalo is an excellent milk producer, given optimal circumstances. Milking of buffaloes is not a difficult task but one should, however, take care not to implement cattle milking techniques directly in buffaloes. As described below, the anatomy and physiology of the buffalo udder differs slightly from that of cattle.

Physiology of milking

For a comparison with cattle, buffaloes are said to be slow and hard milkers because of their slow milk ejection reflex and their hard teat muscle sphincter. The milk ejection reflex appears to be inherited to some extent, but it is also a product of the environment. In buffaloes, let down time averages two minutes, but may be as long as ten. Reasons for this are not fully understood, but it probably relates to the different anatomy of the udder versus that of dairy cows. In the buffalo, the udder cistern is absent, or has a very small volume, and there is little or no cisternal milk available. This leads to no intramammary pressure in the cistern which would otherwise help milk flow. In cattle, milk is already stored in the large cistern, and milk is available for extraction immediately after preparation. High intramammary pressure contributes in pressing out the milk.

The intramammary pressure increases at the onset of milking. It is highest during peak flow and decreases thereafter to zero at the end of milking. Pressure is generally higher in buffaloes during milking than in cattle but, as intramammary pressure varies between individuals and milkings, its level is not always indicative of high milk production. Let down time seems to be negatively correlated with milk yield, and let down time is shorter in early and middle stages of lactation versus late lactation.

Induction of milk let down

Physical stimulation of the teats, either by calf suckling or milkers hands excite receptors from which nerve impulses are sent to the posterior pituitary gland causing secretion of oxytocin, which is transported via the blood to the mammary gland. Because both hormones and nerve impulses are involved in the milk ejection reflex, it is called a neurohormonal reflex. Oxytocin stimulates contraction of the alveoli and small ducts thereby emptying milk into larger ducts and the cistern. Milk can then be evacuated from the udder. Contraction of the alveoli may, to some extent, be enhanced by tactile stimuli of the udder (e,g., massaging, squeezing), the so called 'tap reflex'. When calves suckle, they butt at the udder in order to increase milk secretion, and manual massage of the udder during milking imitates this reflex.

Like cattle, buffaloes get used to different stimuli. It is clear that oxytocin release is triggered by visual or audible stimuli, such as the sight of the milker, the noise of the vacuum pump or when entering the milking parlour. Animals become conditioned to let-down milk and have developed a conditioned reflex (versus an unconditioned reflex is suckling by the calf.). By letting animals get accustomed to a strict routine, time of milk let-down is shortened. In cattle, it has been demonstrated that feeding concentrate during milking speeds let-down, but this is yet to be shown in buffaloes.

Inhibition of milk let down

Buffaloes are sensitive to changes in the environment. They may withhold milk if they are uncomfortable, stressed, scared or in pain. In such cases, the hormone adrenaline is secreted which causes constriction of the blood vessels thereby hindering supply of sufficient oxytocin to the udder. Adrenaline also directly acts on myoepithelial cells in the alveoli by blocking oxytocin receptors. The resulting inhibition of milk let-down will result in leaving of milk in secretary parts of the udder. Continuous exposure of buffaloes to stress negatively affects milk production. Change of milker or milking routine, application of incorrect milking techniques, or milking machines in bad condition are other reasons for buffaloes to withhold milk.

Evacuation of the milk

Actual milking can begin after the letdown reflex has been elicited. Whether this is done by hand or machine, it is important to use proper routines. Milking should be as fast as possible without causing stress or pain and should be as complete as possible without excessive stripping. Elevated residual milk in the secretory part of the udder decreases milk secretion and negatively influences milk yield.

Machines for Milking Buffaloes

Since the udder and teats in buffaloes differ from cattle, milking machines for cattle have to be modified in order to fit buffaloes. In general, a heavier cluster, a higher operation vacuum and a faster pulsation rate is required. Results from recent studies in India indicate that it might be possible to reduce cluster weight and frequency of liner slip by applying an appropriate combination of liner design and cluster weight. While the total weight of the cluster is important, the distribution of its weight on the udder is also important since unequal weight distribution can cause uneven milk output. The long milk and vacuum tubes should be aligned and stretched to ensure equal weight distribution of the cluster on the udder.

Milking characteristics also depend upon vacuum levels and pulsation rates. Studies on Egyptian buffaloes revealed that a vacuum of 51 kPa and a pulsation rate of 55 cycles/min led to much longer milking times than a vacuum of 60 kPa and a pulsation rate of 65 cycles/min (6.21 min. compared to 3.18 min.). However the higher vacuum level caused an increase in somatic cell counts, and the highest milk yield within an acceptable time was with 56 kPa and 65 cycles/min. In all studies, a pulsation ratio of 50:50 was used. Studies in Pakistan indicate that pulsation rate and ratio should be 70 cycles/min and 65:35 respectively for Nili-Ravi buffaloes. In Italy, the majority of farms use the same machines for both buffaloes and cattle. In this case, it is a simple cattle machine with one vacuum level operating at approximately 40 cm Hg. In order to obtain all the advantages of machine milking, the correct technique must be used and milkers and buffaloes must be familiar with the machines. If buffaloes are scared or feel uncomfortable, they will withhold milk and yield less which leads to economic loss.

The concept of machine milking should be introduced slowly and by persons who the buffaloes are used to, and feel comfortable with, under the supervision of an expert. The procedure of introducing buffaloes to machine milking is below and recommended by Alfa Laval Agri as applicable for a whole herd where neither animals nor humans are familiar with machine milking. By carefully following these steps, a successful transition should be possible.

- Training of personnel. Training of milkers should be done by a person from the milking machine company. This person has a good knowledge of the biology of milking, machine milking, as well as with the design, function and maintenance of milking equipment. Training should include introduction procedures, milking routines, handling of machines, cleaning and maintenance, as well as aspects of day-to-day service of the machine.

- Installation of the milking machine in the barn, and any other modification in the barn, should be made well in advance of changing to machine milking.

- It is most appropriate to start with heifers since it is easier to accustom heifers than older buffaloes to machine milking. Older buffaloes may have been hand milked by a certain routine for several lactations and may respond negatively to a change in routine. Heifers, that are not accustomed to any specific routine, are more likely to accept machine milking rapidly. In addition, their udders and teats are more uniform and not damaged by previous milking. Liner slip and other negative effects of machine milking are less pronounced in heifers. Heifers should not be hand milked, but directly introduced to the machine as they will get accustomed to the noise of the machine milking process by being included in the milking routines..

- Calm animals that are comfortable with hand milking should be selected. The udders and teats of animals should be uniform with respect to conformation and size. Buffaloes in heat, or unhealthy animals or animals with previous let-down-problems, should not be selected.

- Milk old and selected animals as usual by hand, but let the vacuum pump run during milking to accustom animals to the noise. However, put the pump on before actual milking, but after the buffaloes have been tied up, since otherwise animals may be startled by the sudden noise. Repeat the procedure (usually 2 to 4 times) until all buffaloes are accustomed to the noise.

- Bring the milking machines into the barn. Connect them to the air line and place them at each buffalo's place at the same time as hand milking. This will allow the buffaloes to get used to the ticking sound of the pulsator, and it will give them a chance to look at the machines, and smell them, and maybe even taste them. Move the machines to the next buffalo to milk her as this makes the buffaloes used to the machines being moved. The procedure should be repeated (usually 2 to 4 times) until all the animals have accepted the presence of the machines.

At this stage, all buffaloes should be well accustomed to the new routine. If some buffaloes are still showing signs of nervousness or stress, it is recommended to repeat the above mentioned steps until the animals are calm. After this procedure, buffaloes that have not accepted being milked by machines should be returned to hand milking. One or two frightened or uncomfortable buffaloes can cause major disturbances in the milking process. Consistency with respect to milking routine, including pre-milking preparation, should be applied from the beginning of the introduction, and the regular milker should carry the machine milking during introduction. When the cluster is firmly attached to the udder, the milker should stay with the buffalo to see that she is comfortable. Soft talking and brushing and scratching are best to calm an animal. These first sessions of machine milking usually require a longer time. However, this time is well worth it to assure calm and easy-milking buffaloes.

Breeding

Throughout the buffalo world, little attention has been paid to breeding techniques aimed at improved productivity, and it is only in a few areas that modern principles have been applied to domestic buffalo. Official policies for encouraging development of buffalo rearing are often opposed by advocates of introduction of exotic breeds of cattle. Where essential husbandry skills are present, and nutrition and health control can be improved, a gradual and enduring change in productivity of buffaloes can be expected by selective breeding. In other countries there are official projects for milk recording, herd books, progeny testing and artificial insemination, and there are signs of awakening interest in this area in Pakistan.

The amount of practical research devoted to improving buffaloes, compared with cattle, is negligible. Resources should be allocated to studies of fodders and management systems. Genetic upgrading requires improvement in all aspects of management.

Reproductive efficiency is defined as activity of an individual to produce offspring. In order to obtain maximum output, the main interest of a breeder is to achieve more calves in a cow's life, reduced mortality as well as healthy and superior calves. There is great potential to increase fertility and productivity of farm animals, perhaps as much as 100% by using a three pronged approach with a weight of 30% on improving reproductive management, 40% by use of modern reproductive tools and 30% by control of reproductive disorders

Low reproductive efficiency of buffaloes remains an economic problem, and its incidence is higher in Pakistan. Climatic stress, nutritional deficiencies, improper management and lack of disease prevention are contributing factors. Major reproductive problems with buffaloes are delayed age at maturity, anestrus in heifers, repeat breeding and certain obstetrical problems such as genital prolapse, torsion and retention of placenta and endometritis.

- Congenital/hereditary causes – ovarian hypoplasia, aplasia and organ malformations.

- Acquired environmental causes – stress on reproduction due to somatic diseases such as Brucellosis and Tuberculosis; Puerperal infections and congenital infections, ration nutrient deficiencies, poor fodder composition and poor climate management.

Subestrus

Subestrus or silent estrus is another important ovarian dysfunction in buffaloes where behavioral signs of estrus are not manifested. Such cases are usually reported from the field by livestock owners. Gynecological examination of such animals usually reveals the presence of a palpable corpus luteum (CL) and characteristic cyclic changes in the genital tract, which shows that the animal is probably normally cyclic and that the heat manifestations are not prominent enough to be observed. The first heat after attaining puberty or after calving in buffaloes are not exactly preceded by behavioral signs of estrus, which leads to a truly silent heat. The incidence reported for this condition is 10-15% in organized farms to as high as 34-36% in villages. The occurrence of subestrus in buffaloes has been reported to vary from 6-30%.

Since nutritional factors are crucial predisposing factor to subestrus, management of this condition relates to regression of the CL of the previous cycle. Thus PG is the drug of choice and has been found effective, but in addition to improving nutrition and management during this phase of reproduction. Many hormonal preparations, such as estrogen, progesterone, gonadotrophins, prostaglandins, either alone or in combinations, and non-hormonal preparations such as Prajana, aloe compounds, clomiphene citrate, Janova and many others have been tried with varying degree of success.

Management of these conditions is usually attempted by either manual rupture or use of hormones such as LH, progesterone, GnRH and prostaglandin. Since delayed ovulation, anovulation and cystic ovaries are always associated with a lack of adequate LH surge, practices of using LH for such conditions are common. Beta-carotene is known to reduce the incidence of ovarian cysts.

Predisposing management factors are genetic selection for high yield, larger groups of animals, stressful conditions, higher parity number and post-parturient uterine infections.

Disease Control

Diseases of buffaloes have assumed considerable economic importance in development of dairy industry in Pakistan. The common buffalo breeds are Nili-Ravi and Kundi in big farms and a substantial number of small farmers keep 1-2 lactating animals for domestic consumption. Animal hygiene deals with numerous factors associated with, or present in, the surroundings in which animals live. In its practical application, animal hygiene covers the causes of all preventable animal diseases and devises means of removing those causes or making them ineffective. It also increases the efficiency of animals as food producers to the optimum level by providing them with favorable conditions of life with regard to water, air, and well-ventilated and well-drained housing.

Disease control is essential for maintaining high standards of animal health, and disease prevention is the first line of defense. It is becoming more and more important in Pakistan for the following reasons:

- With the increasing economic importance of livestock, there has been a change from farmers keeping a few animals for subsistence to livestock farming as an industry. With this shift to intensive livestock farming, a number of organized farms have been established and more are being established.

- The tropical and subtropical climate of the country is conducive to breeding and survival of insects, ticks and other vectors of infectious diseases.

- The density of the animal population is increasing.

- The physical movement of livestock is unrestricted and increasing.

- The density of animal populations in the private and state sectors have a profound effect on animal health. Vast lands, previously available as pastures, or which could be developed into pastures, have been brought under cultivation. This results in intimate contact among animals and between people and animals. This emphasizes the importance of veterinary epidemiology and public health.

- Deforestation to increase availability of cultivable lands has resulted in an ecological imbalance between plants and animals. Similarly canal irrigation has created water logging and, indirectly, parasitic disease of livestock in such areas through intermediate hosts such as snails.

Nutritional and Metabolic Disorders

High yielding animals need special care in feeding and management. Some diseases occur due to faulty feeding management practices. The metabolic disorders most encountered are related to production, especially in high yielding animals, and thus are also called production diseases. Nutritional and metabolic disorders in cattle and buffaloes include indigestion, acidosis, tympany, milk fever, ketosis, hypomagnesaemic tetany, pica, haemoglobinurea, rheumatic syndrome, selenium toxicity, vitamin A deficiency and plant poisoning.

Indigestion is a common disease in cattle and buffaloes due to variable feeding, over feeding, feeding of indigestible roughages (especially those low in protein), feeding of moldy, overheated or roasted feeds, sudden changes in concentrate to roughage ratios (i.e., excess grain or concentrate in diet) or prolonged oral use of antibiotics or chemotherapeutics. The disease is manifested by loss of appetite and atony of rumen. Limited supplies of drinking water or feeding poor quality silage also cause indigestion.

Acidosis, also called acute acid indigestion, or acute impaction of the rumen or rumen overload, is due to incidental or accidental feeding of excess grain or grain mixtures. The disease is characterized by indigestion, ruminal atony, stasis, systemic acidosis, dehydration, injected (bright red) eyes, grinding of teeth, dry nose, increased pulse and respiration rate, passage of soft grey coloured smelly faeces, incoordination in movement and collapse. The disease is associated with sharp decrease in ruminal pH. The disease can be fatal for cattle, buffaloes and other polygastric animals. Access to large quantities of grains (raw and cooked) should be avoided. Any increases in diet concentrates should be gradual. For example, an increase in concentrate: forage ratio from, , 50:50 to 60:40 should be over 6-7 days.

Tympany, or bloat or ruminal tympany, is excess accumulation of gases in the rumen and reticulum either in as free (dry bloat) or mixed with fluid and ingesta (frothy bloat). The disease is very common in animals grazing on rapidly growing, young, succulent pastures during the monsoon season, or consuming pre-bloomed leguminous fodders during the rabi season. The cause of frothy bloat (also called primary bloat) is the presence of compounds such as saponins, pectins, hemicellulose, gums and some proteins, which produce foam in the rumen. Prevention of bloat is difficult under practical conditions, but feeding of straw/stovers in the morning before grazing reduces the chance of bloat. Succulent legumes should be mixed with straw/stovers and introduced gradually. Feeding of mineral oil (60 g twice daily with grain) helps prevent bloat.

Milk fever or parturient paresis is a disease of high yielding animals which usually occurs immediately after calving due to a sudden decrease in blood calcium to 4-5 mg/100 ml. A large amount of calcium is drained out through milk, but the parathyroid gland fails to mobilize bone calcium to restore blood calcium level. The disease is characterized by loss of appetite, reluctance to move, no fever, shaking of the head, grinding of teeth, sternal recumbency (head turned into the flank), unable to stand, dry muzzle, weak pulse, constipation, lateral recumbency and inability to sit. Feeding of high phosphorus (Ca:P ratio 1:3.5) during the last month of pregnancy is helpful in preventing milk fever. Rice and wheat brans are rich sources of P (1.2-1.5%) and has a laxative effect, thus making it beneficial during the last month of pregnancy. Three doses of calcium (100 g daily) with feed or as drench on the day prior to calving, just before calving and 12 h after calving give excellent results in preventing milk fever.

Hypomagnesemia

It is also referred to as grass tetany, grass staggers or lactation tetany, and is characterized by tonic convulsions and muscular spasm. The disease occurs due to a deficiency of magnesium in the body. High producing buffaloes excrete more magnesium in milk and, if it is not replaced by a dietary source, hypomagnesemia develops. Calves maintained on magnesium deficient milk or milk replacers can also suffer from it.

Phosphorus deficient haemoglobinuria

It is also known as haemoglobinuria and characterized by intravascular haemolysis, haemoglobinuria and anaemia. The disease is related to a deficiency of phosphorus and can occur due to feeding of low phosphorus containing feeds for long periods. Molybdenum and copper can compete with the absorption of phosphorus and cause the disease.

Future Perspectives of Buffalo Dairying in Pakistan

A milk buffalo is generally looked upon as a prestigious possession of the family, as the number of buffaloes kept by farmers determines their wealth and status in society. To the rural poor and landless, in house buffalo farming provides a means of subsistence. During the last two decades there has been a growing awareness of the need to develop a buffalo-based dairy and meat industry in the near and far eastern regions.

There are 28.4 million buffaloes in Pakistan and, in spite of having such a large number, the country is spending some US$40 million annually on import of formula milk, which is the highest amount spent by any country in the world. This discrepancy may be due to neglect of buffaloes in the past. Although there are problems related to this species which contribute to its poor performance, such as late age at maturity, long anoestrus period, long calving interval and silent heat, they can be solved through better management. It seems clear that Pakistan has the best dairy buffalo breeds (i.e., Nili Ravi and Kundi) but they are not producing up to their potential, mainly due to poor management. Despite these problems, there is room for improvement and buffaloes can play a role in uplifting Pakistan's economy.

To improve the productivity of buffaloes, following actions are suggested:

- Genetic parameters such as genetic variation, heritability, repeatability, genetic correlation, should be worked out by biometrical techniques. Because genetic studies on buffaloes, specifically Nili-Ravi's, are scanty, this would provide basic information for adopting methods of selection for genetic improvement.

- Systematic milk recording is a prerequisite for progeny testing and to evaluate achievements made by artificial insemination services.

- Milk recording practices seem inevitable but cannot be undertaken without formulation of local co-operative Dairy Herd Improvement Associations.

- Progeny testing and evaluation of sires is a must for breakthrough in the dairy industry. Programs for proving sires would provide opportunities for widespread use of quality sires to upgrade non-descript and low yielding buffaloes. The breeding values of sires, and their evaluation of worth, could be assessed by determining their predicted difference (PD), which is the difference between daughter average and herdmate average, making it the best technique for evaluating and ranking sires. It would take from 5-10 years to get enough proven sires if extensive AI services are available. Castration of all potent non-descript males would minimize chances of entry of detrimental genes into herds. It may be that these castrated calves would have a better growth rate, and produce good quality beef adding substantially to farm income.

- Existing AI services need to be strengthened to help eliminate low fertility and scrub bulls and accelerate the pace of the genetic improvement of buffaloes.

- Research has shown that nutritionally balanced feeding reduces the age at first calving. It is hoped that with selection and feeding, age at first calving could be reduced to about 30 months in buffaloes. Also, vaccination for brucellosis and other diseases at appropriate time would reduce chances of contagious abortion that is so common in Pakistan.

- High yielding fodder varieties grown under improved agronomic practices should increase production of green fodder. Animal herders at the village level should be made aware of the potential to use urea and molasses with roughages to improve their nutritive value and the production of their animals.

- There is a need to establish modern milk processing and packaging facilities based on advanced technology to convert abundantly available raw milk (especially surplus in winter) into high value added dairy products.

- There is a need to improve and extend livestock extension services at the village level. Again, due to scattered livestock herders in the villages, they should be organized in specific areas in a community participation approach.

CHAPTER III

Milk Production, Quality and Storage

(N.F. Perera, U.L.P. Managalika,
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Milk is a complex colloidal dispersion of fat globules and protein in an aqueous solution of lactose, minerals and other minor constituents. The composition of milk varies among species and breeds of mammals. For example, cow milk is about 87.5% water and 12.5% milk solids (3.8% fat, 3.4% protein, 4.6% lactose and 0.7% minerals, while buffalo milk contains 82.7% water, 7.5% fat, 4.2% protein, 4.8% lactose and 0.8% minerals. In addition to differences among species, milk composition among animals within species is affected by factors such as breed, stage of lactation, diet and disease.

Physical Properties of Milk

The colour of milk ranges from bluish white to golden yellow depending on the species, feed eaten and amount of fat and solids. The white colour of milk results from dispersion of reflected light by fat globules and colloidal particles of casein protein and calcium phosphate. The yellow colour is due to the pigment carotene in fat globules.

Milk produced under hygienic conditions has a slightly sweet taste and a fresh flavour and aroma. The sweet taste is due to the milk sugar lactose, while flavour and aroma is principally from milk fat.

Specific gravity of cow milk normally varies between 1.028 – 1.034, making milk slightly denser than water. The boiling point of milk is slightly higher (i.e., 100.3°C) than water because of milk solubles. The freezing point is slightly lower than water and depends on the content of lactose, protein and minerals. The freezing point of cow milk is about -0.513 to -0.551°C. Milk is slightly acidic with a pH that varies between 6.6 and 6.8. The viscosity of milk is slightly higher than water, normally in range of 1.5 to 2.0 cP.

Microbiological Quality of Milk

High quality milk should be free of pathogenic microorganisms and have a low count of total microorganisms. Microbiological quality of milk and milk products is influenced by the initial flora of raw milk, processing conditions and post pasteurization storage.

Raw Milk

Raw milk leaving the udder of healthy animals normally contains very low numbers of microorganisms and the total microbial count is usually less than 10^3/ml. *Micrococcus, Staphylococcus, Streptococcus* and some gram-negative bacteria are the most common bacteria in raw milk. However milk from cows with mastitis may contain large number of infectious organisms, such as pathogenic *E. coli* and *Listeria*, that contribute to higher total microbial counts of raw milk.

Milk can become contaminated with microbes from surfaces of cows, the environment and unclean milking systems after leaving the udder. If the cow is healthy, then the milk secreted from the udder is highly hygienic. Thus, contamination is mainly post extraction. The number of microbes of a psychrotrophic nature are increased in raw milk held at refrigerated temperatures in cooling tanks. *Pesudomonas, Flavobacterium* and *Alcaligenes*, and some coliform bacteria, are known to be as predominant as psychrotrophes. Microbial numbers in raw milk should be minimized.

Pasteurized Milk

The microbial population of freshly pasteurized milk primarily consists of thermoduric bacteria which survive at pasteurization temperature, and spores. Types and numbers depend on the microbial population in raw milk prior to sterilization. Commonly found are *Microbacterium, Micrococcus, Bacillus* spores and *Clostridium* spores.

Milk Synthesis and Secretion (Anatomy and Physiology)

The udder of a cow or buffalo consists of four quarters that are uniquely designed to synthesize and secrete milk for nourishment of the young. The quarters (Figure 1) are independent of each other in structure and function, with the front two being slightly smaller (40%) than the rear (60%). As a result, the rear quarters produce more milk than the front. Each quarter has secretory (parenchyma) and supporting components (stroma). The quarters are joined by connective tissue and muscles, and held to the body wall (suspended) by ligaments with no reinforcement from any skeletal structure. Improper milking procedures, or excessive milking intervals, creates stretching of the ligaments due to weight of the milk filled udder that can result in permanent loss of elasticity of the suspensory ligaments leading to pendulous udders that are prone to physical injury. In judging dairy characteristics, firmness of udder attachments (Figures 1 and 2) is consideration. The udder is covered with skin which functions as a supporting structure, while the ducts that convey milk produced in each quarter open to the exterior through a teat. Skin on the teat is innervated to the sympathetic nervous system and is hairless.

Figure 1. Quarters of the udder

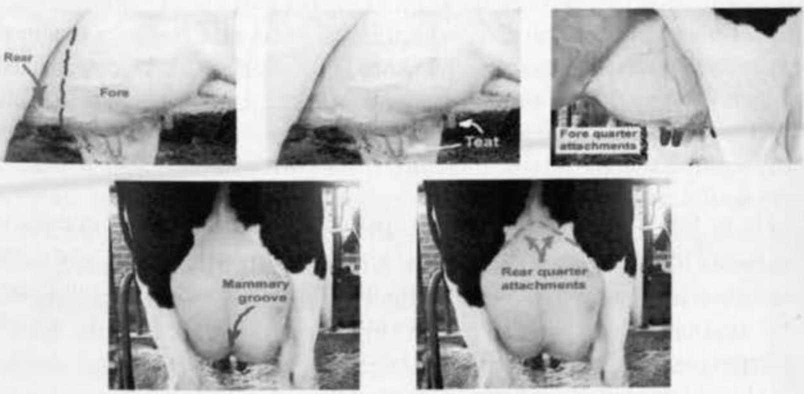
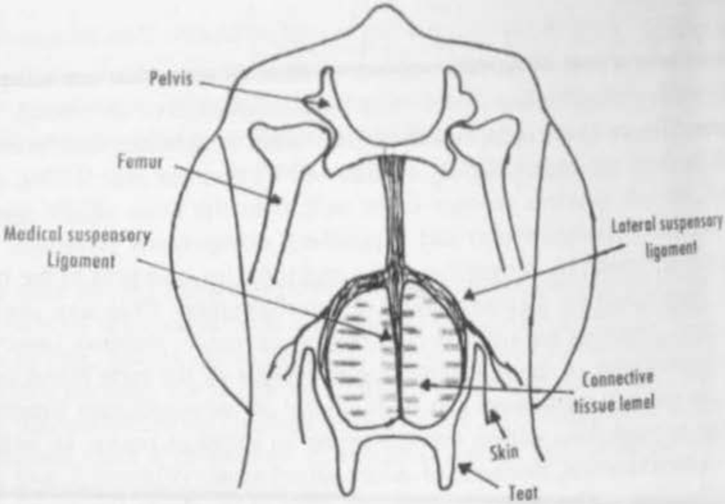


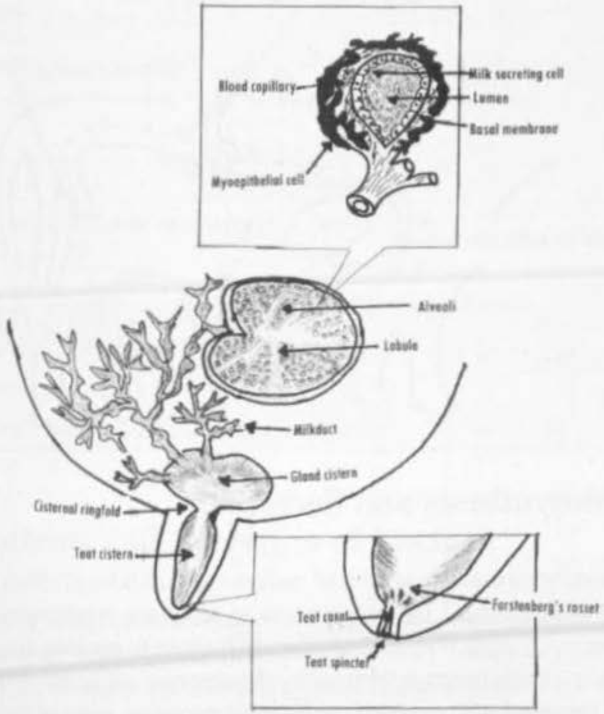
Figure 2. Attachments of udder to the body of a cow



Microstructure of a mammary gland

Internally, the secretory component (parenchyma) of each quarter is comprised of a lobuloalveolar and duct system. The basic unit of the lobuloalveolar system is an alveolus, which is a balloon-like structure made up of a single layer of alveolar epithelial cells attached to a basement membrane located surrounding a central space called the alveolar lumen, which is connected to a duct system. Between the alveolar epithelial cells and the basement membrane is a layer of specialized contractile cells called myoepithelial cells. Alveolar epithelial cells are equipped with all cellular organelles and enzyme systems necessary for biosynthesis and secretion of milk compounds, while a rich capillary network surrounding the alveoli supplies blood precursors for milk biosynthesis. Alveolar lumen stores secreted milk between milkings. About 150-220 alveoli are joined together by connective tissue to form a much larger structure called a lobule. Several lobules are joined together by connective tissue to form a lobe. Each alveolus is drained by a terminal ductuli, which join to form much larger lobular ducts to drain the lobules. Lobular ducts join to form much larger lobar ducts that drain the lobes. The lobular ducts of each quarter empty into a much larger sinus called the gland cistern, which is located within each quarter. The volume of the gland cistern is about 400 ml, and it opens to a smaller cistern space within the teat (teat cistern) through a cricoid fold. The teat cistern ends in a teat canal equipped with keratin secreting Furstenburg's rosette at the upper (cisternal end) end and a canal-closing teat sphincter at the distal external end (Figure 3).

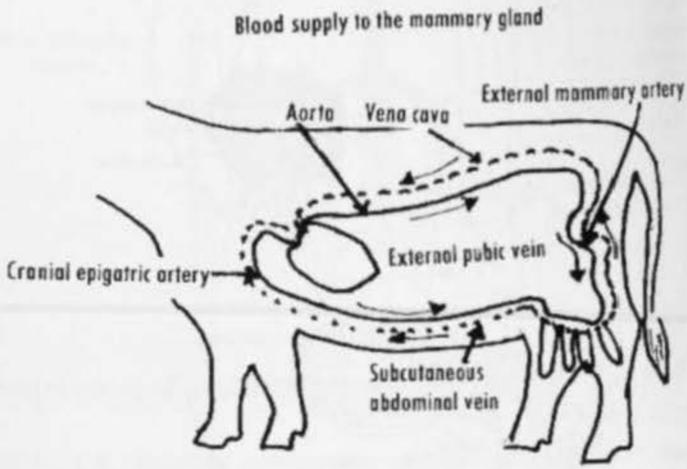
Figure 3. Macro and micro structure of a mammary gland of a cow



Blood supply to the mammary gland

The mammary gland has an extensive vascular network (Figure 4) to ensure a rich supply of blood since all the compounds needed for milk synthesis must be obtained from blood. The rate of blood flow to the mammary gland, the number of alveoli, and the efficiency of synthesis are key-determinants of milk yield. In accomplishing biosynthesis and secretion of milk, the lactating mammary gland exerts a tremendous strain on the body, especially in high producing dairy cows and buffaloes. It has even been suggested that, in terms of nutrient requirements, the cow should be considered as an appendage to the udder rather than the udder being considered as an appendage to the cow.

Figure. 4. Blood supply to the mammary gland



Milk Biosynthesis and Secretion

Milk biosynthesis is the synthesis of milk compounds by alveolar epithelial cells. However, not all the components in milk are synthesized *de novo*. Only mammary specific carbohydrate (lactose), protein (casein) and triglycerides (lipids) are synthesized by the alveolar epithelial cells utilizing absorbed precursors from blood, while some proteins, most of the minerals, vitamins, ions and water are selectively absorbed and/or directly transported into the alveolar lumen through transcellular and paracellular pathways. Milk secretion is the passage of milk components (both synthesized and non-synthesized components) from alveolar epithelial cells into the alveolar lumen.

The primary substrates extracted from blood by the alveolar epithelial cells include glucose, amino acids (both essential and nonessential), fatty acids and minerals. In ruminants, acetate and beta hydroxybutyrate are also major substrates extracted from the blood (Table 1 and Figure 5).

Table 1. Blood nutrients contributing to milk constituents in ruminant mammary glands

Milk Constituents	Blood Nutrient (Precursor)
Water	Water
Lactose	Glucose
Fat	
Long chain fatty acids	Long chain fatty acids
Short chain fatty acids	Acetate,β hydroxy butyrate
Glycerol	Glucose, glycerol from triglycerides
Protein	
Casein	Amino acids
β lacto albumin	Amino acids
α laco albumin	Amino acids
Milk serum albumin	Blood serum albumin
Immune globulins	Immune globulins
Minerals	Minerals
Vitamins	Vitamins

Biosynthesis and Secretion of Lactose

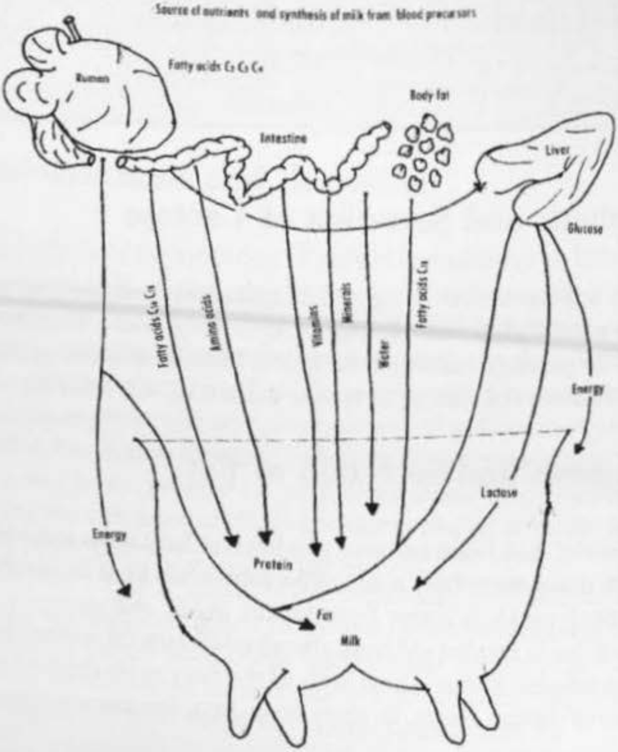
Lactose is a disaccharide composed of galactose and glucose covalently bound by a ß1-4 glycosidic linkage that is only found in milk. In fact, lactose is the primary carbohydrate found in milk of most species, and is the most constant constituent in bovine milk (i.e., 4.5 – 5.1%).

Biosynthesis and Secretion of Fat

Biosynthesis of milk lipids involves synthesis of fatty acids and esterification of glycerol using these fatty acids. The fatty acids used to synthesize milk fat (i.e., triglycerides) come from blood lipids and *de novo* synthesis. Circulating lipids are derived from absorbed dietary fat and mobilized fatty acids from adipose tissue. About 80% of the fatty acids derived from blood plasma are of dietary origin. In dairy cow diets, fats consist mainly of long chain fatty acids (palmitic, C16:0; stearic, C18:0; oleic, C18:1, linoleic, C18:2; linolenic, C18:3), and the unsaturated dietary fatty acids are largely saturated due to biohydrogenation by ruminal microbes. Thus fatty acids in adipose tissue and in milk of dairy cows are more saturated than those of the diet.

Almost all C4 to C14 fatty acids (i.e., short and medium-chain fatty acids) are synthesized *de novo*. The mammary gland of the dairy cow utilizes acetate for short-chain fatty acid biosynthesis and also as an energy source. As much as 40% of the acetate is made available for udder metabolism. Approximately 50-60% of the energy used for milk synthesis is derived from free fatty acids, while 40-50% is used for fat synthesis. Manipulating the diet of the dairy cow can substantially alter the balance between mammary *de novo* synthesis of short and medium chain fatty acids and dietary long chain fatty acids presented to the mammary gland.

Figure 5. Sources of nutrients and synthesis milk from blood precursors



Major Factors Affecting the Composition of Milk

The composition of milk varies due to factors such as genetics (heredity), lactation stage, age, nutrition, milking procedure, infection of mammary gland and environment.

Heredity

Milk fat content varies among animal species. For example, buffalo milk contains higher fat than cow milk. In cow milk, the milk fat content of local breeds is higher than crossbreds and European breeds and, in European breeds, the fat content of Friesians is lower than Ayrshires and Jerseys.

Table 2. Composition of milk from different species (g/100g)

Species	Protein	Fat	Carbohydrate	Energy
Cow	3.6	3.8	4.6	66
Human	1.1	4.2	7.0	72
Buffalo	4.1	9.0	4.8	118
Goat	2.9	3.8	4.7	67

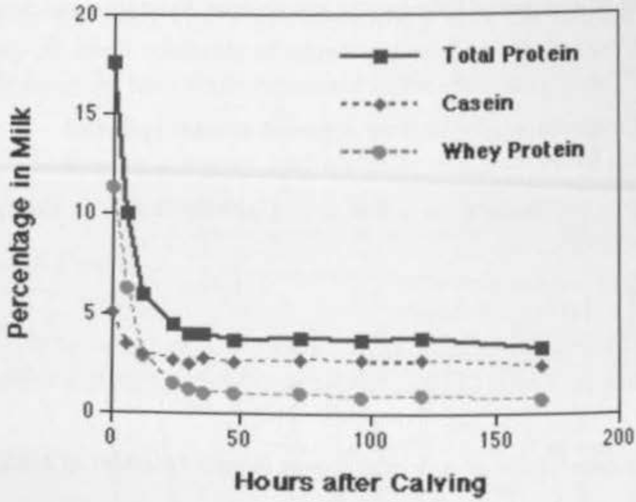
Table 3. Composition of milk of different breeds (g/100g) of cattle

	Fat	Protein	Lactose	Total solids
Friesian	3.54	3.43	4.68	12.34
Brown swiss	3.80	3.21	4.80	13.08
Ayrshire	3.72	3.38	4.60	12.50
Guernsey	4.72	3.75	4.71	14.04
Jersey	5. 37	3.98	4.64	14.72
Shorthorn	3.56	3.32	4.51	12.27

Stage of lactation

Milking of cows for human consumption is initiated 2 – 3 days after calving. Prior to that, the composition of milk differs from the normal milk. This first milk is called colostrum, which is an essential initial feed for the calf. However, after about two days, the composition of colostrum gradually changes to that of normal milk (Figure 6).

Figure. 6. Changes taking place in composition from colostrum to milk



The composition of milk changes with the progress of lactation. The fat, protein and ash exhibit tendencies to decline in concentration during first eight weeks of lactation but, after about eight weeks, these components remain constant or rise gradually until the end of the lactation. Changes in lactose concentrations are small and, in general, are the opposite of those for the other constituents.

Age of the cow

The solids-non-fat content of milk tends to decrease with the age of the cow.

Milking procedure

The proportion of fat increases during the milking process making complete milkout very important to obtain milk with the highest fat content. Milking frequency also affects milk composition, as morning milk contains a lower fat level than evening milk.

Nutrition of the cow

Nutrition has a noticeable effect on milk composition, mainly the fat content. While the solids-non-fat content of milk, which consists of protein, lactose and minerals, also varies with changes in the nutritional status of the cow, it does so to a lesser extent than fat. Inadequate levels of dietary fiber in the diet, due to overfeeding of concentrates and/or low feeding levels of roughages, are the most common causes of low milk fat content.

Due to difficulties in obtaining forages with moderate to high digestibility, cows are often fed excessive levels of concentrates which contain large amounts of soluble carbohydrates. These soluble carbohydrates change in the profile and size of the microbial population of the rumen by disrupting microbial fermentation that leads to a decrease in milk fat content. The major sources of energy for ruminants in plants are generally cellulose and hemicellulose which ferment to volatile fatty acids (i.e., mainly acetic, propionic, butyric) in the rumen and, after absorption, are an important source of energy for ruminants. Acetic acid is a major precursor of milk fat while propionic acid is a major precursor for body fat. The ratio of acetic to propionic acids produced in the rumen is mainly determined by the diet. In general, diets high in fibre result in production of more acetic acid, which increases the milk fat content. In contrast, diets low in fibre and high in concentrate tend to increase propionic acid production which leads to lower milk fat percentage. Therefore, maintaining an optimum level of fibre in the diet is important to obtaining a high milk fat content, and milk yield.

The main reason for low SNF in milk is underfeeding as energy intake is closely associated with the SNF content of milk. Changes that occur in SNF are primarily due to changes in the protein, and occasionally the lactose content of milk. Feeding more protein seldom has an effect on the milk protein content. However feeding extra energy will often increase the SNF content of milk, which can be maintained by good feeding and management practices.

Disease condition

Diseases that cause elevated body temperature of the cow will affect milk yield and composition. A decline in all milk solids is caused by subclinical and clinical mastitis.

Milk Let Down

Milk that is produced in the mammary gland is held at high tension and no force can easily remove it from the udder. Removal of milk requires a stimulus to the biochemical process that relieves tension in the alveoli to release milk from the *gland cistern* to the teat cistern and from there to the outside of the cow via the streak canal. This stimulus is induced by a suckling calf or the touch of the udder by the milker. In addition, the presence of a regular milker, the sound of milking buckets and, often in high producing cows, the regular time of milking, are external factors that stimulate milk letdown. When these physical stimuli are received by the cow, nerve impulses communicate to the brain (hypothalamus), which sends a signal to the posterior pituitary gland to release the hormone *oxytocin*. Once the hormone reaches the udder, it stimulates contraction of the alveoli to release milk. These contractions occur 20 – 60 seconds after the initial stimuli. The squeezing action of milking increases intra-mammary pressure and forces milk through ducts to the gland and teat cistern. *Oxytocin* has very short activity, lasting only 6 – 8 minutes, because its concentration in blood diminishes very rapidly.

Similarly when the physical environment is unpleasant and/or the cow is disturbed by external factors such as pain, fear or excitement, the adrenal gland will immediately release the hormone *adrenaline*. This constricts the blood vessels to reduce the blood supply to the mammary gland thereby restricting the amount of *oxytocin* reaching the mammary gland, which has a negative effect on milk letdown.

Removal of milk from the udder

Once milk letdown is initiated, milk in the udder is withdrawn by a suckling calf, hand milking by a milker or by machine milking.

During hand milking, the hand grasps the whole length of the teat. As the thumb and the forefinger pinch off the upper end, the rest is squeezed by the other three fingers inwards and downwards. This force forces milk through the streak canal. There are many methods of handmilking that vary the pressure exerted upon the teat to withdraw milk. Common ones are full hand milking or dry fist, strip, knuckling and pinch milking.

Milking for High Productivity and Quality

Milking for high milk yield and quality is a primary objective of dairy farming because it is the major determinant of profitability. Therefore lactation is the most important, and essential, physiological function of a dairy animal. The most important factor may be the relationship between the milker and the cow, as milking is a team effort, and closer relationships between the cow and the milker tend to result in higher milk quality and quantity.

Hygienic milking is very important since milk is highly vulnerable to microbial spoilage and rapid spoilage. To achieve hygienic milking, good management practices must be followed, such as the milker ensuring that during milking the udder is not damaged and contamination with foreign matter is prevented. There are few steps that should be followed to ensure hygienic milk production.

Clear identification of the cows to be milked

The cows should be well known to the milker, which is very important when there are many cows in the herd. This may not be a problem in countries where most cattle owned by smallholders. However on larger farms, identification can be done by tattooing, branding or ear, neck or tail tagging.

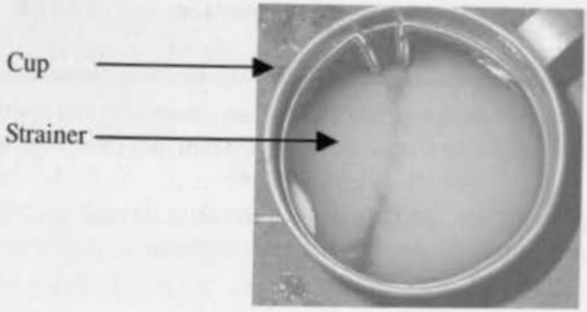
Udder preparation prior to milking

In healthy cows, milk in the udder is relatively hygienic but gets contaminated during or after extraction. Therefore, care should be taken to ensure milk is not contaminated during milking and storage. Cleaning the udder with fresh water prior to milking is a must and, if machine milking is used, cleaning the udder alone is sufficient. However, as practiced in smallholdings, hand milking preparation should include cleaning of the abdomen, and even the rear side. For cleaning, fresh water should be used with, if necessary, a light soap solution. Availability of fresh water during milking is important.

Once the washing is complete, the udder and teats should be dried by cleaning with a disposable tissue or towel. If these are expensive, a clean piece of cloth can be used. If a cleaning cloth is not available, allow the udder and the teats to dry naturally. Udder cleaning should be just prior to milking, since early cleaning may slow milk letdown.

Milking is the best opportunity to closely observe the cow for changes in the teats and udder. Often wounds, edema and other problem related signs can be easily detected. After cleaning the udder, but prior to milking, one must ensure that all quarters of the udder are healthy and the milk is hygienic. To do this, the udder and the teats should be examined physically. Any reddish, swollen teats or quarters must be given special attention as they may be infected. Udder infection means that the milk in that quarter is contaminated with high levels of bacteria. Common abnormalities are clotting and the presence of blood that changes the milk colour from white to pale pink. These udders can be easily identified by the "strip cup test", which uses a strip cup that is a plate with a handle having 4 shallow cups with a black coloured bottom. Since milk is white, any abnormalities can be easily observed on the black background. A strip cup can be made at home for resource poor farmers, by using a normal cup with a handle and fastening a black piece of cloth over the mouth with a rubber band. Draw the first streak of milk into the strip cup from every teat. If any change is observed in a particular streak, then check that quarter for abnormalities. During milking, milk the suspect teat last and do not mix the milk with the other milk unless you are sure that milk is clean and healthy. In case of any doubt, discard this portion of the suspected milk. If this occurs, seek the assistance of a veterinarian.

Figure 8. A strip cup



Adoption of consistent milking techniques

Good milking technique should be adopted to ensure complete milking and low damage to the udder. Machine milking is common on large commercial dairy farms, but smallholder farms generally use a hand milking procedure.

Hand milking

Hand milking is the most common milking method in tropical developing countries. This method is inexpensive and most farmers are experts in the technique. The correct and best milking method is with the whole hand, in which the teat is held in the hand and milk is expressed with the fingers, just as a calf would take the whole teat in its mouth and expresses the milk with its tongue. With this method, no lubricating ointment is necessary. An experienced hand milker never pulls or stretches the teat and, while milking, no body movement of the milker can be observed since only the fingers and palm are active. Full hand milking maintains a strong letdown reflex, and is a rapid technique to withdraw milk from the udder since it is essentially permanent stretching of the teat canal.

Stripping, for which the teat is held between the forefinger and thumb, and then pulled down, should be used only for expressing the first and last milk. This method requires a good lubricating ointment, and a good hand milker will never pull or stretch a teat unnecessarily. However due to inexperience in whole or full hand milking, most farmers practice stripping that can cause severe udder damage. Knuckling is another hand milking method. Knuckling squeezes out milk between the folded-over thumb and the fingers, or between the fingers and a straight thumb, but damages the upper part of the teat and hurts the cow thereby reducing milk flow. Some farmers practice a poor method of milking in which they take the teat between the fingers and pull it. This damages the teat, is uncomfortable for the cow, and can cause mastitis. Stripping, knuckling and pulling can elongate the teats and also damage the teat cistern and sphincter muscles.

Once milking is complete, the teats and the streak canal must be disinfected with an antiseptic solution. There are many commercial preparations, but one of the effective and economical solutions is a dilute vinegar solution.

Machine milking

Machine milking is more appropriate if the number of cows to be milked is high and the farmers can afford a high capital investment. It saves time, produces clean milk and maintains udder health. Milking machines vary in design but, depending on the size of the operation, the two main types of milking machines used are bucket milking machines and parlour milking machines. Bucket milking machines are ideal for farmers with small dairies, as this machine is easily moved and operates on mains electricity or from a battery. Parlour milking machines are fixed where several units operate simultaneously.

Cows can be milked with standard milking machines but, since the udder and teats in buffalo differ from cattle, milking machines for cattle need to be modified for buffaloes. Teats of the buffaloes are different than those of cattle in length, diameter and texture. In general, a heavier cluster, a higher operation vacuum and a faster pulsation rate is required. Results from studies in India indicate that it might be possible to reduce the cluster weight and the frequency of liner slip by applying an appropriate combination of liner design and cluster weight. While the total weight of the cluster is important, the distribution of its weight on the udder is also important as unequal weight distribution can cause uneven milk output. The long milk and vacuum tubes should be aligned and stretched to ensure equal weight distribution of the cluster on the udder.

Whatever method employed in milking, it is important to prepare the udder prior to milking, adopt an appropriate milking technique and fully complete the milking process.

Producing Clean and Hygienic Milk

Sick animals, or those with infected udders have to be milked. Because such milk is not fit for human consumption, it should be immediately discarded in an appropriate manner. If left outside unattended, vectors such as flies and cockroaches may transmit organisms from unhealthy milk to clean milk.

Milking is often done in the same shed where the cow is stalled. The shed is often littered with dung, urine and roughage feed leftovers during milking. Such areas will be heavily polluted with urine, and an ammonia odour is very common. In addition, flies and other insects are common. These pollutants can cause restlessness in the cow, and udder related diseases such as mastitis, as well as contaminating the milk with bacteria that lower milk quality, and its preservation.

Maintaining a clean barn and milking area is very important for hygienic milk production. High standards of cleanliness should be maintained in shed, and feed refusals and the wastes should be scraped away frequently. To facilitate easy cleaning, and cow comfort, the shed should be designed to ease draining of water, scraping of waste, thermoregulation and proper light inside the barn.

The equipment used in milking should be thoroughly disinfected and cleaned. The buckets and milking equipment can retain previous milk particles and this becomes a growth area for bacteria that can cause spoilage of freshly drawn milk. Therefore, milking cans and buckets should be thoroughly cleaned by using a mild detergent and dried soon after use. Usually one cup of washing soda in 10 liters of water is a satisfactory washing solution, or "teepol" is a detergent that is widely recommended. Once washing is complete, the utensils should be placed upside down until they are dry.

In addition to the equipment used for milking, the milker also has to be clean. He should wash his hands with soap and dry them. His clothes should be clean to prevent contamination from them. If the milker has any cuts and wounds, they should be covered to prevent contamination of the milk. Persons with contagious diseases should not milk the cows.

Some guidelines for clean and hygienic milking are:

- A milker can damage a cow's teats if teats are not handled properly.
- A cow will not letdown milk if she has been disturbed or hurried.
- Avoid noise during milking, and do not allow visitors or other animals.
- Dirty milking conditions can cause contaminated milk and mastitis.
- If the milking action is too slow, this can stop milk letdown to cause incomplete milking and mastitis.
- If the cow does not suckle the calf, a complete milking should be done.
- Milking times should be regular as irregular milking times causes a decrease in milk volume.
- Calm and tranquil handling and a brisk and effective milking method allows the highest milk production. In addition, rubbing the udder and washing the teats will make the cow letdown her milk sooner, and she will give more milk. Remember to wash hands after this and before starting to milk.
- A tranquil cow does not need to be shackled.
- Milk must be expressed from the teat and not pulled out. If the correct milking method is followed, no lubricating ointment is necessary. Milk froth or milk must never be used to smear the teat.

The milker must also pay attention to the appearance of the cow. If the flanks are soiled with dust, mud or manure, they should be brushed down. Long hair around the teats must be cut short. The udder must also be washed clean and dried with a clean cloth.

Storage of Milk

Since milk is highly perishable, extracted milk should be stored appropriately until it is shipped since it is an excellent source of nutrients for microbial growth and can be easily contaminated by environmental bacteria. Thus milk should be cooled immediately after milking and be kept as cold as possible (without freezing) before processing. The best temperature to keep milk is 4⁰C. Thus some type of cooling is required in most tropical countries. The most important preservation methods at the farm level are:

- Keep milk in the shade or in a dark well-ventilated place.
- Put milk cans in a water container.
- If there is a good supply of water, put cans into a cooling tank. Normally, the temperature of milk is 3-5 °C above the temperature of the water
- For large quantities of milk, pass cool water through a double envelope.
- If ice is available, it can be used to cool milk.
- If cool (10°C or less) water is available, cool water can pass through a perforated ring so that it flows over the cans.
- Mechanical farm cooling tanks which runs on electricity can be used in big farms which production is >400-500 litres of milk/day.
- Transport milk to milk collecting centre as soon as possible.

Chemical preservation of milk

If milk transportation from the farm to the processing facility takes a long time, and no cooling facilities are available on farm, the lactoperoxidase system can be used. Lactoperoxidase, an enzyme which naturally occurs in milk, inhibits growth of bacteria by oxidizing thiocyanate ions in the presence of hydrogen peroxide. Thiocyanate is converted to hypothiocyanous acid (HOSCN) and, at the pH of milk, HOSCN is dissociated and exists mainly in the form of hypothiocyanate ion. This agent reacts specifically with free sulphydryl groups, thereby inactivating several vital metabolic bacterial enzymes, thereby blocking their metabolism and ability to reproduce. The effect of lactoperoxidase depends on temperature, but even at temperatures of 28-32°C, it prevents spoilage of milk for about 8 hours if the initial microbial load is low. This system should be done by trained personnel at milk collecting points.

Thermal preservation of milk

The main purpose of heat treatment of milk is to make it safe for human consumption and enhance its shelf life.

Thermization

The milk is heated to 63-65°C for 15 second and rapidly chilled to 4 °C. This heat treatment temporarily inhibits bacterial growth. This process is useful for places where immediate pasteurization is not possible. Thermization causes spore forming bacteria to revert to a vegetative state which are destroyed by pasteurization.

Pasteurization

This is a process that heats milk in properly designed and operated equipment to a specified temperature and holds it at that temperature for a specified period of time followed by immediate cooling and storing at low temperature. Pasteurization of milk is either done at 63°C for 30 minutes (batch process - low temperature long time (LTLT)) or at 72°C for 15 seconds (continuous process high temperature short time (HTST)) followed by immediate cooling to 4°C. HTST is more suitable for maintaining the original taste of milk. Pasteurized milk can be kept for several days under refrigeration.

Ultra high temperature treatment (UHT)

In UHT, normally milk is heated 135-150°C for 1-6 seconds. The UHT process is continuous and takes place in a closed system that prevents product contamination by air-borne microorganisms. UHT products packed aseptically in multilayer containers can be stored at room temperature for up to 6 months without bacterial growth.

Sterilization

Milk is packed in containers and subjected to high temperature (i.e., 115-120°C) for 20-30 minutes.

Sampling and Testing of Milk at the Point of Sale

Milk is normally tested for composition, potential preservation and adulterants before acceptance at collection points.

Sampling of milk

Accurate sampling is very important in milk testing. More errors are caused through careless sampling of milk than analytical errors. As the sample should be representative of the milk, it should be thoroughly mixed before sampling. If milk is in a large container, a long handled perforated dipper can be used for mixing and sampling. If milk is in a small container, it can be mixed by pouring from one vessel to another. About 250 ml of milk is generally needed for full analysis, and it should be analysed as soon as possible. If it takes time to transport samples to the laboratory, it should be preserved by suitable preservatives, such as 40% formalin (20 drops/litre of milk) or potassium dichromate (0.5 g/litre of milk). Milk samples used for microbiological parameters should not be preserved with chemical preservatives.

Testing of milk for composition

The milk price is often based on the fat and/or SNF content of milk. Thus milk is often tested for fat and SNF before acceptance. In addition, the preservation potential of milk can be tested by organoleptic tests that rapidly identify poor quality milk at the milk receiving point. This test is inexpensive, quick and does not require any equipment. However, the accuracy of the test is determined by the experience of the milk grader who must have good sense of sight, smell and taste. The result of the test is obtained instantly and milk which cannot be adequately judged by organoleptic tests must be subjected to other more sensitive and objective tests. In this procedure, the milk can is examined for cleanliness, opened, smelled and observed for appearance. If the tester is unable to make a clear judgment, the milk is tasted, but not swallowed.

Testing of milk for adulterants

Milk can be adulterated by water addition and, to maintain measurable quality parameters, it may be further adulterated with chemicals. The most commonly used adulterants are sugar, salt, starch, urea, coconut water, coconut milk, formalin, hydrogen peroxide and neutralizers. As reports of milk adulteration have been received from many milk collection points, testing of milk for adulterants is very important.

Microbiological milk tests

Microbiological examination of milk generally consists of enumeration of viable bacteria present, a quantitative estimation of coliform contamination and determination of the presence of specific pathogenic organisms.

Conclusions

Dairy farming is the business of producing milk. Those dairy farms that produce more milk, with higher milk components and lower contaminants, will be more profitable on the long term. To achieve this situation, it is important that farmers follow practices that are known to enhance milk production and quality.

CHAPTER IV A

Feeds and Feeding

Principles of Digestion in Ruminants

(C.K. Singh)

Dairy cattle and buffaloes are cud chewing animals known as ruminants, whose eating and digestive processes differ from those of non-ruminants. A ruminant's mouth is built to mechanically grind forages and wet them with saliva, and the ruminant stomach has four compartments, being the rumen, reticulum, omasum and abomasum. Because of these many stomachs, ruminant animals are called polygastric and most other animals, including humans, are called monogastric because they have a single stomach. The rumen, reticulum and omasum together are often called the forestomach, and the abomasum is called the true stomach. The largest compartment, the rumen, generally ranges between 15 and 20% of the body weight of the animal and has a small blind sac called the reticulum. The rumen is a highly specialized organ designed to store large quantities of feed, harbour microorganisms that facilitate digestion and fermentation, and promote absorption of fermentation end products that are the major source of energy to the animal. The microorganisms in the rumen are primarily bacteria, with smaller numbers of protozoa and fungi, that together play a vital role in converting carbohydrates (e.g., sugars, starch, pectin, cellulose, hemicellulose) into volatile fatty acids (VFA), and synthesizing protein for digestion in the small intestine of the animal. Rumen microorganisms also synthesize water soluble vitamins, and convert NPN substances such as urea into protein, while detoxifying some plant toxins such as mimosine

Semi-digested feed passes out of the rumen, and some enters a small relatively round compartment called the omasum (a little smaller than a football), where some absorption of water occurs. However most feed leaving the rumen enters the abomasum, which is similar to the stomach in a non-ruminant, and is the first compartment where enzymatic digestion takes place. The abomasum is much smaller than the rumen, often only 5 – 8% of its capacity.

Feeds that are partially fermented and digested flow from the abomasum and enter the small intestine where digestion of carbohydrates, proteins and fats occurs. In a 600 kg cow, the small intestine is about 30 meters long. At the end of the small intestine, there is a small blind sac called the cecum, into which some digesta enters, although most digesta enters the large intestine (so called because its diameter is bigger than that of the small intestine) where more fermentation occurs, although there is little nutrient absorption.

Digestion

Carbohydrates

The carbohydrates in feedstuffs, such as sugars, starches, pectins and structural fibre are fermented in the rumen to produce VFA, carbon dioxide and methane. The major VFA produced in the rumen are acetic, propionic and butyric acids which are absorbed into the blood stream through the rumen wall and provide the energy to animal tissues and allows synthesis of milk and body fat. While acetate and propionate provide precursors for fat synthesis, propionate acts as precursor for glucose synthesis. Almost all starch and easily digestible fibre are fermented in the rumen. However, small quantities of starch escape rumen digestion and is largely digested in the small intestine.

When carbohydrates are fermented in the rumen, the number and size of the rumen microbial population increases. As the partially digested feed passes out of the rumen, microbes also flow out with it to be digested in the abomasum and intestine. Thus carbohydrates fermented in the rumen provide energy to the animal by absorption of VFA through the rumen wall, and protein in the microbes that is digested in the small intestine.

Fat

Fats in feedstuffs are partially digested in the rumen to produce a carbohydrate and free fatty acids. While the carbohydrate is further fermented, the free fatty acids only undergo structural changes, primarily hydrogenation, so that very few unsaturated fatty acids survive the rumen (which is why most ruminant fats are high in saturated fatty acids). Since free fatty acids are not hydrolyzed or absorbed from the rumen, they flow to the abomasum. The undigested fat, and free fatty acids, and some fatty acids in rumen microbes, all flow from the abomasum to the small intestine where they are digested and absorbed. These absorbed fatty acids provide energy to the animal and support production of milk and body fat.

Protein

The proteins and non protein nitrogen (NPN) compounds in feedstuffs are partly fermented by rumen microbes resulting in production of peptides (small protein bits), amino acids (the building blocks of proteins) and ammonia. These compounds are utilized by the rumen microbes to support their own growth. Undigested dietary protein, and the microbes, flowing out of the rumen are only digested to a small extent in the abomasum but, in the small intestine, they are generally completely digested to create peptides and amino acids that are absorbed to support synthesis of tissue and milk protein.

Energy

Energy is required for all physiological functions of animals, and is derived from digested carbohydrates, fats and proteins. Energy is used to support functions such as growth, pregnancy and lactation, and to be deposited in the form of body reserves. Energy required for maintenance of physiological functions or to support basal metabolism is known as maintenance energy. The smallest unit of energy is a joule (j) but, since these units are too small to be used to express energy requirement of animals, larger units such as mega-joules (MJ) are generally used in ruminant ration formulation.

Since the usefulness of feedstuffs for animals depends on the amount of energy in it that they can use, and availability of feed energy to the animal varies due to digestion, metabolism and production, feed energy is defined in different terms. For example, feed energy that is digested is called digestible energy (DE), that is available for tissue metabolism, called metabolizable energy (ME), and that is available for functions such as maintenance, growth and lactation, called net energy (NE). The NE value of feedstuffs varies with class of animal to which it is fed meaning that most feedstuffs have different NE values for different animal functions.

The most widely used energy terms to express energy requirement of animals and feed energy content are ME and NE. Energy is required for all physiological functions of the body, growth, pregnancy, lactation and reproduction. Thus a deficiency of energy results in loss of body condition, poor reproduction, low milk yield and/or low growth rate. A severe energy deficiency can lead to emaciation and death, while excess energy intake causes obesity and poor reproduction.

Proteins and Amino Acids

Proteins are the major organic constituents of muscles, organs, glands, blood, bones and teeth. Therefore, a continuous supply of protein in the diet is necessary to build various organs and to replace worn out tissues. Proteins have specialized functions in the body (e.g., hemoglobin, plasma proteins, antibodies, digestive enzymes, hormones). Amino acids are the smaller units that proteins are comprised of, and are classified as either dietary essential or non essential. Those that are not synthesized in the body in quantities sufficient to meet animal needs are considered to be essential amino acids. In ruminants, since all amino acids are synthesized in the rumen in quantities sufficient to meet animal requirement for lower production levels and growth, dietary essentiality of amino acids is generally ignored. However in high producing cows, some amino acids, such as lysine and methionine, are sometimes regarded as being essential.

The proteins present in the tissue and milk of cows and buffalo originate from proteins synthesized in the rumen (microbial protein) and the feed protein that reaches the small intestine without being digested in the rumen. In cows producing up to about 20 kg milk/day, more than 90% of the protein requirement is met by microbial protein while, in higher milk yielding cows, microbial protein alone will not be sufficient to meet the animals protein requirement. In such circumstances, a part of the protein requirement has to be met from dietary protein that escapes the rumen without being digested so that it can be digested and absorbed from the small intestine.

The protein requirement of a cow is generally expressed in terms of crude protein (CP) and more precisely in terms of rumen degraded (i.e., digested) protein (RDP) and rumen undegraded dietary protein (RUP) that escapes the rumen intact. In general, the ratio of RDP:RUP in the diet should be about 65:35, although for cows producing more than 25 kg milk per day, the ratio of RDP:RUP should be about 55:45.

A deficiency of RDP can negatively affect fibre digestion in the rumen leading to low microbial activity in the rumen, low feed digestibility and low dry matter intake, with resulting poor growth, low milk production, low milk fat production and a low solids-not-fat content in milk. Excess CP in the diet will generally increase the cost of diet, but it can also reduce feed intake and negatively affect health, particularly reproduction.

Minerals Vital for Rumen Function and Digestion

Sulphur (S)

Sulfur is a component of the amino acid methionine and of the B-vitamins thiamin and biotin. Microbes in the rumen utilize sulfur to synthesize these nutrients. Sulfur deficiency is most likely to occur when dairy animals are fed urea containing diets or corn silage. Most protein supplements contain high levels of S. Therefore, when urea or other NPN compounds are used to replace protein supplements, S supplementation becomes essential. For efficient utilization of urea, an N:S ratio of between 10:1 and 12:1 in the diet is recommended.

Cobalt (Co)

Cobalt is essential for synthesis of vitamin B_{12} by rumen microbes. Vitamin B12 deficiency results in severe anemia and muscle wasting.

Sodium (Na), potassium (K) and magnesium (Mg)

Sodium and potassium salts are used as buffers in the diet of dairy cows to improve feed intake, milk production and milk composition. Sodium bicarbonate and magnesium oxide are commonly used as buffers. Buffering action means, for example, countering the acidity of rumen. Feeding large amounts of concentrates or silage often increases the acid concentration in the rumen and upsets fermentation. During these situations, supplementing sodium carbonate or magnesium oxide could increase the rumen pH (i.e., decrease the acid content) and restore normal fermentation. Fat content of the milk can also be increased during situations of milk fat depression by supplementing sodium bicarbonate. Mineral salts help maintain the acid-base balance in the rumen, intestines, tissues and body fluids.

Conclusions

Digestion of feedstuffs in ruminants takes place in two stages, being ruminal and intestinal. Ruminal digestion by microbes is an important aspect of ruminant nutrition since a major supply of nutrients (i.e., energy and protein) is provided by ruminal fermentation. Providing adequate amounts of fermentable carbohydrates and rumen degradable protein in the diet of ruminants is necessary to support the growth and activity of ruminal microbes which optimizes fermentation and, in turn, maximizes growth and lactational performance. While normal ruminal digestion provides nearly the complete nutritional needs of low milk producing dairy cows and buffaloes, the higher requirement for nutrients by high producing cows has to be met by providing nutrients available for digestion in intestines that escape ruminal fermentation intact. Providing some important mineral salts in the diet of cows with buffering action will facilitate fermentation in the rumen.

CHAPTER IV B

Feeds and Feeding

Definitions of Nutrients and Energy

(P.H. Robinson, C.K. Singh)

Feeds for cattle and buffaloes (ruminants) contain a mixture of compounds that contribute its overall nutritional value. These nutrients can be divided between moisture (i.e., what is vaporized at the boiling temperature of water), those that are organic (i.e., that is burned off at a very high temperature) and inorganic (i.e., those that remain after burning). In general, moisture contributes to the water needs of the animal, organic compounds contribute to the protein and energy nutrition of the animal, and inorganic compounds contribute to the mineral nutrition of the animal.

Nutrients in feeds do not all have the same nutritional value in assessing the overall nutritional value of a feed but, in most situations, all are important in determining its overall nutritional value. In fact, feeds are often categorized based upon their dominant nutrients. For example, 'protein supplements' are those feeds that are relatively rich in protein, whereas 'mineral supplements' are rich in the minerals that are needed by animals to grow and produce milk. The definitions below are those of the major nutrients found in feeds and each defines, in general terms, their importance to animals.

Water

Cattle and buffaloes require water to grow and lactate. If water is not provided in sufficient quantities, they will slow, or stop, eating and can die. Water is most commonly consumed from water troughs or natural sources such as streams or lakes, although most feeds contain some water that can contribute to the water needs of the animals. Some feeds, such as silages and liquid by-products such as whey from cheese production, may contain substantial amounts of water and so reduce animal needs for consumed water.

Organic Nutrients

The major organic nutrients can be divided between proteins, fats and oils, and carbohydrates, although the latter are commonly divided between carbohydrates that are structural in the plant (i.e., provide rigidity so that the plant can stand up when it is growing) and those that are non-structural (i.e., provide a readily available nutrient source for the plant to use as a nutrient to grow). Thus nutrients in plants can be defined chemically, as well as functionally to the plant and functionally to the animal that eats the plant.

Carbohydrates

The ability of the bacterial population in the rumen of cattle and buffaloes to digest structural carbohydrates is not shared by animals, such as humans, that do not possess a rumen. This ability gives cattle and buffaloes their ability to survive on low quality feeds that contain high levels of structural carbohydrates. There are several terms that are commonly used to describe structural carbohydrates.

Neutral detergent fibre (NDF)

This is the portion of a feed that is not solubilized when the sample is boiled for 1 hour in a detergent solution at a neutral pH. This fraction contains all of the slowly digested, and undigested, structural carbohydrate in a feed. These major fractions include cellulose and hemicellulose, both of which can be slowly digested in the rumen of cattle and buffaloes, as well as lignin and cutin, which cannot be digested. The NDF level of a feed is generally a good predictor of a feeds voluntary intake by cattle and buffaloes (i.e., as the NDF goes up, voluntary intake goes down).

Acid detergent fibre (ADF)

This is the portion of a feed sample that is not solubilized when the sample is boiled for 1 hour in a detergent solution at an acid pH. This fraction contains all of the slowly digested and undigested structural carbohydrate in a feed sample, except hemicellulose (i.e., ADF is essentially NDF minus hemicellulose). The ADF level of a feed is generally a good predictor of a feeds energy level to the animal (i.e., as the ADF goes up, the feed energy level goes down).

Lignin and cutin

This is the portion of a feed sample that is not solubilized when its ADF is soaked for 3 hours in a solution of 72% sulphuric acid. This fraction contains lignin and cutin, the two major undigested structural carbohydrates in a feed (i.e., lignin and cutin is essentially ADF minus cellulose). The lignin and cutin level of a feed (generally simply referred to as 'lignin' because cutin levels are generally very low) is generally a good predictor of the digestibility of NDF (i.e., as the lignin goes up, the digestibility of NDF goes down).

Crude fibre (CF)

This is the portion of a fat extracted feed sample that is not solubilized when the sample is boiled for 30 minutes in a 1.25% sulfuric acid solution followed by boiling for 30 minutes in a 1.25% sodium hydroxide solution. Crude fibre was originally thought to contain the least digestible fibrous and structural carbohydrates in a feed sample, although that is now accepted to not be the case. Crude fibre is seldom used in ruminant nutrition; although government feed regulatory groups in many countries keep it alive as a 'guaranteed nutrient' in manufactured concentrates.

While ruminants are often fed diets with high levels of NDF, many of the feeds in the diet contain non-structural carbohydrates as well. Unlike NDF, which is only usefully digested in the rumen of cattle and buffaloes, these carbohydrates can also be digested in the small intestine if they escape the rumen undigested. In general, these carbohydrates are close to 100% digested, and so have a much higher energy value to the animal than structural carbohydrates that are only partly digestible, mainly in the rumen. There are three major non-structural carbohydrates.

Starch

This is often found in seeds and grains and is created by the plant primarily as a nutrient source for the seed once it sprouts. Thus starch levels of grains, such as maize, are very high (as much as $^{2}/_{3}$ by weight) and very low in grasses and legumes (as low as less than 1%). Starch typically digests very quickly in the rumen of cattle and buffaloes, although it varies to some degree among starch sources. Nevertheless, too rapid digestion of too much starch (often caused by fine grinding and/or feeding in large meals that causes rapid intake) can cause excess production of lactic acid in the rumen that can cause the cattle and buffaloes to eat less roughage.

Sugars

These are generally found in the stems and leaves of roughages and are created by the plant during daylight hours by photosynthesis to be used as an energy source during the hours of darkness. Sugars are totally digested, almost always in the rumen, and have a high energy value.

Pectins

These compounds are generally classed as a part of the plant 'cell wall' by agronomists but, because they are soluble in neutral detergent (and rapidly digested in the rumen), they are generally considered to be 'non-structural' by animal nutritionists. Pectins are generally totally digested, usually in the rumen, and have a high energy value to the animal.

Protein

Protein is an extremely important nutrient to cattle and buffaloes since they require a great deal of it to create their muscle tissues, as well as to produce the protein that is in milk. Proteins are actually long chemical chains of amino acids, and are unique in that virtually all of the nitrogen (N) in a plant is found in protein. This leads to its most common chemical analysis that determines the total N in a plant sample and then estimates the total protein in the plant by multiplying it by 6.25. This term is called 'crude protein', or 'CP', simply because it is a crude estimate of the total protein in a plant sample. Other important protein terms that are used in ruminant nutrition include:

Ruminally degraded protein (RDP)

This is the part of the CP which solubilizes or degrades (breaks up), in the rumen of the cow or buffalo due to action of the bacteria that are in the rumen. Most of this protein is used by these bacteria to grow, and create bacterial protein, which passes out of the rumen to be digested in the small intestine.

Ruminally soluble protein (SolCP)

This is the part of the RDP which rapidly solubilizes in the rumen of the cow or buffalo. This protein can be used by rumen bacteria to grow, and so create bacterial protein but, because SolCP is degraded very quickly by rumen bacteria, some of it can be lost by absorption through the rumen wall and is expelled in urine. SolCP is a part of RDP.

Non-protein nitrogen (NPN)

This is the part of the nitrogen in CP that is not actually in protein. It includes a group of nitrogen containing compounds such as amino acids, amides, ammonium salts, and short peptides. A common NPN source is urea, which can be used by micro-organisms in the rumen as a nitrogen source to grow and create protein that can later be digested in the intestines. NPN is a part of SolCP.

Ruminally undegraded protein (RUP)

This is the part of the CP which does not degrade in the rumen of the cow or buffalo. This protein passes out of the rumen in the same form that it was eaten by the animal, and is potentially digested in the small intestine. Generally the ratio of RUP to RDP that is needed in the diet increases as the productivity of the animal increases.

Indigestible protein (ICP)

This is the part of the RUP which is not digested by the animal at all. It might be because the protein was chemically linked to other indigestible material in the plant, or it might have been 'created' due to excessive heating of the plant after harvest (e.g., during ensiling or in drying). This protein has no nutritional value to the cow. ICP is a part of RUP.

Digestible CP (DCP)

This is an old term that is now seldom used in ruminant feeding. It provides an estimate of the digestibility of a feed protein in the entire digestive tract of cattle or buffaloes. However because it fails to differentiate between whether the protein is digested in the rumen or the intestine, it has largely been replaced by use of RDP and UDP as protein descriptions in ruminant nutrition.

SolCP, NPN and ICP can be estimated by chemical analyses (i.e., SolCP is CP that solubilizes in a buffer solution and ICP is the CP that is recovered in acid detergent fibre), but the amounts of RDP and UDP in a feed can only be estimated based on how fast the feed is likely to pass through the rumen of the animal. As such, RDP and UDP levels of any feed are estimates of what degrades (RDP), or does not degrade (UDP), in the rumen, and they vary within a feed depending upon the overall feeding conditions.

Cattle and buffalo also have needs for some of the specific amino acids that make up protein. While there are numerous amino acids in protein, there are about 10 that are termed 'essential amino acids' (EAA) because the animal has no ability to create them in its body. However specific amino acid deficiencies are not typically encountered in cattle and buffalo unless their milk production levels are very high.

Protein nutrition of cattle and buffalo has attracted a lot of research effort over the years, and it is emphasized in practical feeding recommendations, since proteins in the diet provide key nutrients to support bacterial growth in the rumen, as well as providing the amino acids required by the animal itself. Diets with low levels of protein, or poor protein balances relative to the terms defined above, often result in rapid declines in animal production.

Fats and Oils

Ruminants are seldom fed diets with very high levels of fats and oils, although fats and oils are found at low levels in the grains and seeds of many plants. The most common chemical analysis for fats and oils is to extract them from feed samples with ether, leading to the commonly used term of 'ether extract' or EE. Cattle and buffalo do not have bacterial populations in the rumen that can digest fats and oils, and so most of them pass from the rumen to be digested from the small intestine. At relatively low levels in the diet (i.e., less than 5% of dry matter), there is no evidence that fats and oils interfere with bacterial growth in the rumen and, since their energy value is over 200% that of digested carbohydrates, they are an excellent source of energy to the animal.

Fats and oils are often differentiated as being 'saturated' or 'unsaturated'. This means that a fat or oil contains the highest possible number of hydrogen (H) atoms (saturated) or that it can still have more (unsaturated). In general, unsaturated fats that are eaten by cattle and buffaloes leave the rumen as saturated fats, since the rumen bacteria have an excess of H. There is some evidence that high levels of unsaturated fats in the diet may have a negative effect on bacterial growth in the rumen.

Secondary Compounds

In addition to the nutrients discussed above, there is one other class of compounds that are found in feeds that are not nutrients, although they can impact the nutritional value of the feed to cattle and buffaloes. Variably referred to as secondary compounds, or anti-nutrients, these compounds are essentially toxins that interfere with some animal function, often leading to reduced animal performance and, occasionally, death. The most common secondary compounds found in feeds are tannins, alkaloids and nitrates.

Tannins

These are a very complex set of chemical compounds that are found in many plants and seeds. Generally created by the plant as a defense against consumption by animals, they often impart the astringent flavours and colours that are common in many plants and seeds. Some tannins can inhibit bacterial growth in the rumen and most tannins can bind with proteins in the digestive tract of the animal to make them indigestible.

Alkaloids

These are a complex set of chemical compounds, which all contain nitrogen, that are found in some plants. These compounds can inhibit digestion, especially at high levels, although they are often absorbed and can have pharmacological impacts on the animals, which can be toxic.

Examples of common alkaloids are morphine, solanine (potatoes) and atropine (deadly nightshade). Mimosine is a common alkaloid found in tropical legumes.

Nitrates

This is a simple chemical compound which contains nitrogen that is found in some plants, particularly if they are heavily fertilized with nitrogen fertilizers. Nitrate can be degraded in the rumen to nitrite and then to ammonia, which is used by rumen bacteria as a source of nitrogen for growth. However the conversion of nitrate to nitrite is much faster than the conversion of nitrite to ammonia. If nitrite accumulates in the rumen, it will be absorbed from the rumen and reduce the oxygen carrying capacity of blood, which can lead to death.

Inorganic Nutrients

Diets fed to ruminants contain several minerals that are required to support various body functions. Minerals are generally divided between those that are required in relatively larger quantities (i.e., macro-minerals) and those that are required in relatively lower quantities (i.e., micro-minerals or trace minerals). The common macro-minerals are calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), sulfur (S), sodium (Na) and chloride (Cl). These minerals are mainly involved in bone growth, reproduction and muscle function.

Calcium

Of the total Ca in the body, 99% is found in bones and teeth and 1% in body fluids. Calcium is required for bone development, muscle contraction, conduction of nerve impulses, activation of enzymes, alteration of cell permeability, blood clot formation and synthesis of milk. A deficiency of Ca retards skeletal development in young calves. Lactating cows require more Ca because of its secretion in milk. Milk fever is an important production disease due to hypocalcaemia (i.e., low blood Ca levels) where blood Ca falls below 5 mg/dl and impairs muscle and nervous function to such a degree that cows are unable to rise.

Phosphorus

Phosphorus is essential for skeletal growth, plays an important role in carbohydrate, protein and fat metabolism, and is a component of nucleic acids and many coenzymes. A deficiency of P causes loss of appetite, poor skeletal development and lowered reproductive performance.

Magnesium

Magnesium is an essential constituent of bones and teeth, and is an activator of many enzymes in the cells. A Mg deficiency can occur in calves fed all milk diets for prolonged periods and in adults grazing on lush pastures that were highly fertilized with nitrogen and/or potassium. A Mg deficiency results in loss of appetite, excitability and, in severe cases, profuse salivation, convulsions and death.

Sodium, potassium, chlorine

These minerals are required to regulate water metabolism, maintain acid base balance and osmotic pressure in tissues, and for gastric secretion. The Na content of many feeds is inadequate to meet the needs of dairy cattle. Signs of salt deficiency are licking and chewing of objects, loss of appetite, unthrifty appearance, lusterless eyes, rough hair coat, decreased milk production and/or loss of weight. Potassium deficiency in lactating cows causes muscular weakness, poor intestinal tone, decreased feed intake, reduced weight gain and/or decreased milk production. The animal's requirement for these minerals, along with Mg, will be higher during heat stress.

Sulphur

Sulphur is important in formation of horn, hoof and hair, and is critical for ruminal microbes to allow them to synthesize protein, especially when urea containing diets are fed. For efficient utilization of urea, a nitrogen to sulphur ratio of between 10:1 and 12:1 in the diet is recommended.

The nutritionally important trace minerals are zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), selenium (Se), iodine (I), fluorine (Fl), molybdenum (Mo) and cobalt (Co). Trace minerals have many functions in the body, and are highly inter-related nutritionally, but in general they are involved with body systems that convert nutrients to animal tissues.

Iron, copper and cobalt

These minerals have important roles in erythropoiesis, and their deficiency results in anemia characterized by paleness of conjunctiva, tongue and vagina. Iron deficiency rarely occurs in adult ruminants except under conditions of parasitic infestations. Copper deficiency results in weight loss, unthriftiness, decreased milk production, diarrhea, rough hair coat and/or stiff gait. Mild deficiencies may affect reproduction by delaying estrus, causing difficulty in calving and/or retention of placenta. Cobalt is essential for synthesis of vitamin B_{12} by rumen microbes, and a vitamin B12 deficiency results in severe anemia and muscle wasting.

Iodine

Iodine is necessary to synthesize thyroid hormones that regulate energy metabolism. A mild deficiency of iodine reduces milk yield, and severe deficiency causes enlargement of thyroid gland, known as goiter.

Manganese

Manganese is required for bone formation, growth and reproduction, and a deficiency results in impaired growth, skeletal abnormalities, reproductive inefficiency characterized by anoestrous and/or a low conception rate.

Zinc

Zinc is an important constituent of most enzymes, and a deficiency is characterized by decreased weight gain, low feed consumption and feed efficiency, decreased testicle growth, swollen feet with open scaly lesions, alopecia and/or a dermatitis that is most severe on the legs.

Fluorine, molybdenum, selenium

Fluorine is required for teeth and bone formation, while Mo and Se are important constituent of many enzyme systems. However, Fl, Se and Mo are of more concern relative to toxicity since their required levels are low and occasionally their levels in diets are too high.

All feeds contain some levels all of macro- and micro-minerals. However it is very common to supplement diets of cattle and buffalo with minerals in order to assure that the animals consume enough of each mineral to meet their nutritional needs.

Energy

In order to live, grow and produce milk, cattle and buffaloes require feed energy. The energy value of a feed or diet reflects the ability of the animal to digest it and use the resulting compounds for productive purposes. There are several energy values (or terms) that are used in cattle and buffalo nutrition.

Gross energy (GE)

This is the total energy in a feed and is measured by burning the sample and measuring the total energy that is released. Gross energy has limited use in animal nutrition because only some of it can actually be used by animals.

Digestible energy (DE)

This is the total energy in a feed that is not in the feces (i.e., was digested). To determine DE, the GE in the feed is corrected for the energy in feces that is determined by burning in the same way as GE.

Total digestible nutrients (TDN)

This is an old term that dates to the 19th century in which the total digestibility of the nutrients in a feed are determined and expressed as a percentage of the total nutrients. In reality, TDN is a simplified representation of DE. To determine TDN, there are several equations that can be used depending upon which chemical assays are available. However none are precise and all require several assumptions on digestibility of nutrients in the feed, most of which will not be correct.

Metabolizable energy (ME)

This is the total energy in a feed that is not in the feces or in urine. To determine ME, the GE in the feed is corrected for the energy in feces and urine, both of which are determined by burning in the same way as GE.

Net energy (NE)

This is the total energy in a feed that is in animal products. In the case of lactating cows and buffaloes, this is the sum of the energy that is in milk, in body weight change and required by the animal to maintain its body.

Availability of feeds, especially feeds with a high nutritional value, is a continuing challenge in most parts of the country. This makes accurate evaluation of the nutritional value of feeds, as well as combining available feeds into a nutritionally balanced ration, of paramount importance to making the most efficient use of limited feed nutrients while maximizing animal performance.

CHAPTER IV C

Feeds and Feeding

Nutrient Requirements and Feeding Practices

(M.Abdullah, M.A. Jabbar)

A successful dairy feeding system is one that delivers needed nutrients to each cow at the stage of life/lactation to support maximum milk production. No feeding system is correct for all dairy producers, as the one selected must consider delivery of forages, grains, proteins and minerals, either individually or in combinations.

Forage Systems

Forages are classified as feeds high in fiber and low in digestible nutrients, and include whole plants of corn, small grains (e.g., oats, barley, wheat), legumes and grasses. Forages are the primary source of fiber that is required by cows to maintain rumen function, as well as stimulate rumen microbial growth, rumination and saliva production. Forages are usually a more economical source of nutrients than grains, protein supplements or mineral-vitamin premixes.

Forage selection depends largely on agronomic considerations (e.g., soil types, climate, yields, nutrient yield), but forage quality must be the primary consideration regardless of forage type. High quality forage will be consumed in larger amounts and is more digestible than mature, lower quality, forages. Addition of grain to diets cannot completely compensate for reduced animal performance from low quality forages. Forages that are fed can be of several types, each varying in chemical composition, moisture content, and physical form. Pastures can provide significant quantities of high quality forages to dairy cows and heifers if managed intensively.

The optimum forage system for a farm depends on the amount of forage required, storage method and ease of accessing forages of different qualities.

Animals utilize different quality forages with differing efficiencies. Forages are most often fed free-choice or in a total mixed ration (TMR). When fed free-choice, forage should be available to cattle at all times. DM intake, and consequently milk production, is reduced when cows are not full fed (i.e., without forage or feed for more than 3 hours per day).

Grain Systems

Feeding cows housed in a tie-stall or stanchion barn generally requires more labor than feeding cows in a free-stall barn. Grain can be fed by mixing all ingredients (complete grain mix) except forage, or can be fed separately (e,g., high moisture corn) from other ingredients (e,g., topdress feeding of protein supplement and/or mineral and vitamin supplement). It can also be included in a TMR.

Feeding the correct amounts of grain in a parlor is difficult due to the limited time that cows are in the parlor. Also, parlor efficiency is usually compromised when all, or a major portion, of the grain is fed in the parlor. Elimination of parlor grain feeding reduces dust and defecation in the milking area, improves cow flow and reduces overfeeding of low producers and underfeeding of high producers. Several mechanized grain-feeding systems are available to replace, or supplement, parlor grain feeding systems. Regardless of which feeder system is selected, successful adoption requires excellent management.

Mineral Systems

The two basic systems for feeding minerals are force feeding systems where the minerals are mixed with grain and/or forage, fed in a total mixed ration, or topdressed, and free-choice systems where cows have unrestricted access to various mineral mixtures (e.g., cafeteria-style mineral feeders).

Studies have demonstrated that dairy cattle are unable to balance their mineral requirements through free-choice feeding. Therefore, a cow's mineral requirement, including salt, should be met through force feeding in the ration, with supplementary salt offered free-choice. Mineral sources should be evaluated on a cost per unit of mineral and quality of mineral source.

Total Mixed Rations

Total mixed rations, or complete rations, are defined as rations with all the forage and grain ingredients blended together, formulated to specific nutrient concentration, and fed free-choice. The main advantages to TMR feeding are:

1. Cows consume the desired ratio of forages when two or more forages are fed.
2. Cows consume the desired amount of forage relative to grain.
3. There is less risk of digestive upsets.
4. Feed efficiency is higher.
5. It allows for higher use of unpalatable feeds, NPN sources and commodity feeds.
6. There is potential to reduce labor required for feeding.
7. It allows greater accuracy in ration formulation and feeding.

Disadvantages include:

1. It requires a significant investment in a mixer.
2. Rations must be carefully formulated and continually checked.
3. Pasture feeding and large amounts of long hay are difficult to use in TMR.

The animals nutrient requirement refers to recommendations for feed nutrients to support their physiological functions. This may be expressed in terms of quantity required per day or in terms of nutrient concentration in the diet. These recommendations are useful in formulating diets using various feedstuffs so as to assure a balanced supply of nutrients. They also serve as a reference standard to check diets for nutrient adequacy. Published nutrient requirements for dairy cattle and buffaloes are available for milk fed calves, growing heifers and bull claves of different frame sizes, lactation and pregnancy.

Feeding Newborn Calves

From birth to about 2 weeks of age, the calf is a monogastric, or simple-stomached, animal. The abomasum is the only stomach compartment actively involved in digestion, and milk or milk replacer provides the nutrients. As the calf begins to eat dry feeds, particularly grains containing readily fermentable carbohydrates, the rumen takes a more important role. The size of the stomach compartments change relative to one another as the calf grows (Table 1).

Table 1. Relative size of bovine stomach compartments from birth to maturity

% of Total stomach capacity				
Age	**Rumen**	**Reticulum**	**Omasum**	**Abomasum**
Newborn	25	5	10	60
3 to 4 mo.	65	5	10	20
Mature	80	5	7 to 8	7 to 8

Colostrum is the first milk produced after a normal dry period and mammary involution, or the first milk secreted by a heifer, and it is an essential part of a newborn calf's survival. Colostrum provides essential nutrients to increase metabolism and stimulate digestive activity, and is also the source of passive immune protection that is essential for keeping the calf healthy. The quality, quantity and timing of colostrum feeding are major factors affecting calf morbidity and mortality. Colostrum contains twice as much DM, three times as many minerals, and five times as much protein as whole milk, and is higher in energy and vitamins

The high content of fat and vitamins A, D and E in colostrum are especially important because the newborn calf has low reserves of these nutrients. In addition, the relatively low lactose content of true colostrum reduces the incidence of diarrhea. Colostrum also contains immunoglobulins (i.e., antibodies), which are critical in providing the calf with immunity from infectious diseases. The calf absorbs antibodies from the gut into the bloodstream without digesting them during the first 24 h of life. This protection, from the dam to the calf via colostrum, is called "passive immunity" which helps protect the calf until its own immune system becomes fully functional. The gap between passive immunity provided by colostrum and the calf's own immunity creates a period where the calf is at greater risk of illness.

Table 2. Typical composition of colostrum and transitional milk

	Milking number			
Item	**1**	**2**	**3**	**Milk**
Solids (%)	23.9	17.9	14.1	12.9
Protein (%)	14.0	8.4	5.1	3.1
IgG (mg/ml)	32.0	25.0	15.0	0.6
Fat (%)	6.7	5.4	3.9	4.0
Lactose (%)	2.7	3.9	4.4	5.0
Minerals (%)	1.1	1.0	0.8	0.7
Vitamin A (ug/dl)	295.0	190.0	113.0	34.0

Nutrient Requirements

Young calves lack some digestive enzymes and are therefore unable to completely digest starch, some sugars (e.g., sucrose or table sugar), and some types of fat. While calves can digest saturated fats, including milk fat, coconut fat, lard and tallow, they have a limited ability to digest unsaturated fats such as corn and soybean oils. Major sources of energy for the newborn are lactose (i.e., milk sugar) and digestible fat. The rate of rumen development and development of microbial growth in the rumen determines how soon young calves can digest complex starches and carbohydrates since microbes convert these energy sources into microbial protein.

Table 3. Energy and protein requirements of calves fed milk or milk replacer and starter

	Calves gaining 1.0 lb/day				Calves gaining 1.5 lb/day			
Body Weight lb	**NE_m[1] Mcal**	**NE_g[2] Mcal**	**ME[3] Mcal**	**CP lb**	**NE_m[1] Mcal**	**NE_g[2] Mcal**	**ME[3] Mcal**	**CP lb**
55	0.96	0.70	2.24	0.34	0.96	1.14	2.92	0.48
65	1.09	0.75	2.46	0.34	1.09	1.21	3.18	0.49
75	1.21	0.79	2.67	0.35	1.21	1.28	3.43	0.49
85	1.33	0.82	2.87	0.36	1.33	1.34	3.66	0.50
95	1.45	0.85	3.06	0.36	1.45	1.39	3.88	0.51
105	1.56	0.88	3.25	0.37	1.56	1.44	4.10	0.51
115	1.67	0.91	3.42	0.37	1.67	1.49	4.30	0.52
125	1.78	0.94	3.60	0.38	1.78	1.53	4.50	0.53
150	2.04	1.00	4.01	0.39	2.04	1.63	4.97	0.54
200	2.53	1.11	4.77	0.42	2.53	1.81	5.84	0.57

Source: Adapted from *Nutrient Requirements of Dairy Cattle*, 2001b

[1]NEm = net energy for maintenance; [2]NEg = net energy for gain; [3]ME = metabolizable energy.

Calves require many of the same vitamins as monogastrics, including vitamin K and the water-soluble B vitamin: thiamine, riboflavin, niacin, choline, biotin, pyridoxine, folic acid, B12, and pantothenic acid. Vitamin K and B vitamins are in colostrum, fermented colostrum, whole milk and most milk replacers. Rumen microorganisms produce these vitamins once the calf's rumen begins to function. Young calves also require the fat-soluble vitamins A, D and E. Whole milk and milk replacers, and concentrates, normally supply these vitamins. Vitamin C is synthesized in tissue and is not required in the diet.

Dairy calves require the same minerals for growth as other animals. Milk and milk replacers generally supply adequate amounts of the needed minerals during the first few weeks of life. The mineral content of colostrum and milk may be low, or deficient, especially in mineral deficient dams.

Feeding options

Supplementing whole milk with calf starter is an excellent calf-feeding program, but overfeeding or sudden changes in the quantity or quality of whole milk can cause digestive upsets and scouring. A calf should be fed approximately 12% of its body weight per day. Calves may be started on a milk replacer when 4-6 days old, but the change from whole milk to milk replacer should be gradual since abrupt changes increase the likelihood of nutritional scours and stress. Milk replacers designed for calves more than 3-4 weeks of age should not be used for younger calves.

Milk replacers typically contain 20–22% CP, 10–22% crude fat, major minerals (i.e., calcium, phosphorus, magnesium), and vitamins A, D, and E. Provide liquid feeds at 8–14% of the calf's body weight.

Table 4: Composition of an Ideal Milk Replacer

NUTRIENTS	QUANTITY	NUTRIENTS	QUANTITY
CP (%)	22.0	Vit.E(IU/Kg)	220
Crude fat (%)	20.0	Thiamine(mg/Kg)	6.60
Crude fiber (%)	0.15	Riboflavin(IU/Kg)	6.60
Ca (%)	0.90	Niacine(IU/Kg)	2.64
P (%)	0.70	Pantothenic.A.(IU/Kg)	13.20
Fe (mg/kg)	100	Biotin(IU/Kg)	0.11
Cu (mg/kg)	10.0	Ascorbic.A.(IU/Kg)	110
Co (mg/kg)	0.10	Folic. A. (IU/Kg)	0.55
Zn (mg/kg)	40.0	Vit.B12 (IU/Kg)	0.07
Mn (mg/kg)	40.0	Pyridoxinhydrochloride(mg/Kg)	6.60
I (mg/kg)	1.00	Cholinechloride(mg/Kg)	1320
Se (mg/kg)	0.30	Neomycin(g/Kg)	275
Vit.A (IU/kg)	*	Oxytetrachloride(g/Kg)	137.5
Vit.D (IU/kg)	11000		

Preweaned calves require liquid and dry feeds. Early intake of dry feed, by 2-3 weeks, is important because dry feed stimulates rumen development and increases the number and variety of rumen bacteria and protozoa. Calf starter must be palatable to encourage intake. A textured grain with coarsely processed corn, small grains and pellets with protein, minerals and vitamins is needed. The recommended nutrient profile of calf starters, and an example of a calf starter are in Tables 5 and 6 respectively.

Table 5. Recommended nutrient profile of calf starter

Nutrient	Amount required
Crude protein (% of DM)	18.0
Fat (% of DM)	3.0
TDN (% of DM)	80.0
Metabolizable energy (Mcal/kg DM)	3.11
Calcium (% of DM)	0.60
Phosphorous (% of DM)	0.40
Vitamin A (IU/kg)	2,200
Vitamin E (IU/kg)	25*
Vitamin D (IU/kg)	300

Nutrient requirements of dairy calves. Source: 2001 NRC.

Table 6. An example of a calf starter

Ingredient	% of total ration
Corn, cracked	52.0
Oats, rolled	20.0
Soybean meal	20.0
Molasses, liquid	5.0
Limestone	1.0
Dicalcium phosphate	0.25
Salt, trace mineral	0.20
Animal fat	1.50
Vitamin supplement	0.05 (or to provide needed vitamins)
Other	(coccidiostat, buffer) as needed

Forage is important to promote growth of the muscular layer of the rumen and to maintain health of the rumen epithelium. Thus calves should be encouraged to eat forage.

Nutrient Requirement of Dairy Heifers from Weaning To 1st Calving

Well grown heifers are a good investment to improve the milking herd as they produce more milk, breed easier and last longer in the milking herd than heifers that suffer slow growth in early life.

A delay in puberty means an increased chance of a later first conception, which disrupts future calving patterns. All heifers should reach minimum live weights before mating, as lighter animals have lower conception rates and more calving difficulties. Mating Friesians weighing less than 260 kg, or Jerseys less than 200 kg, will lead to more calving difficulties.

Nutrient Requirements of Growing Heifers

For Friesians weighing 100 kg at 3 months to reach a weight of 550 kg at calving as 2 year olds, they need to grow at 0.7 kg/day, compared to 0.5 kg/day if they calve at 450 kg. Average weight for ages and the DM intakes of good quality pasture (containing 10-11 MJ/kg DM of energy) is required to achieve this rate.

Table 7. Live weights (LWT) and wither heights (WH) for Friesian and Jersey heifers

Age (months)		Friesian LWT (kg)	Friesian WH (cm)	Jersey LWT (kg)
2-3	Weaning	90-110	86-90	65-85
12	Yearling	250-300	116-120	190-230
15	Mating	300-360	120-124	240-275
24	Pre-calving	500-550	133-137	370-410

Table 8. Weights for ages and DM intakes of heifers grown to 450 - 550 kg as 2 year olds

	450 kg @ 2 years old		550 kg @ 2 years old	
Age range (months)	**Live weight (kg)**	**DM intake (kg/day)**	**Live weight (kg)**	**DM intake (kg/day)**
3-6	125	3.0	132	3.4
6-9	175	3.8	196	4.6
9-12	225	4.7	260	5.8
12-15	275	5.6	324	7.2
15-18	325	6.6	388	8.6
18-21	375	7.6	452	10.4
21-24	425	11.6	516	13.7

Table 9. Dietary quality for heifers of different ages to grow at 0.7 kg/day

	3-6 m	6-12 m	>12 m
Energy (MJ/kg DM)	10.9	10.3	9.5
Crude protein (%)	16	12	12
Calcium (%)	0.52	0.41	0.29
Phosphorus (%)	0.31	0.30	0.23

Feeding Heifers

Grazing management should allow for continuous heifer growth through the first two years. Uniform growth is not necessary and may be impractical with fluctuating pasture availability. However, heifers should never lose weight or grow slowly for long periods during their first year as they may not achieve their ultimate frame size and/or mating live weight by 15 months of age.

Table 10. NRC recommendations for heifers

Replacement Heifers:								
Body Weight[b]	Daily Gain	Crude Protein Lb/Day	NEm Mcal/ Day	NEg Mcal/ Day	TDN[c] Lb/Day	Calcium Grams/ Day	Phos. Grams/ Day	Vit.A IU/day
400	1.5	1.2	4.10	2.06	6.9	20	11	10,000
500	1.5	1.3	4.84	2.44	8.2	19	12	12,000
600	1.2	1.3	5.55	2.79	8.8	19	13	14,000
700	1.2	1.4	6.24	3.13	9.9	19	14	16,000

a Adapted from National Research Council, "Nutrient Requirements of Beef Cattle," 2001

b Average body weight during feeding period.

c The energy (TDN) levels reported are sufficient in relatively mild climates. As a general rule, the amount of TDN should be increased by 1% for each °F decrease in wind-chill temperature below 30°F for cattle with dry, winter hair or below 55°F for wet or summer hair coats.

Grazed pasture

Rumen capacity in young heifers does not reach mature proportions until 5-6 months of age and, unless pasture quality is high (at least 10 MJ/kg DM of energy), feed intake and animal performance may be restricted by rumen capacity. Farmers have traditionally relied on average quality pasture to rear heifers, reserving the best quality pasture for milking animals. However, grazing management of heifers should maximize pasture quality to ensure they consume sufficient energy and protein. Nevertheless, pasture only diets may still not provide sufficient nutrients except for short periods of the year, such as during the spring flush. If heifers need to be fed conserved fodder to supplement limited pasture, it should also be of good quality (9-10 MJ/kg DM of energy). During periods of severe pasture shortages, grazing heifers may need to be fed up to 2 kg/head/day of cereal grain provided pasture protein levels are adequate (at least 16% CP).

Pasture mass and quality are two major factors influencing growth rates of grazing heifers. The main components of pasture quality are digestibility of green herbage, the amount of dead material and the proportion of legume in the sward. Low pasture mass (1300 kg DM/ha of green material) may suffice for very young heifers, but unless this is increased to 1800 or 2600 kg DM/ha in older heifers, supplementation will be required to achieve 0.7 kg/day live weight gain.

Table 11. Nutritive values of pastures and supplements fed to growing heifers

	Dry matter (%)	Energy content (MJ/kg DM)		Crude Protein (%)	
	Mean	**Mean**	**Range**	**Mean**	**Range**
Grazed pastures					
Grass-based, immature	20	11	10-12	14	12-16
Grass-based, mature	35	7	5-9	6	3-8
Legume-based, immature	15	11	10-12	20	16-25
Legume-based, mature	30	8	5-10	12	10-15
Energy supplements					
Barley	90	13	12-13	11	7-15
Wheat	90	13	12-13	12	9-16
Oats	90	11	9-12	9	6-13
Maize	90	14	12-16	10	7-14
Protein supplements					
Cottonseed meal	90	12	-	42	
Urea	100	0	-	250	37-45
Forage supplements					
Lucerne hay	85	8	7-9	16	14-20
Grass-based hay	85	9	6-10	9	7-10
Grass-based silage	30	9	6-10	9	7-10
Maize silage	35	10	9-11	6	5-8

Grazing management of yearling heifers should be planned to complement that of the milking cows. To minimize the quantity of supplements required, heifers should be offered sufficient pasture of comparable quality (at least

10 MJ/kg DM of energy). They can be rotationally grazed ahead of, behind or independently of the milkers. Younger or smaller heifers should be grazed separately from their heavier herd mates, on better quality and/or more pasture. They may require preferential supplementary feeding to achieve target live weights. Heifer growth rates are limited by inadequate water supplies especially in summer when weaners require 25 L/day and yearlings require 45 L/day.

Management of Heifers during Late Pregnancy

To minimize the risk of calving difficulties, heifers should grow no faster than 0.7 kg/day in their last few months of pregnancy and calve in condition score 3.50-3.75. Underfeeding Friesian heifers during late pregnancy can increase time between calving and first heat. Heifers take about 2 weeks longer to commence cycling than older cows, which can be extended to 3 weeks if they are poorly fed during late pregnancy since they lose weight for a longer period during early lactation. This puts them in negative energy balance for longer, thus delaying their first post-calving heat. Jersey heifers do not seem to be as adversely affected as Friesians by underfeeding in late pregnancy.

First-Lactation Heifers

Heifers freshening with condition scores in excess of 3.75 will experience more calving difficulty. First-calf heifers need to be managed somewhat differently from their older herd mates, as they will calve with 100-150 kg less body weight than older cows. Their daily concentrate amount must be adjusted accordingly to maintain appropriate forage-to-concentrate ratios.

The lactation curve of a first calver does not show the early high peak that higher lactation cows demonstrate, but first-calf heifers do have greater persistency of lactation than older herd mates and the negative energy balance in early lactation will not be as demanding on body fat reserves as in older cows. In mid-lactation, the first calver will show an average drop of 4% per month, compared to 8% in older cows, and in late-lactation the first calver will fall in milk at 6-8% monthly while the higher lactation number cows are declining at 10-14%. This greater persistency means that heifers cannot use as high a proportion of energy intake for replenishment of body fat stores.

First and second-calf heifers also have an additional need for energy for growth throughout mid-and late-lactation and the dry period. These cattle must gain 50-75 kg during each of the first two lactations to reach mature body weights. To ensure that the additional nutrients needed for growth are provided, the standard recommendation has been to feed more concentrates. During the mid-and late-lactation phase, first calvers should get 10%, and the second calvers 5%, more concentrates than required for milk and body condition gain. Failure to provide these extra nutrients may be the cause of heifer "burn-out". Today's genetically superior cattle can produce large volumes of milk, even during first lactation. If special care is not provided, they will begin the second lactation stunted and/or lacking adequate energy reserves.

With the mature lactation curve, typical of second lactations, adequate tissue energy reserves are critical to achieving desirable peak milk yields as well as satisfactory milk fat synthesis. Body size is a major factor influencing DM intake. Lack of sufficient growth will limit the increase in feed intake needed to support higher milk yields. As a result of inadequate management, genetically superior heifers could have poor second lactation performance, or burn-out, and may be wrongly culled. Correct management of energy balance throughout the lactation and reproduction cycles of the dairy cow can improve her capacity to generate profit.

Calving to Rebreeding

If a heifer that calves in good body condition loses condition rapidly after calving, her reproductive performance may be poorer. Heavy-milking heifers are especially prone to rapid weight loss, thereby resulting in delayed cycling. Plan to provide the lactating first-calf heifer the highest quality hay or pasture available, and be prepared to provide a grain supplement sufficient to maintain body condition above 3.0. Provide a good, palatable, mineral supplement balanced specifically for early lactation.

It is important to understand a cow's order, or hierarchy, of nutrient allocation. Nutrients are utilized in the following order of maintenance, lactation, growth and reproduction. It is easy to see that a cow in a negative energy and protein balance will experience decreased reproduction and conception. Reproduction is a luxury ,not a necessity, for the heifer, but it is essential for producer profitability.

Second Calving

Second-calf cows often are the most difficult to get bred, but many producers notice the highest rate of open cows in this age bracket. When the young cow is preparing for her second calf, she should be about 90% of mature body weight, and should maintain a body condition of 3 or better after calving. The cow is still growing, especially in the case of later maturing breeds, so she needs a higher level of nutrition than mature cows.

Nutrient Requirements of Lactating Dairy Cattle

Cows need energy for maintenance, activity, pregnancy, milk production and for gaining body condition. Energy is used for maintaining the cow's metabolism, which includes breathing and maintaining body temperature. Physical activities, such as walking and eating, add to the maintenance requirement, as does environmental temperature and physiological state (i.e., pregnancy and lactation). An allowance for grazing activity has been included in maintenance requirements. In flat terrain, 1 MJ ME per km should be added to provide the energy needed to walk to and from the dairy. In undulating terrain, 5 MJ ME are required per km. A pregnant cow needs extra energy for maintenance and development of her calf. From conception through the first 5 months of pregnancy, the additional energy required is approximately 1 MJ/day for each month of pregnancy. Energy requirements for pregnancy only become large in the last 4 months.

Table 12. Energy needed for maintenance

Live weight (kg)		Energy requirement (MJ/day)
100		17
150		22
200		27
250		31
300		36
350		40
400	Typical Jersey cow range	45
450		49
500		54
550	Typical Friesian cow range	59
600		63
700		72

(Source: MAFF, 1984.)

Table 13. Average daily energy requirements in the last four months of pregnancy

Month of pregnancy	Additional energy required (MJ/d)
Sixth	8
Seventh	10
Eighth	15
Ninth	20

(Source: MAFF, 1984.)

Table 14. Energy needed per litre of milk of varying composition

	Protein (%)									
Fat %)	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4
	MJ/litre of milk									
3.0	4.5	4.5	4.6	4.7	4.8	4.8	4.9	5.0	5.0	5.1
3.2	4.6	4.7	4.7	4.8	4.9	5.0	5.0	5.1	5.2	5.2
3.4	4.7	4.8	4.9	4.9	5.0	5.1	5.2	5.2	5.3	5.4
3.6	4.9	4.9	5.0	5.1	5.1	5.2	5.3	5.4	5.4	5.5
3.8	5.0	5.1	5.1	5.2	5.3	5.3	5.4	5.5	5.6	5.6
4.0	5.1	5.2	5.3	5.3	5.4	5.5	5.5	5.6	5.7	5.8
4.2	5.3	5.3	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9
4.4	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.9	6.0	6.0
4.6	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.1	6.2
4.8	5.6	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.2	6.3
5.0	5.8	5.8	5.9	6.0	6.1	6.1	6.2	6.3	6.3	6.4
5.2	5.9	6.0	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5
5.4	6.0	6.1	6.2	6.3	6.3	6.4	6.5	6.5	6.6	6.7
5.6	6.2	6.2	6.3	6.4	6.5	6.5	6.6	6.7	6.7	6.8
5.8	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8	6.9	6.9
6.0	6.4	6.5	6.6	6.6	6.7	6.8	6.9	6.9	7.0	7.1

(Source: MAFF, 1984.)

When an adult cow puts on weight, she puts it on mostly as fat. This is noticeable on the backbone, ribs, hip bones and pin bones, and around the head of the tail. This extra fat, called body condition, can be scored by visual appraisal. A very skinny cow might score 1.5 and a fat cow might score 4.0 in a scale of 1-5. An alternative to scoring the condition of a cow would be to weigh her. Weighing a cow to determine if she has put on condition is more accurate, because condition score is affected by the cow's body shape. More fat is needed to show one extra body condition score on a large-framed cow than on a small-framed cow. Charts are available to help assess condition score. Generally, the amount of weight gain required to increase the cow s condition by one condition score is about 8% of the cow s current live weight.

Table 15. The weight of one condition score on cows of different sizes

Cow s approximate live weight (kg)	Additional weight to increase by one condition score (kg)
550 (Friesian)	44
475 (Friesian X Jersey)	38
400 (Jersey)	32

Energy is stored as fat when a cow gains body condition. Conversely, energy is released when body condition is lost, or taken off. Energy is needed for condition gain and is released when condition is lost. Note that gaining a kilogram in the dry period takes more energy than gaining it in late lactation. Although it is worthwhile for cows to gain condition when dry, it is more efficient to feed for body condition in late lactation.

Table 16. The energy a kilogram of body weight or condition needs or releases

Change in body condition	MJ needed to gain 1 kg of weight	MJ available from 1 kg of weight loss
Late lactation gain	44	-
Dry period gain	55	-
Weight loss	-	28

Cold stress is unlikely to directly influence the energy requirements of milking cows. However, cold wet conditions can influence grazing behaviour which can reduce intake of grazed pasture. When animals are heat stressed to the point of panting, their energy requirements for maintenance increase up to 10%. This is possible for periods of several hours in mid-afternoon, on very hot summer days. When considering the full day, heat stress is unlikely to increase maintenance requirements (Section 6C).

Protein Requirements

The amount of protein a cow needs depends on size, growth, milk production and stage of pregnancy. However, milk production is the major influence on protein needs. Table 17 shows CP needs for various levels of milk production. As discussed earlier (Section 4B), protein is measured as CP, rumen degradable CP (RDP) or undegradable CP (UDP).

Table 17. Crude protein needs of a cow at different production levels

Milk production	Crude protein requirements
Early lactation	16 - 18%
Mid-lactation	14 - 16%
Late lactation	12 - 14%
Dry	10 - 12%

At high levels of milk production, some CP in the diet must be UDP as there is a limit to the rumen s capacity to use RDP to produce microbial protein, which is then passed to the small intestine for digestion. Microbial protein from the rumen can sustain milk production to about 12 L/d. However, for milk production over 12 litres, at least some protein in the diet must be UDP. The need for UDP increases as milk production rises, but it is unlikely that cows grazing good quality pasture and producing less than 30 L/day will need to be supplemented with additional UDP.

Fiber

The minimum percentage of fiber needed in a cow s diet for healthy rumen function (using different measures of fiber) are 30% (NDF), 19% (ADF) and 17% (CF).

Vitamins A, D, E

Vitamin A maintains healthy epithelium (e.g., lining of the teat canal), and deficiencies may increase the incidence of mastitis. About 100,000 IU of vitamin A are needed per day per cow with any surplus stored in the liver for up to 4 months. Vitamin A deficiency is uncommon in grazing cattle, but may occur ion diets high in cereal grains or cereal straw, or if cattle are grazed on dry pasture for more than 6 months.

Vitamin D, formed in the skin when stimulated by sunlight, is required for calcium and phosphorus metabolism in the body, as it stimulates calcium absorption in the small intestine. It also facilitates mobilization of calcium stores from the bones and can be used to alleviate milk fever. Cows need about 50,000 IU of vitamin D per day. Vitamin D deficiencies are very rare in grazing livestock. Vitamin D toxicity (e.g., due to excessive treatment for milk fever) causes calcification of soft tissues, especially the aorta.

Vitamin E, selenium and vitamin A all help the cow's immune system to function. The immune system fights infections and helps cows pass their placenta after calving. Cows need about 1,000 IU of vitamin E per day, but higher amounts may be required at calving. Vitamin E deficiencies can lead to poor reproductive performance. Retained membranes, metritis, cystic ovaries and low conception rates have all been linked to vitamin E deficiency, which also causes muscle degeneration, stiffness, uncoordinated movement, and may cause early embryonic loss.

Minerals Requirements

Mineral requirements depend upon climate, type of work, age, sex, body weight, level of health and many other factors. There can never be one recommended allowance for a mineral that applies to all. Minerals are abundantly supplied in all foods natural to man's diet (e.g., fruit, vegetables, seeds, and nuts). The following 13 minerals are found in appreciable quantities within the body and are listed in the order of their total percentages of the body's composition:

Mineral	Percentage of total body weight
Calcium	2.00%
Phosphorus	1.00%
Potassium	0.40%
Sulfur	0.25%
Chlorine	0.25%
Sodium	0.25
Fluorine	Traces
Magnesium	0.05%
Iron	0.008%
Manganese	0.003%
Silicon	Traces
Copper	0.00015%
Iodine	0.00004%

Minerals are divided into groups based on the amount needed. Macrominerals are required in larger amounts, while microminerals are required in smaller amounts. Cows get some macrominerals and microminerals from their diet. However, minerals must be added to the diet to meet requirements since forages and grains do not provide adequate amounts. If these minerals are not supplemented, problems may occur. For instance, selenium deficiencies can cause retained placentas.

Several items must be taken into consideration when buying a mineral supplement. First, the supplement must contain all the macrominerals and microminerals that are deficient in the ration. Also, the supplement must contain the appropriate amounts of each mineral to be effective. The ingredients which supply these minerals should also be considered because some have a lower bioavailability than others, where 'bioavailability' is the ability of the cow to digest and utilize the minerals provided. If the bioavailability of a mineral is low, then the amount of the mineral that is fed must be increased so that the cow will get the required an receive amount. For example, copper oxide has very low bioavailability and copper sulfate is a better source of copper.

The best way to feed the mineral supplement is by force feeding rather than free choice. When minerals are supplemented free choice, cows do not eat to meet their mineral needs. Force feeding, mixing the mineral supplement with the grain mix or the total mixed ration, ensures that cows get enough of each mineral to meet their requirements. It is equally important not to add a lot of mineral supplement to the grain mix or TMR because too much of certain minerals will cause toxicities, or inhibit functioning of other minerals. Thus, forages fed to cows should first be analyzed for their mineral content if it is not already known. Next, the ration should be balanced so that all of mineral requirements are met. Finally, the mineral deficiencies can be identified and corrected by feeding the correct mineral supplement.

Feed requirements changes during lactation cycle

A number of changes occur in a cow at different stages of lactation. As well as changes in milk production, there are changes in feed intake and body condition, as well as pregnancy. A cow s lactation will start at a low level of milk and rise to a peak at about 7 weeks, and then gradually fall to the end of lactation. She will need more energy and protein as milk production increases, and less energy and protein when production declines. At all stages, she will need about the same amount of energy and protein each day for maintenance.

Dry Period

Maintaining (or increasing) body condition during the dry period is the key to ensuring the cow has adequate body reserves for early lactation. Ideally, cows should calve in a condition score of at least 2.5, and preferably 3.50-3.75. If cows calve with adequate body reserves, one condition score can be lost in the first two months of lactation. Each condition score lost (between score 1.5 3) in early lactation is equivalent to about 220 litres of milk, 10 kg of fat and 6.5 kg of protein. Each additional condition score at calving reduces the time between calving and first heat by 5 6 days. The sooner the cow begins to cycle, the sooner she is likely to get back into calf. If cows calve in poor condition, milk production suffers in early lactation because body reserves are not available to contribute energy. As a result, more dietary energy is channeled towards weight gain. For this reason, high feeding levels in early lactation cannot compensate for poor body condition at calving.

Figure 1. Relationship of milk yield and feed intake during lactation

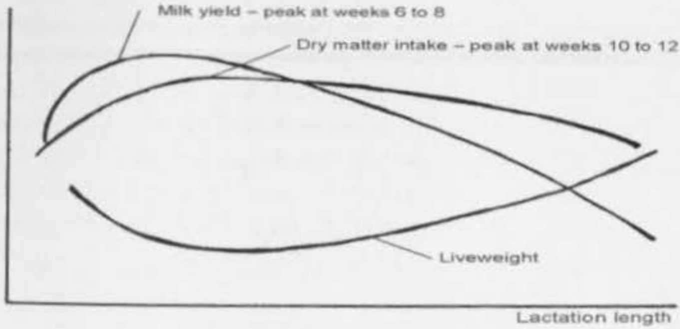


*Table 18. NRC nutrient requirements for maintenance of mature lactating cows.**

Body Wt. (lb)	Crude Protein (lb)	NEL (Mcal)	TDN (lb)	Ca (lb)	Phos (lb)	- Vitamins - A -(1000 IU)-	D
1000	.98	7.86	7.58	.041	.029	34	14
1200	1.18	9.02	8.70	.049	.034	41	16
1400	1.37	10.12	9.76	.057	.040	48	19

*Add 20% for growth of lactating cows during first lactation.

Buffaloes

Feeding and Management of Calves

In principle, buffalo calf management is similar to that of cow calves. Therefore, the section on feeding and management of dairy calves applies to buffalo calves as well.

DM Intake in Calves

Average DMI per kg ($W^{0.75}$ kg) has been found to range between 30-40 g up to 1 month of age, 40-60 g from 1 to 2 month and 60-75 g from 2 to 3 month of age. On such feeding levels, average daily body weight gain (ADG) has been found to vary between 200 to 450 g depending on the quantity of milk fed.

Table 19. Milk production: nutrients per pound of milk of different fat percentages

Fat	Crude Protein	NEL (Mcal)	TDN	Ca	Phos
(%)	(lb)		(lb)	(lb)	(lb)
3.0	.073	.29	.280	.0027	.0017
3.5	.079	.31	.301	.0030	.0018
4.0	.086	.33	.322	.0032	.0020
4.5	.092	.36	.343	.0035	.0021
5.0	.100	.38	.364	.0037	.0023
5.5	.105	.40	.385	.0039	.0024

Table 20. Combined requirements for maintenance and milk production at various levels for cows of three different sizes producing 3.5% milk fat (NRC 1988.)

		Daily Nutrient Requirements				
lb Milk	Body Wt (lb)	CP (lb)	NEL (Mcal)	TDN (lb)	Ca (lb)	Phos (lb)
30	1000	3.35	17.2	16.7	.131	.083
	1200	3.55	18.3	17.4	.139	.088
	1400	3.74	19.4	18.8	.147	.094
40	1000	4.14	20.3	19.7	.161	.101
	1200	4.34	21.4	20.8	.169	.106
	1400	4.53	22.5	21.8	.177	.112
50	1000	4.93	23.4	22.7	.191	.119
	1200	5.13	24.5	23.8	.199	.124
	1400	5.32	25.6	24.9	.207	.130
60	1000	5.72	26.5	25.7	.221	.137
	1200	5.92	27.6	26.8	.229	.142
	1400	6.11	28.7	27.9	.237	.148
70	1000	6.51	29.6	28.7	.251	.155
	1200	6.71	30.7	29.8	.259	.160
	1400	6.90	31.8	30.9	.267	.166
75	1000	6.91	31.1	30.2	.270	.170
	1400	7.30	33.4	32.4	.280	.180

Table 21. Combined requirements for maintenance and milk production at various levels for cows of three different sizes producing 3.5% milk fat (NRC 1988.)

Daily Nutrient Requirements						
lb Milk	Body Wt (lb)	CP (lb)	NEL (Mcal)	TDN (lb)	Ca (lb)	Phos (lb)
80	1000	7.30	32.7	31.7	.281	.173
	1400	7.69	34.9	33.9	.297	.184
85	1400	8.10	36.5	35.4	.312	.193
90	1400	8.48	38.0	36.9	.327	.202
100	1400	9.27	41.2	40.8	.360	.230
110	1400	10.06	44.2	42.9	.390	.240
120	1400	10.85	47.4	45.9	.420	.260

DM Intake in Growing Buffaloes

Body weight gain potential in most buffaloes is 400-800 g during the active growth phase after 3 months of age. The nutritional needs of calves may be supplied by a concentrate fed at 2.0, 1.75, 1.5 and 1.25% of body weight during the growth phases of 50-100, 100-150, 150-200 and beyond 200 kg body weight, respectively. The diet is supplemented with either free choice feeding of a cereal green fodder or a mixture of leguminous green fodder and wheat straw (70:30 in early stage and 60:40 in late cut).

Voluntary DM intake per 100 kg body weight ranges from 2.3 to 2.6 kg in growing buffalo heifers. In growing male buffalo calves, mean DM intake has been found to range from 2.0-3.5 kg per 100 kg at different stages of growth.

DM Intake in Pregnant Buffaloes

Properly fed buffalo heifers conceive at about 24-30 month of age at 350-400 kg body weight. The nutritional requirements of pregnant buffalo heifers are somewhat higher than adult buffaloes because they are still growing. Additional feeding is generally not required during the first half of the gestation period, which increases gradually to become about 50% higher than the maintenance requirement during the final trimester of pregnancy. The target is that animals gain 50-60 kg during last trimester of pregnancy, except for over conditioned animals. A dry period of 6-8 weeks helps animals to replenish their body, and store nutrients for the next lactation. Feeding during the last trimester is as important as during lactation.

DM Intake in Lactating Buffaloes

DM intake of lactating buffaloes is influenced by body size, age, milk yield, milk fat content, climate and the palatability of feed. DM intake of lactating buffaloes ranges from 2-3 kg per 100 kg body weight equivalent to 89 to 155g per kg $W^{0.75}$.

DM Intake in Non-Lactating and Empty Adult Buffaloes

A reduction in DM intake of non-producing adult buffaloes is common. Since their requirement is limited to maintenance, they consume about 1.5-2.0 kg DM per 100 kg body weight equivalent to 65-100g DMI per kg $W^{0.75}$. DM intake depends on the palatability, and protein and energy content, of the diet.

Nutritional Requirements of Buffaloes

The nutritional requirements of buffaloes are generally lower than requirements of cattle suggested by NRC (1988, 2001), but feeding standards of various groups vary. Therefore, for nutritional requirements suggested for dairy cattle by the NRC has been used as the basis for preparation of nutritional requirements for buffaloes. Values in Tables 22 and 23 should be used for preparation of rations and feeding schedules.

Table 22. Non-lactating animals

	Requirements				
	DM kg	CP kg	DCP kg	TDN kg	ME (Mcal)
Calves 6-12 months (150 kg)	3.4	0.55	0.30	2.3	8.3
Young stock 1-2 years (300 kg)	6.9	0.80	0.44	4.2	15.1
Young stock over 2 years (400 kg)	9.7	1.00	0.56	5.1	18.3
Grown Calves (450 kg)	11.2	0.41	0.22	4.1	14.8
Dry, last trimester (450 kg)	11.2	0.93	0.52	4.5	16.2
Breeding bulls (550 kg)	12.3	0.85	0.47	4.6	16.6

Calves from Birth to 3 Month of Age

In early life, a larger part of the diet of a calf is milk, with highly digestible concentrates such as calf starter and good quality fodders. The rumen is non functional and its development is mostly complete by about 8-10 weeks in calves fed limited quantities of milk, but takes 4-5 months in suckling calves consuming higher quantities. Just born calves (neonates) should be fed colostrum, preferably within 2 h of birth, and continued daily for 4 days. Colostrum feeding is essential to provide antibodies, which can be absorbed intact in the first few days of calf's life. It is also rich in all nutrients and, being laxative, helps to remove first faeces. If the dam does not produce colostrum, a substitute consisting of two eggs with about 30 ml of castor oil, may be fed to the calf.

Table 23. Lactating Animals (body weight 500 kg)

Milk Yield (kg)	DM 100 kg B. wt.	Requirements				
		DM kg	**CP kg**	**DCP kg**	**TDN kg**	**ME (M cal)**
Up to 5	2.5	12.5	0.99	0.55	5.9	21.2
6to 8	2.5	12.5	1.30	0.72	7.1	25.5
9to 11	3.0	15.0	1.7	0.95	8.6	30.9
12 to 15	3.0	15.0	2.2	1.23	10.4	37.4
16 to 17	3.0	15.0	2.5	1.40	11.3	40.6
18 to 20	3.5	17.5	2.8	1.56	12.7	45.7

(1 kg CP = 0.56 kg DCP, 1 kg TDN = 3.6 Mcal ME, 1.0 kg of milk (with 7% fat) requires 0.125 kg CP and 0.450 kg TDN)

Milk is a relatively complete food and a calf should receive about one litre of milk in the morning and evening up to 30 days of age. The quantity could be slowly decreased thereafter and, beyond the age of 4 months, the calf is used for milk let down and milk intake could be only up about 500 ml. Legume forages such as berseem, lucerne, cowpea, saftal and methi, or succulent cereals as oat, barley, maize, paragrass, guinea grass should be fed to calves after 10 days of age, or it may be allowed to nibble forage fed to the mother. A good quality concentrate of about 25% CP and 75% TDN should be fed.

Table 24. Ration Schedule for Buffalo Calves

B. Wt. (kg)	Age (Approx.)	Colostrum	Whole Milk	Skim Milk	Calf Starter
20-35	0-5 days	**1/10th of B.W**			
25-45	Up to 1 month		1/10th of B. wt.		
35-55	Between 1-2 m		1/15th of B. wt.	1/25th of B. wt'	125 g
50-70	Between 2-3 m		1/25th of B. wt.	1/15th of B. wt.	250
	3-4 month			6.5 litre	650 g
	4-5 month			6.5 litre	1.0 kg
	5-6 month			5.0 litre	1.5 kg

Suckling up to 6 months of age, or even beyond in certain cases, may be appropriate. Suckling is said to be a solution to the problem of not letting down of milk in early weaned buffaloes. Average milk intake through suckling has been estimated to be about 200-300 kg during the first 3 months of life. Thus, a tentative feeding schedule of calves through 3 months of age includes supplementary feeding of a concentrate mixture and green fodder, or good quality hay, (Table 24) along with routine deworming. The calf starter and green fodder should be offered from the second week of age.

Table 25. Typical Composition of calf starter

Crushed cereal grain	40 Parts
Crushed groundnut cake	20 Parts
Crushed mustard cake	20 Parts
Wheat bran	17 Parts
Mineral mixture	2 Parts
Common salt	1 Parts

Calves from 3 to 6 Month of Age

Although suckling is allowed to continue beyond 3 months of age to facilitate let down of milk, calves are allowed to suckle only a small quantity. Thus, the major nutritional requirements of calves have to be supplied through feeding of concentrates, green fodders and wheat straws. Since the rumino-reticulum of the calves is still growing, and animals generally do not eat large quantities of roughages, feed intake remains limited. Therefore, to supply the optimum nutritional requirements a high protein and energy diet is required. However, there is reasonable scope for compensatory feed intake and calves raised on feeding the milk diet supplemented with calf starter and fodder can eat about 3-3.25 kg DM per 100 kg body weight and this may continue to 150 kg body weight. Thus, a palatable diet containing 13-14% CP and 60-62% of TDN may support 500–600 g ADG. One of the following feeding schedules may be followed for feeding growing calves of 3-6 months of age.

Feeding with cereal green fodder

Calves should be fed 1 kg concentrate mixture, 5 kg green cereal fodder and ad libitum wheat straw. Average DM intake is expected to range from 2.8-3.25% of body weight, which will support about 400-500 g of ADG.

The amount of concentrate mixture and wheat straw to be fed to calves depends on the supply of green berseem fodder. Feeding 1 kg of a concentrate mixture with 15 kg green berseem and ad libitum wheat straw will support 400–500 g ADG up to 6 months. A concentrate mixture containing about 20% CP in air dry feed should be prepared by mixing crushed cereal grain, groundnut cake or cotton seed cake or soybean cake, mustard cake, wheat bran, mineral mixture and salt in the ratio of 30:27:10:20:2:1. The diet should be made of 1.5 kg concentrate, 1-3 kg available green fodder (or synthetic vitamin A) and ad libitum wheat straw. However calves may not consume enough of this feed, but intake should support 300–400 g of ADG.

Buffalo Heifers from 6 Months of Age

The ration of growing buffalo heifers occurs in two parts, being feeding up to the second trimester of pregnancy and feeding during the last trimester of pregnancy.

Feeding up to Second Trimester of Pregnancy

The roughage part of the daily ration will be straw supplemented with available green fodder and a suitable concentrate to meet requirements to support at least 500 g of ADG. The roughage part of the diet may be variable quantities of cereal or leguminous green fodder and concentrates. In most places, availability of green fodder for feeding of non-lactating stock is limited to 5-20 kg per head per day. Thus, staple roughages are straws and stovers. The following feeding schedules support about 500 g ADG in growing buffalo heifers.

(i) A concentrate mixture containing about 20% CP and 63% TDN (air dry basis) fed at 1.5, 2.0, 2.5 and 3.0 kg/head daily at 100, 150, 200 and 250 kg body weight along with 5-10 kg cereal green fodder and ad libitum straw or chaffed kadbi.

(ii) A concentrate mixture containing about 15% CP and 63% TDN (air dry basis) fed along with 25-30 kg green berseem and ad libitum straw or chaffed kadbi.

(iii) The quantity of concentrate mixture as in (ii) but reduced to 1.0, 1.5, 2.0 and 2.5 kg at the corresponding body weight when plenty of leguminous green is available for feeding.

Feeding of Buffalo Heifers During the Last Trimester of Pregnancy

Buffalo heifers and other non-lactating pregnant animals should be fed to gain about 700 g during the last 3 months of gestation period. Options include:

(i) For feeding with straw/ kadbi as staple roughage

Pregnant buffaloes should be fed 5 kg concentrate mixture, at least 2-3 kg available green fodder and ad libitum straw or kadbis. However, during the last week of pregnancy the entire concentrate mixture may be wheat bran.

(ii) Feeding with variable amounts of cereal green fodder (Tables 26 and 27).

Lactating Buffaloes

Table 26. The quantity of concentrate mixture and green fodder

Amount of green fodder (kg)	Concentrate mixture (kg)	Straw / Kadbi (kg)
05	4.5	Ad libitum
10	4.0	-do-
15	3.5	-do-
20	3.0	-do-

Table 27. Composition of ration with leguminous green fodder

Green legume (kg)	Concentrate mixture (kg)	Straw / Kadbi (kg)
10	4.0	Ad libitum
15	3.5	-do-
20	3.0	-do-
25	2.5	-do-
30	2.0	-do-

A lactating buffalo should be allowed to consume adequate feeds and fodders to maintain her body weight, or grow if she has not achieved her mature body weight, and also to produce an optimum quantity and quality of milk. Diets of buffaloes may be made of the following combination of roughages, and the source of roughages may differ as:

Feeding with cereal green fodder and grasses

Green fodder supply per head per day is about (i) 5, (ii) 10, (Hi) 20, (iv) 30, (v) 40 or (vi) 50 kg. The quality of cereal fodders changes with stage of maturity, being highest in protein, energy, minerals and vitamins at its vegetative stage, which gradually decreases with maturity for most nutrients. An average value of 20% DM, 10% CP and 60% TDN on a DM basis for forages up to dough stage of maturity has been considered in calculating requirements for other feeds in balancing the diets for a buffalo (body weight 500 kg) producing 10 kg milk (with 7% fat).

Feeding with different quantity of green leguminous fodder

Berseem, lucerne, cowpea and clusterbeans are main leguminous fodders and, among them, berseem is more popular in large parts of India. Lush growing berseem, alone or mixed with green mustard, contains about 10% DM, and the CP and TDN contents in DM are about 18 and 65% respectively, besides high calcium (1.5-2.5%). Therefore, a low CP and low calcium concentrate should be prepared to avoid wastage.

Table 28. Suggested feeding levels

Amount of green fodder (kg)	Concentrate mixture (kg)	Straw / Kadbi (kg)
05	8.0	Ad libitum
10	7.5	-do-
20	7.0	-do-
30	6.5	-do-
40	6.0	-do-
50	5.0	-do-

Comparative Digestion and Nutrition of Riverine Buffaloes and Cattle

There is no difference in the digestive tract of buffaloes and cows, as both have four-pouched stomachs and similar post-ruminal gastro-intestinal tracts. The rumen in cows and buffaloes is well adapted to utilizing cellulosic matter and the main fermentative compartment preceeds the main site of digestion, thereby allowing maximal use of fermentation products. Functionally there might be a difference between riverine buffaloes and cows in their ability to digest poor quality roughages such as rice straw. The reason for this difference is not clear, although differences in rumen bacterial growth rate between species were reported by Zaki El-Din et al. (1985) as a result of feeding the same roughage diet with or without added urea and/or molasses. The ability of buffaloes to consume more DM from rice straw than the cow could further explain the difference in digestion.

In Egypt, research on comparative digestibility and efficiency of feed utilisation between buffaloes and cows has reported that local buffaloes and cows digest concentrates and good quality roughages, like berseem hay, equally well. With poor quality roughages, such as rice straw, buffaloes exceed cows in digesting DM and CF, and buffalo steer calves produced more meat per unit of feed intake than either local steers or native or Friesian breeds.

Research from India has shown the superiority of riverine buffaloes over cows in digestion. Results also show that the TDN output/input ratio varied from 6-30% and protein output/input ratio from 5-40%, indicating that buffaloes fed straw, and a grain-based diet, were more efficient than cows. It has also known that maintenance and production requirements are higher in Murrah buffaloes than in Brown Swiss x Sahiwal cows, indicating that cows were more efficient in utilizing metabolizable energy for milk production than buffaloes.

References

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CHAPTER IV D

Feeds and Feeding

Feeds and Forages

(M.A. Jabbar, M. Abdullah)

Pakistan is blessed with abundant livestock resources. Apart from providing milk, meat and draught power, livestock play an important role in subsistence farming and is used as cash in times of emergency. Feed plays an importanr role in the productivity of animal. However no concrete measures have been taken in the past to assure quality feed and a consistent year-round supply of green fodder. Shortage of fodder is the major limiting factor to livestock production in the country. Pakistan is currently short by about 38% in TDN and 24% in CP (Sarwar et al. 2002).

The national average yield of fodder crops is about 23 tonnes per hectare and, in 2004-05, fodder crops were grown on 2.36 million hectares with a total fodder production of 54.4 million tonnes. The area under fodder crops was 2.77 million ha in 1985 and fodder production was 53.2 million tonnes, compared to 2.36 million ha land under fodder crops and total fodder production of 54.4 million tons in 2004-05, a decrease of 15% in area from 1980-85 to 2004-05, although fodder production increased by 2.24%. The slight increase in total fodder production is due to increased yield per unit area, perhaps showing the impact of research and development in the field of fodder research. However, compared to yield increases per unit area with crops such as wheat, maize and rice, this increase is low.

Fodder is a common feed resource for livestock feeding. It is grown more in Punjab and Sind and less in Sarhad and Balochistan provinces and, in these provinces, it is available only during certain seasons. Based on season of growth, fodders can be divided into summer and winter fodders.

Summer Fodders

Summer (*Kharif*) fodder crops are maize (*Zea mays*), sorghum (*Sorghum bicolor*), millet (*Pennisetum americanum*), sorghum-sudangrass hybrid (*Sorghum bicolor* x *Sorghum bicolor* var. Sudanense) cowpeas (*Vigna* *unguiculata*) Moth (*Vigna aconitifolia*), rice bean (*Vigna umbellata*), jantar (*Sesbania glandiflora*) and guar (*Cyamopsis tetragonoloba*). Maize is the most nutritious, succulent and palatable summer fodder and can also be grown in mixtures with legumes such as cowpeas, moth, guar and rice beans. Sorghum is an important kharif fodder grown in rain fed and irrigated areas, and it can be grown in mixtures with summer legumes. Cowpea fodder is rich in protein, and is an excellent mixture with summer cereals. Guar is a hardy leguminous fodder crop that tolerates drought and, to some extent, soil salinity. Millet is another common summer cereal in low rain areas.

Until recently fodders were mostly single cut but, with advances in breeding technology, multi-cut fodders are now available. This has resulted in higher per area yield of fodder and also helped in reducing periods of low fodder availability. In general, summer fodders have higher DM, but lower CP contents. The DM ranges from 20-40%, CP varies from 6-8% and TDN is usually 50-55%. Quality of summer fodder is based on its age, and leaving fodders in field for longer lowers its quality. Mature fodders are neither liked by animals nor useful to livestock due to their low nutrient contents. As summer fodders have higher DM contents, they do not need supplementation with wheat straw, but do need supplementation with concentrates.

Winter Fodders

Winter (*Rabi*) fodder crops include berseem (*Trifolium alexandrinum*), Shaftal (*Trifolium resupinatum*), lucerne (*Medicago sativa*), vetch (*Vicia* species), oats (*Avena sativa*), barley (*Hordeum vulgare*) and mustard (*Brassica spps*). Lucerne is generally grown alone or in mixtures with oats and is a highly nutritious fodder. It is sometimes preferable over berseem because it is a perennial and supplies green fodder throughout the year. Berseem is the major fodder crop of Pakistan grown under irrigated conditions, and it is also called the "king of fodder crops" as it yields 75-100 t/ha of green fodder yield from 5-7 cuts during the growing season. Berseem can be planted either alone or in mixtures with *Brassica*, oats and barley. These fodder crops are generally grown in late September to October. Oats is another annual Rabi fodder and is an excellent combination when fed with legumes such as berseem, lucerne and shaftal. Winter fodders have high CP contents (18-22%) with TDN values of 55-60%, and are best relative to nutritive value. As they usually have lower DM and, if they are tender, wheat straw or chaffed rice straw can be added to increase the DM contents of fodder to reduce chances of loose feces due to their higher moisture contents. If abundantly available, animals producing 4-5 liters of milk need little concentrate supplement. However, in cases of fodder shortage and with high producing animals, use of concentrates becomes necessary.

Table 1. Per acre yield and chemical composition of summer and winter fodders

	Per acre yield (Tonnes)	Dry matter (%)	Crude Protein (%)
Summer fodders			
Maize	18-20	29.30	7.04
Sorghum	20-25	30.00	6.20
Sadabahar	50-60	27.59	6.98
Millet	20-22	29.50	6.08
Mott grass	70-90	16.54	7.52
Guar	15-18	20.90	17.35
Winter fodders			
Berseem	30-35	15.62	19.90
Lucerne	50-60	24.26	22.83
Oats	25-35	22.10	9.98
Rye grass	30-40	14.21	22.85
Dry fodders			
Wheat straw	-	92.75	2.59
Rice straw	-	92.82	3.06
Maize stalks	-	82.50	5.45
Sorghum stalks	-	85.50	3.74
Millets stalks	-	85.00	4.00
Maize stovers	-	90.50	1.66
Dried berseem	-	85.50	18.46
Dried lucerne	-	87.50	18.86

Jabbar and Pasha (2007)

Classification of Fodder Based on their Nutritional Value (Protein Contents)

Non-leguminous fodders

Summer fodders predominantly fall into this category and include maize, sorghum, sadabahar, millet and Mott grass. In addition, fodders grown during winter (i.e., oats and sugarcane tops) are also included. These fodders have low CP and high DM contents. If animals are solely reared on these fodders, then addition of higher CP concentrates or fodders is necessary.

Leguminous fodders

These fodders are grown during winter and include berseem, lucerne, cowpeas, guar and janter. The CP contents of these fodders are 10-15%, and the DM is usually low. To increase the DM of fodder, wheat straw is often mixed with it before feeding. Combinations of cereal and leguminous fodder are desirable when possible.

Present Status of Fodder Production in Pakistan

In Punjab and Sind, fodder is available year round, but shortages occur especially during May/June and November/December. This shortage negatively affects productivity of animals. The length of these periods were longer in the past but, due to introduction of multi-cut fodders, their duration has decreased.

Fodder crops cover about 16% of the total cropped area of the country (Table 2). Over time, the area has been constant but production and yield have increased mainly due to research and development efforts undertaken by the national research system. The major problem faced by farmers is a shortage of green fodder during the months of May/June due to high temperatures and low precipitation, and in December/January due to low temperatures. However due to recent research and development activities in the field of fodder crops, growing of fodder crops such as S.S. Hybrids, lucerne, mixtures of cereals and legumes and Mottgrass can fill this gap.

Table 2. Area, Production and Average Yield of Fodder Crops in Pakistan Since 1980

Year	Area (000 ha)	Production (000 tones)	Average yield (tonnes/ha)
1980-85	2770	53211	19.2
1985-90	2753	54438	19.9
1990-95	2698	57704	21.4
1995-00	2649	60215	22.7
2000-01	2490	56944	23.0
2001-02	2512	56083	22.0
2002-03	2467	56058	23.0
2003-04	2468	56323	23.0
2004-05	2359	54403	23.1

Source: Agricultural Statistics of Pakistan 2004-05

Provincial production of fodder crops for 2004-05 is in Table 3. The Punjab produces 80.3% of total fodder crops followed by Sindh, NWFP and Balochistan, which produce 13.2, 4.1 and 2.3% respectively. Current fodder production is insufficient to feed the existing livestock population and the situation is getting worse. Fodder crops cover 11.5% of the total cropped area in the country (Table 4), behind both wheat and cotton, with almost no funds for development. More than half of animal feed comes from fodder crops and crop residues (Table 5). However the availability of forage from grazing lands will likely remain stagnant, or even reduce further, unless sound programs of rangeland management are initiated.

Table 3. Provincial area (000 ha) and production (000 tones) of fodder crops in 2004-05

Province	Area	% of Total Area	Fodder Production	Total Fodder Production (%)
Punjab	1952	82.75	43689	80.31
Sindh	264	11.19	7210	13.25
NWFP	101	4.28	2235	4.11
Balochistan	42	1.78	1268	2.33
Total	2359	100	54402	100

Source: Agricultural Statistics of Pakistan 2004-05

Table 4. Area (%) under Different Fodder Crops

S. No	Crops	% Area
1.	Wheat	37.00
2.	Cotton	14.27
3.	Fodder crops	11.51
4.	Rice	9.70
5.	Pulses	6.32
6.	Sugarcane	4.58
7.	Maize	4.31
8.	Orchard	3.04
9.	Oil seed	2.65
10.	Others	6.62

Straws

Cereal straws

Paddy and wheat straw, which are by-products after grain harvesting, are the bulk of roughages, and are the staple feed for cattle and buffaloes in the country. Though low in nutritive value, containing about 3% CP and 40%

TDN, these straws, along with small quantities of protein supplements can maintain adult non-producing cattle. However, factors such as low palatability and dustiness may limit their use as cattle feed.

Pulse straws

The most common pulses are moong *(Phaseolus radiatus)*, moth *(P. acontii folius)*, Cow peas *(Vigna catiang)*, masoor *(Lens asculenta)*, and arhar *(Cajamus indicus)*. After harvesting, seeds are threshed from the pods. The husks of the pods, with leaves and tender stems, are by-products that can be utilized as fairly nutritious cattle feeds.

Among these straws, those of moong and moth are highly palatable and nutritious. Straws of arhar and masoor, although of comparable nutritive value, are not as palatable. The energy value of these straws is comparable with those of cereal straws and they are a fairly good source of digestible CP.

Table 5. Livestock Feed Resources

S. No	Feed Resources	% Contribution
1.	Fodder and crop residues	51
2.	Forage/grazing	38
3.	Cereal by-products	06
4.	Post harvest grazing	03
5.	Oilcakes, meals, animal protein	02

Source: Fodder Crops Production in Pakistan, 1996

Table 6. Crop-wise Area and Production of Fodder Crops in Pakistan

Crop	Area (mha)	Fodder Production (mt)
Kharif Fodder Crops		
Sorghum	0.52	7.88
Millet	0.11	0.76
Guar	0.31	3.55
Maize	0.05	0.96
Other Kharif Crops	0.46	7.00
Rabi Fodder Crops		
Berseem	0.82	25.42
Lucerne	0.15	5.32
Shaftal	0.03	0.81
Rape & Mustard	0.02	0.34
Other Rabi Crops	0.19	4.72
Total	2.66	56.76

Source: Cooperative Units of National Fodder Research Program

Groundnut straw

Groundnut is produced in some areas of the country. At harvest, large quantities of leaves and stems become available for livestock feeding. The DCP value of groundnut straw is superior to that of non-leguminous hays and comparable to cowpea hay. As represented by TDN, groundnut straw is energetically superior to most grass hays, and can be safely fed with wheat bran and wheat straw to meet the nutritional requirements of milking cows producing up to 5 kg of milk daily.

Rape bhoosa

Being quite fibrous and lower in nutritive value than pulse straws and groundnut straw, it should be fed in limited quantities in conjunction with cereal straws to non-productive animals.

Rice husk

Rice husk has little to no value as a feedstuff and should be used primarily for bedding as they are high in silica and fiber. The TDN value is only about 15% but, during extreme roughage shortages, it may substitute for 10-15% of roughages in the ration.

Coarse ground corn cobs

Coarse ground com cobs are similar to cottonseed hulls in feeding value but slightly less palatable. They are used primarily as a roughage extender in rations, rather than as a major roughage source.

Sugarcane bagasse

Sugarcane bagasse is the fibrous residue of sugarcane stalks which remains after juice is removed. Sugarcane bagasse pellets are fed like cottonseed hulls and are similar in feeding value. In recent years, bagasse has become unavailable as a feedstuff due to its high fuel value at sugar mills.

Non-Conventional Feed Resources

Citrus pulp

As early as in 1911, it was suggested that citrus pulp had potential value as a feed for cattle. In the 1930's, dried citrus pulp began to be produced commercially as a byproduct feed and, since that time, production and availability of citrus pulp has increased steadily. Citrus pulp is classified as an energy concentrate byproduct feed, containing low CP and a moderate amount of digestible energy. Dry and wet citrus pulp sources contain similar nutrient profiles, less the difference in DM content. Tabular values typically assign citrus pulp a TDN of 80-84% on a DM basis. However TDN values of current citrus pulps may to be lower, ranging from 68-75%, likely result of improved processing technologies. The CP has always been low in citrus pulp and ranges from 5-9% on a DM basis, with an average of 6% a value that does not provide adequate CP in the diet of cows in winter.

The most commonly reported condition associated with citrus pulp feeding is ruminal parakeratosis, a digestive disorder associated with feeding high concentrate diets. As this condition progresses, ruminal papillae become keratinized and nutrient absorption is restricted. Citrus pulp at more than 60% of the concentrate for cattle full-fed in feedlots can result in rumen parakeratosis. When supplementing citrus pulp to grazing cattle, make certain that there is sufficient pasture forage available.

Molasses

Molasses is a by-product of the sugar industry that is the end product of sugar manufacture or refining from which no more sugar may be economically crystallized. About 75% of the world's molasses is from sugar cane (*Saccharum officinarum*) with the bulk of the remainder from sugar beet (*Beta vulgaris*). The most important constituent of molasses is sugar, being predominantly sucrose with some glucose and fructose. For every 100 tonnes of sugar cane processed, 3-4 tonnes of molasses is produced while, for every 100 tonnes of sugar beet there is 4-6 tonnes of molasses.

Molasses is a rich source of minerals in comparison to other commonly used sources of dietary energy such as cereal grains. The calcium content of cane molasses is high (up to 1%), whereas the phosphorus content is low. Cane molasses is also high in sodium, potassium (which are present as chlorides), magnesium and sulphur. Beet molasses tends to be higher in both potassium and sodium, but lower in calcium. Molasses also contains trace minerals such as copper (7 ppm), zinc (10 ppm), iron (200 ppm) and manganese (200 ppm). Molasses may be fed to livestock as molasses meal, molasses blocks, and in liquid form to provide energy directly or be used as a carrier for non-protein nitrogen, vitamins and minerals as well as medicinal compounds. Molasses supplies the rumen with rapidly fermentable energy in the form of sugars, primarily sucrose. Supplementing grass silage with molasses or sucrose reduces ruminal ammonia N concentrations compared to other carbohydrate sources such as starch.

Up to 25-31% molasses inclusion in the diet of dairy cows can increase DM intake, milk yield and protein yield without adverse effects on cow performance. However, a level of 10-15% is recommended. Molasses can replace more common energy sources.

Wheat middlings

These are moderately high in CP and energy. Wheat midds, which can be safely fed up to 8 pounds/head/day, are a by-product of the flour milling industry and are comprised of several grades of granular particles containing different proportions of endosperm, bran and germ. It has 96% of the energy value of barley and 91% of the energy value of corn. Midds are palatable, and can be included in the grain mixture at high levels.

Table 7. Chemical composition and energy value of wheat bran and middlings

Typical Analysis	Wheat Bran	Wheat Midds
Dry matter	89 %	89 %
Crude Protein	15.5 %	16.5 %
Fat	03.5 %	04.5 %
Crude fiber	11.0 %	07.5 %
Neutral Detergent Fiber	45.4 %	32.0 %
Acid Detergent Fiber	13.4 %	09.9 %
Calcium	00.1 %	00.1 %
Phosphorus	1.10 %	0.80 %
Total Digestible Nutrients	62.0 %	72.8 %
Net energy—Lactation	64.6 Mcal/100 lbs	83.8 Mcal/100 lbs

Use of Concentrates in Livestock Feeding

In most Asian countries, including Pakistan, animals are raised on green and dry roughages. However, fodder alone cannot meet their nutrient requirements. Normally there should be 12% CP in livestock diets but, in summer fodders, the CP contents are 7-8% and most fodders fed to animals have CP contents of 4-5%. Under such feeding systems, a 500 kg cow producing 10 liters of milk would require about 120 kg of green fodder to meet their CP requirement. In contrast, winter fodders have high CP contents but are low in energy and so they do not provide balanced nutrition to the animals. Fast growing young animals and high milk producing animals need additional feed to balance nutrient deficiencies in fodders. Farmers usually try to meet such deficiencies through cottonseed cake, but this is not appropriate due to its high CP level. A well balanced concentrate would be more appropriate than cottonseed cake alone.

Concentrates are made from agro-industrial byproducts that are sources of energy and CP and suitable for feeding to livestock. These byproducts can be divided into those which are good sources of CP (i.e., cakes, meals, glutens) and those that are good sources of energy (i.e., grains, bran, rice polish, molasses).

Protein Sources in Animal Rations

Cottonseed Cake

Cottonseed cake is the most commonly used cake in the market. It has 20-22% CP and 63% TDN and is very palatable. Its production is low but demand is high. Due to higher demand and price in the market, adulteration with low quality material occurs. Cottonseeds contain an anti-nutritional factor called gossypol, although its activity can be decreased by boiling the cake in water. Cottonseed cake has a high nutritive value for milk and meat production. In the diet of breeding bulls, it is used at the minimum as gossypol negatively affects semen quality. In addition, mycotoxins (aflatoxins) also occur and negatively affect milk production and animal health.

Cottonseed meal

This is better form of cottonseed cake, also called decorticated cottonseed cake, which is prepared by removing the outer covering of cottonseed and pressing the internal soft part after extracting the oil. It has 40% CP and 80% TDN. Due to its higher CP content, it is more economical than cakes. It is palatable and has less gossypol and so is safer for use in the diet of breeding bulls.

Soybean meal

Due to its high quality protein this meal is mostly used in poultry feed. It has 48-50% CP and 88% TDN. Due to its higher price, it is not commonly used in cattle feed. It is an excellent source of high quality protein and is extensively used in dairy rations in other countries. When its price is competitive, it can be used in dairy rations.

Peanut and til cake

These cakes are common in the regions where such crops are grown, such as the South Punjab and barani areas. These are not as palatable as cottonseed cake, and have lower digestibility and some anti-nutritional factors. However, they can be used 15-20% in cattle rations.

Rapeseed cake

This is a less commonly used cake because it is not very palatable to animals due to the presence of glucosinolates. Rapeseed cake has 30-40% CP and 80% TDN. It should not be used at more than 10% in the ration because its bitter taste makes it unpalatable and animals do not eat it readily. Over the last few years improved forms of rapeseed cake have been introduced which contain no glucosinolates or erucic acid. The common name for such genetically improved varieties of rapeseed is canola, and the meal is called canola meal, which is becoming popular as a CP source for poultry and ruminants.

Maize gluten feed

This is a by-product of the maize industry. Maize gluten is available in four forms (i.e., maize gluten feed 20, 30, 40 and 60% CP). Maize gluten 20 and 30% can be used in cattle feed for milk and meat production. Its quality is lower than that of cottonseed cake and not very palatable. Maize gluten is cheaper than other CP sources.

Sunflower meal

This is obtained as a by-product after extracting oil from sunflower seeds, and contains 30-37% CP. It has a high fiber content, which limits its use in poultry rations, but there is no such limit in ruminant diets, and can be used up to 15% in dairy rations.

Maize oil cake

This is a product of the Rafhan Maize Company. It contains 26-27% CP and also has residual oil. It is useful in rations of large animals. In view of its price and utility, it may be used at 15-20% in dairy rations.

Grams and peas

These leguminous grains have 20-28% CP and are also good source of energy, although they have some anti-nutritional factors.

Urea

In ruminant diets, some feed protein can be replaced by urea to make the final feed less expensive. Ration CP can be replaced up to 40% but, in dairy rations, the maximum recommended level of urea is 2%. If an animal eats too much urea at a time, or if it is not mixed properly, it can be toxic. Toxicity symptoms include staggering, excessive salivation, tympani and falling over. If such symptoms develop, one gallon of acetic acid diluted with one gallon of water should be drenched. The best feeding strategy is to mix the urea into the feed. When urea is used, feeding of grains and molasses is beneficial.

Energy Sources

Cereal grains

This includes grains from maize, sorghum, wheat or oats, although usually these grains are costly and not used in the ration. However, their use at up to 10-15% gives good results. Maize grain is considered the best among all cereals due to its higher starch content. Wheat grains should not be fed in large quantities as it produces acidity in the rumen and lowers the pH which is harmful to animals.

Corn grain

Corn is the world's most important feed grain as it is a high-energy feed that produces more energy per acre than any other cereal grain. It is high in starch and oil and low in fiber. The major energy-yielding fraction is the starchy endosperm. In ruminants, corn starch is subject to rumen fermentation where microbes ferment starch anaerobically, producing organic acids as end products. Starch digestion is inherently less efficient in the rumen than in the small intestine, and starch digested in the small intestine has 42% more energy to the animal than starch digested in the rumen.

Whole grain corn is poorly digested in cattle making it necessary to break the waxy external shell of the kernel to permit its degradation in the rumen. Some of the common processing procedures include steam rolling, dry rolling, grinding, extruding, popping, and flaking. Besides breaking the structure of the grain, processing improves corn starch digestibility in ruminants.

A factor contributing to the high energy value of corn is its oil content, which averages about 4%, and it is high in unsaturated fatty acids. Corn grain has a low CP content, ranging from 8-10%, but is an excellent energy source. Corn grain CP is recognized as poor quality, being deficient in lysine and tryptophan. For non-ruminants, corn must be supplemented with a CP supplement to supply deficient amino acids.

Yellow corn is the only cereal grain to have significant vitamin A activity. Its yellow color is due to carotenoid pigments, some of which are precursors of vitamin A, with the main one being b-carotene. As is true for all cereal grains, corn contains very little calcium and a calcium supplement is needed for grain-based diets. Corn is moderately high in phosphorus. Unlike most feedstuffs, corn does not contain significant levels of toxic or deleterious compounds. However, it is often contaminated with mycotoxins, which are of concern in animal feeding.

Grain sorghum and millet

Sorghum and millet are the major food grains in the semi arid tropics. In developed countries, approximately 96% of total sorghum and millet is grown for animal feed, whereas in developing countries only 8% of these crops are used for livestock, with the rest used as human food. Sorghum (*Sorghum bicolor*) is a hardy, drought-resistant crop adapted to environmental conditions too harsh for the production of corn. It requires less water than corn and can survive dry conditions and then resume growth when moisture becomes available.

Sorghum is equal to, or slightly lower, than corn as an energy source. For ruminants, it requires more vigorous processing to achieve optimal digestibility. However, there is considerable variability in feeding value among sorghum cultivars and types, mainly because of variations in tannin content and seed coat color. Brown, high-tannin bird-resistant sorghums result in poorer animal performance and lower digestibility than low-tannin types. Like corn, sorghum is a fairly poor source of CP (7-10%). Tannins inhibit digestive enzyme activity and form complexes with proteins that resist digestion. In ruminants, higher tannin contents in bird-resistant sorghum greatly reduce CP availability in both the rumen and small intestine.

Various processing methods can be used to at least partially overcome effects of sorghum tannins. Treatment with alkali or anhydrous ammonia is effective, and polyethylene glycol, which forms complexes with tannins, is also an effective additive to improve its feeding value.

Wheat grain

Wheat is virtually identical to corn in digestible energy content, and is equal to corn as an energy source for all livestock. It is more likely than corn to cause digestive disturbances in ruminants because of the rapid digestion rate of its starch. Wheat is superior to corn in terms of CP content and quality, and soft white wheats contain 10-11% CP, whereas hard spring wheat usually contains 12-14%. Lysine is the most limiting amino acid for swine and poultry, followed by threonine and methionine.

As with corn, there are no significant toxins in wheat, and it is not normally infected in the field with mycotoxin-producing fungi although occasionally it may be infected with ergot. In ruminants, lactic acidosis is more common with wheat-based diets than with other grains because of its rapid fermentation rate in the rumen.

Rice polish

Rice polish is a by-product of rice milling. It consists mostly of bran and germ of rice with some fragments of hull and broken rice. The calcium level in rice bran varies with the amount of added calcium carbonate, and when it exceeds 3% (total calcium >1.2%), then the percentage of calcium carbonate must be stated in the product name. During summer, some rancidity develops and this makes the product unpalatable for animals. It is usually cheaper than other energy sources.

Maize bran

This is obtained as a by product of processing of maize for preparing maize food products. Its price is usually lower than that of wheat bran and there is less fluctuation of price during the year. It can be used in the ration at up to 25%.

Oils and Fats

These are very good source of energy as the energy level of these products is 2-3 times that of other energy sources. Rumen inert fats, now available in the market, are safer than using free oil in the ration, albeit very expensive.

Feed Additives

Feed Additives are nonnutritive substances added to feeds to improve the efficiency of feed utilization and feed acceptance, or be beneficial to the health and/or metabolism of the animal in some way. Some feed additives, such as antibiotics, are controversial, with claims that their use has adverse effects on human health.

Additives that influence feed stability

Antifungals

Antifungal agents prevent fungal (mold) growth in stored and mixed feeds. Molds reduce palatability and may produce mycotoxins, with aflatoxin and Fusarium toxins among those are of most concern. Mold growth in stored grains and feeds is prevented by drying to a moisture content of 12% or less, storage under dry conditions, and use of mold inhibitors (antifungals). The use of a mold inhibitor is strongly recommended when the moisture content of the grain exceeds 13-14%, the relative humidity is above 80-

85%, the temperature is 55°F or above, or the grain is damaged, broken, or insect-infested. Propionic acid or its salts (sodium or calcium propionate) are particularly effective at about 1% of the grain. Propionates provide protection for at least 90 days.

Antioxidants

Antioxidants are preservatives that prevent auto-oxidation of fats (rancidity). Unsaturated fatty acids may react with oxygen to produce undesirable products with offensive odors and toxic properties and destruction of nutrients, such as the fat-soluble vitamins. Examples of natural antioxidants are vitamin E and vitamin C (ascorbic acid).

Additives that modify animal growth, feed efficiency, metabolism, and performance

Feed flavors and buffers

A number of commercial feed flavors are available that may increase acceptance of diets with low palatability, increase intake of unpalatable diets or increase the intake of diets during periods of stress such as weaning.

A buffer is a salt of a weak acid or base that resists a pH change. Sodium bicarbonate is probably the most frequently used buffer. Other widely used buffers and neutralizing agents include magnesium oxide, calcium carbonate and tetrasodium pyrophosphate. Buffers are particularly useful in the adaptation period from high-roughage to high-concentrate diets and as an aid in prevention of lactic acidosis. They are also useful in rations for dairy cattle fed high-concentrate diets, particularly when corn silage is the major roughage. Buffers are not as useful when high roughage diets are fed.

Methane inhibitors

Methane production reduces efficiency of rumen fermentation as it represents a loss of carbon that could otherwise be metabolized by the host animal. Methane formation is also a "hydrogen sink" by which hydrogen formed in fermentation is removed. Inhibition of methane production increases efficiency of ruminant production, as well as reduces methane emissions, which have been linked to global warming. Various chemicals inhibit methanogenesis. The main methane inhibitors with practical application are ionophores, a class of antibiotics that are extensively used as feed additives for cattle. The major ionophores are produced by strains of *streptomycis* fungi and include monensin, lasalocid and narasin. Feeding ionophores to cattle may improve feed conversion and production.

Probiotics

Probiotics is a term coined to describe microbes used as feed additives that are defined as live microbial feed supplements which beneficially affect the host animal by improving its gastrointestinal microbial balance. The majority of probiotic products are based on *Lactobacillus acidophilus*, although organisms such as *Streptococcus faecium*, *Bacillus subtilis*, and yeasts are also used. The organisms must be able to survive passage through the highly acidic stomach. Most lactobacilli meet this criterion, but it is important that they resist bile if they are to survive in the intestine. The organisms should be capable of competing with existing gut microflora and must be host-specific.

Yeast (single-celled fungi) and other fungi are also used as probiotics. The main species used are *Saccharomyces cerevisiae* and *Aspergillus oryzae*. "Yeast culture" refers to dry products containing yeast and the media on which it was grown. Feeding yeasts and yeast cultures often improves production of lactating cows, and increases in feed intake with yeast and yeast culture supplementation may be due to favorable effects on rumen fermentation, and increased digestibility.

Acidifiers (Organic acids)

Organic acids, commonly referred to as acidifiers or acidifying agents, have shown favorable effects when used as additives. Feeding organic acids may aid in lowering stomach pH and preventing digestive upset. Citric and fumaric acids have been the primary acidifiers examined. Falkowski and Aherne (1984) reported a 4-7% increase in average daily gain and a 5-10% improvement in feed efficiency with feeding of 1 or 2% fumaric or citric acid to weanling pigs. In calves, acidification of milk replacers may improve milk clot formation in the abomasum and so reduce the risk of digestive upsets.

Metabolism modifiers - antibiotic growth promoters

Antibiotics are natural metabolites of fungi that inhibit growth of bacteria. The mechanism of action of antibiotics in their growth-promotion effects is not conclusively known, but appears to be due to actions on gut microflora.

Subtherapeutic levels of antibiotics increase an animal's ability to withstand stress and aid in control of postweaning diarrhea. The response to antibiotic feeding is highest in young, unthrifty or stressed animals. Although antibiotics have been used as feed additives since about 1950, their effectiveness has not diminished with time. This suggests that development of microbial resistance to antibiotics, which is documented, does not alter their growth-promoting activity. Some of the most commonly used growth-promoting antibiotics are bacitracin, bambermycins, chlortetracycline, erythromycin, lincomycin, neomycin, oxytertracycline, oleandomycin, penicillin, streptomycin, tylosin, flavomycin, and virginiamycin.

Anti-nutritional Factors

Tannins

The word tannin is very old and stems from the traditional technology of tanning, which is the process of transforming animal hides into leather by using plant extracts from different plant parts of different plant species. By definition, tannins are phenolic compounds that precipitate proteins and are widely distributed in the plant kingdom. Within Angiosperms, tannins are more common in dicotyledons than monocotyledons. Tannins are usually subdivided into hydrolysable tannins (HT) and proanthocyanidins (PA), or condensed tannins. Tannins have a major impact on animal nutrition because of their ability to form complexes with numerous types of molecules, including, but not limited to, carbohydrates, proteins, polysaccharides, bacterial cell membranes and enzymes involved in protein and carbohydrates digestion.

Tannins are a defense mechanism in plants against pathogens, herbivores and hostile environmental conditions. Generally, tannins induce a negative response when consumed. These effects can be instantaneous, such as astringency or a bitter or unpleasant taste, or can have a delayed response to anti-nutritional/toxic effects. Tannins may reduce intake by decreasing palatability due to their astringency, the sensation caused by formation of complexes between tannins and salivary glycoproteins.

Free tannins and their complexes remain in the rumen and decrease protein and plant cell wall digestibility. Several studies have shown that tannins decrease fiber digestion. Lower digestibility is the result of the interaction of tannins with cellulose enzymes and rumen bacteria. In some cases, lower fiber digestibility can be the result of a shortage of ruminally fermented nitrogen due to complexing of proteins with tannins. Tannin toxicity to rumen microorganisms has been described for several bacteria species. Field drying and treatments with PEG are able to limit these negative effects.

In ruminants, tannins can induce beneficial effects. For example in sheep and cattle higher retention of nitrogen occurs with low to moderate levels of tannins in forages, and moderate levels of tannins (<4%) in forage legumes can have beneficial responses in ruminants, resulting in higher growth rates and milk yield.

Gossypol

Gossypol is a natural toxin present in the cotton plant that protects it from insects. Its name is derived from the scientific name of cotton (*Gossypium spp.*). Chemically it is a polyphenol found as a yellow pigment in the glands of the seeds. Gossypol is found in free (toxic) or protein-bound (less-toxic) forms. In the seeds, almost all gossypol is in the free form. Heat and moisture processing converts free into the less toxic bound gossypol.

Gossypol, a cardiotoxin, causes destruction of the cardiac muscle and, in acute cases, can cause sudden death although chronic symptoms include labored breathing. Most cases have been reported when cattle have consumed a lot of seed over a long period of time. Gossypol levels more than 0.2% in feed are often toxic. Toxicity has also been reported in young calves fed several pounds of cottonseed per day. It is not recommended to feed calves cottonseed before they have a well developed rumen. Cattle have the ability to detoxify gossypol because the microorganisms in the rumen bind it to prevent absorption. This ability can be overcome by very high levels of cottonseed feeding, but cattle will not normally be affected at recommended feeding levels of 3.5 kg/d, although intake of 5-7 kg/day will cause toxic symptoms. This problem can often be solved by using cottonseeds in a mixed ration rather than by feeding it separately. Gossypol can cause a temporary reduction in sperm cell formation in bulls when fed above recommended levels. Because of the importance of bull fertility to profitable beef production, the general recommendation is that bulls should not be fed whole cottonseed 60-90 days before the start of the breeding season.

Aflatoxins

Aflatoxins are a group of heterocyclic metabolites produced by storage fungi of the genus Aspergillus, particularly *A. flavus* and *A. parasiticus*. Even though 18 different Aflatoxins have been identified, only aflatoxin B1, B2, G1 and G2 have been detected as natural contaminants of feeds and feedstuffs. Of the other aflatoxins, M1 is found in milk.

The presence of aflatoxigenic molds on grains does not necessarily mean presence of aflatoxin, just as the absence of molds does not mean an absence of aflatoxins. In stored grains, the most important factors influencing growth of *aspergillus spp*. and aflatoxin production are relative humidity around and in the substrate, and storage temperature. Equilibrium relative humidity of 80-85%, equilibrium moisture concentration of 17% and temperature of 24-45°C are optimal conditions for aflatoxin production. Mold growth generally does not occur in grains dried below 12% moisture.

Aflatoxin B1 is classified as a highly toxic compound (LD^{50} 1-50 mg/kg) for most animal species, although it is extremely toxic (LD^{50}<1mg/kg) for susceptible species such as cats and ducklings. Toxic effects of aflatoxin exposure are both dose and time dependent in two distinct forms (i.e., acute and chronic). The acute form is characterized clinically by depression, anorexia, icterus and hemorrhages while the chronic form causes reduced weight gain and milk yield in cattle. Aflatoxin B1 causes acute hepatotoxicity at levels less than one half of the LD^{50} level; (the toxicity of aflatoxins, G1, B2 and G2 is approximately 50, 20 and 10% respectively, that of aflatoxin B1). Toxicity at reduced levels may produce deleterious effects on growth, reproduction, and the immune system of ruminants. Dietary treatment for aflatoxicosis includes raising diet CP by 3%.

Hydrated sodium calcium alumino-silicate (HSCAS)

Available as an anticaking agent for animal feeds, HSCAS (a phyllosilicate clay) has been used to reduce levels of bio-available aflatoxins by selective chemisorption. HSCAS has been reported to remove aflatoxins from aqueous suspensions and to reduce uptake and distribution of aflatoxin in biological systems, prevent aflatoxicosis in domestic animals and reducing aflatoxin M1 residues in milk due to contaminated diets (Park and Liang, 1993). Activated charcoal, chemical methods and other adsorbents are also used to reduce aflatoxin levels in contaminated feeds.

Ration Preparation

Hand mixing

If the ration is to be prepared on a small scale for few animals, it can be made by hand. For this purpose, ingredients are weighed according to a formula and spread on concrete or a clean floor. Molasses is usually poured on at the end for easy and thorough mixing. Contents are mixed either by hand or with the help of a spade. If urea is included in the formula, it should first be dissolved in water and this solution mixed with the ration to ensure thorough mixing of urea into the ration.

Machine mixing

For preparation of rations, mixers and grinders may be required. These units are available in different capacities. If the ration is to be made for a small farm, then a mixer of 100 kg will be sufficient.

Total Mixed Rations

Total mixed rations (TMR) are mixtures of roughages and other feeds, that are formulated and mixed to supply the cow's requirements in a form that minimizes selection. It is designed to be the sole feed over a 24 h period and is fed ad libitum for optimum results. Use of TMR cannot be accomplished without use of accurate weighing equipment and adequate and proper mixing equipment (e.g., a feed mixer wagon) if necessary. The concept of a TMR is quite popular in developed countries, but in developing countries it is at initial stages of development. TMR used in Pakistan are often only the concentrate items mixed with wheat straw. This is more common in peri-urban areas versus rural areas where they mainly rely on fodder with small amounts of concentrate fed separately. Advantages of TMR include:

- Peak DM intake occurs 4-8 weeks earlier than conventional systems.

- Increased milk production by approximately 5-8%. Each additional kg of DM consumed increases milk yield by 0.9-1.5 liter.

- Improved fat tests as a result of improved rumen fermentation, and more optimal pH (acidity) levels in the rumen, resulting in maximum rumen fermentation and cellulose digestion leading to formation of acetic acid, the precursor of milk fat.

- Reduced digestive upsets due to each bite of feed having the same composition, thereby minimizing pH fluctuations in the rumen.

- Optimal protein synthesis in the rumen, as microbial protein synthesis due to less variability in rumen pH during the day.

- A wide variety of less palatable feeds can be utilized in the ration as these are masked by the other ingredients to eliminate selection.

- Better control of the cow's diet.

To maximize DM intake, feed the ration in 3-4 portions over the day avoiding rations with over 50% moisture. Ensure that the ration contains a minimum of 27% NDF or 19% ADF (DM basis), with 75% of ration NDF derived from forage/roughage. Non structural carbohydrates (NSC) should be 38- 40% of DM for optimal rumen fermentation, as higher NSC levels can lead to lactic acid fermentation and acidosis, thereby reducing DM intake. The ration should contain a rumen degradable protein (RDP) to undegradable (UDP) CP ratio of 60-40 to ensure adequate rumen fermentation, as well as adequate rumen escape protein for high production. Excess RDP can be detrimental to DM intake.

Urea Molasses Blocks

As the name indicates, these are lick blocks containing urea, molasses, vitamins and other nutrients. Feeding of blocks is a convenient and inexpensive method of providing a range of nutrients required by both rumen microbes and the animal which may be deficient in the diet. The main benefit of using blocks is convenience for packaging, storage, transport and ease of feeding. The ingredients are designed to provide a wide range of nutrients to cover all potential deficiencies.

The consistency of molasses plays a major role in successful manufacture of urea molasses blocks. As molasses from a sugar factory has good consistency and sugar contents, it should not be diluted with water to make it easier to handle as this leads to difficulties during the process of block solidification. Because of its taste and flavor, molasses makes blocks very attractive and palatable to animals.

Urea, which provides fermentable nitrogen, is an important component of the block. Intake of urea must be limited to avoid toxicity, but must be sufficient to maintain appropriate ammonia levels in the rumen for growth of microorganism and high rates of fiber degradation. Blocks are an excellent way of controlling urea intake while allowing continual access by cattle. Urea used in blocks is generally fertilizer grade, and cement (or quicklime) as a gelling agent or binder, is necessary to solidify the blocks. Other ingredient include magnesium oxide, bentonite, calcium oxide and calcium hydroxide.

Wheat or rice bran has a multiple purpose in the block. If there is no bran available, it can be replaced by fiber sources such as bagasse, rice bran or ground straw. Rice polish is used to give a good look to the blocks. Oilseed meals provide soluble and insoluble CP and are good source of phosphorus. Salt is generally added because it is often deficient in the diet and is inexpensive, but mineral mixtures should be used even though it makes the product more expensive.

Drugs or various chemicals to control parasites, or for manipulation of rumen fermentation, can be added to the blocks, which can be an excellent carrier. For this purpose, Phenothiazine (10 gm/100 kg), Levamisole (0.08–0.8% of ration) or Thiabendazole (6-11 gm/kg) may be added to the block.

Blocks can be produced according to the rate of production foreseen and the level of investment. If adequate labor is available and only few blocks are needed, then manual mixing is possible. However, for producing larger numbers of blocks (over 150 blocks /day) a concrete mixer is recommended.

Urea–molasses multi-nutrient blocks as supplements for forage based diets must only be fed to adult ruminants as the aim of the block is to improve utilization of low quality roughages, especially during and at the end of the dry season, when livestock are often dependent on crop residues or low quality dry season grazing, which are both low in CP and high in fiber. Therefore, production and use of blocks should be limited to these periods. Different formulae have been suggested in the literature. A formula of urea molasses block (Table 8) is provided as a general guideline.

Table 8. Composition of urea molasses blocks

Ingredients	Percentage
Molasses	50
Urea	6
Common Salt	5
Mineral mixture	2
Calcium oxide (Un-booja choona)	5
Cement / bentonite	4
Cotton seed meal / sunflower meal / canola meal	10
Bran / rice polishing	18
Total	100

Factors Affecting Intake of Blocks

The hardness of a block affects its intake. If it is soft, it may be rapidly consumed with risks of urea toxicity. However if it is too hard then its intake may be limited. High levels of urea may reduce block intake due to unpalatability. Blocks should be introduced progressively, and cannot constitute the entire diet, with roughage available. Where there is bulk dry feed, the risk of toxicity is unlikely. Intake of blocks varies with the type of animal (Table 9).

Table 9. Intake of blocks by different types of animals fed a basal diet of straw

Type of animal	Grams of block consumed per animal / day
Lambs	88
Calves	165
Young buffaloes	380
Zebu heifers	300

Feeding blocks usually stimulates intake of the basal diet. With a basal diet of unsupplemented straw, the increase in straw intake is 25-30%. Digestibility of straw DM increased from 43 to 49% when blocks were supplemented with 150 g of concentrate.

Effect of blocks on animal growth

Compared to urea supplied by spraying onto straw, urea from blocks gives superior results, and part of the response may be due to the small amount of supplementary energy provided by molasses as well as by a stimulatory effect of the other ingredients in the blocks on the rumen ecosystem.

Effect of blocks on milk production

Use of multi-nutrient blocks has allowed a substantial reduction in concentrate in the diet of buffalo cows fed rice straw, with no change in milk yield, and the amount of straw in the diet (and thus the profit per animal per day) were greatly increased. Use of blocks reduces the amount of concentrate from 5 to 3.5 or 4 to 2.5 kg/day, which did not reduce milk production but increased fat percentage by about 10%.

Summary

Fodder and forages are the main ruminant feeds in Pakistan. In lean periods, when availability of fodder is inadequate, productivity of animals is adversely affected. The situation has improved over the past few years due to introduction of multi cut fodder varieties including sadabahar, mottgrass and some oat varieties. However nutrients are still deficient by about 40-45%, and this needs to be supplied as fodder and concentrates. During summer, fodders are mostly cereals with low CP contents and there is a need to introduce a new legume fodder which grows during summer and fits into cut and carry feeding systems. In winter, there is a need to introduce a crop which gives good per area yield. Dry roughages, which predominately include wheat and rice straw, are also common sources of livestock feeds. During winter, and at some other times of the year, there is a shortage of these straws and availability is deficient. Thus new feed resources such as stovers, cobs and bagasse need to be explored for inclusion as dry roughages and made more palatable through grinding or threshing. In the past, there have been efforts to improve the nutritive value of straws through treatment with sodium hydroxide, ammonia and urea, but these methods did not become popular among farmers.

Fodder preservation as hay and silage is another possibility for ensuring a regular supply of fodder to livestock. These methods were not very common among farmers in the past but, with introduction of commercial farming, farmers have started preparing hay and silage. If these methods become common, it is possible that the fodder shortage problem will be minimized.

Concentrates are a very small proportion of livestock diets. Most concentrates are prepared from agro-industrial byproducts which include cakes, meals, bran, gluten and molasses. Preparation of a balanced ration from these ingredients is not common with farmers, and the quality of commercial rations remains questionable. However, for optimum animal productivity, supplementation of a concentrate is necessary. There is the possibility of adding new by products to the feed which are not being used presently. Total mixed ration (TMR) is not a new concept in the country and is being used in urban and peri-urban livestock production systems. However, in these situations the concentrate ingredients are mixed with wheat straw to prepare a balanced ration. Feed additives which improve efficiency, or enhance productivity, are not yet common and use of hormones and biological products are controversial. Use of urea molasses blocks have been beneficial in Barani areas where availability of high quality fodder is limited.

There is not much hope for increases in fodder availability in the future as research on fodder production is limited. Moreover, due to urbanization and competition with cash crops, the area under fodder production is gradually decreasing. To overcome this problem it is necessary that multicut fodder varieties with good nutritional value be introduced. In addition, new feed resources should be exploited as livestock feeds.

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Feed Composition Tables

Table I. Composition and energy values of concentrate ingredients (DM basis)

	Mois-ture	Dry mat-ter	Crude pro-tein	Ether Ex-tract	Crude Fibre	Min-eral Mat-ter	TDN	Cattle & Buffalo						Sheep & Goats		
								TDN	DE	DE	NEm	NEg	NE_l	TDN	DE	ME
	%	%	%	%	%	%	%	%	%	——— Mcal/kg ———				%	— Mcal/kg —	
Bajra	9.10	90.90	10.55	4.67	10.00	3.11	5.70	77.20	3.40	2.79	1.86	1.22	1.76	81.14	3.59	2.91
Barley	8.60	91.40	10.21	2.68	7.26	2.67	5.39	77.20	3.40	2.79	1.86	1.22	1.76	83.40	3.68	3.01
Gram Black	8.60	91.40	20.35	3.17	7.33	2.62	14.70	75.20	3.31	2.72	1.79	1.17	1.7	81.10	3.57	2.93
Gram large	8.30	91.70	18.43	2.62	6.87	3.05	12.94	75.20	3.32	2.72	1.80	1.17	1.71	81.40	3.59	2.94
Maize (y: desi)	11.00	89.00	11.80	4.07	3.03	1.71	6.85	80.60	3.55	2.91	1.96	1.31	1.85	88.50	3.9	3.20
Maize (y: desi)	10.64	89.36	11.25	4.80	2.98	1.69	6.35	81.30	3.58	2.94	1.98	1.33	1.87	88.90	3.92	3.21
Maize (y: hyb)	10.39	89.61	9.80	4.11	2.84	1.53	5.02	81.20	5.58	2.94	1.98	1.33	1.87	89.30	3.94	3.23
Maize (w: hyb)	10.55	89.45	10.44	4.92	2.79	1.47	5.60	81.70	3.6	2.95	1.99	1.34	1.88	89.30	3.94	3.23
Matri	4.00	96.00	30.04	1.53	8.47	6.49	23.60	70.00	3.08	2.53	1.63	1.02	1.56	74.80	3.30	2.70
Oats	8.06	91.94	9.52	6.31	14.68	4.45	4.76	75.10	3.31	2.71	1.79	1.17	1.7	75.20	3.32	2.72
Rice basmati	8.50	91.50	9.67	1.65	0.68	1.42	4.90	80.60	3.55	2.91	1.963	1.31	1.85	90.80	4.00	3.28
Rice Begmi	7.87	91.13	9.37	2.26	0.75	1.77	4.62	81.00	3.57	2.93	1.97	1.32	1.86	90.80	4.00	3.28
Rice Permal	8.80	91.20	8.40	1.19	1.17	2.87	3.73	80.40	3.55	2.91	1.95	1.31	1.85	89.50	3.95	324
Rice Russian	8.85	91.15	8.57	1. 78	0.82	2.19	3.89	80.60	3.55	2.91	1.96	1.31	1.85	90.30	3.98	3.27
Sorghum (chari)	9.00	91.00	17.03	3.13	4.32	3.08	11.65	77.40	3.41	2.8	1.86	1.23	1.76	81.40	3.72	3.05
Sorghum (juar)	9.80	90.20	15.75	2.62	2.47	2.66	10.48	78.50	3.46	2.84	1.90	1.26	1.79	86.90	3.83	3.14
Wheat Chen 70	8.23	91.77	10.67	1. 73	2.48	2.53	5.82	79.00	3.48	2.86	1.91	1.27	1.81	87.90	3.87	3.18
Wheat 591	8.30	91. 70	13.02	1.22	2.16	2.8	7.97	78.10	3.44	2.82	1.88	1.25	1.79	87.30	3.85	3.15
Wheat Max Pak	8.38	91.62	14..09	2.150	2.80	2.18	8.95	78.50	3.46	2.84	1.90	1.26	1.8	87.20	3.84	3.15
Wheat SA 421	7.30	92.70	12.80	1.80	2.31	1.92	7.77	78.90	3.48	2.85	1.91	1.27	1.81	88.10	3.88	3.18

Table II. Composition and energy values of vegetable protein concentrate ingredients (DM basis)

	Moisture	Dry matter	Crude protein	Ether Extract	Crude Fibre	Mineral Matter	TDN	Cattle & Buffalo						Sheep & Goats		
								TDN	DE	DE	NEm	NEg	NE_l	TDN	DE	ME
	%	%	%	%	%	%	%	%	%	—Mcal/kg—				%	—Mcal/kg—	
Almond cake	6.98	93.02	39.68	11.29	5.47	8.52	32.43	89.5	3.95	3.24	2.22	1.54	2.10	88.3	3.89	3.19
Castor seed cake	6.90	93.10	28.12	8.05	21.16	6.23	21.83	68.5	3.02	2.47	1.58	0.98	1.52	74.2	3.27	2.68
Cottonseedcake (undec)	6.50	93.50	23.04	9.52	26.20	6.52	17.17	63.4	2.79	2.29	1.42	0.84	1.38	69.9	3.08	2.53
Cottonseed cake (dec.)	7.30	92.70	39.59	5.61	9.49	7.64	32.36	79.8	3.52	2.88	1.93	1.29	1.83	81.1	3.57	2.93
Groundnut cake (undec)	8.30	91.70	24.75	5.78	18.43	5.89	18.74	68.5	3.02	2.48	1.59	0.98	1.52	73.9	3.26	2.67
Groundnut cake (dec.)	6.05	93.95	40.50	4.36	7.29	5.96	33.20	83.4	3.68	3.01	2.04	1.38	1.93	89.1	3.93	3.22
Linseed cake	7.50	92.50	32.22	7.35	10.70	7.03	25.60	79.7	3.51	2.88	1.93	1.29	1.83	82.5	3.64	2.98
Poppy seed cake	7.20	92.80	32.48	11.10	12.82	9.75	25.84	83.6	3.69	3.02	2.05	1.39	1.94	91.5	4.03	3.31
Suntlowt.'r cake	8.10	91.90	30.47	16.21	26.66	7.40	23.99	69.7	3.07	2.52	1.62	1.02	1.55	72.9	3.21	2.63
Sesame cake	6.86	93.14	36.07	8.70	6.66	9.34	29.13	84.7	3.74	3.06	2.08	1.42	1.97	83.1	3.68	3.02
Rape seed cake	7.00	93.00	37.10	8.17	11.61	8.39	30.08	79.8	3.52	2.88	1.93	1.29	1.83	81.5	3.59	2.95
Maize oil cake	4.10	95.90	18.66	8.45	13.14	2.81	13.15	78.5	3.46	2.84	1.90	1.26	1.80	87.4	3.85	3.16
Sarsoon cake	6.80	93.20	32.30	13.52	11.37	9.01	25.67	84.0	3.70	3.04	2.06	1.40	1.95	83.8	3.70	3.03
Guar meal untoasted	8.70	91.30	47.86	6.57	7.78	6.90	39.96	83.8	3.69	3.03	2.05	1.39	1.94	84.1	3.71	3.04
Guar meal toasted	7.70	92.30	49.40	6.72	7.58	6.39	41.37	84..5	3.73	3.06	2.08	1.41	1.96	85.0	3.75	3.07
Corn gluten feed 20 %	7.10	92.90	21.85	7.00	1.26	7.75	16.08	79.10	3.51	2.88	1.93	1.29	1.83	83.3	3.67	3.01
Corn gluten feed 30 %	7.00	93.00	30.70	4.84	6.56	3.44	24.20	83.6	3.68	3.02	2.05	1.39	1.93	90.2	3.98	3.26
Corn gluten feed 50 %	7.40	92.60	55.72	2.91	1. 73	1.08	47.17	90.5	3.99	3.27	2.25	1.56	2.12	94.8	4.18	3.43
Corn gluten meal 60 %	8.20	91.80	64.70	8.17	3.48	2.61	55.41	94.6	4.17	3.42	2.37	1.66	2.24	97.10	4.28	351
Maize bran	6.90	93.10	9.88	3.'76	11. 71	3.65	5.09	71.6	3.15	2.59	1.68	1.07	1.60	76.0	3.35	2.75
Rice bran	7.40	92.60	9.99	15.12	14.25	15.44	5.19	77.4	3..41	2.80	1.86	1.23	1. 76	74.8	3.30	2.70
Rice polishing	7.40	92.60	12.36	15.82	4.16	11.66	7.37	89.9	3.96	3.25	2.33	1.54	2.11	85.4	3.76	3.09
Wheat bran	8.60	91.40	14.99	4.27	12.47	5.69	9.78	71.0	3.13	2.57	1.66	1.05	1.59	73.2	3.23	2.65
Matri	5.40	94.60	25.95	2.67	8.56	3.38	19.8	78.5	3.46	2.84	1.90	1.26	1.80	86.3	3.81	3.12
Swank	6.90	93.10	12.03	8.81	17.83	7.30	7.11	70.9	3.12	2.56	1.66	1.05	1.59	77.3	3.41	2.79
Berseem leaf meal	7.40	92.60	22.14	1.29	15.87	8.10	16.34	64.6	2.85	2.34	1.46	0.87	1.41	66.5	2.93	2.40
Lacero leaf meal	9.90	90.10	23.80	2.33	30.96	5.55	17.12	51.4	2.26	1.86	1.02	0.46	1.05	60.8	2.68	2.20
Molasses	17.70	82.30	3.04	—	-	10.33	—	80.5	3.55	2.91	1.96	1.31	1.85	84.7	3.74	3.06
Beet pulp	9.70	90.30	12.21	2.04	19.93	2.77	7.23	63.8	2.81	2.30	1.43	0.85	1.39	75.8	3.34	2.74
Maize germ cake	4.20	95.80	15.97	8.14	0.29	2.82	10.68	88.4	3.63	2.98	2.01	1.33	1.90	91.2	4.02	3.30

Table III. Composition and energy values of animal protein concentrate ingredients (DM basis)

	Mois-ture %	Dry matter %	Crude protein %	Ether Extract %	Crude Fibre %	Mineral Matter %	Cattle & Buffalo						Sheep & Goats		
							TDN	DE	ME	NEm	NEg	NE_l	TDN	DE	ME
								%	——Mcal/kg——			%	——Mcal/kg——		
Blood meal	8.20	91.80	72.98	1.98	1.74	6.21	88.9	3.92	3.21	2.21	1.52	2.08	86.1	3.79	3.11
Bone meal	5.80	94.20	25.05	1.86	1.54	66.35	57.7	2.54	20.08	1.23	0.66	1.22	85.6	0.30	0.25
Feather meal	4.70	95.30	83.84	1.89	1.11	7.97	89.8	3.96	3.24	2.23	1.54	2.10	83.5	3.68	3.02
Fish meal	6.80	93.20	53.56	7.19	1.18	22.1	85.8	3.78	3.10	2.11	1.40	1.99	70.1	3.09	2.53
Hoof and horn meal	10.30	89.70	18.95	5.24	2.79	6.24	85.8	3.78	3.10	2.11	1.44	2.10	90.8	4.0	3.28
Li'er meal	7.10	92.90	64.91	1.85	1.83	6.89	87.6	3.86	3.17	2.17	1.49	2.05	85.3	3.77	3.09
Meat meal	4.20	95.80	50.63	9.08	2.45	24.74	84.7	3.73	3.06	2.08	1.42	1.97	66.9	2.95	2.42

Table IV. Composition and energy values of green fodders (DM basis)

	Mois-ture %	Crude protein %	Ether Extract %	Crude Fibre %	Mineral Matter %	D.P.	Cattle & Buffalo						Sheep & Goats		
							TDN	DE	ME	NEm	NEg	NE_l	TDN	DE	ME
							%	Mcal/kg					%	—Mcal/kg—	
Maize, early/ full bloom	14.20	9.58	1.55	33.80	9.58	5.42	51.3	2.26	1.85	1.01	0.46	1.05	52.8	2.33	1.91
Maize milk stage	20.10	7.11	2.30	30.40	7.00	3.13	55.1	2.43	1.99	1.14	0.58	1.15	54.6	2.41	1.97
Maize dough stage	29.30	6.04	2.29	27.81	5.52	2.13	56.9	2.51	2.06	1.20	0.64	1.20	55.9	2.47	2.02
Maize mature stage	40.15	6.10	2.12	23.73	4.80	2.19	58.8	2.59	2.12	1.27	0.70	1.25	57.7	2.54	2.08
Bajra, early/ full bloom	16.70	8.26	1.20	31.62	11.60	4.19	49.4	2.18	1.78	0.94	0.40	1.00	51.1	2.25	1.84
Bajra, milk/ dough stage	29.50	6.08	1.73	30.40	8.20	2.17	52.9	2.33	1.91	1.07	0.51	1.09	53.2	2.34	1.92
Bajra, mature, ears removed	35.80	3.12	0.56	41.12	7.23	—	46.4	2.04	1.68	0.84	0.30	1.91	49	2.16	1.77
Sorghum, early/full bloom	14.40	9.51	2.22	32.92	12.50	5.35	50.3	2.21	1.82	0.98	0.43	1.02	50.8	2.24	1.84
Sorghum, milk/dough stage	30.00	6.20	1.67	31.67	9.20	2.28	51.4	2.26	1.86	1.01	0.46	1.05	51.9	2.3	1.88
Sorghum, mature stage	42.00	4.88	1.62	30.74	7.04	1.05	52.9	2.33	1.91	1.07	0.52	1.09	53.2	2.34	1.92
Moth, early/full bloom	16.00	19.88	2.06	24.94	15.31	14.99	54.7	2.41	1.97	1.13	0.57	1.14	56.4	2.49	2.04
Moth, milk/dough stage	21.50	17.39	1.91	28.50	15.20	12.68	52.2	2.30	1.89	1.04	0.49	1.07	54.1	2.39	1.96
Guara, early/ full bloom	17.10	20.00	2.00	28.31	12.70	15.1	55.5	2.44	2.00	1.16	0.60	1.16	57.6	2.54	2.08
Guara, milk/ dough stage	20.90	17.35	2.44	30.97	11.90	12.64	54.8	2.42	1.98	1.13	0.58	1.15	56.1	2.47	2.03
Swank early/full bloom	15.80	10.57	1.65	30.19	17.40	6.34	46.7	2.06	1.69	0.85	0.51	0.92	48.2	2.12	1.74
Swank milk / dough stage	12.30	7.97	2.34	31.42	14.77	3.92	48.6	2.14	1.75	0.92	0.37	0.97	48.7	2.14	1.76
Sarsoon, early/full bloom	15.30	20.26	2.16	18.75	16.08	15.34	56.7	2.50	2.05	1.20	0.63	1.20	57.7	2.54	2.09
Sarson, milk/dough stage	21.70	18.39	2.67	20.97	14.90	13.60	57.0	2.51	2.16	1.21	0.64	1.20	57.1	2.52	2.06
Mongi, early/full bloom	17.35	18.27	1.21	19.98	13.24	13.49	56.3	2.48	2.03	1.18	0.62	1.18	58.4	2.57	2.11

	Moisture %	Crude protein %	Ether Extract %	Crude Fibre %	Mineral Matter %	D.P.	Cattle & Buffalo						Sheep & Goats		
							TDN	DE	ME	NEm	NEg	NE_l	TDN	DE	ME
							%	Mcal/kg					%	—Mcal/kg—	
Mongi, milk / dough stage	22.10	17.31	1.76	20.59	15.32	12.60	54.9	2.42	1.98	1.14	0.58	1.15	56.2	2.48	2.03
Berseem, early vegetative	14.23	21.50	3.66	14.18	14.00	16.49	63.1	2.78	2.28	1.41	0.83	1.37	61.6	2.72	2.23
Berseem, early bloom	15..62	1.90	2.64	18.59	12.20	15.01	60.7	2.67	2.19	1.33	76	1.30	630.2	2.68	2.2
Berseem, full bloom	22.67	18.90	2.24	19.06	1150	14.08	60.0	2.65	2.17	1.31	0.74	1.29	60.6	2.67	2.19
Berseem, late bloom	28.33	15.00	2.11	21.69	11.15	10.46	57.4	2.53	2.07	1.22	0.66	1.22	57.7	2.54	2.09
Lucerne, early vegetative	18.29	24.60	3.19	14.40	13.45	19.37	63.9	2.82	2.31	1.44	0.85	1.40	63.6	2.8	2.3
Lucerne, early bloom	24.26	22.83	2.68	19.03	10.10	17.73	63.4	2.79	2.29	1.42	0.84	1.38	63.9	2.82	2.31
Lucerne, full bloom	27.16	21.20	2.37	20.62	9.02	16.21	62.6	2.76	2.26	1.39	0.81	1.36	63.4	2.79	2.29
Lucerne, late bllom	30.10	16.38	2.22	23.18	9.76	11.74	58.9	2.60	2.13	1.23	0.7	1.26	59.4	2.62	2.15
Oats, early bloom	15.98	12.20	2.88	22.15	14.96	7.85	54.5	2.40	1.97	1.12	0.56	1.13	53.5	2.36	1.93
Oats, full bloom	22.10	8.98	2.30	22.25	12.38	4.86	52.5	2.32	1.9	1.06	0.5	1.08	51.9	2.29	1.87
Oats, milk stage	26.89	7.20	2.08	24.37	11.19	3.21	53.3	2.35	1.92	1.08	0.53	1.1	52.7	2.32	1.9
Oats, dough stage	33.84	6.38	3.07	27.48	10..40	2.45	54.3	2.39	1.96	1.12	0.56	1.1	52.5	2.31	1.9
Barley, early bloom	15.60	13.85	1.80	15.38	12.44	9.39	58.1	2.56	2.1	1.24	0.68	1.23	58	2.56	2.1
Barley, full bloom	20.37	10.80	2.48	21.31	12.57	6.55	55.6	2.45	2.01	1.16	0.6	1.17	54.8	2.41	1.98
Barley, milk stage	24.86	8.77	2.09	23.17	12.19	4.67	53.8	2.37	1.94	1.1	0.54	1.12	53.4	2.35	1.93
Barley, dough stage	29.20	6.71	2.09	29.49	10.45	2.75	52.0	2.29	1.88	1.04	0.49	1.07	51.9	2.29	1.87
Turnips tops, early bloom	9.70	13.81	3.92	14.23	14.64	9.35	60.1	2.65	2.17	1.31	0.74	1.29	57	2.51	2.06
Turnips tops, full bloom	16.50	13.88	3.82	15.45	12.36	9.41	61.4	2.71	2.22	1.36	0.78	1.33	58.5	2.58	2.11
Turnips	11.90	9.66	1.60	18.99	9.16	5.49	57.S	2.53	2.08	1.22	0.66	1.22	57.3	2.53	2.07
Sugarcane tops	33.50	6.20	1.60	29.50	9.10	2.28	52.2	2.30	1.89	1.04	0.49	1.07	52.6	2.32	1.9

Table V. Composition and energy values of dry forages (DM basis)

	Dry matter %	Crude protein %	Ether Extract %	Crude Fibre %	Mineral Matter %	D.P.	Cattle & Buffalo						Sheep & Goats		
							TDN	DE	ME	NEm	NEg	NE_l	TDN	DE	ME
								% ——Mcal/kg ————					%	—Mcal/kg —	
Wheat straw	92.75	2.59	1.18	41.31	12.18	0.00	43.0	1.89	1.55.	0.71	0.18	0.82	44.8	1.98	1.62
Rice straw	92.82	3.06	1.18	35.55	11.79	0.00	45.7	2.01	1.65	0.81	0.28	0.89	47.0	2.07	1.70
Oats straw	89.80	4.90	2.45	39.51	10.27	1.18	49.1	2.17	1. 78	0.94	0.39	0.99	49.2	2.17	1. 78
Barley straw	90.00	4.22	1.78	41.67	8.44	0.59	46.7	2.06	1.69	0.85	0.31	0.92	47.9	2.11	1.73
Maize stover	82.50	5.45	1.45	34.06	8.24	152	50.6	2.23	1.83	0.99	0.44	1.03	51.6	2.27	1.86
Sorghum stover	85.50	3.74	1.29	34.03	11.11	0.18	47.3	2.08	1.71	0.87	0.33	0.94	48.3	2.13	1.75
Bajra stover	85.00	4.00	1.41	36.23	10.29	0.40	47.7	2.09	1. 71	0.87	0.33	0.94	48.5	2.14	1.75
Cotton seed hlls	90.20	4.66	1.23	51.55	3.88	0.97	46.8	2.06	1.69	0.85	0.31	0.92	49.7	2.19	1.80
Sugarcane bagasse	90.50	1.66	0.66	50.28	4.97	0.00	44.3	1.95	1.60	0.76	0.23	0.86	47.4	2.09	1. 71
Maize cobs.	90.50	1.66	0.55	36.46	2.76	0.00	48.8	2.15	1.76	0.93	0.38	0.98	50.6	2.23	1.83
Rice hulls	91.50	2.73	0.76	44.26	22.68	0.00	32.4	1.43	1.17	0.31	0.20	0.53	35.7	1.57	1.29
Berseem hay	85.60	18.46	2.45	31.31	12.27	12.93	54.8	2.42	1.98	1.13	0.57	1.14	56.3	2.48	2.04
Lucerne hay	87.50	18.86	2.28	33.14	11.43	13.27	54.6	2.41	1.97	1.13	0.57	1.14	56.6	2.50	2.05

CHAPTER IV E

Feeds and Feeding

Feed Processing and Manufacturing

(Tariq Mahmood)

Although animals have been domesticated for thousands of years, the concept of a manufactured or processed animal feed is a relatively recent development. Indeed most of the information presently used in feed formulation is less than 125 years old, and it was started primarily as an outlet for milling byproducts. As the feed industry grew, new processing methods, such as dehulling, extrusion, grinding, rolling, flaking, popping, roasting, microwaving and pelleting, were shown to improve responses in growth rate and feed efficiency of food animals.

The feed manufacturer of today must monitor ingredient quality, keep an inventory of ingredients and feed additives, be familiar with computer technology, be able to manage people and, above all, be in touch with the changing needs of the customer. The feed manufacturer must also know his immediate market, familiarize himself with international factors that govern world demand and understand new technological developments in feed manufacturing that arise throughout the world.

Pakistan has 215 feed mills, but only a few prepare compound feeds for livestock as the animal feed industry has not yet developed to a sizeable extent. Indeed, the feed industry is presently at only 60% of installed capacity, which is enough to satisfy domestic demand. While underutilized capacity is available at existing mills, only sporadic efforts have been made to increase the cattle feed industry to utilize it. In this chapter, the basic concepts involved in establishing a physical facility, manufacturing operations and quality consideration in the feed manufacturing are outlined.

Physical Facilities ˘ Feed Plant

Establishment of a physical facility is the first step in the manufacture of livestock feed. This facility is called feed plant, or a feed mill, and is comprised of buildings, feed processing equipment, storage for raw materials and finished feeds, and infrastructure such as electricity, gas, water, sewer and roads. There is no static model for the location and size of the feed plant, which is determined by business needs.

Plant Feasibility

A feasibility study can determine, by careful long range planning, a design to improve the profitability of the firms through an orderly business structure. The key components of a feasibility study include:

- Assigning responsibility.
- Setting time schedules.
- Determining market area.
- Defining market area.
- Determining feed sales potential.
- Analyzing market competition.
- Determining marketing program.
- Developing long range forecasts.
- Developing a preliminary plant design.
- Selecting the site.
- Preparing a preliminary survey for utilities and infrastructure.
- Estimating cost and returns on investment.

Feed Plant Layout, Design and Construction

Feed mill design theory incorporates fundamentals of many disciplines, including engineering, mechanics, materials science, economics, chemistry and ergonomics. Before a designer can apply his or her knowledge and skill to the development of plans and specifications, the following inputs are needed from operations personnel, nutritionists and corporate level managers in strategic planning, marketing and finance.

Strategy, Objectives and Goals

Review the company's long range strategic plan and list corporate objectives affecting plant operation. These may include maintenance costs, customer services, operating costs, product quality, new product/process and production capacity.

Ingredients, Formulas and Delivery

Provide the list of formulas, identify ingredients by percent of total, include major, minor, micro-ingredients and liquids. Describe ingredient deliveries, provide volumes, frequency of deliveries, method of delivery, and distance from the supplier to determine needed storage capacities. Current volume and proposed increases over the next three, five and seven years should also be outlined.

Operations

State the desired number of days and hours (shifts) per day of operation to determine requirements for manpower and equipment capacities. Provide a plot plan of the site, copy of the soil report and local government rules and regulations. Identify available utilities and supplies (e.g., electricity, gas, water). Determine costs of establishing and running utilities. In the light of these inputs, a design process undergoes a logical sequence of a master plan, a detailed design, the project manual and finally construction.

Phase 1: The Master Plan

A master plan is the first comprehensive look at the physical and fiscal aspect of a project. The design detail of the feed mill project contains:

- Documented Processing Capacity Analysis.
- Documented Storage Capacity Analysis.
- Conceptual Drawings of the mill which includes:
    - o Process Flow Diagram
    - o Site Plan
    - o Facilities Layout
    - o Elevation
    - o Equipment Layout Drawings at the
        - Ground Floor
        - Work floor
        - Roof Plan
        - Bin Arrangement
- Line-Item Cost Estimate for equipment, Labor and Material
- A narrative explaining design options, analysis process, and pros and cons.

Phase 2: The Detailed Design

The more concrete and complete the plan, the more likely it is to get financial support. It would be difficult, if not impossible, to fully outline a designer's procedure in analyzing and evaluating each step in the design of the structure and mechanical components. However these considerations are the foundation of feedmill design:

- Balancing capital cost with maintenance
- Operating and labor cost
- Potential for expansion
- Efficiency
- Safety
- Appearance

- Utility
- Expected useful lifetime
- Flexibility
- Quality control
- Value

Feed Manufacturing Operations

This section describes manufacturing operations within six operating sections, which are outlined schematically in a process flow diagram in Figure 1.

Receiving of the Raw Materials

The receiving centre includes activities after procurement of materials used directly or indirectly in manufacturing. This centre encompasses actual receiving, which starts when the material arrives at the facility, and terminates when the material is at its destination, and includes scheduling of ingredients, quality control analysis and claims on received materials, as well as actual operation and management of the receiving centre.

The receiving centre begins as the truck is located at the unloading area. It includes receiving, drying, cleaning, storing and handling. It also includes all incoming raw materials including empty bags and other supplies, and ends as materials arrive at storage bins or the receiving warehouse. Records must be kept on ingredients received by the receiving operator. Receiving records should provide:

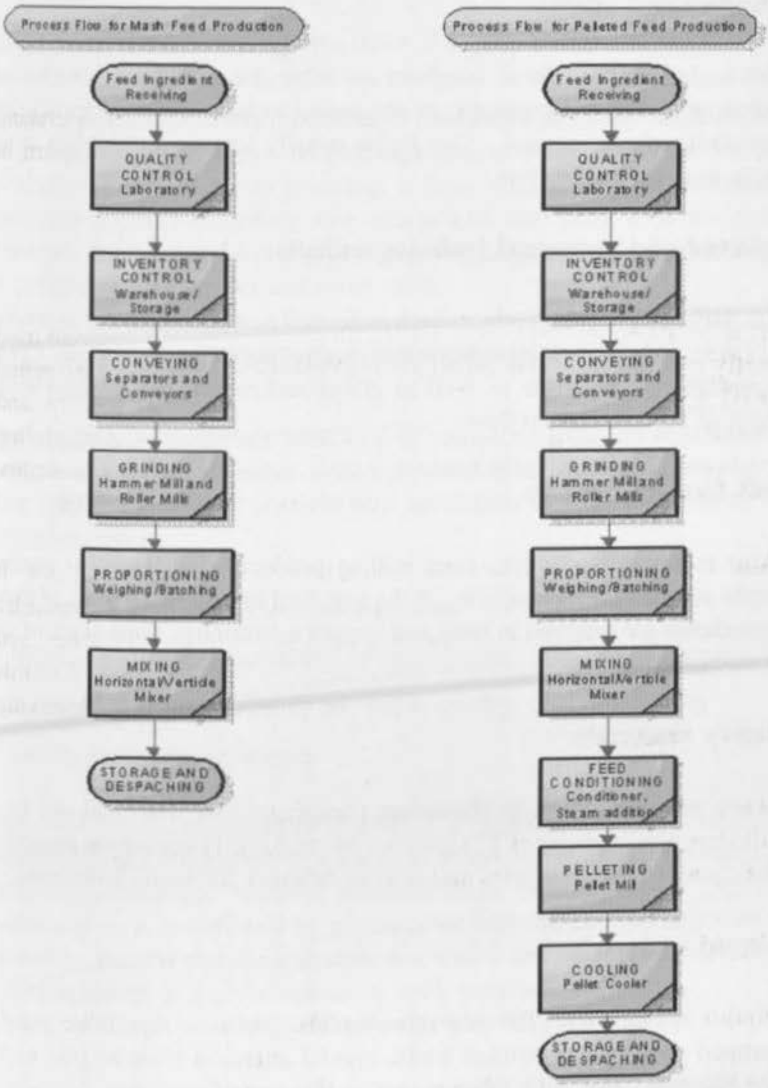
- Identity of the goods and the arriving vehicle.
- Quantity.
- Name of the supplier.
- Date of receipt.
- Condition of the product (approval or rejection must be stated).
- Initials of the receiver.

• Manufacturer's lot number and expiration date for drug/vitamin premixes.

• Bin number or storage area where the ingredients are placed.

• Time and sequence of unloading.

Figure 1. Process Flow Diagram



The equipment and the building area allocated for the receiving center are dependent to a large extent on the volume and variety of products to be manufactured. When allocating space for the receiving center, one of the most important points is a material handling system that considers capacities, ingredients, formulas and other special operational needs. Materials handled in the receiving area can be grouped into one of the following categories:

Unprocessed grains

This includes, corn, wheat, sorghum and other grains that need processing before use. These ingredients are the easiest to handle due to density and flowability characteristics. Dry grains usually require a minimum slope angle to sustain good flow.

Pelleted and processed bulk ingredients

This includes pelleted products such as deoiled rice bran meal and vegetable oil cakes, and all other ingredients that require processing before use. These ingredients do not flow as well as grains and require a minimum slope angle of 50° to maintain flow.

Soft feed ingredients

Flour milling by-products, corn milling products and numerous protein meals account for the majority of the soft feed ingredients. Most of these ingredients are received in bulk and require a minimum slope angle of 60° to sustain good flow.

Heavy materials

Heavy materials, such as dicalcium phosphate, limestone and salt have bulk densities in excess of 22 kg/cubic foot, making it necessary to designing dedicated handling systems and storage facilities for such ingredients.

Liquid materials

Liquids are molasses, fats and other liquids. Because liquids are usually pumped directly into storage tanks, special attention must be paid to in-line filtering. Very little labor is used in this part of receiving.

Drugs and micro-ingredients

The category of drugs and micro ingredients account for a very small portion of ingredients received. However special handling and storage facilities are necessary because they are expensive and sensitive to degradation. Most of these materials are received in special containers or bags which are handled manually.

Material Processing

Material processing is any procedure to change the physical characteristics of an ingredient to improve its blending characteristics or increase nutrient availability. This includes grinding, rolling, flaking and movement of materials to and from processing equipment, and ends with processed materials delivered to blending or storage bins. Common equipment used in processing are hammer and roller mills.

Measuring and Defining Particle Size

The majority of materials used in feed manufacturing are subjected to particle size reduction either within the feed plant or prior to receiving. The major reasons for particle size reduction in feed manufacturing operations are to:

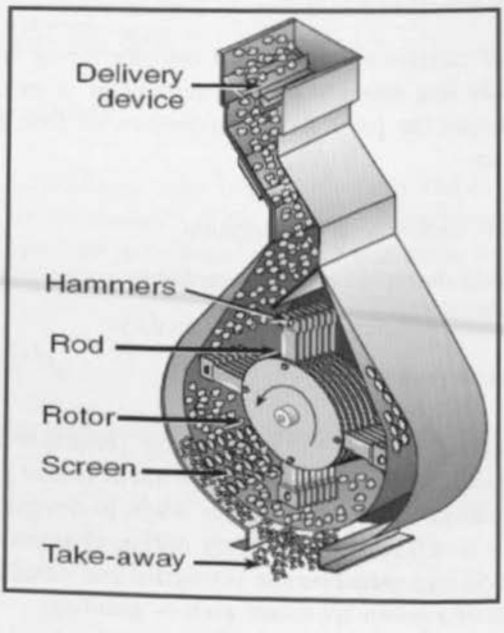
- Expose greater surface area for digestion.
- Improve mixing characteristics of ingredients.
- Increase Pelleting efficiency and pellet quality.
- Satisfy customer preference.

The most important reasons for particle size reduction are to improve digestibility and mixing homogeneity and to aid in further processing (e.g., pelleting, extruding). Without adequate ways to describe and measure particle size, it is difficult to precisely define changes to improve an operation. Particle size measurement is a useful and meaningful technique to define results of a given operation, such as grinding.

Hammer Mill Systems

A typical hammer mill consists of a horizontal rotor assembly inside a metal housing. The rotor assembly includes the shaft and several circular plates. Mounted on the rotor assembly are rows of hammers (also called knives) which typically are flat steel blades or bars punched with one or two holes. A steel rod (also called a pin) passes through one hole of each hammer in a row and then through the rotor plates to hold the hammers in place. A perforated metal screen forming either a full circle or half circle fits around the rotor assembly. The screen opening diameter matches the desired particle size. A material inlet is located at the housing's top and a material outlet is located below the housing. A flow deflector is mounted below the material inlet above the hammers. An air system, which can be located elsewhere in the plant, can be connected by piping to the hammer mill, which creates an air-assisted grinding system.

Photo#1. Grinding Process in Hammer Mill



Grinding Process in Hammer Mill

Operating and maintaining a hammer mill system is easier and less expensive if design factors, such as feed material characteristics, hammer mill factors and final product specifications, are considered when selecting the hammer mill. Though a hammer mill is more likely to have problems when improperly designed, installed, or maintained, a variety of problems can occur even when these steps are completed correctly. Problems include improper feeding, too much or too little power, improper screen to hammer clearance, screen wear and excessive vibration.

Roller Mill Systems

Roller mills are commonly referred to by the type of service they perform. A mill used to crack grain or other friable materials may be called a cracking mill. All roller mills will have a framework to house the rolls and contain the roll separating forces experienced in operations. This basic frame must be robust enough to hold the rolls securely in position during operation, yet allow easy access to the rolls for maintenance. In any roller mill, the rolls will need to be removed periodically for recorrugation. This very important task must be carefully studied when roller mill selection is made and the installation is laid out. Roller mill generally perform one of thee processes:

- *Cracking/Crimping*: are the most basic roller mill processes for feed grain preparation. Cracking breaks the kernel of grain into two or more pieces while crimping opens up the seed coat for more ready digestion.

- *Flaking*: can normally be achieved only if the grain to be processed is conditioned before being rolled. Typical conditioning systems include dry heat or live steam. The purpose of conditioning is to make the grain soft and pliable so that, when subjected to roll pressure, a tough durable flake will be produced.

- *Grinding*: Factors to be considered include energy costs, product quality and environmental factors. Essentially, a roller mill grinder will utilize rolls from 9 to 12 inches in diameter operating at differential speeds. Differential ratios vary from about 1.2:1 up to 2:1 for typical feed milling operations.

Proportioning and Mixing

Since feed manufacturing is the compounding business, the proportioning and mixing system is the heart of any feed manufacturing plant. Each ingredient has its own identity until it is mixed with other ingredients to make a formula feed. The proportioning and mixing operations can be accomplished using a continuous line, or a batch type, system. However batch systems are used most commonly in full-line commercial feed plants.

Batch Mixing System

Continuous mixing systems were predominant in the early years of the feed industry when the number of ingredients was limited to two or three. Batch systems became dominant as the number of ingredients (particularly micro-ingredients) available to the feed industry, and the number of types of feed produced in a feed plant, increased. Batch mixing systems range from manual to highly computerized operations. Some advantages of batch systems are that they are relatively compact and adaptable to small plants, assure accurate allocation by weight, and that formula changes can be accomplished efficiently.

Weighing Equipments

There are several modifications of manual weighing systems, with the simplest being the single platform scale, where ingredients are handled in sacks, weighed on a scale and manually dumped into the mixer. Most scales are equipped with a digital read-out from a load cell allowing for faster and more accurate weighing.

Computerized batch controllers are comprised of a scale hopper and computer software that controls the sequencing of ingredient addition according to inclusion weight. Electronic loadcells are used in most weighing operations because of their reliability, sensitivity, speed and ability to interface with other portions of the batching system. The load applied to the load cell through weighing causes a small deflection within the cell that changes its electrical resistance. This change in resistance is transmitted to a digital readout, or sensed by the process computer to control weighing.

Regardless of type, it is imperative that scales be calibrated regularly and certified by professional inspectors. Routine checks should be made by in-plant quality control or supervisory personnel. Records of these inspections should be made and maintained.

Mixing

There are different types of mixers used in batch mixing, but the two most often used are the vertical screw mixer and the horizontal mixer, either ribbon or paddle. More recently, use of rotating drum mixers has increased, particularly in smaller grind and mix operations and specialty feed manufacturing. Factors to consider when choosing and sizing a mixer are:

- Production capacity requirements.
- The bulk density of the ingredients or mixed feed.
- The amount of liquid to be added.
- Location and space restrictions.
- Degree of clean-out required.
- Mixer performance criteria.

Although mixers are often described gravimetrically (e.g., 1 tonne) they are volumetric by design. In sizing and operating the mixer, it is critical that the bulk density of the mixed feed be determined and the batch size be consistent with it. For example, a mixer can hold more of a corn grain and soybean meal mixture than one high in wheat middlings. There are two types of mixer used in the feed industry, being vertical and horizontal mixers.

Vertical Mixers may have only one elevating screw, or two screws, to move more material and speed the mixing process. Some advantages of vertical mixers are:

- They are relatively inexpensive.
- Installation costs are usually lower than for a horizontal mixer.
- They require less space and can often be installed on a scale, eliminating the need for a scale hopper.

Disadvantages of vertical mixers include:

- They usually require a longer mixing time.
- Liquids cannot be added at levels as high as in horizontal mixers.
- Complete mixer cleanout is difficult.

Horizontal mixers, double ribbon type, are most commonly used in the feed industry, and conveys material from one end to the other while tumbling. These mixers may have one or several discharge ports, or a complete drop bottom. Liquids can be added up to 5%, and these mixers can be equipped with paddles to allow even higher percentages.

The capacity filling of horizontal mixers is critical. Under and overfilling mixers inhibits mixing, and most mixers should be filled to two-thirds. When low density ingredients are used, the batch weight may have to be reduced. Ribbons or paddles should come slightly above the surface of the mixture during mixing.

Pelleting

The pelleting center within the feed manufacturing facility provides a means of molding feed mash into larger particles. Pelleting is accomplished through a mechanical process in combination with moisture, heat and pressure. There are many reasons why feed is pelleted, but two of the primary ones are:

- *Pelleting improves feed efficiencies*: Moisture, heat and pressure combine to gelatinize, or break down, components in the feed ingredients permitting better nutrient utilization by the animals. Pelleting also reduces segregation of different ingredients within the finished feed and feeding pellets reduces natural losses, such as from wind and spillage.

- *Pelleting improves feed handling characteristics*: Pelleting increases bulk density thereby allowing more product in a space. Increased density will vary depending on the type of ingredients pelleted. For example, fibrous materials will increase density considerably more than non-fibrous materials when pelleted. Flowability is also improved when comparing pelleted to meal type feeds.

A typical pellet mill has three functional parts, being a feeder, conditioner and pelleting press. Feed mash from the pellet mash bin flows into the feeder and then to the conditioner where steam and liquids are added. The conditioned mash then flows into the pelleting chamber ,or the pelleting press, where the pellets are formed and sent to the cooler. The hot pellet passes through the cooler where it is cooled by air movement from a fan. Fines in the cooling air are separated in a collector and returned to the pellet mill for reprocessing. Cool pellets are discharged from the cooler and pass around, or through, the crumbler depending on the product being manufactured.

Pellet mills are available in a wide range of sizes, from 20 to 700 horsepower (15 kW to 522 kW). There are two types of main drives available on pellet mills to transfer motor horsepower to the pellet die, being the belt and gear drive. Gear driven pellet mills are normally available in higher ranges of horsepower than belt driven mills. To determine the appropriate size of pellet mill, some factors need to be considered:

- Type of formulation or ingredients used.
- Capacity requirements.
- Pellet quality requirements.
- Product mix, to include pellet diameter and run sizes.

Blocking

Machines developed to manufacture mineral and protein blocks for the feed industry have been designed on the basis of one of two processes incorporating a single press or a continuous extrusion. In one of the most exacting operations in the feed mill, a force of 50, 75, or 100 tonnes is employed to form a block in the molding chamber of a block machine. To form a block of a specified weight and dimension from a mixed meal, there are several equipment arrangements which include:

- Protein block ingredients are mixed dry in a continuous, or batch type, mixer and conveyed to a holding bin above the block press.
- A feeder conveyer is used to transfer the dry mix material to a mixer. The weight can be handled by a variable speed feeder or a scale system on the mixer. A typical batch size is 500-1000 kilograms. Liquids are metered into the mixer and mixing time can vary from 4-8 minutes depending on product.
- The mixer discharges into a surge bin which feeds the block press.
- The block machine presses the block and discharges it onto a conveyer or to a discharge chute. The chute can guide the block on to a table for manual wrapping or to an automatic shrink wrapping machine.

Feed Packaging

The packaging center begins with the finished feed in the supply bin above the packer and ends when the bagged feed is placed in the warehouse. The packaging center includes weighing the feed for each bag, placing product in the bag, closing the bags, placing a tag on the bag and moving the bag to a warehouse.

The packaging operation may be the placing of a bag on a platform scale and filling it to the desired weight by hand, or with automatic equipment which weighs, closes the bags, and places the bags on pallets. The bag type mostly used is woven polyethylene. It is essential for the packer operator to perform these quality checks:

- The feed is being packed from the correct bin.
- The correct bag and tag are used.
- The feed is free of cross contamination.
- The feed is sampled according to quality control procedures and requirements.
- Bag weights are within tolerance.
- The swing line is straight across the bag.
- The bags are clean.
- The bag code is correct and legible on each bag.
- Set off and sweeping are identified correctly.
- The packer report is completed correctly.

Warehousing and loading of finished products is an important and costly function in manufacturing and distribution of feeds, and it is an area where progress has been slower than in other sectors of the industry. There has been less management emphasis on control of warehousing and loading costs, and improvement of handling methods.

Quality Assurance

Quality assurance is everything that goes into producing a product. This stretches from the initial concept through ingredient specifications, formulation of the feed, manufacturing and distribution, feeding trials, customer service, employee commitment and dedication to quality products.

Customers require a high return on their investment and deserve, and have a right to expect, the highest quality feed that can be produced. The assurance of high quality begins with an effective quality control program. This comprehensive program has several critical components:

Sampling

Sampling affects many more decisions than is commonly supposed. As stated by Ghert (1976). "No analysis can be better than the sample from which it was made." Some of the decisions affected are:

- The selection of an ingredient for a feed formula.
- The selection of supplier for an ingredient.
- The acceptance or rejection of a shipment of an ingredient.
- The status of a process in control or not in control.
- The status of a product. Does it meet its specification and guarantee?
- Should an official report be challenged?
- Are all guaranteed items stable for the required period?

Persons concerned with feed manufacturing and quality control may have numerous decisions that require a sample and their decisions will be affected by sample quality.

Laboratory Testing

Laboratory testing is the process of measuring specific components of a feed or ingredient sample to assure its quality. This may be a chemical, physical and/or electronic measurement to determine the quality of a product when compared to a predetermined standard. Laboratory testing is an important part of any quality assurance program. Laboratory test data, or summaries, can be used to evaluate quality in the manufacturing process. Test data may be used to:

- Evaluate ingredient and ingredient suppliers.
- Evaluate formulated nutrient content of feed.
- Establish product standard deviation, variation, and trendlines.
- Measure performance of plant equipment.
- Assist in trouble-shooting manufacturing difficulties.
- Assure that a feed meets the label guarantee.
- Promote marketing and sales programs.
- Defend the firm against claims from complaints and/or regulatory action.

For these reasons, most feed manufacturers require a laboratory testing program to support their product facilities. Laboratory testing is available from:

- Company laboratories;
- Commercial laboratories: and
- Regulatory agency laboratories.

Laboratory Test procedures

Physical Tests

Tests conducted by the laboratory may be very basic physical type tests such as pellet durability, fines test, particle size, and pellet hardness.

Pellet durability index (PDI)

This is a test developed by the Department of Grain Sciences and Industry of Kansas State University to measure the relative ability of the feed pellet to resist breaking up in bulk handling systems.

Fines testing is the process of screening or sieving a bag or a sample of a pellet feed to determine the fines portion. The original weight of the bag or sample is obtained and the sample is screened to remove small particles of fine material which are also weighed. The fines content of a lot of feed will vary greatly from one portion to another, and more than one sample or test may be required to obtain representative results.

Particle size testing

This is the process of determining the mean particle size of a sample of a feed or ingredient. The particle size is a very important factor in mixing characteristics of ingredients and pelleting ability. Particle size is also a factor that impacts feeds or ingredient bridging in bulk bins.

Hardness testing

This is a measure of the relative hardness of a pellet by using the Stokes Pill Hardness Tester. Because of the high degree of variability of this test, a relatively large number of pellets must be tested to get an average that is representative of the feed.

Chemical Tests

Chemical tests require the sample to be broken down, or altered, by some chemical process. This process usually requires that the sample be dissolved or digested in an acid solution, or be extracted using a solvent. The most common chemical tests are analyses for moisture, crude protein, fat, fiber, ash, pepsin digestible protein, total sugar as invert, and non protein nitrogen (NPN), calcium, phosphorus and salt.

Mycotoxins (i.e., toxins produced by molds) tests may be required on ingredients such as grains and feeds. The most requested mycotoxin tests are aflatoxin, T2 toxin, vomitoxin (deoxynevalenal), zearalenone and fumonisin, and most commercial laboratories are equipped to test these mycotoxins. Vitamin tests may be required on some dairy and starter feeds to confirm vitamin levels of the feed, and most commercial laboratories are equipped to assay for vitamins. Most vitamin assays are very expensive.

In˘plant Quality Commitment

Quality assurance is a comprehensive program of controls directed at ensuring production of products that consistently meet their predetermined quality standards. Many in the feed industry use the terms 'quality control' and 'quality assurance' interchangeably. However the term 'quality control' refers to individual control endeavors, while the term 'quality assurance' refers to the overall program of actions providing assurance that products meet the standards set for them (Boyd, 1993). A feed company, through its policies, procedures and standards, assures quality by prudent purchasing, formulation, and laboratory analyses, but the ultimate control of quality is vested in the manufacturing process. Quality is the fine-tuning accorded to any activity which gives the end product real value, and is the degree of excellence which a product or service possesses. Real quality control takes place in facilities where quality commitment stressed.

CHAPTER IV F

Feed and Forage Evaluation Techniques

(Imdad Hussain Mirza and R.S.N. Janjua)

A feed may appear to be nutritious and of high quality, but unless it is analyzed by physical, chemical and/or biological means, there is no way to be certain about its true nutritional value for livestock. For example, a feed that is high in nutrients, but low in digestibility, is of little value as a livestock feed. Profit is the ultimate criterion of success in any livestock operation, and the cost of digestible nutrients is an important factor that determines this success. As there is considerable variation in the nutrient content of many feeds, the value of a well-planned feed analysis program is substantial.

Importance of Proper Sampling

A feed analysis is only as good as the sample obtained since, if the sample is not representative of the entire batch, its evaluation is less useful regardless of how extensively the sample is analyzed. Feeds tend to be highly variable in composition. For example, a bale of hay may dramatically differ in its feeding value from the bale immediately next to it. For this reason, several samples are taken from various representative bales and the samples are thoroughly mixed to form a representative sample of the entire stack. From this, an aliquot is taken for analysis so that it accurately represents the average of the feed sampled. Occasionally, samples are split for analysis after collection and mixing, often with the purpose of sending them to different laboratories to determine inter-laboratory variation.

When a hay bale is sampled correctly with a coring device and compared with a grab sample taken from the same bale, the analyses will differ (Table 1). Good sampling technique involves using the proper sampling equipment, and collecting an appropriate number of sub-samples.

Table 1. Differences in Alfalfa-Orchard grass hay bale sampled by two methods

	Sampling Method	
	Cored	**Grab**
Crude protein, %	16	13
Neutral detergent fiber, %	56	63
Acid detergent fiber, %	37	42
Net energy of lactation, Mcal/kg	1.23	1.08

Methods of Feed Analysis and Evaluation

Feeds can be analyzed by physical, chemical and/or biological procedures. Although physical evaluation may be the least accurate, it provides quick and easily obtained information about the overall quality of a feed. Chemical procedures are more accurate than a physical evaluation, but they take time and money. Biological methods are generally more expensive and time consuming, and results are often variable. Some of the methods used in forage evaluation are:

Visual Appraisal

Appraisal of a forage based on sight, smell and touch can provide general information. Color, leaf content, stem texture, maturity, contamination from weeds, molds or soil, and observations on palatability are useful visual appraisals. In Pakistan, the majority of the farmers use this method due to a lack of resources to afford others.

Microscopic Examination

Some laboratories in other countries use microscopes for feed evaluation. Referred to as 'feed microscopy', use of a microscope by a trained technician can identify and quantify feed ingredients and determine the amount of contamination. Weed seeds, foreign objects, mold and damaged grains can all be observed under the microscope.

Wet Chemical Analysis

Wet chemical procedures, based on chemical and biochemical principles, are widely used for feed evaluation internationally, as well as in Pakistan. However these assays take a considerably longer time to complete and are relatively expensive.

Proximate analysis

This wet chemical set of procedures determines moisture, total nitrogen (crude protein; CP), ether extract (EE; lipids and fats), ash (total mineral content) and crude fiber (CF). Through proximate analysis, it is also possible to calculate total digestible nutrients (TDN; an estimate of digestibility and digestible energy level).

Moisture

In order to assess the nutritional value of feeds, a first step is often to determine how much water is contained in them. Many high-moisture feeds, such as sugar beets, compare very favorably with corn and other traditional feedstuffs on a dry matter (DM) basis, but their high moisture content may restrict their DM intake of livestock. The DM is the proportion of a feed that is not water. On a DM basis, the CP content of many grasses may be equivalent to grains but on an as-fed basis they will be lower because of the higher water content in grasses.

Crude protein analysis

It is mostly measured by a Kjeldahl method and measures total nitrogen which is then multiplied by 6.25 to calculate the CP level of the feed. This 6.25 figure is used because most feeds have about 16% nitrogen in their protein. CP includes true proteins and non-protein nitrogen compounds. Ruminants are able to utilize a portion of both types of CP.

When excessive heating has occurred in the forage, such as in poorly managed silage or hay, a portion of the CP may become indigestible. If heat damage is suspected, an analysis for bound, or unavailable, CP should be requested. Laboratories typically report bound protein as the CP in ADF

(ADICP). If bound CP exceeds 12% of CP, then there has been enough heating to reduce protein digestibility. If bound protein is over 15%, then there has been extensive heating in the forage. This analysis is essential because CP is one of the most expensive nutrients of the feedstuffs, and economical ration formulation is not possible unless the indigestible protein level of the CP is known.

Crude fiber analysis

Crude fiber (CF) consists of cellulose, hemicellulose and lignin. In ruminants and herbivorous non-ruminants, a portion of CF can be digested through microbial degradation in the rumen but CF is an indicator of the relative digestibility and bulkiness of a feed. The feed sample is first boiled in dilute acid and then in dilute alkali to simulate the digestive action of gastric secretions. The residue of the sample that remains undigested after these boiling procedures is then weighed and ashed.

Ash

The ash fraction of a feed is the inorganic or mineral constituents of the feed. Samples in porcelain crucibles are placed in a muffle furnace and ignited at a temperature in excess of 600°C. The residue left after burning is ash. In plants, ash composition is highly variable since soil characteristics determine the makeup of this fraction. This analysis is of low value unless further analyzed for its mineral levels (e.g., Ca, P, S).

Ether extract (EE)

Many refer to this fraction as the fat portion. However, ether also extracts organic acids, oils, pigments, alcohols and fat-soluble vitamins. The sample is extracted with ether using a specially designed apparatus. After extraction is complete, the ether solvent is evaporated and the residue that remains is called ether extract. This analysis is of less importance in roughages because EE content is low. However in some grains and industrial by-products it is very important because of the higher content of fat, and its high energy level.

Usefulness of the proximate analysis

1. Expensive and sophisticated equipments are not needed.
2. It provides a good general evaluation of the feed.
3. The TDN system is a widely used feeding standard.
4. Most available data on feed composition is reported in terms of proximate analysis.

Some of the disadvantages of the proximate analysis are:

1. It does not define the individual nutrients of the feed.
2. It is not very accurate and is time consuming.
3. It does not tell about the indigestible components in a feed.
4. It does not provide information relative to palatability, texture, toxicity, digestive disturbances, associative effects of feedstuffs, or nutritional availability.

Detergent or Van Soest method of cell wall determination

This is a newer wet chemistry method for evaluating the plant cell wall content of forages (Van Soest, 1994), as CF is criticized for undervaluing good quality forages and overestimating poor quality forages. The key fiber fractions in the Van Soest system are neutral detergent fiber (NDF) and acid detergent fiber (ADF). In this system, the insoluble portion of the forage (NDF) contains cellulose, hemicellulose and lignin. It is commonly referred to as the cell wall fraction. NDF has been shown to be negatively correlated with DM intake (i.e., as the NDF of a forage increases, animals consume less of it). NDF tends to increase with the advancing maturity of plants. In contrast, ADF (NDF minus hemicellulose) has been shown to be negatively correlated with digestibility (i.e., as ADF increases, the forage becomes less digestible). The classification of forage fractions using the Van Soest method is in Table 2. A schematic diagram of this detergent system of forage analysis is in Figure 1.

Table 2. Classification of forage fractions using the Van Soest method

		Nutritional Availability	
Fraction	**Component included**	**Ruminant**	**Non-Ruminant**
Cell Contents	• Sugars, starch, pectin	Complete	Complete
	• Soluble carbohydrates	Complete	Complete
	• Protein, non-protein N	High	High
	• Lipids (fats)	High	High
	• Other solubles	High	High
Cell Wall Contents	• Hemicellulose	Partial	Low
	• Cellulose	Partial	Low
	• Heat damaged protein	Indigestible	Indigestible
	• Lignin	Indigestible	Indigestible
	• Silica	Indigestible	Indigestible

In Vivo and *In Vitro* Disappearance Evaluation

In vivo (in the animal) and *in vitro* (in the glass/in the test tube/in the laboratory) procedures are also commonly used to evaluate forage/feed quality (Tilley and Terry, 1963). Most often, DM disappearance at a specific period of time is measured and this value indicates the digestibility of the forage.

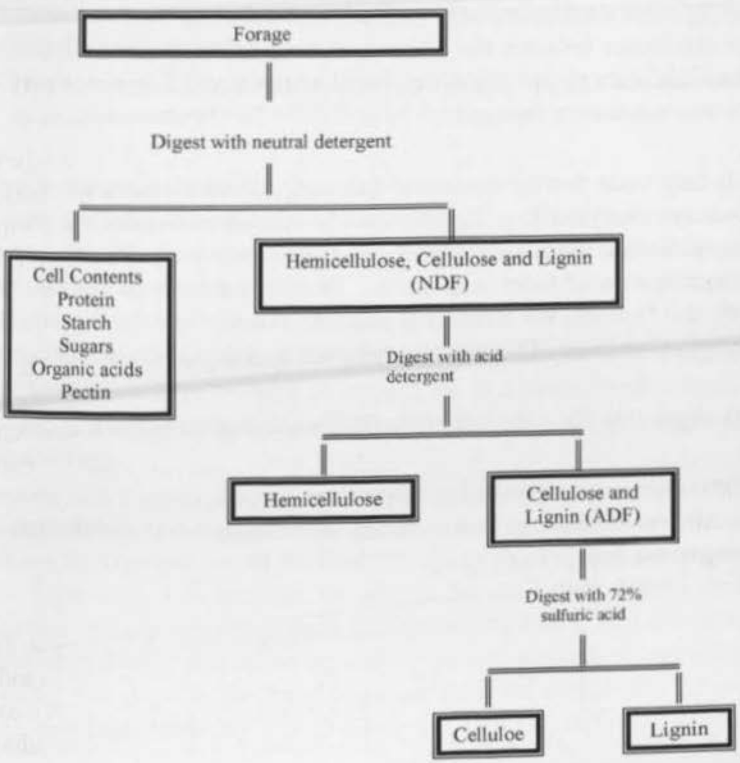
In vitro is usually a two-step procedure done in test tubes. The forage sample is digested using rumen fluid from a donor animal to simulate rumen digestion. The sample is then digested in an enzyme solution to simulate digestion in the small intestine. Both *in situ* and *in vitro* are excellent techniques for forage evaluation.

The nylon-bag technique

In situ techniques provide a means of ranking feeds according to the rate and extent of degradation of their DM, organic matter, nitrogen and other nutritional parameters. It involves incubating samples of feeds in the rumen of rumen-fistulated animals for periods up to 120 hours and subsequent determination of the disappearance of the various feed components. The rumen nylon-bag technique is often appropriate because it does not involve large amounts of inputs.

The technique uses bags (6.5 x 14 cm) made of nylon mesh (30-50 μm). A sample of feed is tightly sealed in a nylon bag and placed in the rumen of a fistulated animal. After the required period, the sample is removed, washed, dried and weighed. Degradability (or disappearance) of substrate is determined by weight loss during the incubation period. The pore size of the bags must allow entry of rumen microbes and escape of accumulated gases. Efflux of feed particles from the bags without their degradation by rumen microbes is corrected by using zero-hour bags that are filled with the substrate, but are not incubated in the rumen, before washing and drying in the same way as incubated bags.

Fig 1. Schematic diagram of the detergent system of forage analysis



When nitrogen disappearance of low nitrogen feed is of interest, the nylon-bag technique may not be precise enough as microbial contamination will bias results. However, overall, the nylon-bag technique is a simple and useful biological tool to evaluate the nutritional value of feeds. If determination of DM disappearance is the only analysis of importance, then the main analytical equipment needed are an accurate balance and drying oven. In general, apart from rumen-fistulated cows, the materials required are: nylon bags; nylon string/cord; analytical balance; drying oven or drying device; washing machine or running tap water; desiccator.

Digestion studies

As animals are not able to utilize all nutrients in feeds, the actual nutritional value of a feed is dependent upon their digestibility. A digestion study is conducted by determining the proportion of each nutrient in the feed through chemical analysis; feeding the feed to the test animals for a preliminary period (~7-10 days), so that all residues of the former diet will pass out of the digestive tract; collecting, weighing and analyzing the feces; determining the difference between the amount of the nutrient fed and the amount in feces; and then computing disappeared nutrients as the digestion coefficient for that nutrient in the feed.

It is important that the urine and feces are collected separately, since only feces are analyzed in a digestion study. Anatomical problems often limit use of female animals in digestion studies since it is difficult to prevent contamination of feces with urine. Because an analysis can be done on both the feed and the feces, it is possible to determine the digestibility for each feed nutrient. This may be followed by calculation of TDN as:

$$(\%\ \text{digestible CP} + \%\ \text{digestible NDF} + (\%\ \text{digestible EE} \times 2.25))$$

TDN is not commonly used in ration formulation because it does not account for all losses that can occur during fermentation and metabolism when forages are fed.

Determination of Voluntary Intake, Digestion and Retention Coefficients

Voluntary intake is determined by offering animals a known quantity of feed and determining the amount remaining at the end of the feeding period. Digestion and retention coefficients are determined by collecting excreta (i.e., urine and feces) and then analyzing feed and excreta samples. The difference between the nutrients absorbed and retained in the body can also be determined by analyzing urine and milk.

Direct method

The experiment can take as little as 23 days if feed is in short supply, but 28 days are preferable. Offer the animals 2% of live weight for a minimum of 5-10% uneaten feed. Uneaten feed should be weighed and discarded. The first 14 (or 21) days of the experiment are a preliminary, or adaptation, period with days 15 through 21, or 21 through 28 (7 days), forming the intake measurement period.

Feed intake measurement and collection of faeces and urine

a) Weigh the animals on the first day of the study and place them in individual metabolism cages. The type of metabolism cage will determine whether fecal bags are needed to reduce chances of contamination of urine by feces.

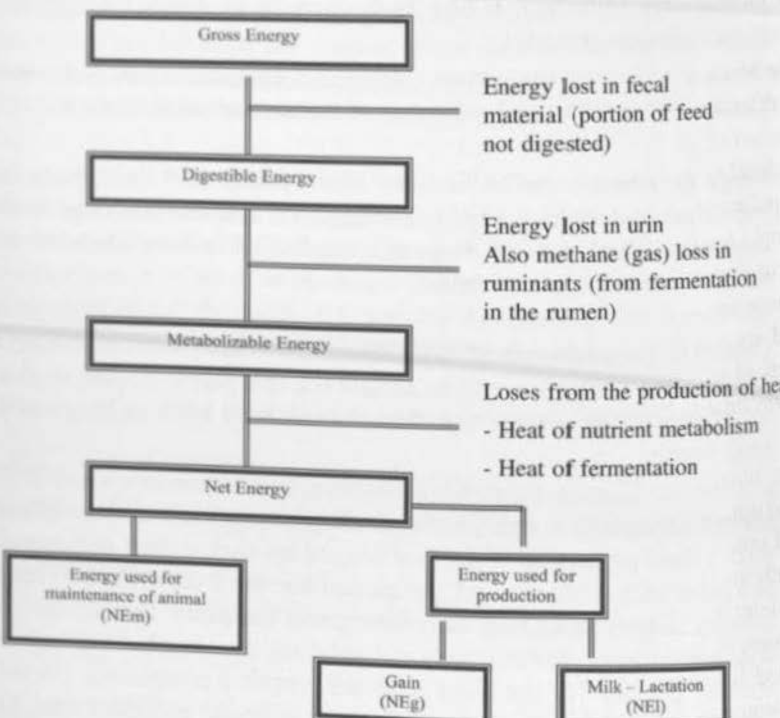
b) On each intake measurement day, collect 5-10% sample of feed offered and save it in a large bin with an airtight lid, in a plastic bucket, or in a strong plastic bag. Freeze samples of fresh feed such as silage and fresh forage.

c) Clean the feeders thoroughly before feeding on day 15. Each day, collect all or a fixed proportion of the feed refused by each animal and save it in a paper sack. Use one sack per animal for the 7 days. Freeze fresh samples. Empty feces bags daily throughout the study. This should be done immediately after removing and weighing uneaten feed and before feeding. On day 16, the feces bags are emptied completely. [Note: attaching bags from day 1 is to allow the animals' sufficient time to adapt to carrying fecal bags. Collection starts from day 17 so bags should be emptied completely on day 16].

d) On days 17 through 23, collect all voided feces during the previous 24 hours. Weigh, mix and take a sample for DM for each day. Place 5-10% sample aliquot in a plastic bag and save it frozen or dried pending chemical analysis.

e) Collect and sample urine in the same way. Add acid (e.g., 0.2 N HCl, 0.01N H_2SO_4) to ensure that pH is less than 3 to avoid loss of nitrogen.

Apparent digestibility of a nutrient in a diet can be estimated using a natural constituent of the feed as an indicator. Acid insoluble ash (AIA) can be used in this way (Van Keulen and Young, 1977). The ratio between the concentration of AIA/nutrient in the feed and the concentration of AIA/nutrient in the feces gives an estimate of digestibility.



Nitrogen Balance Trials

Nitrogen balance trials are used to determine the availability of CP in feeds, which requires that both feces, urine and milk be collected to estimate the balance between nitrogen consumed, digested, metabolized and retained in the body.

Feeding trials

Each method of evaluating feedstuffs discussed earlier has a place and is valuable, but none of them takes into consideration factors such as voluntary intake and impacts on animal health and well being. Answers to these questions can only be determined by feeding those ingredients, or rations, under controlled conditions to particular classes of livestock in what are referred to as feeding trials.

In Vitro gas-production technique

The Menke in vitro gas-production technique (Menke et al, 1979) is used to determine the amount of gas produced over an incubation period. The amount of gas released when a feed is incubated in vitro with rumen fluid is closely related to its digestibility. However, this technique has not gained popularity in Pakistan. The in vitro gas production technique is a relatively simple method for evaluating feeds, as large numbers of samples can be incubated and analyzed at the same time. More than half of the nutrients consumed by ruminant animals leave the animal unutilized and undigested, and are excreted in feces, urine and gases. The in vitro gas production method is used to examine animal waste components that impact the environment and facilitate development of appropriate mitigations.

The nutritive value, and energy content, of a feed is predominately determined by its digestibility, which affects voluntary intake. Digestibility and intake determine the feed's nutritive value, such as to support milk synthesis or muscle growth. However, studies with live animals (in vivo) to determine the digestibility of feeds are time consuming, laborious, expensive and require large quantities of feed. Such experiments are not suited for rapid and routine feed evaluations undertaken by commercial laboratories that provide feed information to livestock producers and feed manufacturers. However the digestibility of feeds can also be estimated by biological methods known as in vitro techniques, which are conducted outside of the animal system to simulate digestion. In vitro techniques generally measure either fermentation residues or products.

This method of forage evaluation was first reported by Tilley and Terry in 1963 in a procedure that used ruminal fluid obtained from a sheep with a rumen fistula. Rumen fermentation by anaerobic microbes results in production of short chain fatty acids (SCFA), gases such as carbon dioxide [CO_2] and methane [CH_4] and microbial mass. The amount of gas produced is proportional to acid production, thereby serving as an indicator of acids produced by fermentation. The amount of gas produced during incubation is measured to predict the extent and rate of feed digestion.

Gas measuring techniques have been routine in feed evaluation since the early 1980's, when a high correlation was found between metabolizable energy (ME) measured in live animals and that predicted from gas production. The in vitro gas technique has several advantages over other in vitro methods that are based on measuring residues, as gas production reflects all nutrients fermented, soluble as well as insoluble, and the feed fractions that are not fermentable do not contribute to gas production.

Gas measurement is a direct measure of microbial activity and can be a good predictor of forage ME content. The gas technique is relatively simple and does not require sophisticated equipment, making it easy to use for research and commercial purposes. Rumen fluid is collected from a cow with a rumen fistula and fermentations are conducted in large (100 ml) calibrated glass syringes in an anaerobic medium inoculated with rumen fluid. Incubations can be in an incubator with a rotating disc or in a thermostatically controlled water bath (39°C). The volume of gas produced in 24 hours from incubating 200 mg of feed, together with the concentration of CP and EE, is used to predict ME.

Rumen fluid is collected after the morning feeding using a manually operated vacuum pump. The fluid is placed into a prewarmed thermos flask, mixed and filtered through four layers of cheesecloth and flushed with carbon dioxide in the laboratory. One part rumen fluid is mixed with two parts buffered mineral solution (1:2 volume/volume) and maintained at 39°C.

Compared with laborious and expensive in vivo testing, the in vitro gas production method provides a quick and easy way to calculate organic matter digestibility, quantify the energy value of feed mixtures and monitor microbial change in the rumen. The gas method is also repeatable among laboratories (Getachew et al. 2002)

Some feeds, such as forage legumes and cottonseed, contain phenolics, alkaloids and saponins that have negative biological effects on rumen microbes and reduce microbial growth in rumen. Tannins are naturally occurring polyphenolic compounds found in plants, which form complexes with feed and microbial proteins and can depress digestibility. The effect of tannins on the nutritive value of feeds can be studied using tannin-binding agents, such as polyethylene glycol (PEG), which strongly bind to tannins and inhibit their biological effects. For example, after adding PEG to limit tannin effects, gas production increased by 22%, 71% and 211% in browse plants of apple ring acacia *(Acacia albida)* beach acacia (*Acacia cyanophylla)* and red calliandra (*Calliandra calathyrsus)*, respectively, (Getachew et al.2000b)

The gas method is also utilized to study feed additives and rumen fermentation modifiers, such as monensin sodium, by incubating feeds in their presence or absence. A comparison of in vitro, gas production and nylon bag techniques is in Table 2.

Table 2. Comparison of three feed evaluation techniques to predict digestibility

	Two-stage in vitro	Gas Production	Nylon bag
1. Requirements:			
· Incubator	Yes	Yes	No
· Electricity	Yes	Yes	No
· Chemicals for buffer	Yes	Yes	No
· CO_2 tank	Yes	Yes	No
· Fistulated animals	Yes	Yes	Yes
· Relative labour needs	Low	Low	Low
2. Technical Features:			
· Relative precision	Good	Good	Good
· Ease of standardization	Easy	Easy	Diff
· Estimate rate of digestion	Yes	Yes	Yes
· Estimate extent of digestion	Yes	Yes	Yes
· Relative number of samples/batch	High	High	Low
3. Relative cost of analysis:			
· Instruments	High	High	Low
· Chemicals	High	High	Zero
· Labour, laboratory technician	Low	Low	Low
· Feed, labour for fistulated animals	High	High	High
· Other materials (glassware etc.)	High	High	Low
4. Overall possibilities of adoption in Pakistan	Low	Low	High

Near Infrared Reflectance Spectroscopy (NIRS) Analysis

This is a rapid and low-cost method to analyze feeds for their nutritive value. Instead of using chemicals, as in conventional methods, NIRS uses near-infrared light. The method requires drying and grinding of samples which are then exposed to infrared light in a spectrophotometer. The reflected infrared radiation is converted to electrical energy and fed into a computer for interpretation. Each nutrient in a feed absorbs and reflects near-infrared light differently. By measuring these different reflectance characteristics, the NIRS unit and a computer determine the quantity of these nutrients in the feed.

Detection of specific nutrient levels is possible because reflectance spectra from forage samples with known nutrient values determined by wet chemistry are programmed into the computer. When a similar feed sample is evaluated by NIRS, the computer compares the wavelength reflections caused by the sample, and matches them to previously tested samples. The NIRS method of determining forage nutritional content is about 25 times faster than conventional laboratory procedures, and less expensive than wet chemistry methods. However the calibration set that is used must be developed from an adequate number of wet chemistry samples, similar to those being analyzed. Without proper calibration, NIRS analysis can create seriously incorrect values.

Chromatography

Numerous nutrients from feeds, such as proteins, amino acids, sugars, fatty acids, minerals, and many other components, can be routinely identified and quantified through this analytical technique. In addition to nutrient analysis, chromatography can be adapted for detection of drug residues, hormones, pesticides, and other feed contaminants. Some of the disadvantages of this technique are:

1. It involves sophisticated equipment.

2. Most samples require some preparation before they can be chromatographed. This may involve procedures such as extraction, hydrolysis and/or evaporation.

3. Samples must be small in order to be chromatographed. This means that the sampling procedure must be carefully planned if the results are to be valid.

Colorimetry and Spectrophotometry

These are chemical analysis wherein light is passed through solutions to yield information about the concentration of various compounds. Many nutrients, drugs and vitamins can be analyzed through these techniques. Atomic absorption spectrophotometers are one of the most widely used instruments for mineral analysis, having the ability to detect many minerals at parts per billion concentrations.

Biological Analysis

Biological assays tend to be laborious and time consuming. Large numbers of samples are needed to produce statistically reliable results, and quite often data obtained from these assays is variable. Assays utilizing nutrient deficient animals are particularly cumbersome because it requires that animals be of about the same age, sex and weight, and a longer time is required to induce deficient conditions in the animals.

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CHAPTER IV G

Feeds and Feeding

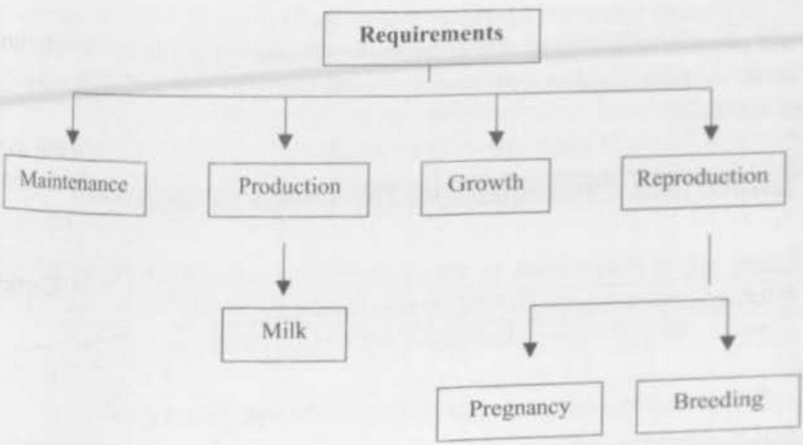
Diet Formulation

(Zia-ul-Hasan)

Nutrient Requirements

Diet formulation is a process by which various feed ingredients are combined in the proportions needed to provide animals with appropriate amounts of nutrients for specific levels of production. The basic principle of diet formulation is to design a balanced and cost effective diet to fulfill the animal's nutrient requirements in order to obtain maximum economic returns. It requires a knowledge of feedstuffs, nutrients and the physiological stage of animal. Various classes of dairy animals have different requirements for energy, fiber, protein, minerals and vitamins. These requirements can be classified into needs for maintenance, production, growth and reproduction (Figure 1).

Figure 1. Classification of nutrient requirements for dairy cattle



Maintenance Requirements

The nutrient requirement for maintenance in non-producing animals is the amount needed to maintain body weight with normal physiological functions under resting conditions. These functions include body tissue replacement, maintaining body temperature, normal functioning of vital organs such as the liver, heart, lungs and brain. For example a dairy cow weighing 500 kg needs about 12.5 kg dry matter, 0.4 kg crude protein and 3.7 kg TDN for maintenance.

Production Requirements

The amount of nutrients required over maintenance requirement that is used for synthesis of milk is known as the production requirement. The body meets the maintenance and production requirement simultaneously. For example a dairy cow weighing 500 kg producing 15 litres of milk with 5% fat needs about 1.9 kg crude protein and 9.3 kg TDN.

Reproduction Requirements

Reproduction requirements are the nutrients required to meet pregnancy requirements of cows and breeding requirements of bulls. Usually the pregnancy requirement of cows increases after the 5th month of pregnancy with the increasing size of the fetus. Therefore during the last two months of pregnancy, besides maintenance requirements, a dairy cow weighing 500 kg needs about 1.0 kg crude protein and 4.9 kg TDN for maintenance and support of the fetus. To maintain health and sexual libido in breeding bulls, nutrient requirements increase dependent upon breed, size and age of the bull.

Important Prerequisites for Diet Formulation

Dairy ration formulation is the mathematical calculation of an animal's nutrient requirement relative to the feedstuffs available. A nutritionist requires the following information for diet formulation:

- Physiological stage and nutrient requirement of the animals
- Nutrient composition and digestibility of the feedstuffs available

- Nutrient bioavailability of the feedstuffs available
- Non-nutrient feed characteristics such as palatability and physical properties
- Deleterious factors of feeds
- Costs of available feedstuffs

Importance of Nutrition to Production

The productive performance of dairy animals reflects its nutritional status, as animals require nutrients in sufficient quantity, and proper balance, for normal body functions. Nutrients are either metabolized or aid in metabolism to fulfill body needs. There are six main nutrients, being water, carbohydrates, protein, fat, minerals and vitamins, which are all required for the body maintenance, milk production and reproduction.

Dairy animals can live without food for days but not without water. Dairy cattle consume 3-4 litres of water for each kg of dry feed consumed, which amounts to 50-75 litres per day for high producing cows and buffaloes. Water intake is also related to milk production with each kg of milk production requiring a water intake of about 2.5-3.0 litres. Carbohydrates are the major source of energy for rumen microorganisms and the single largest component (60-70%) of a dairy cow's diet. Carbohydrate nutrition influences the composition of milk as nutrients for lactose, fat and protein production. Carbohydrates are generally classified into structural and nonstructural components, with structural carbohydrates consisting of elements found in plant cell walls and assayed as neutral detergent fiber (NDF). Nonstructural carbohydrates are located inside the cells of plants and are usually more digestible than the structural ones. These are generally expressed as non-fiber carbohydrates (NFC). Adequate levels of structural carbohydrates are required to maintain normal rumen function and milk fat levels.

Ruminal microorganisms ferment carbohydrates to volatile fatty acids (VFA), which are absorbed and utilized as energy sources for maintenance, milk synthesis and tissue synthesis. The main VFA (i.e., acetic, propionic, butyric acids) provide carbon units for production of milk components such as fat. Propionic acid is converted into glucose in the liver and then utilized in various body tissues. Glucose is required for synthesis of milk lactose in the mammary gland. Acetic acid supports about 50% of milk fat produced in the udder. Rapidly fermenting carbohydrates favor production of propionic acid, whereas slowly degrading structural carbohydrates promote acetic acid production.

Rations low in fiber may result in too little acetic acid being produced in the rumen, resulting in acidosis and reduced milk fat production. Adequate amounts of effective fiber are needed in the ration for maintenance of rumen health. A key to a successful feeding program for dairy cows is to balance the needs of ruminally available proteins and carbohydrates that optimize microbial growth and metabolism in the rumen.

Dietary CP for a dairy cow should consist of true protein (amino acids) and non-protein nitrogen (NPN). Feed protein can be further categorized as rumen degradable protein (RDP) or rumen undegradable protein (RUP), with RDP available for use by rumen microbes to create microbial protein (i.e., cellular protein of bacteria and protozoa). Ruminal microbes also degrade RDP to produce ammonia, and other microbes use this ammonia, along with readily available carbohydrates, to form microbial protein. RUP is protein that escapes degradation in the rumen, and flows to the abomasum, where it is digested to amino acids which can be absorbed through the wall of the small intestine into blood. The quantity of amino acids required by lactating cows depends on the level of milk production since, as milk yield increases, amino acid requirements increase. Lysine and methionine are the two amino acids that often limit milk protein synthesis.

Feeding appropriate amounts of minerals and vitamins is essential for health, growth and optimum milk production of dairy cattle. Feeding less than the optimum amount of any mineral or vitamin can result in an increased incidence of disease, reproductive problems and reduced milk production. To prevent these problems, appropriate amounts of minerals and vitamins must be supplied to dairy cattle. It has been suggested that slight deficiencies of some trace minerals may detrimentally affect a cow's immune function and her natural ability to fight off infections, such as mastitis and other diseases. A decrease in immune function may be seen before decreases in milk production or severe deficiency symptoms, such as change in hair coat color or skin lesions.

Diet Formulation Methods

A nutritionally balanced diet is one that provides nutrients in such proportions and amounts that it will fulfill the nutrient requirements of the animal (Morrison, 1956). Generally there are three steps in diet formulation, being to calculate the probable dry matter intake of animal, calculate the nutrient requirements of the animal and finally to determine the amount of available ingredients that must be fed to fulfill the animal's nutrient requirements within its expected DM intake.

There are several methods of diet formulation that include thumb rule methods, the Pearson square method, substitution method, simultaneous equations and computer assisted diet formulation based on substitution or linear programming. All of them have the same objectives of providing the required balanced nutrients at the least possible cost. The most commonly used methods of diet formulation are:

Thumb rule method

This is the simplest method of ration formulation and is helpful to farmers having a small dairy operation. Not much technical expertise, except mathematical calculations, are required. The basic principle to formulate a diet using this method include that DM be provided at 2.5% of body weight (BW) for cattle and 3.0% for buffalo with 1 kg of concentrate for each 3 litres of milk produced in a diet containing 15% CP and 75% TDN where 30% of DM (minimum) should be provided from roughages. The following is an example of diet formulation using this method.

Example: Compute a balanced daily ration for a *Nili-Ravi* Buffalo weighing 600 kg and yielding 15 litres of milk. Feeds available are maize fodder, wheat straw and a commercial dairy feed having 15% CP.

Solution:

a. Quantity of DM required = 18 kg (3% of BW)

b. Quantity of concentrate required = 5 kg (1 kg/3 litres of milk)

For production	= 5 kg
For maintenance	= 1 kg
Total	= 6 kg

Quantity of dry matter supplied by 6 kg concentrates = 0.90 x 6 = 5.4 kg

c. Balance of DM to be supplied by roughages = 18 – 5.4 = 12.6 kg

If 6.3 kg DM is provided by maize fodder and wheat straw then:

6.3 kg DM will be provided by = 1.11 x 6.3 = 7 kg wheat straw

6.3 kg DM will be provided by = 4 x 6.3 = 25.2 kg maize fodder

So the total feed composition is:

Dairy feed	= 6 kg
Maize fodder	= 25.2 kg
Wheat straw	= 7 kg

Pearson Square method

The Pearson square method of balancing rations is a simple procedure that has been used for many years. It is designed for simple rations with limited options in terms of nutrients and feedstuffs. The following are a few considerations for a Pearson Square.

1. This method allows calculation of one nutrient need at one time using two feeds.

2. The major limitation of using this method is that the level of the nutrient being computed must be between the nutrient levels of the two feed ingredients being used. For example, the 14% CP requirement has to be intermediate between soybean meal (that has 45% CP) and corn (that has 10% CP). If barley is used (that has 12% CP) and corn (that

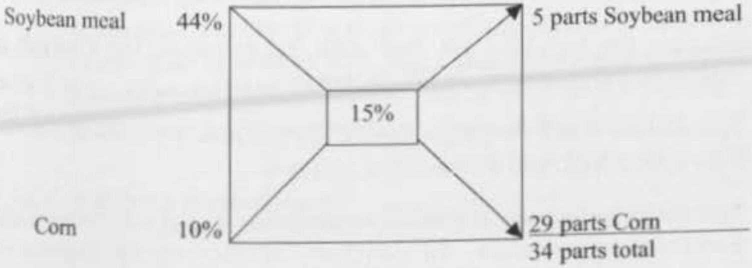
has 10% CP), this calculation method will not work because the 14% is outside the range of the values of two ingredients.

3. Disregard any negative numbers that are generated on the right side of the square. Be concerned only with the numerical differences between the nutrient requirement and the ingredient nutrient values.

4. This method cannot handle inequalities and both are independent of price.

5. Use a %DM basis for nutrient composition of ingredients and requirements, and then convert to an as fed basis after the formulation is calculated

Diet formulation with the Pearson square method is very simple. For example, a farmer has to formulate a concentrate mixture having 15% CP using corn and soybean meal. First draw a square and connect the corners with arrows as shown below. Then place the required % of the needed nutrient in the center (i.e., CP - 15%). This number represents the nutritional requirement of an animal for a specific nutrient, which may be CP, TDN, amino acids, minerals or vitamins. Now write the names of the two feeds (corn and soybean meal) near the left corners and label them with their % of CP.



Subtract the smaller numbers from the larger along the diagonal lines and write the difference along the opposite diagonal. The numbers on the right give the amounts of feedstuffs needed in "parts". The sum of the diagonals on the right equals the difference between the numbers on the left.

Divide the "parts" of each ingredient by the total on the right side of the box. This gives the % of each feed in the diet (i.e., 29/34 x 100 = 85.29 kg of corn and 5/34 x 100 = 14.71 kg of soybean meal).

Spreadsheet formulations

Spreadsheet based feed formulation programs can provide a fast and accurate way to solve both linear and non-linear feed formulation problems. These feed formulation spreadsheets are relatively easy to build and manage and can be altered manually (e.g., change in feedstuff inventory or the composition and prices of feedstuffs). The expertise required to build and manage a spreadsheet based computerized feed formulation program are not high, but include basic expertise in using spreadsheet program, feed composition, requirement tables and their prices. Spreadsheet based software commonly used are Microsoft Excel, Lotus 1-2-3 and Quattro Pro. Advantages to use of spreadsheet based feed formulation program are:

1. Spreadsheet based feed formulation programs usually generate nutrient requirements after entering the animal description, thereby avoiding the need to look up nutrient requirements from a table.
2. These programs provide a list of feed ingredients and their nutrient composition.
3. Computer programs show the balance of all nutrients simultaneously.
4. Because the formulas are built into the program, the chances of mathematical mistakes are eliminated.
5. Spreadsheet based programs can be learned in a much shorter period than specialized feed formulation programs.
6. Spreadsheet programs are much less expensive than commercial feed formulation software. In contrast, besides being expensive, sophisticated feed formulation software may be difficult to learn.
7. With the use of macros, spreadsheets could be used to create 'turnkey' feed formulation applications.

Spreadsheets are easy to customize, so that features can be added by operators with minimal training. For example, equations can be added to the spreadsheet to calculate prices that could be expected from changing an ingredient. Small producers benefit from using spreadsheets to formulate diets, and can tailor the spreadsheets to fit their situation.

Construction and solving of linear feed formulation problems in spreadsheets is not as easy as with programs designed specifically for feed formulation. But the process is much easier than with dedicated programs because of the capability and flexibility of modern spreadsheet programs. Microsoft Excel comes with a programming capability of "SOLVER" function which has linear programming functionality that can be used in least-cost ration formulation. The basic principle of a spreadsheet based feed formulation program is to simultaneously solve a series of equations by minimizing or maximizing parameters such as feed cost and/or nutrient levels. For example, formulate a dairy feed having 3.0 Mcal ME/kg and 17% CP by using corn and soybean meal

Corn = 10% CP 2.79Mcal/Kg ME, and Rs.1,350/100 kg costs

Soybean meal = 44% CP 3.10Mcal/Kg ME, and Rs.3,700/100 kg costs

Here arises a question that what is the least expensive combination of corn and soybean meal that meets the requirements?

To find solutions for two ingredients and two constraints (i.e., CP and ME), it is possible by solving equations by a Pearson square approach. However if more constraints and feeds are added then the solution will be impossible to find by hand calculations. Computer programs, such as Microsoft Excel, can formulate least cost diets with many ingredients and constraints. A feed formulation spreadsheet package can be obtained, at no cost, from American Soybean Association (IM) at: asaascpk@cyber.net.pk

Least cost feed formulation

Least-cost feed formulation combines many feed ingredients to provide the target animal with a balanced nutritional feed at the least possible cost. The only practical technique to formulate a least cost feed is by linear programming. A linear programming problem may be defined as maximizing, or minimizing, a linear function of many variables subject to a number of linear inequality or equality constraints on those variables. There are many possible solutions to each series of equations, but when cost is included, there can only be one least cost combination.

As least cost formulation is a mathematical solution based on linear programming, it requires the knowledge of animal nutritionists to consider the nutrient requirements of the target animal and its capability to digest and assimilate nutrients from available feeds. Linear programming performance is based on information entered by the formulator, and so the formulation is only as good as the nutrient and ingredient parameters entered.

Use of linear programming equations is only practical if computers make the computations, as a computer is capable of making millions of calculations in a few micro-seconds. However, the program is incapable of correcting errors due to incorrect input data. A few advantages of using linear programming for feed formulation include:

1. These formulation softwares solve simple to very complex problems, such as applications for formula costing, inventory control, control of usage of ingredients in limited availability.
2. Specialized feed formulation programs also have built-in nutrient requirements tables and feed composition tables. Most programs also have the option to allow users to build personalized feedstuff libraries.
3. Linear programming based feed formulation softwares have many options, which give the formulator choices during formulation, such as calculation of shadow (or opportunity) prices.

A fundamental rule of least cost diet formulation software is that adding extra constraints can only maintain or increase the minimum diet cost. It is a common error to drive a formulation by adding unnecessary feed or nutrient constraints. Another common error is to over-constrain minerals, which can have a bigger effect on the final solution than energy and protein. Mineral constraints should be avoided unless there is a readily available, and cheap, source of the mineral available. Usually a program can be forced to satisfy some mineral constraint by taking a large quantity of the only raw material containing a sufficiently high concentration of it, thereby forcing energy and protein constraints to be satisfied by including expensive concentrates. An experienced formulator should always look hard at the marginal costs associated with mineral constraints, as this is the indicator of a true least cost formulation.

Feed formulation problem can be of two types, being batch mix or complete diet. In a batch mix formulation, a fixed quantity of a batch of feed (e.g., at a feed compounder) is subjected to constraints on minimum and maximum nutrient concentrations as well as minimum and maximum feed inclusions. Complete diet formulations are commonly used to formulate diets for animals where the underlying principle is to provide absolute quantities of nutrients per animal per day, rather than nutrient concentrations. Thus MJ/kg becomes MJ and g/kg becomes g. However, structurally, batch mix formulation and complete diet formulation are the same, with the only difference being that the software creates a fixed batch size with a desired nutrient concentrations, whereas diet formulation creates a variable feeding level that provides desired amounts of nutrients per animal per day.

A least cost feed formulation can be fine tuned by checking the shadow prices, which are the amount that a formula price could potentially be reduced if a particular nutrient limit is relaxed up to one unit. For example, in a formulation problem, where the minimum crude protein limit is set at 15%, when this problem is solved, and the formula price is Rs. 25.00 with a shadow price of crude protein of Rs. 1.00, it means that if the minimum limit of protein is set at 14% and the problem is solved again, then the formula price could be reduced up to Rs. 24.00. Hence it shows the formulator the costs of his nutrient constraints. There are number of least cost feed formulation softwares available. One software package is available at: http://www.winfeed.com/download/site1.

Table 1. Dairy feeds formulae

	1	2	3	4	5	6
			Percent			
Soybean meal	-	-	-	-	10	5
Cottonseed cake	-	25	20	15	-	10
Cottonseed meal	13	-	-	-	-	-
Rapeseed cake	-	-	15	15	15	3
Sunflower meal	-	15	-	-	-	10
Corn, crushed	10	10	20	20	-	16
Maize gluten 30%	25	15	-	-	-	-
Rice bran	-	-	-	-	10	-
Rice polishing	20	15	-	20	25	20
Wheat bran	20	8	28	28	25	24
Molasses	10	10	15	-	12	7
Urea	-	-	0.5	-	-	-
DCP	-	-	-	-	-	2
Limestone	-	-	-	-	-	1
Salt	-	-	-	-	1.5	-
Mineral mixture	2	2	1.5	2	1.5	2

Cornell net carbohydrate and protein system (CNCPS)

The CNCPS model for diet formulation was developed to predict requirements, feed utilization, animal performance and nutrient excretion for dairy cattle using accumulated knowledge about feed composition, digestion and metabolism of dairy cattle. This software, which is relatively complex to use and fully understand, can allow dairy cattle to improve the efficiency of conversion of low quality feed nutrients to human food under various conditions. The goals of improving ruminant nutrition to improve productivity, reduce resource use and protect the environment may be furthered by use of the model. Improvements in ruminant production efficiency will result from use of sophisticated models to predict nutrient requirements and feed utilization in specific production settings, as accurate prediction of nutrient requirements and supply enable nutritionists to identify and control more of the factors that impact cattle performance. The CNCPS can be accessed at: http://www.cncps.cornell.edu/

Practical local ration examples

Tables 1 and 2 contain examples of dairy diets that can be used in Pakistan

Table 2. Calf starter formulae

	1	2	3	4	5	6	7
	Percent						
Soybean meal	-	25	-	25	12.5	-	14.5
Cottonseed cake	28	5	7	5	-	7	7
Canola meal	-	-	20	-	9	20	-
Skim milk	-	5	7	5	-	7	2
Maize gluten 30%	10	-	-	-	-	-	-
Maize gluten 60%	-	-	-	-	2	5	5
Corn, crushed	40	21.5	7	26.5	-	13.5	20
Pea	-	-	15	-	20	-	15
Oats	-	20	-	20	-	12	-
Barley	-	-	8	-	20	-	5
Wheat bran	10	15	18.5	10	-	16	-
Rice polishing	-	-	8	-	25	11	20
Molasses	10	7	8	7	10	7	10
DCP	-	0.5	0.5	0.5	0.5	0.5	0.5
Mineral mixture	2	1	1	1	1	1	1

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CHAPTER V A

Soybean Products as Ruminant Feeds

Definition of Soybean Products

(V. Anand, S.P. Vinil)

Soybean [*Glycine max* (L.) Merrill], a legume species that originated in China, is one of the oldest crops of East Asia. The plant is bushy with height ranging from 0.75–1.25m that branches sparsely or densely depending on cultivators and growing conditions. The pods, stems and trifoliate leaves (sometimes with 5 leaflets) are covered with fine brown or gray pubescence.

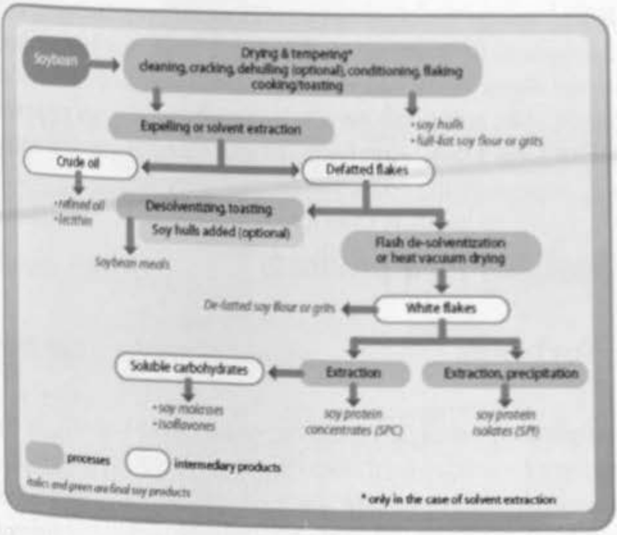
Soybean crops build soil fertility by fixing large amounts of atmospheric nitrogen through root nodules and through leaf fall on the ground at maturity. This benefits other plants, thereby enabling crop rotations. Soybean is an annual plant and the bean, after suitable processing, is one of the most important sources of dietary protein and oil for humans, as well as being widely used as an ingredient in dairy, poultry, aqua and pet foods. For this reason, and because of the higher amount of protein produced by soybeans per unit area of land than any other crop, it has been called 'wonder bean' and 'nature's miracle bean'. Soybean has now become the largest source of vegetable oil and protein in the world, and its large scale production is concentrated in the USA, Argentina, Brazil, Canada, China, India and Paraguay. Global soybean production reached a record 235 million tonnes in 2006/07 with the major share from the USA (38%). The annual production of soybean in India is around 7 million tonnes.

Soybean Processing

A large number of soybean varieties exist and beans vary greatly in shape and colour. Soybean consists of two cotyledons, which are about 90% of its weight, a seed coat or hull (8% of weight), and two much smaller and lighter structures being the hypoctyl and plumule. The cotyledons contain the proteins and lipids (oils) that constitute the main nutritional components of the products obtained from soybeans. They are also main storage areas for the carbohydrates, and various other important components, most notably the enzymes lipoxygenase, urease, as well as several secondary compunds. Various soybean products are obtained through separation or extraction of the soybean components.

In the "crushing" process of soybeans, which includes a series of preparatory operations, crude oil is obtained as a major product. This is refined and separated into lecithin and the refined oil that is used in human as well as animal nutrition, especially in young animal diets. Soybean meal, which on a volume basis is the most important product obtained from soybeans, have the defatted flakes as an intermediary product that requires further treatment. The two main processes used to extract oil and obtain the defatted flakes are the expeller process (i.e., mechanical extraction of oil by a screw press) or solvent extraction where non-polar solvents (commonly hexane and hexane isomers) are used to extract the oil. All processed soybean meal uses a heating or cooking process to destroy the secondary compounds contained in raw beans. Figure 1 provides a schematic representation of transformation of soybeans into the various products that are for human and animal consumption.

Figure 1. Schematic representation of soybean processing



Source: Manual of quality analyses for soybean products in the feed Industry

Soybean Meal

Whole soybeans contain about 18% fat with the remaining 82% being the soybean meal that is the residue after extracting most of the oil from soybeans by expeller or solvent processes. Soybean meal is a high protein and energy feed that is a major protein supplement in animal rations, and is the most produced largest oilseed meal in the world. Soybean meal used in Asian countries exists in several forms with solvent extracted material containing hulls being the most common. Many locations use imported de-hulled soybean meal, obtained mostly from the USA and to a lesser extent Brazil and Argentina. In less developed areas, meal derived from expeller cake is used.

The protein and energy content in soybean meal varies depending on the protein level in the soybeans, residual fat after fat extraction and whether or not the hulls have been removed. The protein content of de-hulled soybean meal ranges from 47-50% and material with hulls range from 40-50%. All soybean processing methods use a heating or cooking process to destroy the secondary compounds in raw beans which, if not de-activated, will reduce availability of dietary nutrient to the animal.

Soybean meal is an excellent source of the amino acids lysine, tryptophan and threonine, but is deficient in methionine. The variation in the total amino acid content of soybean meal is lower than that in other popular meals, and the digestibility of lysine and methionine is over 85% in most soybean meals. The amino acid combinations derived from soybean meal and corn grain form a basic diet for many species of domesticated animals and birds.

Other Soybean feed products

Whole Soybeans

Ground soybeans

These are obtained by grinding whole soybeans without cooking or removing any oil. While ruminant animals such as cattle, sheep and goats can utilize soybeans without being processed, warnings frequently occur on feed tags for dairy animals to avoid excessive use of urea, or similar compounds, since raw soybeans contain the enzyme called urease which, when in contact with urea, will degrade it. Thus mixed feeds containing both urea and ground raw soybeans will gradually gain an ammonia smell upon storage. Because of the degradation of urea, and release of ammonia, urea should not be added to ruminant diets containing ground raw soybeans. Heat-treating raw soybeans inactivates the urease enzyme, increases the storage life of the beans by destroying the lipase enzyme, and increases the rumen escape protein content of the soybeans [IFN: 5-04-596] (INFIC, 1980).

All animal feeds have IFN numbers, which refer to its international feed name and number and, in this system, ingredients are divided into 8 classes on the basis of composition and use (NRC, 1982).

Ground extruded whole soybeans

This is the meal product resulting from extrusion by friction heat and/or steam of whole soybeans without removing any of the component parts. It must be sold according to its crude protein, fat and fiber contents [IFN: 5-14-005].

Heat processed soybeans (Dry roasted soybeans / Full fat soybeans)

This is the product resulting from heating whole soybeans without removing any of the component parts. It may be ground, pelleted, flaked or powdered. It must be sold according to its crude protein content [IFN: 5-04-597].

Soybean meals

Soybean meal, solvent extracted

This is the product obtained by grinding the flakes which remain after removal of most of the oil from soybeans by a solvent extraction process. It must contain not more than 7% crude fiber. It may contain an inert, non-toxic conditioning agents, either nutritive or non-nutritive or any combination, to reduce caking and improve flowability, but in an amount not to exceed that necessary to accomplish its intended effect and, in no case to exceed 0.5%. It shall contain less than 7 percent crude fiber [IFN: 5-04-604].

Soybean meal, dehulled, solvent extracted

This product is obtained by grinding the flakes remaining after removal of most of the oil from dehulled soybeans by a solvent extraction process. It must contain not more than 7% crude fiber. It may contain an inert, non-toxic conditioning agents, either nutritive or non-nutritive or any combination, to reduce caking and improve flowability, but in an amount not to exceed that necessary to accomplish its intended effect and, in no case to exceed 0.5%. The name of the conditioning agent must be shown as an added ingredient. It may also be required to be labeled with guarantees for minimum crude protein, maximum crude fat and maximum moisture [IFN: 5-04-612].

Soybean meal, mechanically extracted

This is the product obtained by grinding the cake or chips which remain after removal of most of the oil from soybeans by a mechanical extraction process. It must contain not more than 7% crude fiber. It must contain not more than 7% crude fiber. It may contain an inert, non-toxic conditioning agents, either nutritive or non-nutritive or any combination, to reduce caking and improve flowability, but in an amount not to exceed that necessary to accomplish its intended effect and, in no case to exceed 0.5%. The name of the conditioning agent must be shown as an added ingredient [IFN: 5-04-600].

Kibbled soybean meal

This is the product obtained by cooking ground solvent extracted soybean meal, under pressure and extruding from an expeller or other mechanical pressure device. It must be designated and sold according to its protein content and can contain no more than 7% crude fiber [IFN: 5-09-343].

Soybean Feed By-products

Soybean hulls

This product consists primarily of the outer covering of the soybean. Soybean hulls are an excellent, highly digestible, source of fiber, energy, minerals and protein. Soybean hulls are often a palatable and economically priced energy and/or fiber source for livestock diets. Soybean hulls provide value to beef and dairy cattle because they are readily fermented in the rumen and supply energy to the animal [IFN: 1-04-560].

Soybean mill feed

This is composed of soybean hulls and the offal from the tail of the mill which results from manufacture of soy grits or flour. It must contain no less than 13% crude protein and not more than 32% crude fiber [IFN: 4-04-594].

Soybean mill run

This is composed of soybean hulls and such bean meats that adhere to the hulls after normal milling operations to produce dehulled soybean meal. It can contain no less than 11% crude protein and no more than 35% crude fiber [IFN: 4-04-595].

Soy grits

This the granular material resulting from the screened and graded product that remains after removal of most of the oil from selected, sound, clean and de-hulled soybeans by a mechanical or solvent extraction process. It must contain no more than 4% crude fiber. Soybean grits mechanical extracted are IFN 5-12-176 and soybean grits solvent extracted are IFN 5-04-592.

Condensed Soybean Solubles

This is the product obtained by washing soy flour or soybean flakes with water and acid at a pH of 4.2-4.6.The wash water is then concentrated to a solid of no less than 60% [IFN: 5-09-344].

Dried Soybean Solubles

This is the product resulting from washing soy flour or soybean flakes with water and acid; water, alkali and acid; or water and alcohol. The wash water is then dried [IFN: 5-16-733].

Soybean Flour Products

Soy flour

This the finely powdered material resulting from the screened and graded product after removal of most of the oil from cleaned and de-hulled soybeans by a mechanical or solvent extraction process. It must contain no more than 4.0% crude fiber. Some countries also require labeling guarantees for minimum crude protein and maximum crude fat and moisture [IFN: 5-12-177].

Soybean flour solvent extracted (Soy flour)

This is the finely powdered material resulting from the screened and graded product after removal of most of the oil from de-hulled soybeans by a solvent extraction process. It must contain less than 4% crude fiber and have minimum crude protein, maximum crude fat, maximum crude fiber and maximum moisture guarantees [IFN: 5-04-593].

Soy flour chemically and physically modified

This the product resulting from treating soy flour by chemical and physical processes (i.e., heat and pressure). It must be labeled with guarantees for minimum crude protein, maximum crude fat, maximum crude fiber and maximum moisture [IFN: 5-19-651].

Soybean Protein Products

Protein modified soybean

This a product that has been processed to primarily modify the natural protein structure by utilizing acids, alkalies or other chemicals, but without removing significant amounts of any nutrient. The defined name under section 84 of the applicable soybean product so modified shall be declared in the product name [IFN: 5-26-010].

Soy protein concentrate

This prepared from high quality, sound, de-hulled soybeans by removing most of the oil and water soluble non-protein constituents from selected, sound, cleaned, de-hulled soybeans (CFIA 2003) and must contain not less than 65% protein on a moisture-free basis. It must be labeled with guarantees for minimum crude protein, maximum crude fat, maximum crude fiber, maximum ash and maximum moisture [IFN: 5-08-038].

Soy protein isolate

This is the protein fraction of soybeans from dehulled soybeans that is prepared by removing most of the non-protein components, and contain not less than 90% protein on a moisture-free basis. The CFIA (2003) adds that the original material must consist of selected, sound, cleaned, dehulled soybeans and that it shall be labeled with guarantees for minimum crude protein (90%), and maximum ash and moisture [IFN: 5-08-038].

Soybean Fat Products

Soybean oil

This consists of the oil from soybean seeds that are commonly processed for edible purposes. It consists predominantly of the glyceride esters of fatty acids. If antioxidants are used, their common name or names shall be indicated on the label. It shall be labeled with guarantees for maximum moisture, insoluble matter, unsaponifiable matter and free fatty acids [IFN: 4-07-983].

Soy lecithin or Soy phosphate

This the mixed phosphatide product obtained from soybean oil obtained by a degumming process. It contains lecithin, cephalin and inositol, phosphatides, together with glycerides of soybean oil and traces of tocopherols, glucosides and pigments. It must be designated and sold according to conventional descriptive grades with respect to consistence and bleaching [IFN: 4-04-562].

Incorporating soybeans and its byproducts into rations of dairy cattle is a common practice as they are an excellent source of essential amino acids and fit into any type of forage-based ration. Depending on how they have been processed, soybean products can provide energy, fat, and fiber, as well as high quality protein including ruminally degradable, undegradable and soluble proteins. The soybean products used in most Asian countries exist in several forms with solvent extracted materials containing hulls being the common. The composition of the most common soy products used in Asian dairy rations are in Table 1.

Table 1. Chemical composition of some common soy products

	Dry matter	Crude protein	Crude fiber	Ether extract	Ash	NDF	ADF
Heat Processed Full Fat Soybeans	89.44	37.08	5.12	18.38	4.86	12.98	7.22
SBM, mech. extr.	89.80	43.92	5.50	5.74	5.74	21.25	10.20
SBM, solv. extr.	88.08	45.02	6.26	1.79	6.34	13.05	8.76
Soybean hulls	89.76	12.04	34.15	2.16	4.53	56.91	42.05

Comparison of Soybean Meal to Other Plant Protein Meals

Protein sources such as cottonseed meal, peanut meal, sunflower meal, copra meal, sesame meal, palm kernel meal, corn gluten meal, rapeseed and canola meal have lower protein contents than soybean meal. The amino acid profile of peanut, copra and palm kernel meal is very poor in terms of amino acid balance and digestibility compared to soybean meal. The variation in the amino acid content of soybean meal is lower than in canola meal, and most other protein meals. Thus soybean meal is a high quality feed that can be used as the sole protein supplement for virtually all classes of cattle. Due to its consistent nutrient values, it is popular with feed millers who value low variability in feed ingredients and strive to produce high quality, and consistent, animal feed products.

Rapeseed and canola meals

Canola was developed from rapeseed by Canadian researchers in the 1970's, and differs from rapeseed in having much lower levels of secondary compounds. These meals have lower protein and energy than soybean meal. In addition to a higher fiber content, the lower energy value is also attributed to compounds such as pentosan polymers that have low digestibility. Rapeseed meal has 37% protein, 2% fat and 3.1% crude fiber, while canola meal has 38% protein, 3.7% fat and 11.1% crude fiber. Rapeseed and canola meals have higher calcium and phosphorous levels than soybean meal, although 65% of the phosphorous is in the phytate form and not digestible. Rapeseed and canola meals have a reasonably well-balanced amino acid profile, but is lower in lysine than soybean meal.

Cotton seed meal (CSM)

CSM, when compared to soybean meal, has slightly less protein (41%) but is much higher in crude fiber at 11-13%. The fat level is about 3.5%, but varies depending on the fat extraction process. However CSM is inferior in four of the most important essential amino acids, being lysine, methionine, threonine and tryptophan, and the digestibility of these amino acids is lower than in soybean meal.

Corn gluten products

Corn gluten feed contains 20-25% protein and 7-10% crude fibre, and is mostly used in ruminant diets. Corn gluten meal contains 40-60% protein and 3% fat and is an excellent source of methionine and xanthophylls, but is very low in lysine. Use of corn gluten meal is usually limited by its high price, and is susceptible to aflatoxin contamination due to mold growth during storage.

Sunflower meal

Unlike soybean meal, sunflower meal is high in methionine but low in lysine and threonine. Therefore the two ingredients, when used together, improve the amino acid balance in feeds. However if the sunflower meal inclusion rate is too high, supplementation with lysine will be necessary. Sunflower meal generally has lower amino acid digestibility than soybean meal, and this should be considered when partially replacing soybean meal.

The quality of sunflower meal depends on whether the seeds are de-hulled prior to oil extraction. De-hulled sunflower meal has a protein content in excess of 40% and crude fiber of 13% or less. Partial de-hulling produces meals of 30-35% protein, whereas whole sunflower meal will have about 25% crude protein. The crude fiber of partially de-hulled or non-de-hulled meal will exceed 20% and the fat content is 1.5 - 2.0%. Sunflower meal contains high levels of chlorogenic acid, a tannin-like compound that inhibits activity of digestive enzymes including trypsin, chymotrypsin, amylase and lipase.

Peanut meal (Groundnut cake)

Peanut meal has a poor amino acid profile that is deficient in methionine, lysine and tryptophan. Like most legume seeds, peanut contains trypsin inhibitors and other protease enzyme inhibitors. The most common undesirable constituent found in peanut meal is aflatoxin produced by the fungus *Aspergillus flavus* that infests peanuts before, during and after harvest. The nutrient composition of the meal varies according to the oil extraction method. The quality of hulls directly affects fiber level, and therefore energy content, of the meal. Solvent extracted peanut meal generally has lass than 1.5% fat and about 43% protein. With prolonged storage under the warm and humid conditions in the tropics, residual oil is a negative feature as it is easily oxidized. The meal quality is then greatly reduced due to poor palatability, potential toxicities and a decreased energy level.

Copra meal (Coconut cake)

Copra meal has a protein content that is much lower than soybean meal (i.e., 19 - 23%) while the residual oil content is 9 - 16%. Some meals produced by small scale expeller extraction processes, or using poor equipment, may have residual oil contents above 20%, but solvent extracted meals have less than 2% oil. When meal contains a high residual oil content it is a valuable source of energy, and copra oil is predominantly short chain saturated fatty acids that are easily digested. However the protein quality is poor in amino acid balance and digestibility, and digestibility may be further reduced when excessive temperatures are used during processing. The amino acid composition of copra meals is inferior to many other protein sources as it is deficient in the essential amino acids lysine, methionine, threonine and histidine, although high in arginine.

Palm kernel meal

As with the peanut and copra meal, the amino acid profile of palm kernel meal is very poor in terms of amino acid balance and digestibility, as it is deficient in lysine, methionine and tryptophan. The poor amino acid digestibility is attributed to protein entrapment in carbohydrate complexes, as well as high temperatures used during oil extraction. Palm kernels are covered by thick shells that must be cracked open, removed and subjected to steam conditioning before oil extraction. The quality of the meal depends largely on the amount of shell removed. Meal is normally produced by an expeller process leaving a residual oil content of about 6%. With solvent extraction, the meal will have only 1 - 2% residual oil. Among oil meals, palm kernel has the lowest protein content (i.e., 16 - 18%), but protein levels as low as 13%, and crude fibers as high as 20%, can occur if shells and fruit fiber is not removed efficiently.

Sesame meal (Til cake)

This is a minor oil seed crop that is often available in Asian countries. The nutrient composition of high quality sesame meal compares favorably with that of soybean meal. As the hull of the sesame seed accounts for 15 to 29% of the whole seed, its removal reduces the crude fiber and increases the protein content, digestibility and palatability of the meal. The protein content of various varieties of sesame meal ranges from 41% - 58%, with average protein and fat contents of 40% and 5% typical of expeller meal. Almost 80% of sesame protein is digestible. Solvent extracted meals contain slightly a higher protein content of 42 - 45%, and less than 3% fat. The energy content is lower than in soybean meal and appears to be related to its high ash content of 10 - 12%. Sesame meal is an excellent source of methionine, cystine and tryptophan, but is very low in lysine and threonine. The amino acid composition of sesame meal compliments most other oil seed proteins including soybean meal in particular. Sesame seeds are known to contain high levels of oxalic acid which interferes with mineral metabolism and decreases digestibilility of calcium, phosphorus, magnesium, zinc and iron.

Lupin meal

The protein content of lupin meal, about 30%, is lower in soybean meal. Lupin protein is low in lysine and methionine, but rich in threonine. Lupin meal has about 5% fat and the crude fiber is normally about 13%. Lupin meal should be made from seeds low in quinolizidine alkaloid content since these alkaloids cause neurological problems and are bitter thereby causing palatability problems. Although sweet lupins are low in alkaloids, they are easily contaminated with bitter varieties. Lupin meals should be produced with decorticated seeds to avoid dilution of energy with indigestible hulls. Manganese levels should be monitored as some lupin varieties contain extremely high Mn concentrations, which favor fat oxidation.

Rubber seed meal

Rubber seed meal contains about 30% protein and 9-10% fat. The crude fiber content of meals from decorticated rubber varieties is about 5%. Rubber seed meal is relatively low in methionine, while the levels of lysine and cystine are moderate. However, the main constraint to using rubber seed meal is hydrocyanic acid in the seeds, about 9 mg/100g, which can be reduced by heat or storage.

Conclusions

Compared to other sources of plant proteins, soybean products stand out by their diversity and advantageous levels of many critical nutrients. Soybean meals are a concentrated source of digestible amino acids, energy and digestible fibre. Although these soybean products are used in dairy rations, the extent of their use varies with local availability and their cost relative to other protein sources. In general, soybean products are more expensive than other vegetable protein sources but, on a unit nutrient basis, soybean products are generally comparable with other feeds. General advantages of soybean products versus other vegetable protein sources are their high nutrient levels and bioavailability, as well as low levels of secondary compounds. Although complete replacement of other vegetable protein sources with soybean meal is often not economically viable, their use at low levels in the diet with other vegetable protein sources will generally improve the nutritional quality of the diet.

Table 2. The crude protein values of plant protein meals used in dairy rations

Protein sources	Crude protein (in % dry matter basis)
Soybean Meal	45
Rapeseed (canola) meal	37
Cotton seed meal (CSM)	41
Corn gluten meal	20-25
Sunflower meal	25
Peanut meal	43
Coconut cake	19-23
Palm kernel meal	16-18
Sesame meal	42
Lupin meal	30
Rubber seed meal	30

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CHAPTER V B

Soybean Meal as a Dairy Feedstuff

Practical Feeding Experiences with Soybean Meal

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Soybean meal is one of the most commonly used protein supplements in ruminant rations, particularly dairy cattle diets. The USA produces approximately 30% of world soybeans followed by Brazil and Argentina that are responsible for another 55% of world production. In the USA, more than half of that production is processed into soybean meal, resulting in more than 30 million tonnes of meal, of which 6 to 7% is consumed by dairy cattle in the USA.

Soybean meal is produced from grinding the cake after removal of almost all of the oil by expeller or solvent extraction. In addition, other methods of oil extraction that generate heat during processing are used commercially to reduce degradation of soy protein by rumen microbes. The decline in ruminal protein degradation with methods that generate heat occurs because of Maillard-type reactions between carbohydrate residues and amino acids. Roasting and extrusion are the two most common commercial methods of heat treating whole soybeans. Methods for producing heat-processed soybean meal include cooking and expeller processing of soybeans, extruding and expeller processing of soybeans, and non-enzymatic browning of solvent extracted soybean meal. During expeller processing, soybeans are pressed under high pressure, which generates heat and makes the resulting protein less degradable by rumen bacteria. Expeller processing can vary from cold pressing in which temperatures remain below 50°C to heat pressing with temperatures that can go as high as 180°C. All methods have minor effects on the chemical composition of the soybean meal, usually with some increase in fat and neutral detergent fiber contents, and a decrease in crude protein, but with marked decreases in its ruminal degradability. The typical composition of soybean meal sold in the US as cattle feed is in Table 1.

The concentration of protein on a dry matter basis in solvent extracted soybean meal typically ranges from 48 - 54% depending upon whether the hulls are mostly removed and the processing method. The 48% protein soybean meal (44% on as fed basis) produced by solvent extraction is usually produced from soybeans without removing hulls, whereas 54% protein soybean meal (48% on as fed basis) is produced with soybeans after the hulls are removed and the oil extracted.

Table 1. Typical chemical composition of soybean meal produced under different oil extraction processes

	Soybean meal		
	Solvent extract	**Mechanically extracted**	**Expeller extracted**
Dry matter, %	90	89	89
Crude protein, %	48 – 54	49	49
RUP, % CP	35	75	60
Fat, %	1 – 1.5	5 – 6	7
NDF, %	9 – 14	24	16

Relative to other protein supplements for lactating cattle and baby calves, soybean meal is an excellent feed. It has a favorable amino acid profile, particularly for lactating cattle in which dietary protein should complement the amino acid profile of rumen microbial protein. It is also very palatable and the protein is highly digestible. Furthermore, of common vegetable protein supplements, soybean meal contains a high energy content and its total digestible nutrient content is usually higher than 80%.

Use of Soybean Meal in Calf Rations

Most nutrients consumed by calves during the first 3 to 4 weeks of life originate from milk. When calves are kept with their dams and allowed to suckle, dry feed consumption can be delayed, making the contribution of dry feeds to the protein needs for maintenance and growth very limited. In production systems in which milk is fed at limited amounts, typically 3 - 6 litres/day, and dry feed is available, consumption of grains becomes an important source of nutrients, primarily after 4 weeks of age.

When calves are fed 4 litres of whole milk, intake of protein typically ranges from 130 to 150 g/d, whereas when they are fed 4 litres of milk replacer reconstituted to 11% dry matter and containing 20% CP in its dry matter, the protein intake is less than 100 g/d. When whole milk is fed and protein intake is approximately 150 g/d, calves weighing up to 50 kg consume enough protein to meet their maintenance requirements and can gain up to 350 g of body weight/day. This is usually sufficient for calves in their first 3 to 4 weeks of life but, for calves gaining more than 500 g/day after 3 weeks of life, adequate grain consumption containing more protein is needed.

Soybean meal is a common protein source used in calf grain mixtures. It is usually incorporated into pellets to minimize fine particles in the grain, which can reduce intake in the first weeks of life. Depending upon the desired weight gain of the calves, the CP content in calf grains for the first 3 months of age should be 18 - 22% of total dry matter. For calves not fed milk after 50 to 60 d of age, and weighing 70 kg, the protein requirements for maintenance and 700 g of weight gain is approximately 400 g/d. Most calves at that stage of life consume between 2.5 - 2.8% of their body weight as dry matter/day. Assuming that this calf is capable of consuming 2.7% of its body weight as grain, or 1.9 kg/d, the CP content of the grain would have to be 21% of the dry matter of the grain mixture to provide 400 g/d of CP. Typical ingredients in calf grains include a source of starch, usually corn grain, but also barley, wheat or oat grains. The latter three also good sources of fiber, but fiber source such as beet pulp, soybean hulls, wheat bran, or other high fiber by-products as well as a protein source, typically soybean meal and molasses at 4 to 6%, minerals, vitamins and drugs to control coccidiosis are all necessary.

Soybean meal is commonly incorporated into calf grain mixtures at 10 - 25% of total dry matter to increase the CP content by 5 – 12 % points, depending upon the desired CP level of the grain mixture and the CP content of the other ingredients. When soybean meal is the only protein supplement, inclusion rates can be as high as 25% of dry matter. There is no restriction to the amount of soybean meal that can be used in diets of young calves, although if whole soybeans are fed to young calves the levels of some secondary compounds, such as trypsin inhibitors, should be considered because they may reduce protein digestion. Soybean protein should not be used as a protein source in milk replacers in liquid feeding programs because it usually results in inferior growth compared to milk proteins. Soybeans also contains allergens, such as antigenic proteins that can cause gut inflammation, indigestible carbohydrates that can cause gas production and diarrhea, and lectins that can cause intestinal damage, all of which reduce intestinal absorption of nutrients and impair calf growth.

Use of Soybean Meal in Heifer Rations

Typical dairy heifer growth programs aim to result in proper growth for optimum production in first lactation. Although weight gains in heifers can be kept constant between 3 and 24 months of age, dairy heifers typically grow in height at a faster rate during the first 12 months of age than after puberty. Because height is associated with frame growth, it is important to provide young heifers with adequate amounts of protein to meet nutrient needs for adequate skeletal growth.

The protein supplied by soybean meal is mostly degradable in the rumen, approximately 65 to 70% depending upon the rumen retention time, and it provides N in the form of NH_3, peptides and amino acids for microbial growth. It is important to maintain adequate concentrations of NH_3-N in the rumen for NDF digestion, and adequate supplies of NH_3-N, amino acids and peptides for optimum microbial growth. If protein is limiting, rumen fiber digestion declines and intake is compromised. Even in situations in which heifers graze pastures with high protein contents, feeding soybean meal might improve growth because of increased supply of rumen undegradable protein. Most of the protein present in forages rich in N is highly ruminally degradable, which might limit the supply of protein to the animal if microbial growth is inadequate.

As a protein supplement for growing heifers, soybean meal can be fed in a complete ration or as part of a grain supplement. When heifers are grazing forages with moderate to low protein content (i.e., <14% CP), feeding a supplement that contains a true protein source usually improves growth although, in those systems, energy intake (primarily rumen degradable carbohydrates), is often the most limiting factor for adequate growth. Providing a supplement that combines a starch source or a high fibrous by-product with a source of true protein will benefit rumen microbial growth and the overall supply of amino acids to the animal. In grazing systems in which the CP content of the forage is low, adding soybean meal as protein supplement is an excellent option because of its rumen degradation rate and its ability to increase NH_3 and amino-N in the rumen, but also to increase the flow of ruminally undegraded amino acids to the small intestine.

The amount of soybean meal supplemented in the grain mixture of growing heifers depends on the other sources of nutrients consumed by the animal. In most production systems, growing heifers consume limited amounts of grain supplements. If forage intake is unlimited, diets can be formulated with 1 - 2 kg of supplemental grain for heifers to achieve growth rates of 750 to 900 g/d. In those cases, soybean meal is usually fed at 0.5 to 1 kg/day.

Soybean meal is also commonly fed as part of a complete ration to heifers. When combined with grain silages, the amounts of soybean meal as the sole protein supplement can be as high as 1 kg/d for diets that contain 14 - o 15% CP. For instance, when corn or wheat silages are the primary forages of the complete ration, the diet might have to be supplemented with as much as 10% of dry matter as soybean meal. Combining soybean meal with forages that contain highly fermentable carbohydrates, such as corn silage or cereal silages, is an attractive way to increase rumen microbial protein synthesis. Furthermore, the soybean protein that escapes rumen digestion has a desirable amino acid profile relative to tissue amino acid profile, which is beneficial to improve the efficiency of growth and protein utilization. Unless energy intake is limiting, it is unlikely that replacing soybean meal with other protein sources will improve growth of heifers.

Use of Soybean Meal in Dry Cow Rations

Dry cow rations are formulated to provide the nutrients required for maintenance of the dam, growth of the gravid uterus and fetus, and mammary development, and to minimize risks of postparturient disorders. During the first weeks of gestation, feeding diets to meet the nutrient requirements for maintenance of the animal has usually proven adequate. Cows that gain excessive weight during the first weeks of the dry period are more likely to develop postparturient disorders of intermediary metabolism such as fatty liver and ketosis. It has been postulated that supply of protein prepartum is important for proper lipid metabolism. A shortage of methionine in late gestation and early lactation is thought to limit phosphatidil choline production, which could predispose cows to hepatic lipidosis because of impairment of lipid export from hepatic tissue. Nevertheless, increasing the dietary protein content above that needed to meet the tissue requirements for amino acids of prepartum cows has not been demonstrated to influence the risk of development of fatty liver in dairy cows.

In the last weeks of gestation, requirements for amino acids increase at the same time that appetite is suppressed. Although feeding diets with an adequate protein supply is important, the amount of protein consumed by the cow has little if any effect on dry matter intake in the last 3 weeks of gestation. In one report, the amount of rumen degradable and undegradable protein accounted for less than 2.5% of the variation in dry matter intake in late gestation cows when diets provided at least 10% of dry matter as CP. In fact, low CP content in the diet (i.e., 11% of the dry matter), is sufficient to maximize NDF digestion and dry matter intake by prepartum cows. Therefore, for prepartum diets, 11 - 12% of dry matter as CP should be sufficient to meet the amino acid requirements of mature cows. In contrast, heifers, because of their lower dry matter intake as a proportion of body weight and increased needs for growth, might require diets with more protein than those fed to prepartum multiparous cows. In those cases, feeding diets with 14 to 15% CP seem to be adequate.

Soybean meal can be incorporated either into the grain mixture or in a complete ration to meet the protein needs of prepartum cows. It can be the only protein supplement or it can be replaced by protein supplements with lesser rumen degradability. It has been suggested that replacing solvent-extract soybean meal with heat-treated soybean meal, such as expeller processed, might benefit cows in the last 2 to 3 weeks of gestation when intake of dry matter declines and microbial protein synthesis is compromised. Prepartum multiparous cows might receive 0.5 kg/d of soybean meal, whereas heifers are typically fed 1 kg/d. In heifer diets, the higher amino acid requirements and reduced intake usually favor use of expeller or heat-treated soybean meal, which can partially or completely replace the solvent extract soybean meal.

Use of Soybean Meal in Lactating Rations

The general guideline for protein feeding of lactating cattle is to offer diets that provide approximately 15 to 18% of the dry matter consumed as CP. This varies by production system, type of feed offered, level of milk production, concentration of protein in milk and potential intake of the cow. Optimizing protein utilization by lactating cattle requires the ability to formulate diets that provide sufficient N for adequate rumen metabolism, and absorbable amino acids in an amount and balance as required by the animal. Because feed proteins differ in their degree of ruminal degradability and in amino acid composition, it should be no surprise that different protein sources alter the pattern of amino acids flowing to the small intestine, which influences yields of milk and milk protein.

An important aspect of formulating diets for lactating dairy cattle is to feed ingredients that maximize the flow of rumen microbial protein to the small intestine at the same time that the protein fraction that escapes rumen degradation supplies absorbable amino acids that complement the amino acid profile of the rumen microbes. Unfortunately, not all protein supplements have an adequate amino acid profile when compared to those of rumen microbes and milk. This becomes important when feed protein sources are highly undegradable, which increases the contribution of their amino acids to the protein that passes to the small intestine. When protein sources with an unbalanced amino acid profile, or of low intestinal digestibility, are fed, absorption of limiting amino acids may be compromised and yields of milk and milk protein might suffer. It is important to note that soybean meal protein is mostly degradable in the rumen, but the protein that escapes rumen degradation has an amino acid profile that is desirable for milk yield and has a high intestinal digestibility. In many instances, simply replacing soybean meal with other protein sources that are less degradable in the rumen reduced yields of milk and milk protein by lactating cows. Therefore, attention should be paid to the supply of N to the rumen for proper microbial growth and the amino acid profile of the fraction that escapes rumen degradation.

Early lactation cows require more protein in their diets because feed intake is usually inadequate for the level of production, and this may limit microbial protein synthesis. For these cows, replacing some of the solvent extract soybean meal protein with soybean meal that has been heat-treated, such as expeller soybean meal, usually benefits production of milk and milk protein. For cows of low milk production, it is unlikely that replacing soybean meal with heat-treated soybean products will improve milk yield, unless energy intake is limiting.

Practical Feeding Experiences with Soybean Products in SAARC (South Asian Association for Regional Cooperation) Countries

Incorporating soybeans and/or its byproducts into the rations of Asian dairy cattle has improved their production and health as they are excellent sources of essential amino acids and they fit into any type of forage-based ration. Depending on how they have been processed, soybean products provide energy, fat and digestible fiber, as well as high quality protein including ruminally degradable, undegradable and soluble protein.

Calves and heifers

A calf needs a relatively large proportion of protein in its ration to provide the amino acids required for rapid growth. The quality of the protein fed to the calf depends on its age. Since the rumen is not yet developed, the protein in the calf ration should be high quality. An ideal calf starter contains about 18 to 22% CP and 75% total digestible nutrients (TDN). Calf feeds prepared commercially contain ground grains, oil cakes like soybean meal, animal protein supplements and bran fortified with vitamins and minerals.

Studies conducted by the Gujarat Cooperative Milk Marketing Federation (GCMMF) with inclusion of 35% soybean meal in calf feed found an average body weight increment of 500 g/day at the end of four months compared to 400 g/d in calves fed a non-soymeal formulation, and only 350 g/d in a control herd fed traditional feeds. Faster growth rate leads to earlier maturity which is important to farmers. In Sri Lanka, inclusion of soybean meal in calf feed has produced good results in terms of body weight gain.

Dry cows and buffaloes

Success in dairying includes managing all phases of production. Research and practice have shown that, for maximum return, lactation management starts during the cows dry period. While dry cows are often not fed properly on Asian dairy farms, proper dry cow management provides the foundation for a successful lactation. During the transition from lactating to dry, and from the dry period to lactation, the dairy cow is under enormous stress both physically and metabolically. Excessive stress during these transition periods, especially just prior to calving, is associated with reduced feed intake and milk yield, reduced reproductive efficiency, increased susceptibility to metabolic and digestive disorders and increased incidence of mastitis.

Compared with other sources of plant proteins, soybean products stand out by their diversity and their advantageous levels of many critical nutrients. Farmers in India have adopted a variety of strategies for feeding their animals. The type of feed resources available are generally limited to compound feeds, concentrates, roughages, crop residues and agricultural by products. Regardless of these limitations, good quality feeds should be fed during the dry period to maximize performance in the upcoming lactation.

Lactating cows and buffaloes

Soybean fed as both whole oil seed and solvent extracted soybean meal to cows during early lactation (i.e., first 3-5 months) overcome the negative energy balance. A feeding study conducted with full fat soybeans in Murrah buffaloes showed improved milk fat concentration from 6.69 to 7.48%. Since most high-yielding cows and buffaloes are in negative energy balance during first 4 - 6 weeks of lactation, soybean feeding can be advantageous to boost milk and milk fat %. Adequate nutrition during the ascending phase of lactation is important because there is a correlation between peak milk production and full lactation production. As dry matter intake is also lower during early lactation, feeding high energy diets with soy products are beneficial in early lactation.

Inclusion of soybean meal and full fat soybeans in dairy diets improves milk yield and milk component levels. A feeding study conducted in south India with soybean meal and full fat soybean in dairy cows showed that the soybean meal fed group had higher milk yield (21.7%) and fat percent (15.8%) and solids-not fat (1.1%).

In recent years, research has demonstrated the importance of ruminally undegradable protein (i.e., protein that escapes rumen fermentation and is available for absorption in the small intestine) for high-producing cows. As milk production increases, an increasing proportion of dietary protein must escape rumen fermentation in order to meet the animal's protein requirements. In general, it has been calculated that about 35-40% of dietary protein should be undegraded protein. Rumen protein undegradability (as a % of total protein) of solvent extracted soybean meal is about 33% and 68% for solvent and expeller extracted soybean meal, 29% for raw soybeans and 38% for roasted soybeans.

Soybean hulls are a high fiber, but low lignin, byproduct of soybean processing that has a high fiber digestion. Although high in NDF, approximately 65% of total dry matter, it is not as effective in stimulating rumination as forage, so replacement of forage NDF with soybean hull NDF can only be partial. No processing of soybean hulls is needed before feeding. In some parts of India, cattle are commonly fed soybean hulls and feed manufacturers also adding it to dairy feeds.

Using soybean protein blocks is a way of supplying protein to cattle. While urea molasses block licks are a well-known source of nitrogen and essential minerals for ruminants, these blocks rely on non-protein nitrogen source such as urea. High protein blocks with use of soybean meal or full fat soybean meal provide better nutrition to dairy animals by supplying important amino acids and rumen escape protein.

Conclusions

Soybean meal is the most common protein supplement fed to dairy cattle. It can be incorporated into grain supplements or complete rations for cattle of all ages, but feeding it as a replacement for milk protein in milk replacer products usually compromises growth because of increased diarrhea. Soybean meal can be used as the only protein supplement for cattle and, unless animals have low dry matter intake and energy intake is limiting, replacing solvent extracted soybean meal with other protein supplements rarely benefits growth or production of milk and milk components. For recently weaned calves, heifer cows prepartum or high-producing cows in early to peak lactation, feeding heat-treated soybean meal often improves performance because of an increased supply of protein delivered to the small intestine that has a high intestinal digestibility.

CHAPTER VI A

Nutrition and Health

Nutrition and Health Management

(Zia-ul-Hassan)

Animals must receive adequate quantities of nutrients to avoid their deficiency. The diet must have the appropriate nutrient balance, and should be free from toxins and microorganisms that could cause digestive, metabolic and health problems. Nutritional imbalances, deficiencies, or erratic management of feeding programs for dairy cows, can create various types of health problems that are generally categorized as metabolic diseases, the most common of which are milk fever, ketosis, acidosis and hypomagnesaemia.

Metabolic diseases have economic importance on dairy farms because lactating dairy cows are more prone to abnormal homeostasis. The transition from the pregnant, non-lactating state, to the non-pregnant lactating state is often a disastrous experience for a cow. Most of the major metabolic problems of dairy cows, such as milk fever, ketosis and displaced abomasums, occur within the first two weeks of lactation due to sudden changes in nutrient demand that require coordination of metabolism to meet energy, mineral, amino acid and glucose requirements of the body. Often low body nutrient reserves further complicate the situation by reducing nutrient availability below critical levels and clinical metabolic diseases may occur. This situation is characterized by either variation in milk secretion or sudden variations in feed intake, which lead to changes in the metabolism of the animal. Understanding the factors that account for the high disease incidence in parturient cows enhances the well being and profitability of the cow. There are many metabolic disorders of dairy cows, but the economically important ones are low milk fat and solids, milk fever, ketosis, acidosis and hypomagnesaemia.

Low Milk Fat and Milk Solids

Milk is a whole, clean, lacteal secretion obtained from the mammary gland that contains about 85% water. The milk solids include fat, protein, lactose and minerals. Normal milk fat values range from 4.6% in cow to 7.1% in buffalo (Table 1). Milk composition is affected by genetics, lactation stage, level of milk production, cow's age, environment, disease (mastitis) and nutrition. The variation in milk composition is contributed by heredity (55%) and environmental factors (45%).

A normal milk fat level reflects a good rumen fermentation and normal animal metabolism. Generally a diet which causes low milk fat levels also causes sore feet (laminitis), acidosis and reduced feed intake. Milk protein levels often follow changes in milk fat, except during milk fat depression and when high levels of fat are fed. The following guidelines can help dairy farmers increase production of milk fat and protein:

1. The minimum level of acid detergent fiber in the ration DM should be 19-21% of DM, whereas the level of neutral detergent fiber should not fall below 26-28%. If acid and neutral detergent fibers go below these levels, cows are at risk of low milk fat level, acidosis, lameness, chronic feed intake fluctuations and poor body condition, especially in early lactation.

Table 1. Comparative nutrient composition of buffalo and cattle milk

Nutrient	Cattle	Buffalo
Water, %	86.8	83.8
Fat, %	4.6	7.1
Lactose, %	4.7	4.8
Protein, %	3.2	3.7
Ash, %	0.7	0.7
Total solids, %	13.2	16.3
Solids not fat (SNF), %	8.6	9.2

2. In order to assure adequate particle length, it is suggested not to chop forage to less than 3/8 inch as finer chopping may decrease milk fat level and increase milk protein.

3. About 75% of dietary NDF should come from long or coarsely chopped forages. Rations that are too high in fiber, or too low in energy, may limit milk protein production.

4. The level of dietary non-fiber carbohydrate (NFC) should range between 30-40% of the diet. Diets with high amounts of high-quality forage and minimal grains may be too low in NFC. Feeding appropriate levels of NFC can enhance milk fat and protein levels. However, overfeeding of NFC can lead to rumen acidosis, off-feed problems and milk fat depression, but may increase milk fat percent.

5. Feeding excessive ruminally degradable CP, such as urea, can reduce the milk protein level. Urea should make up only 1-2% points of dietary CP to maintain palatability, and it works best when well mixed into the diet.

6. The amount of ruminally undegradable protein should range from 33-40% of CP in early lactation to maintain normal milk protein levels.

7. It is necessary to follow guidelines when feeding fat to avoid a decline in the milk protein level. Added fat often results in increased milk fat level and increased milk production, if fed properly. Generally recommended guidelines for fat feeding are:

   i. Feeding niacin (6-12 g/day) may correct the milk protein depression common with high levels of fat feeding.

   ii. Limit fat feeding to the first 120 days in milk, because of low DM intake and the possibility of a negative energy balance.

   iii. Dairy farmers should follow the recommended limits for fat supplementation of <4% of dietary DM.

   iv. Increase the calcium (Ca) and magnesium (Mg) concentrations to 0.95% and 0.35% of ration DM, respectively. Higher levels of these minerals counteract their losses as Ca- and Mg-soaps when higher levels of fats are fed.

Table 2. Summary of feeding management changes which alter milk solids production

Management Factor	Milk fat level	Milk protein level
Maximum dry matter intake	Increase	Increase
Increased grain feeding	Increase	Slight increase
High diet NFC[1] (> 45%)	Decrease	Increase
Normal diet NFC (30-40%)	Increase	Maintain normal level
Excessively high diet fiber	Marginal increase	Decrease
Low diet fiber (<26% NDF)	Decrease	Increase
Small particle length in diet[2]	Decrease	Increase
High diet crude protein	No effect	Increase, if previous diet was deficient
Low diet crude protein	No effect	Decrease
Diet escape CP (33-40% of CP)	No effect	Increase if previous diet was deficient
Added dietary fat (> 7-8%)	Variable	Decrease

[1]NFC = non-fiber carbohydrates

[2]Less than 15% of particles greater than 2 inches indicates inadequate particle length

Milk Fever

Milk fever is an unhealthy condition of older (often 3rd to 6th lactation), high-producing dairy cows. It is associated with parturition and usually occurs within 72 hours of giving birth. The high volume of milk produced after parturition, and subsequent high Ca demand creates a condition in cows that is characterized by abnormally low blood Ca levels. This condition is known as milk fever, hypocalcaemia or periparturient paresis. It is an economically important disease as it can reduce the productive life of a dairy cow by 3-4 years. The average cost per case has been estimated at Rs.15,000, which includes the value of treating clinical cases and estimated production losses.

Milk fever is characterized by a rapid decline in plasma Ca concentrations resulting from its loss to formation of colostrum and milk. For example, a cow producing 10 litres of colostrum loses about 23 g of Ca in a single milking which is about nine times as much Ca as is in the entire plasma Ca pool of the cow. This plasma Ca loss must be replaced by increasing intestinal Ca absorption or by increasing bone Ca resorption, or both. During the dry period, when Ca requirements (10-12 g/day) are low, the mechanisms for replenishing plasma Ca are inactive. However, at parturition (and after first milking) the cow must bring 30 g, or more, of Ca/day into the blood Ca pool. This sudden change in Ca requirement produces some hypocalcaemia in every cow during the first few days after calving. Common symptoms of milk fever include:

a. It occurs suddenly after parturition due to continuous Ca loss in milk.

b. The total amount of circulating Ca in the blood of cow is 1.5-2.0 g.

c. Serum Ca levels decline from a normal of 10-12 mg/dl to 2-7 mg/dl.

d. Milk fever may occur in cows of any age, but is most common in high-producing dairy cows above 5 years of age.

There are three progressive stages of parturient paresis:

i In the first stage, cows are able to stand but show signs of hypersensitivity and excitability and may appear restless and bellow. If Ca therapy is not instituted, most cows will progress to stage two.

ii. In the second stage, cows are unable to stand, and show signs of anorexia, dry muzzle, subnormal body temperature and cold extremities.

iii. In the third stage, cows progressively lose consciousness to the point of coma. They are unresponsive to stimuli and can suffer from severe bloat. Cardiac output worsens, heart rate can approach 120 beats/min and pulse may be undetectable. Cows in stage three may survive only a few hours.

Cows contracting milk fever also are susceptible to other secondary problems, which significantly increase production costs. Following are some conditions that may occur, as a result of milk fever:

1. Decreased teat sphincter muscle tone may lead to increased chance of bacteria entering the teat canal, hence producing "mastitis".

2. Poor tone of uterine wall muscles makes it flabby causing "uterine prolapse".

3. Reduction in uterine muscle contractile activity may produce "retained placenta/ metritis".

Treatment of milk fever should focus on restoring serum Ca to normal levels as soon as possible to avoid muscular and nerve damage. The response to properly administered Ca therapy is quite characteristic with the recumbent cow sitting up, usually within one hour, as her bodily functions affected by hypocalcaemia begin to reverse. Some guidelines for the treatment of milk fever include:

1. Contact a veterinary physician.

2. An intravenous injection of calcium gluconate salt (the general rule for dosing is 1 g Ca per 45 kg of body weight).

3. Repeated treatment may be necessary in 12 hours if the cow is still unable to rise.

There are several effective pre-partum strategies to prevent milk fever.

1. Pre-calving Ca intake should be low because feeding it in excess tends to inhibit normal Ca mobilization from bones.

2. Total Ca requirement for a 500 kg dry cow is approximately 40 g/day. Therefore, try not to feed in excess of 0.40% calcium (DM basis) to dry cows.

3. Avoid feeding high levels of phosphorus. The phosphorus requirement is 28-30 g/day and should be maintained near this level. It is suggested to feed phosphorus at approximately 0.24% of ration DM.

Ketosis

Ketosis, or acetonemia, is a common metabolic disease of dairy cows that occurs during the first 10-60 days after calving, with the three week period after calving being most critical. The disease results from lowered blood sugar in circulating blood, which allows formation and release of ketone bodies from excessive fat mobilization to provide the energy needed by the udder. Ketone bodies (specifically acetone) are volatilized and account for the "sweetish" smell detectable in the breath and milk or urine of affected cows. The incidence of ketosis is higher in older, and higher producing, cows.

Volatile fatty acids (e.g., acetic, propionic, butyric acids) arising from ruminal fermentation provide 40-70% of a ruminant energy requirements. Among these acids, propionic acid is by far the most vital in prevention of ketosis, and high energy rations favor propionate production. An increase in butyric acid would be undesirable since this acid is a potential source of ketone bodies. The most common types of ketosis are primary or production ketosis and secondary ketosis:

Production or primary ketosis

This type of ketosis occurs in cows that are in good to excessive body condition, have good production and are being over-fed. The risk factors associated with primary ketosis are excessive body condition at calving, rations with inappropriate protein/energy ratios, extended dry periods and inadequate exercise. Primary ketosis occurs when not enough feed is consumed to meet energy requirements. Dairy cows in negative energy balance have low blood glucose contents. In this situation, fat mobilization occurs which may result in high serum non-essential fatty acids levels and â-hydroxybutyrate. These metabolites contribute to the rise of ketone bodies in the blood.

Secondary ketosis

Secondary ketosis occurs when other diseases cause a reduction in feed intake and energy demands are not met. These other diseases include milk fever, mastitis, metritis, ruminal acidosis or displaced abomasum, as they all depress feed intake, and energy intake, that predisposes cows to clinical ketosis.

he following are some important symptoms of ketosis in dairy cows:

. It includes rapid loss of weight, sudden drop in milk production, constipation, mucus covered feces, incoordination and partial paralysis.

. Shallow breathing with an acetone smell in the breath.

. Cows will usually consume hay, straw or other roughages, but generally refuse grain and concentrates.

he 'ketone test' is a simple diagnostic tool for determining the presence f ketone bodies and can be used by dairy farmers. As it is used to determine e presence of acetone in milk and urine, the resultant blood ketone level the best test for determining the degree of ketosis. Most accepted ketosis eatments are an attempt to increase blood sugar levels. The following are me recommended treatments for ketosis:

Contact a veterinary physician.

An intravenous infusion of about 500 ml of 50% glucose solution is an ideal treatment. However some veterinarians also recommend intravenous injection of insulin as a part of the therapy.

Supplementation of corticosteroids (dexamethasone = 10 mg) for a few days following treatment to boost blood glucose levels may be beneficial.

Supplementation of vitamin B_{12} and Niacin can help increase blood glucose levels.

ne following are some preventive measures for ketosis in dairy cows:

Avoid over-conditioning cows in late lactation.

In early lactation, avoid diets that are too high in CP as excess levels of CP have been associated with an increased incidence of ketosis.

Diets high in carbohydrates, or too low in ruminally effective fiber, may cause ruminal acidosis. The diet should contain minimums of 19-21% acid detergent fiber and 30% effective fiber from forage.

4. Addition of sodium propionate or propylene glycol to the dairy ration pre-calving may reduce the incidence of ketosis.

5. Provide exercise to housed cows of at least one hour per day.

Acidosis

Acidosis is a metabolic problem characterized by an abnormal increase in ruminal acid production and a resultant reduction in ruminal pH. It occurs due to consumption of high starch (i.e., non-fiber carbohydrate) concentrates in a short span of time. In a normal healthy rumen, lactic acid production will be equal to lactic acid use and lactic acid is rarely detected. There are number of factors which can easily lead to an imbalance in lactic acid metabolism (Table 3), resulting in acute or sub-acute ruminal acidosis.

Table 3. Common factors leading to acidosis in dairy cattle

Too high quantities of fermentable carbohydrates in diets
Too high concentrate: forage ratio
Too fast shift from high forage to high concentrate diets
Low fiber diet
Diet composed of very wet and highly fermented feeds
Over mixed TMR resulting in excess particle size reduction
Mycotoxins

Carbohydrates contribute 70-80% of diet DM and are the primary source of energy for most ruminants. There are two carbohydrate categories in feeds, being cell-solubles (sugars and starches) and cell walls (cellulose, hemicellulose, lignin and pectin). Sugars, starches and fiber are fermented by rumen microbes and converted into volatile fatty acids which are a main source of energy for the animal as volatile fatty acids are absorbed from the rumen.

The three most important VFA are acetate, propionate and butyrate. Acetate is the primary VFA, produced primarily from fermentation of fiber. Propionate is a VFA produced primarily from digestion of starch which is converted into glucose in the liver, which is a precursor of milk lactose. Butyrate is used for milk fat synthesis. Under optimal rumen fermentation conditions, the acetate to propionate ratio should be higher than 2.2 to 1. High levels of acetate indicate a high fiber/low NFC ration while high levels of propionate indicate reduced fiber digestion and acidosis.

Acidosis occurs when feeding high concentrate diets that are rich in fermentable carbohydrates. Starch and sugars stimulate lactic acid producing bacteria, but bacteria that normally utilize lactic acid cannot keep up with its production. As lactic acid is about ten times stronger than the other rumen acids, it causes rumen pH to decrease from normal levels of 6.0-6.2 and, as rumen pH drops below 6.0, bacteria that digest fiber begin to die thereby depressing fiber digestion. As the end products of fiber digestion are used for milk fat synthesis, a drop in milk fat is a sign of potential acidosis.

The most common clinical sign of acidosis is diarrhea, which occurs due to continuous acid accumulation in the rumen which causes an influx of water into the gut. A continuous accumulation of lactic acid in the rumen may cause gut ulcerations and result in infiltration of bacteria into the blood that can cause liver abscesses. Lactic acid is also absorbed into the blood and lowers blood pH and, if blood pH drops too low, this can result in death of the animal. Endotoxins resulting from high acid production in the rumen may affect blood capillaries in the hoof to cause them to constrict thereby resulting in laminitis. The two types of acidosis reported in the field are acute and sub-acute.

Acute acidosis

The acute form of acidosis is less common but symptoms are more severe. Affected animals are depressed, go off-feed and have an elevated heart rate with diarrhea, and may die. The most common symptoms of acidosis are in Table 4.

Sub-acute rumen acidosis (SARA)

Cows experiencing sub-acute rumen acidosis have mild diarrhea and depressed DM intake. Rumen pH drops below 6.0 and remains low for several hours as VFA production shifts to higher levels of propionate.

Table 4. Common symptoms of acidosis

Low milk fat test i.e. <3.0 to 3.3%
Sore hooves; laminitis
Sudden changes in feed intake
Diarrhea
Liver abscesses
Low rumen pH (< 5.8)
Limited cud chewing

Diagnosis of ruminal acidosis before economic loss has occurred is difficult, making prevention the best approach. Recommended feeding guidelines and practices for prevention of ruminal acidosis are:

1. Avoid sudden changes in the ration from forage to concentrate.

2. Feed additives such as sodium bicarbonate and yeasts may have a beneficial effect by maintaining or increasing milk fat level. Sodium bicarbonate at 100-200 g/cow/day is recommended when feeding high quantities of NSC.

3. The minimum quantity of acid detergent fiber (18-21%) and NDF (27-30%) and maximum quantity of non-forage carbohydrates (35-40%) should be met.

4. The forage particle size of the diet should not be less than 3/8 inch.

Hypomagnesaemia

Magnesium (Mg) in the body is mainly in the bones (~50%). The normal concentration range in plasma of a dairy animal is 1.8-3.5 mg/dl. Mg is essential for normal bone metabolism, nerve function and muscle irritability. It also plays an essential part in the coenzyme systems which link normal carbohydrate metabolism with phosphate metabolism, and the provision of energy for muscle contraction.

Hypomagnesaemia is a metabolic disorder caused by a Mg deficiency. It is known by various names including hypomagnesemic tetany, grass tetany, lactation tetany or grass staggers. As the name implies, it is most likely to occur after animals are turned out on pasture. Hypomagnesaemia often occurs in high producing cows grazing lush pastures, most commonly during cool, cloudy and rainy weather of the spring and fall, but is not common on legume pastures. Hypomagnesaemia occurs most frequently on pastures grown on soils low in available Mg (<0.2%) and high in available potassium (>3%).

The symptoms of hypomagnesaemia, in the order in which they occur, are excitement and nervousness, incoordination, muscle twitching, teeth grinding, frequent urination, viciousness, staggering and falling, labored breathing, tetanic contraction of muscles, convulsions and death. The complete sequence of visible symptoms often occurs in only 6-10 hours. Hypomagnesaemia can be complicating factor in milk fever, but is less commonly associated with calving than hypocalcaemia. The symptoms of milk fever in lactating cows are quite similar to hypomagnesaemia, except that animals become paralyzed rather than show a violent muscular response.

A low level of serum Mg is generally associated with tetany. Normal blood Mg levels are about 2 mg/100 ml of plasma. If the level drops to 1 mg/100 ml, it is referred to as hypomagnesemia and, if it drops below 1 mg/100 ml, tetany can be expected. There are two types of clinical hypomagnesaemia, which are defined as:

Acute hypomagnesaemia

This is an often fatal type which usually follows abrupt changes of diet, especially from indoor feeding to outdoor grazing. Animals affected by the acute form suddenly stop grazing and show unusual alertness, followed by a staggering gait, stiffening of muscles and violent jerking convulsions with the head pulled back. Between convulsions, the animal may appear relaxed. At this stage, a noise or touching may result in a vicious response. An increase in body temperature and respiratory rate is common and animals usually die during or after a convulsion unless treated. This form of disease develops slowly, but convulsions may occur if animals are driven or handled roughly.

Sub-acute hypomagnesaemia

The sub-acute type is usually recurrent and indicates borderline Mg deficiency. In mild cases, milk yield is decreased and the animal is nervous. These signs indicate the need for preventive measures.

Hypomagnesaemia may lead quickly to death if left untreated. Treatment can be successful if given early, in conjunction with gentle handling of affected animals. In most cases of hypomagnesaemia, moderate hypocalcaemia accompanies it. Hypomagnesaemia cases can be treated by a combination of Ca, phosphorus and Mg injections as Mg-dextrose injections, Ca borogluconate-Mg injections or 50% Mg sulfate injections.

About 200 ml of a 50% solution of Mg sulfate provided subcutaneously will generally increase blood Mg levels within 15 minutes. Injections of Ca borogluconate-Mg must be administered slowly since there is a danger of heart failure if it is given too rapidly. Heart and respiratory rates should be monitored closely and, if they increase rapidly, treatment must be suspended or continued at a slower pace.

Summary and Conclusions

Milk fever, ketosis, acidosis and low milk protein are common metabolic problems of dairy cattle in Pakistan. Although milk fever and ketosis tend to be diseases of high yielding dairy animals, they are commonly found in medium to low producing zebu cattle due to poor dietary management practices.

Buffaloes exhibit variable degrees of milk fever symptoms after parturition due to improper management during the dry period as dairy animals are usually kept at a low feeding level during the dry period, such as grazing on low quality pastures with little or no concentrate feeding.

Ketosis and acidosis are common in peri-urban dairy farming since it is characterized by an intensive farming system where the animals are kept in close confinement for high milk production. In combination with often inappropriate diet energy/protein levels and inadequate exercise, animals are more prone to contracting ketosis. The commercial dairy feed industry often lacks expertise in practical feed formulation techniques, and may provide nutritionally imbalanced dairy feeds.

Unavailability and high prices of roughages, and/or an imbalance in the diet roughage to concentrate ratios, are major reasons for occurrence of acidosis in peri-urban areas. In these situations, dairy farmers try to meet animal requirements with concentrates, which sometimes leads to acidosis.

CHAPTER VI B

Nutrition and Health

Nutrition and Reproduction

(T.N. Pasha)

The relationship between nutrition and reproduction is a topic of increasing importance among dairy farmers, veterinarians, feed dealers and animal nutritionists due to a recognition that reproductive efficiency in dairy herds is largely dependent upon nutrition. Inadequate supplies of trace minerals or vitamins, as well as energy-protein imbalances, are major contributors to infertility and poor reproductive performance.

Infertility

Nutritional factors influencing fertility

It is known that reduced DM intake in early lactation, and reduced nutrient flow to the mammary gland, results in a negative energy balance and associated metabolic disorders (Zhang, 2002). High DM intake, and increased ratios of plasma glucose to 3-hydroxybutyrate, are positively associated with fertility. Reduced fertility is most obvious in cows where milk yields were above 6000 litres per lactation, and in cows fed excess energy during the previous dry period. Most high producing cows are in negative energy balance when they normally initiate their first reproductive cycle after calving (Staples et al., 1998), suggesting that factors associated with negative energy balance may be related to reproductive failure.

Influence of nutrition on gonadotrophin & progesterone concentrations

The larger the negative-energy balance, the longer the interval to first ovulation. Most importantly, proper functioning of normal estrous cycle activity after calving depends on the energy balance during the first 3 weeks of lactation. Animals with poor body condition may not cycle until 60 days post partum, thus increasing days open.

Canfield (1990) found a strong correlation between negative energy balance in early lactation and resumption of ovulation postpartum. While ovulation may not occur in animals on low dietary intakes, follicle growth and atresia will occur. Furthermore, negative energy balance adversely affects normal development of follicles, given the involvement of local and systemic production of growth factors, in particular the insulin growth factor (IGF-1.) as well as with concomitant increases in â-hydroxy butyrate, non-esterified fatty acids (NEFA) and triacylglycerol.

Management Practices to Increase Fertility

In order to avoid large post-partum negative energy balances, and maximize DM intake, well-known management practices, such as feeding fresh feeds, correct ration formulation, feeding ad libitum, higher feeding frequency, adequate bunk space, regular cleaning of bunk space, shading/cooling feeding area, monitoring body condition and feeding fats at 3%-6% of DM intake are advised.

Table 1. Consequences of negative energy balance and high metabolic rates on reproduction in dairy cows

Metabolic profile	Metabolic and high level functional changes	Endocrine changes	Functional changes
Negative Energy Balance	Impaired synthesis and secretion GnRH and LH	• anoestrus • poor follicular growth and estrogenic capacity • delayed LH peak and ovulation	• poor oestrus demonstration • poor quality of oocyte • increased early embryonic mortality
	Emergency energy production from adipose tissue and proteins	• increased levels of triacylglycerols in circulation (impaired liver function) • increased levels of urea in circulation	• impaired immune function of endometrium and increased suscepti-bility to uterine infections • uterine environ-ment less favourable for the embryo

Importance of Energy, Proteins and Minerals

Energy

Energy is the first limiting dietary component for cows in early lactation, as the demand for energy for milk production and body maintenance exceeds energy inputs in the diet. Cows then mobilize body energy stores, mostly fat, to make up the difference between energy intake and energy output.

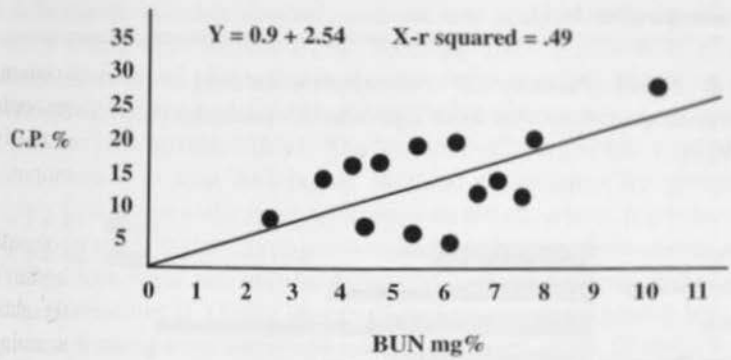
About two weeks before the expected calving date, the cow's rumen should be prepared by a gradual increase in concentrates (increase by 0.5 kg/day). Low energy intake during late pregnancy can result in lowered birth weights, higher death rates in newborn calves, lower milk production, lower weaning weights, increased days to first heat and reduced conception rates. Villa-Godoy et al. (1988) reported that in the first two to three weeks of lactation, energy supply plays an important role for the onset of ovarian activity and uterine involution. Therefore, an energy deficiency leads to acyclia, silent heat, delayed ovulations and follicular cysts.

Protein

The recommendations for dietary concentration are 17% CP during the first 3 weeks post partum and 15-17% thereafter, depending upon the amount of milk produced. The reason for a higher recommended level immediately after calving is low DM intake. It is also during this period that cows undergo metabolic changes, primarily the shift from a homeostatic to homeorhetic state, to prioritize milk production. Thus the demand for glucose is intense and gluconeogenesis is prominent, and protein reserves in body tissues are used to supply carbon skeletons for glucose synthesis. It has been noted that about 11.4-16.0 kg of body protein are often mobilized during the first 60 days of lactation.

Canfield et al. (1990) reported that during the first 10 weeks post-partum, cows undergo tremendous changes as they shift from the pregnant to non-pregnant state. If more protein is consumed during this stage, urea levels increase in body fluids.

Figure 1. Relationships between BUN concentrations and intake of crude protein. Calcium and Phosphorous



Ward (1968) reported that protein supplemented cows (Groundnut cake at 908 g cow/d) in the dry periods maintained body weight, while those without supplementation lost weight. Garcia-Bojali et al. (1992) found that cows fed fed 20% CP diets had more reproductive health problems than cows fed 13%. Similarly, cows fed high amounts of CP had more days to first ovulation (37 vs. 16 days) than cows fed low CP (Figure 2).

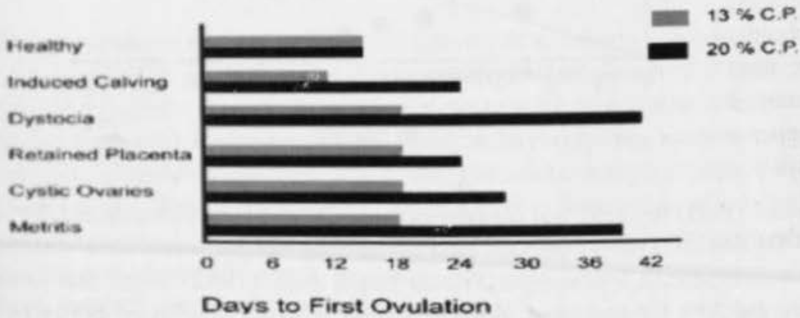
Table 2. Effect of groundnut cake (GNC) and Phosphorus (P) supplementation on various production parameters (adapted from Ward, 1968)

Reproductive parameters	Mean Values			P + GNC	Probability of effects	
	-	P	GNC		P	GNC
Calving Rate (%)	56.7	61.7	72.2	76.7	ns	***
Weaning rate (%)	56.7	61.7	68.5	76.7	*	***
Birth weight (kg)	20.6	21.0	22.7	23.6	ns	***
Birth to weaning gain (kg)	104	117	113	123	**	Ns
Weaning weight (kg)	125	138	135	146	**	**
TWC*	425	511	556	673	**	**
Percent improvement as compared to the control:						
Weaning rate (%)	-	8.9	20.8	35.3		
Weaning weight (%)	-	10.5	8.2	17.0		
Cow's weight at weaning	-	20.2	30.8	58.4		

TWC* - Total weight of calves weaned/cow/6yrs (kg).

ns - not different (P>0.05) ; * different (P<0.05) ; ** different (P<0.01); *** different (P<0.001).

Figure 2. Effect of dietary CP concentration on days to 1st ovulation in healthy cows and those that have reproductive problems (Garcia-Bojali et al., 1992)



Minerals

Calcium and phosphorous

Phosphorus and calcium are important minerals for dairy animals. A phosphorus shortage is more likely to occur than a calcium deficiency under conditions where forages are used abundantly, as forages tend to be good sources of calcium, whereas grain mixtures are better sources of phosphorus. A phosphorus deficiency has been associated with reduced appetite, retarded growth, less efficient feed utilization, decreased milk production and impaired reproduction. From mid to late pregnancy, a bred cow's requirement for calcium increases by 22% and, after calving, by an additional 40%. A deficiency can lead to "milk fever" around the time of calving, particularly in high milk producing beef breeds. Moreover, a greater incidence of calving difficulty, retained placenta and prolapsed uterus may also occur. Calcium interacts directly with phosphorus and Vitamin D. If dietary calcium levels are extremely high, phosphorus availability is reduced. Conversely, high levels of phosphorus impair calcium absorption.

Copper and manganese

The most important reproductive effects of copper deficiency are similar to deficiencies of other minerals and include delayed puberty and poor fertility. Other signs include repeat breeding and a higher than expected number of retained placentas. Bulls may have reduced libido and poor semen quality. If the deficiency is severe, bulls can become sterile because of damage to testicular tissue. The amount of manganese required for reproduction is at least 30% higher than the requirement for growth and animals with severe manganese deficiency do not show heat, have decreased conception rates, higher abortion rates and low birth weight calves, which are often born weak and may be deformed with twisted legs and enlarged joints. Harrison et al. (1986) observed that cows supplemented with both copper and manganese improved conception from about 62-84% by 150 days postpartum.

Selenium

Selenium deficiency has been associated with reduced fertility, more retained placentas, abortions, premature or weak calves, reduced ability to resist disease and "white muscle disease" in calves. Recently, selenium deficiency has been identified, in combination with vitamin E, in more endometritis and cystic varies. Harrison et al. (1986) state that only combined selenium and vitamin E treatments improved fertility.

Zinc

Zinc deficiency results in reduced sperm production and delays sperm maturation. In addition, low zinc diets affect testicular development of bulls. Animals fed zinc deficient diets may have low conception rates even though bulls are normal. Moreover calves grow slowly and reach puberty at a later age.

Table 3. Effects of minerals on reproduction (from Harrison et al. 1986)

Mineral	Possible Impact of Deficiency	Possible Impact of Excess
Calcium	Dystocia Retained Placenta Metritis	
Phosphorous	Anoestrous Low Conception Rate Delayed Puberty	Unbalanced Ca:P ratio
Manganese	Abortion Ovarian Cyst Anoestrous Silent Oestrous	Abortion
Cobalt	Anoestrous	
Copper	Anoestrous Low Conception Rate Retained Placenta Abortion	
Selenium	Retained Placenta Low Conception Rate	
Iodine	Low Conception Rate Retained Placenta	

Iodine

Iodine deficient animals may have delayed puberty, and frequently do not show signs of heat. Other deficiency symptoms include poor conception rates, abortions, longer gestation periods and birth of dead, weak or hairless calves.

Sodium and chloride

Salt deficiencies can affect efficiency of digestion and so indirectly affect reproductive performance. Lotthammer and Faries (1975) reported that, depending on soil quality and fertilizer use, a deficiency of sodium (and an excess of potassium) could reduce fertility by causing irregular oestrus cycles, endometritis and follicular cysts.

Use of Body Condition Score as a Diagnostic Tool

Body Condition Scores (BCS) are numbers on a scale used to describe the relative fatness, or body composition, of cows. Scores are on a 1-5 scale considering 1 to emaciated and 5 being grossly obese. As such, it provides an indication of the energy status and fat reserves of dairy animals. In routine practice, beef and dairy herds use BCS in circumstances where weighing may be impractical to help regulate feeding and management, thus ensuring that breeding animals attain appropriate BCS at different stages of their production cycle. Cows should freshen in good BCS to support production of more milk in early lactation, and it is often 50-60 days after calving before they are in a positive energy balance. One kg of body fat equals about 7 kg of 4% fat corrected milk. If the cow is in good body condition at dry-off, she should calve at approximately the same body condition score. As it is recommended that a cow go dry with a body condition score of 3.50-3.75, calving BCS values should be similar. Failure to attain proper body condition, or rapid changes in BCS during early lactation, indicate problems in herd health or feeding management. Condition score should be monitored at each reproductive stage such as at calving, postpartum, breeding, pregnancy confirmation, late lactation (about 250 days in milk) and at dry-off.

Figure 3. Anatomic areas used for BCS in beef cows

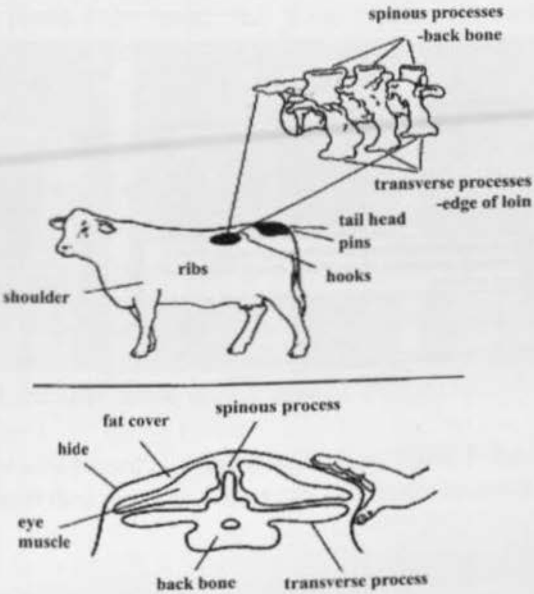
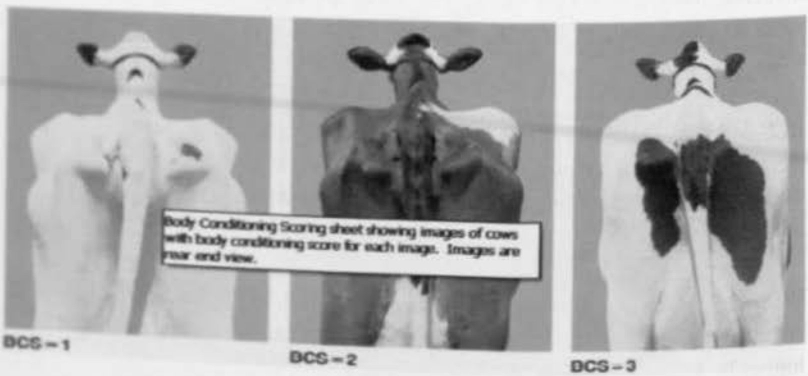


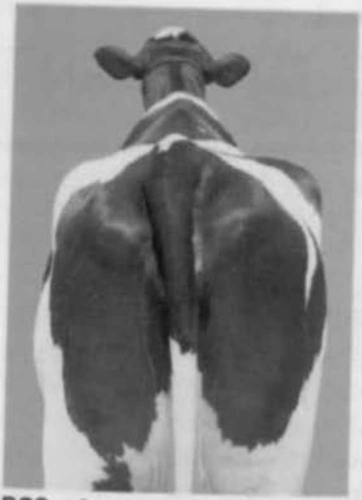
Table 4. Range of ideal body condition scores

Stage of lactation	Score
Drying-off	3.5-4.0
Calving (Older cows)	3.5-4.0
One month post-partum	2.5-3.0
Mid-lactation	3.0
Late lactation	3.25-3.75
Calving (first lactation)	3.5

The body condition of cows at calving is associated with length of the post-partum interval, subsequent lactation performance, health and vigor of the newborn calf, and the incidence of calving difficulties. The condition of cows at breeding affects their reproductive performance in terms of services per conception, calving interval and the percentage of open cows. In older cows, high BCS can lead to dystocia. In contrast, cows that are too thin are prone to metabolic problems and diseases and decrease milk yield. The pictures of cows in different BCS are shown in Figure 3a.

Figure 3 a. Cows differing in Body Condition Score of 1 to 5





BCS=4

BCS=5

BCS 1: Deep body cavity around tail head. Bones of pelvis and short ribs sharp and easily felt. No fatty tissue in pelvic or loin area. Deep depression in loin.

BCS 2: Shallow cavity around tail head with some fatty tissue lining it and covering pin bones. Pelvis easily felt. Ends of short ribs feel rounded and upper surfaces can be felt with slight pressure. Depression visible in loin area.

BCS 3: No cavity around tail head and fatty tissue easily felt over whole area. Pelvis can be felt with slight pressure. Thick layer of tissue covering top of short ribs which can be still felt with pressure. Slight depression in loin area.

BCS 4: Folds of fatty tissue are seen around tail head with patches of fat covering pin bones. Pelvis can be felt with firm pressure. Short ribs can no longer be felt. No depression in loin area.

BCS 5: Tail head is buried in thick layer of fatty tissue. Pelvis bones cannot be felt even with firm pressure. Short ribs covered with thick layer of fatty tissues.

Target body scores of dairy animals

Dairy cows generally are in a negative energy balance in the early weeks of lactation, and managing body condition loss can help their breeding performance. Roughage and concentrate feeds are needed for production of milk, which typically peaks slightly after the maximum negative energy balance.

Cows with low BCS will tend to become too thin in the first weeks after calving, resulting in low conception rate and an uneconomically long calving to breeding interval. This is similar to beef cattle, where a delay to the onset of first estrus is seen in cows with a BCS of 2. Many dairy cows fail to exhibit heat until they are in positive energy balance. However calving difficulties increase when heifers are fatter, and this may result in fetal death, bruising of the birth passage and pinched nerves that can lead to lameness. Over-conditioned cows are prone to ketosis, which is caused by too rapid mobilization of body fat. Thus, in the first three months of lactation, the BCS of a dairy cow should not drop more than 1.5 points, or below about 2.5. However, at 120 days after calving cows should be at their optimal weight and BCS should be 2-3.

Effect on reproductive performance

Studies indicate that cows with lower body condition scores have lower conception rates and decreased heat detection compared to cows that are gaining weight and have higher body condition scores. Gearhart et al. (1990) reported that body condition was an important predictor of potential reproductive efficiency, and ideal BCS was observed to be 3-3.75 at calving, 2.25-2.75 at peak yield, 3-3.5 at 150-200 days post partum and 3.0-3.75 at dry off. It was further reported that cows which were over conditioned at dry off, with a BCS of 4 or more were 2.5 times more likely to experience reproductive diseases (i.e., dystocia, metritis, abortion) in their next lactation than cows having BCS 3-3.5.

Effect on calving interval

Calving intervals in excess of 12 months are often caused by nutritional stress, either before the calving season or during the subsequent breeding season, which results in low body condition and poor reproductive performance. The thinnest cows have the longest calving intervals, while fatter cows have shorter calving intervals. Producers should evaluate their cows for condition and provide supplemental feed to correct nutritional deficiencies, which are indicated by cows becoming thin. The influence of nutrition before calving is a major factor that controls the time between calving and return to estrus. Dairy cows with BCS of 2 or less at calving have longer intervals from calving to first estrus than cows with BCS of 2.5 or higher.

Young cows require about one BCS unit higher to achieve the same reproductive performance as mature cows since they have an added nutrient requirement for growth. Furthermore, it is easier to increase condition in cows before calving rather than after calving because after calving nutrients are often directed to milk production. It has been observed that feeding cows to gain condition early in lactation leads to increased milk production, but has little effect on body condition. Thus an acceptable BCS prior to calving is 3 or higher and more than 3.75 will not be helpful. However, BCS at calving of less than 2.5 will impair reproduction.

Effect on breeding

The influence of nutrition after calving is a major factor that controls fertility of an animal during the breeding season. A lower conception rate occurs in cows losing condition from calving through breeding versus cows that maintain, or gain, condition during this time. Thus, dairy animals should be in a condition score of 3 or better at calving and should maintain good body condition during the breeding period.

Table 5. Effect of body condition during breeding season on pregnancy

Body condition score	2 or less	2.5	3 or more
Number of cows	122	300	619
% pregnant at 150 d	58	85	95

Major aspects of feeding management that can be adjusted to control body condition include maximizing feed intake, adjusting diet energy concentration, adjusting CP and rumen escape CP levels, providing adequate fiber to prevent off-feed problems or chronic intake fluctuations and assuring mineral (Ca, P, Mg and K) levels and water availability.

Conception

Wiltbank et al. (1962) affirmed that cows that lost weight from parturition to breeding had lower conception rates than those that had not (i.e., 43 vs. 67%, respectively). Following these studies, Ferreira et al. (2005) evaluated effects of feed restriction and subsequent weight loss on the interval from parturition to conception, number of services per conception and service period length in Gir-Holstein cows with a high BCS at parturition. The mean weight loss of 11.8% from parturition to first estrus was not sufficient to increase the time to 1st estrus past the desired period of 85 days post-parturition, considering a 12 month calving interval. These results are in agreement with Diskin et al. (2003), which showed that cows started anestrous when the average loss of initial body weight was about 22-24%. Thus a low BCS at the beginning of feed restriction might be one of the factors that affected the interval to anestrus. Ferreira et al. (2005) further reported that the length of service periods for groups fed control and restricted diets were different, and might be related to the higher number of services per conception in the feed restricted group (Table 6). Lower conception rates associated with follicles, which grew under a negative energy balance, might be due to an effect of a metabolic imbalance on oocyte or follicle (Britt, 1994). Ferguson (1996) showed that cows in a negative energy balance had lower conception rates. Higher number of services per conception for the feed restricted group might explain the difference of 39.9 days in service period between the two groups.

Differences in estrus detection might be a consequence of feed restricted animals having lower expression or intensity of estrus behavior (Ferguson, 1996). The causes of silent or undetected estruses in relation to a negative energy balance had been discussed by Spicer et al. (1990), who verified that 40% of first post-partum ovulations were not associated with estrus in cows in negative energy balance, compared to 16.7% under positive energy balance. They also mentioned occurrence of silent estrus or ovulation without visible signs of estrus in feed restricted animals, which contributed to the low conception rate to these animals. Thus, it was concluded that higher detection of animals in heat would increase the conception rate in animals.

Table 6. Effect of feed restriction from parturition to conception on reproductive parameters of Gir-Holstein cows

	Groups	
	Control (I)	**Feed Restriction (II)**
Number of animals	25	25
Interval from parturition to 1st estrus (days)	46.3±11.0[a]	55.4±11.3[a]
Service Period (days)	74.7[a]	114.6[b]
Services/ conception	1.44[a]	2.12[b]
Live Weight (kg)		
Parturition	462.0±18.8[a]	470.8±21.5[a]
1st Estrus	456.0±17.5[a]	415.2±18.5[b]
WLRP (%)	6.0 (1.3)	55.3 (11.8)
DWL	0.13	1.00
Conception	453.8	408.4
WLRP (%)	8.2 (1.8)	62.2 (13.2)
DWL	0.11	0.54
Body Condition Score		
Parturition	3.73±0.23[a]	3.82±0.21[a]
1st estrus	3.64±0.21[a]	3.0±0.19[b]
Conception	3.63±0.21[a]	2.92±0.20[b]
Unidentified estrus or ovulations without estrus		
Signs (%)	36.3	39.5

WLRP = Mean weight loss related to weight at parturition (kg and %); DWL= Mean weight loss by day (kg); [a,b] Values followed by different letters, in the same row, differ (P<0.01).

Ferreira et al. (2005) concluded that cows under post-partum feed restriction, and with a high BCS, had a live weight loss of 11.7 and 13.2% from parturition to first estrus and to conception, respectively, but that this did not affect the interval from parturition to first estrus interval while the number of services per conception and length of the service period increased. Another factor that could explain lower conception rates of feed restricted cows was the lower progesterone level produced by CL of cows in negative energy balance. It seems clear that excellent nutritional and reproductive management may compensate for negative effects of high milk production on reproduction.

Calving

Optimal reproductive performance in animals is often limited by prolonged postpartum anestrous intervals. Wiltbank (1970) observed that heifers bred to calve at 2 years of age resumed ovarian function 20-40 days later than mature cows. Furthermore, the stress of calving, and the combined effects of growth and first lactation, imposed nutritional requirements that were often not fulfilled when animals were fed low-quality pastures. Thus, inadequate nutrient intake before or after calving had a greater detrimental effect on postpartum reproduction in primiparous than in mature animals. Bellows and Short (1978) reported that first-calf heifers usually had a longer postpartum anestrous interval than mature cows. Selk et al. (1988) concluded that BCS at calving was the most important factor determining whether cows would become pregnant during the breeding season, because postpartum weight gain influenced ovarian activity of first-calf heifers during a restricted breeding season.

Dystocia

Birth weight is usually the major factor causing calving problems and this trait is highly correlated with dystocia, or calving difficulty, which increases calf losses and cow mortality. Furthermore, a difficult birth can also set back a calf's performance to weaning, and frequently delays rebreeding for the dam. Many of the management and nutritional factors are directly related to birth weight and should be considered.

Figure 4. Time to breed cows for best conception

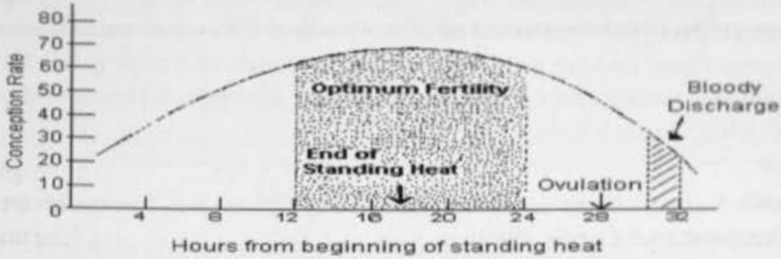
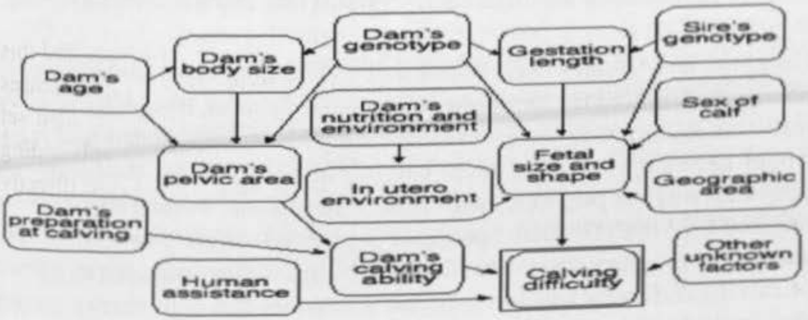


Table 7. The relationship between estrous signs and conception rate (Smith, 1982)

Estrous Signs	Milk progesterone level	No. of cows bred	Conception rate
Standing	Low (in or near estrus)	163	55%
Not standing	Low (in or near estrus)	193	37%
Total	-	356	45%

Figure 5. Factors affecting calving difficulty



Studies to determine effects of feed intake level prior to calving on the incidence of dystocia revealed that feed levels during gestation has little influence on dystocia. Thus, excess energy intake during gestation is not as much of a problem as excess protein, as the latter increases birthweight of the calf and the incidence of calving difficulty. Therefore, particular attention should be paid to the amount of protein fed to heifers during gestation. The best experiments on this subject show the need to feed a balanced ration that allows proper growth as described above. In a practical context, if pregnant heifers are on winter pastures (i.e., wheat, oats, ryegrass, clovers), limit grazing to 30 minutes per day rather than grazing full time. This helps avoid excess protein in the diet and its associated increase in the offspring's birth weight.

Table 8. Two energy levels of pre-calving rations for 2-year-old cows (Houghton and Corah, 1989)

Energy level	Pre-calving cow weight	Pre-calving condition score	Calf birth weight	Incidence of dystocia
Low (7.5 lbs TDN)	725 lbs		58.6 lbs	40%
High (13.9 lbs TDN)	811 lbs		62.8 lbs	36%

Many cattle producers believe in reducing dietary energy intake during late pregnancy to decrease fetal size and reduce dystocia. However, research does not support this view. Randel (1990) reported that increasing the level of dietary energy resulted in increased birth weights, but did not increase the incidence of dystocia. Indeed, the incidence of calving difficulty was lower in the medium- and high-energy groups than in the low-energy group.

Houghton and Corah (1989) found that overfeeding cows to the point of obesity experienced the increased incidence of dystocia. However, the cows that were underfed to the point where they became emaciated and weak would likewise experience more calving difficulty. Thus, depending on body size, stage of pregnancy and climatic conditions, weaned heifer calves required 8-12 lbs TDN daily; pregnant 2-year-old heifers, 9 to 13 lbs TDN; and mature pregnant cows, 8 to 12 lbs TDN. In a similar study, the incidence of calving difficulty was lower in the moderate- and high energy groups than in the lower energy group.

Table 9. Effect of pre-calving energy level on birth weight and dystocia in 2-yr-old cows (Houghton and Corah, 1989)

Energy Level	Birth Wt, lb	Dystocia (percent)
Low (10.8 lb TDN)	58.0	26
Medium (13.7 lb TDN)	61.5	17
High (17.0 lb TDN)	63.9	18

Recommendations for reducing dystocia include managing heifers so they reach required calving weights in fat score 2-3 only, providing heifers hilly paddocks to graze from pregnancy testing to calving (these paddocks should have enough feed to keep the heifers gaining at around 0.5 kg per day up to calving but should not give access to big feed flushes) and, after calving, give heifers sufficient of high quality feed.

Retained placenta

Retained fetal membranes (RFM) is still the biggest problem during the periparturient period, since it is often followed by postpartum metritis, abomasal displacement, ketosis and mastitis.

The relatively low plasma glucose, and high non-esterified fatty acids (NEFA) levels, in cows during the late dry period were associated with an increased incidence of retention of fetal membrane. Boer et al. (1985) reported that the plasma concentrations of the (NEFA), glucose and cholesterol were considered to be good indicators of negative energy balance in cows. Calcium is known to play an important role in uterine contractions, and a relatively low plasma Ca concentration during the late dry period was associated with an increased incidence of retention of fetal membrane in this study.

Maternal nutrition during the second trimester of pregnancy and later influence feto-placental growth and development, while nutritional state during late pregnancy has effects on retention of fetal membranes in dairy cattle. Bearden and Fuquay (1992) summarized effects of inadequate and excessive nutrients on reproductive efficiency and showed that excessive protein and/or energy could have negative effects on reproduction. Often, there are questions by livestock producers who are concerned that excessive dietary nutrients during the last trimester of pregnancy may negatively influence calf birth weights and dystocia, although reducing protein or energy pre-partum had little effect on dystocia rates, even though birth weights were altered in some cases. Of the nine studies summarized, seven showed that increased energy intakes during the last trimester of gestation did not increase calving difficulty, but that supplemental CP increased calf birth weight. Of the five studies reviewed, one study showed that excessive CP increased calving difficulty, while four other studies did not show any effect on dystocia, birth weight, calf survivability or weaning weight.

Feeding and management practices to prevent retained placenta include:

1. Feed nutritionally balanced rations to dry animals, especially during the last 2-4 weeks prior to expected calving. Pay particular attention to levels in dietary levels of calcium, phosphorus, selenium, vitamins A, D and E, and beta-carotene. Avoid deficiencies or excesses of calcium, phosphorus and vitamin D. Use an anionic diet if necessary when milk fever is a herd problem. Check levels of sulfur, chloride, potassium, and sodium in all feeds and in the total ration.

2. Avoid extremes in body condition before and after calving, especially over-conditioning.

3. Keep cows on feed during the pre- and post-partum period. Animals should not have access to corn silage free choice. Intake of concentrates should be limited.

4. Minimize stressful conditions, including dirty calving areas, during the dry period and at parturition.

Conclusions

Negative effects of poor nutrition on reproduction can be minimised by feeding a balanced diet, particularly as milk production increases. By maintaining BCS throughout pregnancy, and slowly adapting the rumen to changes in the diet, particularly during late gestation, post-calving fluctuations in BCS which inhibit fertility during early lactation can be minimized. Major impacts of energy on fertility occur from the last trimester of gestation until pregnancy is re-established. Cows which spend late gestation with a low BCS, and calve in such a conditions, are predisposed to a number of metabolic diseases and difficulties at calving which may result in serious illness and, in some cases, death.

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CHAPTER VI C

Nutrition and Health

Managing in Hot and Cold Conditions

(M. Abdullah, S. Shafiullah Khan)

Heat stress is caused by factors which decrease the heat transfer from an animal to its environment. High air temperature is usually the primary cause of heat stress. Other factors that intensify this effect include high air humidity, low air movement and thermal radiation load. Hot and humid conditions cause stress to lactating dairy cows, the consequences of which include reduced feed intake, production losses, exposure to diseases, severe or prolonged elevations in body temperature, reduced gains and feed efficiency, reduction in fertility and a drop in conception rates from 40-60% to 10-20%.

Dairy cows have a natural body heat balance which is optimal for normal physiological processes and productive functions. A normal body heat balance exists only when the net heat gain equals the net heat loss. The most comfortable and productive environmental temperature for dairy cows range between -5°C and 25°C, which is the thermal comfort zone. When environmental temperatures exceed 26°C, milk production declines, mainly because of a decrease in the dry matter (DM) intake.

One way to measure the combined effect of temperature and humidity is to use the temperature-humidity index (THI). Table 1 contains the THI from different combinations of temperatures and humidities. A THI exceeding 72 is sufficient to cause minor heat stress and cause a response such as reduced DM intake in cows. Note that with high relative humidity, the temperature that causes a THI of 72 can be quite low. When the THI is in this range, livestock are at risk and environmental modifications will be necessary to avoid sharp declines in production and, in some cases, death losses.

Effects of Heat on Animal Performance

Moisture in the air influences the rate of evaporative heat loss from animals through both skin and the respiratory tract. There are no differences in live-weight, body temperature (BT), and respiration rate (RR) between 28°C-40% relative humidity (RH) and 28°C-80% RH. However, 28°C has more effect on cows DM intake, milk yield, milk composition, heat production (HP), evaporative heat loss (EHL), and time spent lying down at a high humidity (80% RH) than when humidity was low (40% RH). The ratio of evaporative heat loss to heat production at 28°C-40% RH is 65%, while at 28°C-80% it is 53%. In the latter case, cattle spent more time standing which increased the area of the body surface exposed to the air and so increased heat loss.

Table 1. Table of temperature-humidity indexes (THI)[1] at various temperatures and humidities.

Temp	-------- Relative Humidity, % --------																				
(F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
---------- THI ----------																					
70	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	69	70	70	Heat Stress Begins
71	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	70	70	70	71	71	
72	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72	
73	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73	
74	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74	
75	67	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	
76	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	Sharp drops in production occur
77	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77	
78	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78	
79	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79	
80	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80	
81	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81	
82	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82	
83	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83	
84	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84	
85	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85	

Temp	-------- Relative Humidity, % --------																				
(F)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
-------------------- THI --------------------																					
86	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86	
87	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87	
88	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88	
89	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89	
90	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90	
91	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91	
92	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92	Danger Zone
93	75	76	77	78	79	80	80	81	82	83	84	85	86	87	88	89	90	91	92	93	
94	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	
95	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	
96	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96	
97	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97	
98	77	78	79	80	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97	98	
99	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	96	97	98	99	
100	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	100	

[1]THI = td - (0.55 x RH)(td - 58), where td = dry bulb temperature (degrees F) and RH = relative humidity in decimals.

Radiant heat from the sun and the animal's surroundings affects the rate of heat loss from radiation, convection and conduction. The level of radiant heat from the roof of a livestock barn is very high in summer. As a consequence, the DM intake and milk yield can be reduced in cows exposed to radiant heat.

Wind affects heat loss from the body surface by the processes of convection and evaporation. At 10°C, the effect of wind on the milk production of Holstein cows is low. However, at 27°C, the effect of wind moving only 2 meters/second (m/s) is beneficial. There is no difference between a wind speed of 2.24 m/s, and one of 4.02m/s.

The environmental temperature (ET) at which the respiration rate starts to increase is lower (17°C) for high-producing cows (>35 kg milk/day) than that (22°C) of low-producing cows. The body temperature of high-producing cows rises to a higher level than that of low-producing cows because of the higher metabolic rate and heat production.

The milk production of cows which consumed more than 20 kg of DM per day decreased with a rise in ET. Milk production also fell, especially when the ET rose to 25°C. However there were no differences with a higher ET on milk production of cows which consumed less than 20 kg of DM per day.

It is more difficult for bulls to detect estrus in cows which are suffering from heat stress. The number of mounting episodes per estrus in Holstein cows was only 4.5 in summer compared to 8.6 in winter. The exposure of spermatozoa to elevated temperatures in the uterus or oviduct of a female suffering from heat stress could compromise sperm survival in the uterus and fertilization.

Early embryo development can be compromised by heat stress. It is known that embryos recovered from superovulated cows in Arizona (USA), from June to September were less able to develop in culture than similar embryos collected from superovulated cows from October to May. Exposure of follicles to high temperatures in summer, during the early stages of development, impairs oocyte quality and subsequent embryo development in autumn. A period of about two months is needed for low autumn fertility to be restored to the level seen in winter.

Practical Management to Reduce Heat Stress

There are many tools available to help dairymen combat heat stress, but management must be excellent if performance is to be maintained. Aspects of hot weather management for lactating dairy cows include management of the cow's environment, ration management, feed bunk management and cow management. Two factors to be considered when cattle are exposed to heat stress are:

Energy requirement of cattle increases in order to reduce heat load

This results in an increase in their maintenance energy requirement. The energy that a cow requires to maintain herself, is 20% higher at 95°F than it is at 68°F. Therefore, additional energy, or more accurately, additional DM intake is required to support this increased requirement. Temperatures around 68 to 70°F are considered to be "thermal-neutral." In other words, no added energy is needed to heat or cool the cow's body. But when temperatures increase or decrease significantly from these levels, added energy is needed to maintain normal physiological processes.

Table 2. Effect on maintenance energy and dry matter intake at different temperatures

Temperature Levels			
Temperature (°F)	**Maint. Req. (% of 68 °F)**	**DMI Req[1] (% of 68 °F)**	**Expected DMI[2] (% of 68 °F)**
68	100.0	100.0	100.0
86	111.0	103.7	93.5
95	120.0	105.5	91.7
104	132.0	111.0	56.0

[1]% of dry matter intake required to maintain normal production plus maintenance requirements.

[2]% of DM predicted to be consumed at level of heat stress produced at temperature indicated.

Dry matter intake decreases as heat stress increases

It is obvious from Table 3 that dry matter intake decreases when temperature increases. The data also reveal that milk production decreases and water intake increases when heat stress increases.

Adapted from National Research Council. 1981. *Effect of environment on nutrient requirements of domestic animals.* National Academy Press. Washington, DC.

Table 3. Relative changes in maintenance requirements, dry matter (DMI) and water intake, and milk yield with increasing environmental temperature.

	Required for 59.5 lb milk		Expected intakes & milk yield		
Temperature	**Maintenance requirements**	**DMI required**	**DMI**	**Milk yield**	**Water intak**
(degrees F)	(% of req. at 68 degrees F)	(lb)	(lb)	(lb)	(gal)
68	100	40.1	40.1	59.5	18.0
77	104	40.6	39.0	55.1	19.5
86	111	41.7	37.3	50.7	20.9
95	120	42.8	36.8	39.7	31.7
104	132	44.5	22.5	26.5	28.0

Feeding and Management During Hot Weather

In most situations this becomes a matter of insuring that adequate shade is available and that air-flow is adequate to dissipate heat. Thus a shed with three closed sides would not be helpful. Dairy producers typically use movable shade structures, fans and/or sprinklers. Under hot and dry conditions it may be helpful to utilize sprinklers, especially in dry hot conditions, to help control dust to reduce respiratory stress and the potential incidence of dust pneumonia. Management during hot weather should be aimed at measures to encourage DM intake because it is difficult to provide sufficient nutrients if DM intake is severely depressed. These include:

1 Feeding a balanced ration

2 Providing adequate feed for all cows at all times

3 Providing adequate bunk space for all cows

4 Creating a desirable environment around the feed bunk

5 Frequent cleaning of the feed bunk

6 Checking of ration to ensure adequate nutrient density

7 Purchase or harvest of high quality ingredients.

8 Minimizing drastic ration changes that can make cows to go off-feed

9 Use of total mixed rations to ensure consistent intake of a balanced diet with little sorting of ingredients.

Water during hot weather

Water is the most important nutrient for the cow and it should always be available, always be fresh and clean and there may be advantages to providing cool water during summer. Waterers should be cleaned regularly and be conveniently located to encourage drinking. Shading the water trough encourages drinking during the hot part of the day and helps to keep the water cool. Chilled drinking water helps cool the cow and increase DM intake.

Feed energy during hot weather

Energy is a critical nutrient because of the decline in DM intake which occurs during hot weather. Because energy is usually the nutrient which is most limiting in dairy diets, especially during high production and heat stress, the diet should be made more energy dense. This can be achieved by increasing concentrates (grains) and decreasing forages in the diet. However, increasing concentrates to greater than 55 to 60% of the diet DM is risky and can result in depressed milk fat content, acidosis, cows going off feed, laminitis and reduced efficiency of nutrient use. Some strategies to adopt to fulfill energy requirements during hot season include:

Addition of fat

Added dietary fat is an excellent way to increase the energy content of the diet when feed intake is depressed. Fat is high in energy (about 2.25 times as much as carbohydrate), does not add starch to the diet (minimizes rumen acidosis), and may reduce heat load in summer. Added dietary fat often boosts milk fat test by a point or two. Dietary fat content should not exceed 5 to 6% of the total diet DM. Some sources of supplemental fat are in Table 4.

Oilseeds such as whole cottonseed and whole soybeans are excellent sources of fat, as are tallows. Manufactured rumen inert or "escape" fats are specialty fats which are inert or inactive in the rumen. These are often used when high milk yield requires energy supplementation above that which can be supplied with oilseeds or tallows without causing digestive upsets. A rule of thumb when high fat addition is required is that 1/3 come from natural feed ingredients, 1/3 come from oilseeds or tallows, and 1/3 come from rumen inert fats.

Supplementation of crude protein

Often the amount of CP in summer diets must be increased because of lower DM intake, but careful attention must be given to the amount of CP needed by the cow, not the percentage in the diet. Caution must be taken to feed adequate, but not excess, dietary CP as excess dietary CP must be metabolized and excreted by the cow; a process which creates heat and consumes energy that could be used to produce milk.

Table 4. Sources of supplemental fat for dairy cow diets

	Nutrient Content[1]				Total intake	Guide-lines for feeding
	NE_L	TDN	Crude protein	Fat		
Source	(Mcal/lb)	- - - - (%) - - - -			lb/day	% of diet
Cottonseed	0.01	96	23	20	6	12-15
Soybeans	.96	91	42.8	18.8	4-5	10-12
Tallow	2.65	177	-	99.5	1-1.5	2-3
Rumen escape fats[2]	-	-	-	-	-	-

[1]From National Research Council. 1989. *Nutrient requirements of dairy cattle*. National Academy Press, Washington, DC.

[2]Nutrient content and feeding rate depend on the product being used. Follow manufacturer's guidelines.

Rumen "escape" protein is usually beneficial for cows producing in excess of 60 pounds of milk daily. Escape protein values of 36 to 40% of total dietary CP are desirable. The amount and type of escape CP needed varies by the type of diet being fed, and a nutritionist should be consulted to help make decisions for your herd. Research indicates that heat-stressed cows benefit from escape CP when shaded, and that the benefit may be greater for those cows receiving extra cooling. Diets should not contain an excess of 17% CP with greater than 62% degradable intake CP during hot weather. However rations should be formulated for adequate CP intake based on the amount of DM that the cow is actually consuming.

Fiber supplementation

Fiber is required in the cow's diet for proper rumen function. However digestion and metabolism of fiber creates more heat than digestion of concentrates, and heat-stressed cows will reduce the amount of forages consumed relative to concentrates if allowed to select. This upsets the ration balance and can lead to reduced fat test, rumen acidosis and digestive upsets. There are several steps which can be taken to prevent cows from sorting and selecting their diets that include:

1. Chop hays and mix into a total mixed ration.
2. Use silages as the sole forage source and mix into a total mixed ration.
3. Use wet ingredients such as wet brewers grains and silages to make dry hay diets wetter and more palatable.
4. Add water to dry diets during mixing to improve intake and reduce sorting.
5. Feed high quality, more palatable forages.

Chopping hays for mixing into total mixed rations also helps to reduce waste and improves utilization of lower quality hays when necessary. The fiber content of the ration should be reduced slightly to encourage higher intake in hot weather, but the ADF content should not be less than 18% and NDF not less than 28-30% of ration DM to maintain normal rumen function. As mentioned previously, increasing concentrates to greater than 55 to 60% of the ration is risky because of the reduced amount of effective fiber in the diet. Excellent quality forage helps to maintain feed intake and is especially important during the summer. When excellent quality forage is used, more forage can be included in the ration. In addition to higher DM intake, feed costs are often lower and fiber levels can be maintained at a higher level.

Minerals

The requirement for some minerals increases during hot weather. Table 5 contains National Research Council mineral recommendations for lactating cows and suggested mineral levels for hot weather feeding. The mineral content of the ration should be boosted before the onset of hot weather so that the cows are prepared and a sharp drop in production can be avoided. Higher levels of sodium (from 0.18-0.5%) of total ration DM are beneficial under heat stress. This is equal to 50-140 grams (1.6-5 ounces) of salt fed daily. Sodium is excreted in urine while potassium losses occur through sweating. Maintaining a ration of 3 parts potassium to 1 part sodium is desirable. Magnesium should also be boosted from 0.2-0.3% in overall DM when potassium levels are elevated.

Other minerals such as copper and zinc should also be increased in supplements. As with sodium, during stress, significant amounts of many of the trace elements are lost through urination and must be replaced to maintain normal levels. Since intake levels are not optimal as indicated above use of organic or chelated mineral sources is often warranted due to higher bioavailabilities of these elements and improved efficiency of absorption.

Table 5. Recommendations for selected dietary mineral elements

Mineral	NRC[1]	Heat Stress
	-------- (% of diet dry matter) -------	
Potassium	.9	1.2-1.5
Sodium	.18	.4-.6
Magnesium	.2	.3-.35

[1]National Research Council. 1989. *Nutrient requirements of dairy cattle.* National Academy Press. Washington, DC.

Use of buffers

Buffers such as sodium bicarbonate should be used during hot weather, especially in low fiber, high concentrate diets. Diets should contain at least 0.75% sodium bicarbonate on a DM basis. This amounts to a minimum of

0.34 pound of buffer per day for a cow consuming 45 pounds of DM. Magnesium oxide at 0.35 to 0.4% of diet DM also helps to maintain milk fat test.

Succulent feedstuffs

Succulent feedstuffs are those feeds which are high in moisture, including silages, green chop forages and by-products such as wet brewers grains. Cows like succulent feeds and their inclusion in the ration may encourage intake during hot weather. However a ration that is too wet may restrict intake, so care must be taken to not exceed 50 to 55% moisture in hot weather rations. Succulent feeds spoil more rapidly than dry feeds, especially during hot weather, and feed bunks should be cleaned daily to prevent spoiled feed from reducing feed consumption.

Night grazing

Although air temperature and the level of solar radiation begin to fall after about 2 pm, the temperature of the roof remains high. As a result, body temperature and respiration rate both rise. Cattle kept in a shed maintained a rapid heart beat during the night. However, when the cattle are allowed out into a pasture at night, these physiological responses decreased immediately. This is the result of the reduction in radiation heat from the surrounding cattle and the rise in heat loss from the cattle.

If grazing is a part of feeding program, cows will consume more if grazed very early in the morning or at night. During the day, cows will seek shade. If cows are moved a long distance from pasture, heat stress will be increased, especially if cows are moved during the hot afternoon hours. Hurrying cattle to the barn further stresses the cow. Since long distances often separate pastures from the barn, feeding of chaffed green forage can be an option. This allows the use of fresh green forage, allows better control of the ration and keeps cows near the barn, increasing the opportunity to cool the cow. Green chopping may also help improve forage utilization.

Feeding management

Frequent feeding provides fresh feed, stimulates the cow's curiosity and encourages more frequent eating, all desirable during hot weather. The heat associated with digestion of feed peaks about 3-4 hours after feeding. By feeding cows in early morning (5-6 am), the heat of digestion peaks at 8-9 am, and allows the cow to dissipate some of that heat before the day gets hot. A cow fed at 8:00 am will have her peak of heat production at 11:00 am to noon when the day is hotter, which is undesirable. Similarly, cows fed during the evening will be more comfortable, and likely to consume feed, and their peak of heat production will occur during the night, when environmental temperatures are lower. Frequent small meals result in less heat generated than fewer, but larger, meals.

Locate feeders and water sources (if possible) closer to shaded areas. If intake of supplemental products is lower than desired, move feeders closer to shaded or loafing areas so cattle do not have to venture out as far or for as long into the heat to eat.

Heat stress was associated with reduced activity by antioxidants in the blood plasma. The treatment of cows with antioxidants to improve fertility in summer has given inconsistent results.

Shades and cooling

The easiest and most obvious way to help heat stressed cows is to provide adequate shade. Simple shade in summer is the basic method of protecting animals from direct solar radiation during the day. The most effective sources of shade are trees and other tall plants. They provide protection from sunlight and create a cooling effect through evaporation of moisture from their leaves. Shade has a beneficial effect on the physiological response of dairy cattle to heat as body temperature, heart rate and respiration rate all decrease when shade is provided during summer.

Mesh shadecloth

Mesh shadecloth is light-weight, available in numerous sizes, has reinforced grommets which make installation easy, and can be used in portable or permanent installations. A commonly used shadecloth is an 80% mesh, which means 80% of the sunlight is blocked. Because 80% of the sunlight is reflected and 20% passes through. Shadecloth is not as effective as other types of shading, but is far better than no shade at all. The passage of some sunlight through the mesh may help to dry the area underneath the shade.

Ease of installation and relatively low cost lends shade cloth to many uses. Portable shades using mesh shadecloth and placed in pastures can be moved so that mudholes are not created.

Loose housing barns

Loose housing barns provide shade for cows without the costs of freestalls or concrete floors. These barns have a sand base mounted in the center of the barn to minimize accumulation of moisture. The bedding must be cleaned and maintained regularly to prevent pitting and fresh sand must be added as needed. However, separate feeding facilities must be maintained.

In a hot and humid environment, shading alone does not provide adequate heat stress relief. Additional cooling in the form of fans and sprinklers is usually beneficial. Sprinkling (not misting) the cow with water to fully wet her body and using fans to evaporate the water cools the cow and encourages greater feed intake and milk production. Sprinklers and fans are best placed next to the feedbunk so that the feeding area is the coolest place on the farm, helping to encourage higher feed intake.

Shading concerns and cautions

Orientation of the shading structure relative to the path of the sun is important to minimize intrusion of sunlight under the structure during summer. As little sunlight penetrates under a structure with an east-west orientation in June, while the north-south orientation allows a great deal of sunlight penetration. In December, the east-west orientation allows some sunlight under the structure, providing warmth in the cooler months. An east-west orientation is most desirable so that the barn is cooler in summer while allowing sunlight to warm the barn during cold months.

Overcrowding under shades reduces their effectiveness. A minimum of 38-48 square feet per cow is needed to minimize heat build up between the animals. Cows should have access to adequate shading at all times; in the holding pen, at the water trough, at the feed bunk, and while resting. Highly reflective roofs reflect sunlight and minimize heat transfer to the cattle underneath. White galvanized metal or aluminum roofing is very reflective. A layer of insulation underneath the roofing also minimizes heat transfer. Roofs high enough to minimize heat transfer but low enough to reduce intrusion of sunlight are necessary. An eave height from 11.5 to 14.5 feet is desired.

Table 6. Effect of shade on heat stress indicators in lactating dairy cows

Measurement	Shade[a]	No Shade	% Change	Shade[b]	No Shade	% Change
Black globe temp., °F	86.2	101.8	-18.1	84.4	105.8	-25.3
Rectal temperature, °F	101.7	103.3	-1.6	102.6	105.4	-2.7
Respirations/minute	78	115	-47.4	83	133	-60.2
Daily feed intake, lb				45.6	37.0	+23.2
Daily milk yield, lb				42.8	37.5	+14.1
[a]Adapted from Collier, et al., 1981. *J. Dairy Sci.* 64:844.						
[b]Adpated from Scheider, et al., 1984. *J. Dairy Sci.* 67:2546.						

Housing

Fans

Air movement increases the rate of heat loss from a cow's body surface, as long as the air temperature is lower than the animal's skin temperature. Wind reduces body temperature and respiration rate, and improves weight gain, milk yield and milk composition. However, if the air temperature is higher than the skin temperature, the skin will gain heat from the surrounding air. At air temperatures above 39°C, moving air becomes a source of heat stress for dairy cows.

Ventilation systems in livestock housing serve an important function, maintaining a comfortable animal environment. Typically, a mature dairy cow will breathe out four to five gallons of water per day as water vapor and produce 2000-2400 BTU/hr or 600-700 Watts of heat. Ventilation systems continuously remove the heat, moisture, and odors created by livestock, and replenish the oxygen supply by bringing in drier, cooler outside air. Adequate air exchange also removes gases such as ammonia (NH_4), hydrogen sulfide (H_2S), and methane (CH_4) which can be harmful to both animal and operator health.

Water sprinkling

Water from sprinklers must not be blown into free stalls by fans, which creates a mastitis hazard, or onto the feed, which increases spoilage. Sprinkler water can be confined to desired areas by choosing the right nozzle and placing nozzles correctly in the barn. Also, having fans and sprinklers run in sequence (for example 13.5 minutes for fans, 1.5 minutes for sprinklers) so that fans and sprinklers do not run at the same time and prevent water from being blown where it is not wanted.

A cooling system which is thermostatically controlled ensures that the system runs as long as temperatures are high, and not just until the evening milking is over. If cows are sprinkled with water in the holding pen they must be dry by the time they are milked. Sprinklers are likely to be of most value under hot, dry conditions and may be counter-productive under hot, humid conditions. The following recommendations have been suggested if sprinklers are used:

- Sprinklers should produce large water droplets of at least 150 micron diameter.
- Provide a minimum of two and preferably three sprinklers per pen.
- Sprinkler range should avoid areas adjacent to water troughs, shades and feed bunks and cover at least 2.5 to 3.0m per standard cattle unit (SCU).
- Sprinklers should be supplied by a stand alone water supply that does not compete with water trough requirements.
- It is believed that sprinklers are best applied for 5–10 minutes on and 15–20 minutes off (to allow cooling by convection to be most effective), rather than continuously and their use should be guided by observing the cattle's response and the pen environment.

Combination of sprinkling and forced ventilation

A method of cooling dairy cattle has been examined, based on wetting them repeatedly to trap the maximum amount of water in the coat, followed by its rapid evaporation using forced ventilation. This simple system is a combination of short-duration (0.5-3 minutes) sprinkling with water from overhead sprinklers, followed by forced ventilation with electric fans lasting 4-15 minutes until the cows are almost dry. An automatic device can be installed so that sprinkling and ventilation are alternated continuously while cows are in holding areas (360° pattern) or a feeding area (180° pattern).

Managing Dairy Cows in a Cold Environment

When temperatures start to decline in winter, particularly as they approach 0°C, impacts on cow productivity and efficiency increase. Like all mammals, cows are warm blooded and need to maintain a constant core body temperature. Normal rectal temperature for a cow is around 38°C (101°F). Within the "thermoneutral zone," animals do not have to expend any extra energy to maintain their body temperature. At the lower end of this range, normal metabolic processes supply enough heat to maintain body core temperature. Within their thermoneutral zone, animals may modify their behaviour, such as seeking shelter from wind, and respond over the long term by growing a thick hair coat for winter, without affecting their nutrient requirements. However, below the lower limit of the thermoneutral zone, in the "lower critical temperature," the animal experiences cold stress. To combat cold stress, the animal must increase its metabolic rate to supply more body heat. This increases dietary requirements, particularly energy. Typical lower critical temperatures for beef cattle are affected by a number of factors. Table 7 shows the impact that different hair coat types can have on lower critical temperature.

Table 7. Lower Critical Temperatures for Beef Cattle Assuming No Wind Chill

	Lower Critical Temperature	
Coat Description	**°F**	**°C**
Summer coat or wet coat	59	15
Fall coat	45	7
Winter coat	32	0
Heavy winter coat	18	-8

Cattle, like humans, actually experience the "effective temperature," which takes into account both air temperature and the effect of wind chill. Cool or cold wind passing over an animal draws heat away from it much more quickly than still air at the same temperature. Wind chill effects for cattle are in Table 8. These figures assume a dry and clean hair coat. If the animal is wet and/or dirty, consider the data to be an underestimation of the effect of the wind.

Table 8. Wind Chill Effects for Cattle With Winter Coats (values are effective environmental temperatures)[1,2]

Wind Speed (kph)	Air Temperature (degrees Celsius)								
	-18	-15	-12	-9	-7	-4	-1	+2	+4
0	-18	-15	-12	-9	-7	-4	-1	+2	+4
8	-21	-18	-16	-13	-11	-8	-5	-2	+1
16	-24	-21	-18	-16	-13	-11	-8	-5	-2
24	-26	-23	-21	-18	-16	-13	-10	-7	-4
32	-29	-26	-23	-21	-18	-16	-13	-10	-7

1. Assumes that hair coat is dry and clean.

2. For example, when air temperature is –18°C and wind speed is 24 kph, the effective temperature experienced by the animal is the equivalent of a still air temperature of –26°C.

If cows are exposed to wind or drafts, it is important to adjust for effective temperature and take appropriate steps to ensure that cows can maintain body temperature and weight.

Factors affecting an animal s ability to withstand cold

Cattle adjust or acclimatize to colder weather by growing a longer thicker coat to provide additional insulation against cold weather. The coat must be clean and dry to provide maximum protection to the cow. Cattle in good condition with a thick fat layer are better able to withstand the cold than thin cattle as the fat layer acts as another insulating layer between the animal's core and the environment. Cows will also increase their metabolic rate to increase heat production and help maintain body temperature. This increases the need for dietary energy, so appetite is usually increased and cows eat more.

It is generally accepted that for every 1°C drop below the lower critical temperature, there is an approximately 2% increase in energy requirements. The amounts of additional feed required for a cow under cold stress can be calculated, but as a rule of thumb, a cow with a dry winter coat should be fed the additional feed as in Table 8. Cows may not be able to eat the amount of extra DM required to maintain body weight and may have to be fed more grain instead of additional hay to meet their energy requirements.

A practical rule of thumb is to increase energy intake by 1% for every degree of coldness below the lower critical temperature of a cow. As an example, a 20°F temperature can be used as the lower critical temperature. Thus, if the outside temperature is 0°F with calm wind speed, then energy intake will need to be adjusted 20%. If the daily TDN requirement is 11.2 lb, then an additional 2.24 lb of TDN are required to prevent environmental stress or weight loss on the cow.

Table 8. Effective Temperature and the Additional Feed Required to Meet the Cow's Energy Requirements

Effective Temperature (°C)	Extra Energy Required (%)	Extra Hay or Grain Required	
		extra hay (kg/cow/day)	extra grain[1] (kg/cow/day)
-1	0%	0	0
-12	20%	1.6-1.8	0.9-1.0
-23	40%	3.2-3.6	1.8-2.3

Depending on forage quality, supplementation may be necessary when nutrient demands are not met by the basic diet that the cow is offered. Typically, diets of late gestation cows will meet nutrient needs if they contain a minimum of 55% TDN and 8% CP. However, lactating cow minimum requirements during the winter increase to 62% TDN and 11% CP, such as with fall calving cows. If cows are not fed additional feed, or the quality does not allow them to eat enough to meet their additional energy requirements, body mass will be "burned" to produce metabolic heat. These cows lose weight as both feed energy and stored fat are diverted to maintain body temperature and vital functions. Cows in this situation that start to lose weight soon enter a downward spiral — the more weight (fat) they lose, the less insulation they have, the more susceptible they are to further cold stress, and they lose weight even faster.

Cows, and especially heifers that lose weight, will calve in poor condition. The consequences are increased calving difficulties, an increase in the number of lighter, weak calves and higher calf mortality. These dams produce a reduced amount of lower quality colostrum and have lower milk production, increased neonatal mortality and reduced growth rate in surviving calves. These cows usually have delayed return to estrus, longer days open and poorer reproductive success.

Healthy teat skin is a critical component of the dairy cow's defense against mastitis, but frequently it is given limited consideration. Skin condition can be directly influenced by many environmental factors but winter situations often pose the largest challenge. Skin that is healthy and free of cracks and sores provides much less growth opportunity for certain mastitis causing bacteria than skin that suffers from such problems. Unfortunately winter conditions have a tendency to produce many of these problems and with them come mastitis.

During cold windy conditions, provide protection from the direct impact of the wind by some form of windbreak, even if it is temporary. Cows can tolerate cold, but cold coupled with windy conditions has the potential to cause serious damage quickly. Teat dipping under such conditions needs to consider this. One way to lessen the risk is to dip the teats, allow the dip about 30 seconds of on time and then blot dry using a paper towel. Teat dips, incorporating significant amounts of emollients, primarily glycerin (5-10%), are recommended for these conditions and are helpful in minimizing these problems. Dirty, wet cows are at risk of increased mastitis due to the teats being coated with soils that increase the exposure of the teat ends to large numbers of environmental bacteria such as the coliforms and environmental Streptococci. Such conditions force milkers to spend extra time and effort attending to cleanliness and dryness of the teats and teat ends.

Key management factors to limit the effects of cold stress

- Monitor the weather. Monitor temperature and increase feeding in response to cold weather. Cows in the last trimester require additional grain feeding during periods when the effective temperature falls below the lower critical level.

- Protect animals from the wind. Wind markedly reduces the effective temperature, increasing cold stress on animals.

- Bed cows well. Providing adequate dry bedding makes a significant difference in the ability of cattle to withstand cold stress.

- Keep cows clean and dry. Wet coats have greatly reduced insulating properties and make cows more susceptible to cold stress. Mud-caked coats also reduce the insulating properties of the hair.

- Provide additional feed. Feed more hay and grain. If wet feeds are fed, make sure they are not frozen.

- Provide water. Make sure cows have ample water available at all times. Limiting water will limit feed intake and make it more difficult for cows to meet their energy requirements. Frozen troughs and excessively cold water seriously limit water intake.

CHAPTER VI D

Nutrition and Health

Nutritional Management Under Forage Scarcity

(M.A. Jabbar and S. Janjua)

In Pakistan, more than half of animal feed comes from fodder crops and crop residues (Table 1). The availability of livestock feed will need to increase 2-3 times from fodder crops and crop residues in the near future to meet anticipated needs. However, availability of forage from grazing lands will remain stagnant, or reduce, if sound programs of rangeland management are not initiated. Feeds from all sources meet only about 70% of current needs.

Table 1. Livestock Feed Resources (Fodder Crops Production in Pakistan, 1996)

S. No.	Feed Resources	Percent Contribution
1.	Fodder and crop residues	51
2.	Forage/grazing	38
3.	Cereal by-products	06
4.	Post harvest grazing	03
5.	Oilcakes, meals, animal protein	02

Availability of green fodder year round is a production constraint. Due to variation in availability of green fodder in different months of the year (Figure 1), the major problem is a shortage of green fodder during May/June due to high temperatures and low precipitations, and in December/January due to low temperatures. However due to recent research and development activities on fodder crops, growing of fodder crops such as S.S. Hybrids, Lucerne, mixtures of cereals and legumes and Mottgrass are filling this gap. To overcome the shortage of fodder, short and long term strategies must be adopted.

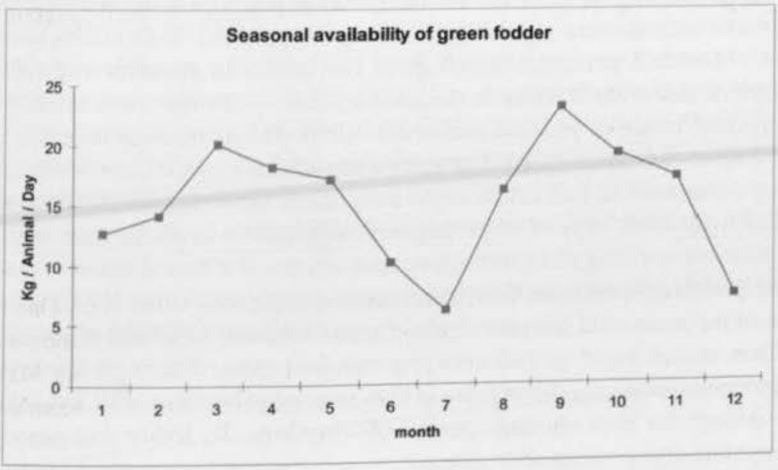
Short term strategies include use of multicut fodder varieties, fodder preservation, improving the quality of dry roughages, use of total mixed rations, use of feed supplements and developing programs to ensure year round availability of fodder. In contrast, long term strategies include increasing per acre yield of fodder through genetic improvement of fodders, fodder seed production and improving the nutritional quality of fodder through introduction of leguminous fodder crops.

Short Term Strategies

Use of High Yielding Multicut Fodder Varieties

Previously used single cut fodder varieties had low yields per acre, and there were frequent periods of fodder shortage during the year. New multicut fodders have recently been introduced. The best example is the Sorghum-Sudan grass hybrid which gives multiple cuts and results in high yield and regular supply of fodder during the year. Other varieties include Mott grass, napier grass and some oat varieties. By sowing such fodder varieties, shortages of fodder can be minimized.

Figure 1. Seasonal availability of green fodder



Sorghum-sudan grass hybrids

These are the most popular in Pakistan. They have larger stems and are less leafy than Sudan grass, but perform best in our climate. Sorghum-Sudan grass hybrids fit best in summer feeding programs as they are thick stemmed and hard to dry for hay, but can supply ample yields of silage, green chop and pasture when perennial grasses are slowing down or going dormant. Once Sorghum-Sudan grass begins to head out, the quality and feeding value drop drastically. It is difficult to meet nutrient requirements of high production milking cows when Sorghum-Sudan grass is a large part of forage intake. It is more suited to rations for dry cows, replacement heifers over 12 months of age and beef cows and calves. As the crop matures, the CP content drops rapidly while fiber levels increase. This decreases the energy value and rumen digestibility. Sorghum-Sudan grass can contain as much CP as mature alfalfa, but only if harvested at the vegetative stage. Energy levels in vegetative material are similar to corn and higher than in alfalfa.

Mott grass

Recently a number of high yielding forage crop varieties have been introduced in Pakistan and Mott grass (pennisetum purpureum sechum) is one of the promising to meet the challenge, as it provides more herbage per unit area and ensures regular green forage supply due to its multicut nature. Mott is a perennial bunch grass that grows to an uncut vegetative height of just over 1.66 m. It does not spread or colonize new areas, but individual bunches produce numerous tillers and increase in diameter at the base to 0.6 M or more. The leaf canopy from a single bunch may occupy a diameter of 1 to 1.3 m. Since the grass is heterozygous and does not breed from seed, it must be propagated vegetatively to obtain true to type population by using stem cuttings or root stocks. It is best adapted to moderately well drained soils. Cold tolerance is comparable to that of Merkeron, one of the most cold tolerant elephant grass cultivars. In a field of one acre a fresh matter yield of 192 tons/year can be produced through improved agronomic practices. Mott grass is also important because of its availability during the feed shortage period of May/June. Its fodder can also be converted into good quality silage.

Table 2. Fodders used in Pakistan

Name of fodder	Yield per acre (Tonnes)	Dry Matter (%)	Crude Protein (%)
Summer Fodders			
Maize	18-20	29.30	7.04
Sorghum	20-25	30.00	6.20
Sadabahar	50-60	27.60	6.98
Millet	20-22	29.50	6.08
Mott grass	70-90	16.54	7.52
Guar	15-18	20.90	17.35
Winter fodders			
Berseem	30-35	15.62	19.90
Lucerne	50-60	24.26	22.83
Oats	25-35	22.10	9.98
Rye grass	30-40	14.21	22.85

Oats

Oats (Avena sativa L. and Avena byzantina Koch) rank fifth in terms of world production of cereals, and are widely used as a companion crops for undersowed forage legumes. Oats are mainly grown in temperate and cool subtropical environments. In Pakistan, they are important winter fodder in irrigated and rain fed areas. The ideal fodder oat should be high in CP and digestibility, and low in fiber. Fodder yield and quality is greatly influenced by plant age, CP content and DM digestibility, which falls as the forage crop matures while DM yield increases with advancing maturity. Appreciating the importance of oats as a promising fodder to alleviate winter feed problems, oat cultivars were obtained from areas most likely to be sources of suitable germplasm.

Use of Non-Conventional Feed Resources

In Pakistan, most livestock feed is based on agro-industrial by products which include cakes, bran, gluten and molasses. However, there are products which are not being used for livestock feed which have the potential for use as feeds. Such non-conventional by-products include yeast from the fermentation industry, fruit pulps and bagasse.

Yeast sludge

This is a by product of the fermentation industry and sugar mills which produce ethanol from molasses. It is a good source of CP and a good aflatoxin binder in livestock feeds. It also makes the rumen environment favorable for digestion and performance. This product is currently not being utilized as a feed, and research is required to determine its feed utility and diet inclusion levels.

Citrus pulp

This is a waste product of juice industry after extracting juice from the fruit. This pulp and peel pulp can be used as an animal feed. The pulp has good palatability and digestibility and high energy values. It can be added to the feed of small ruminants as well as that of dairy cows. As the pulp has a high moisture content, its preservation is short. It can be used as such, in silage making, or it can be dried as a in livestock feed.

Sugarcane bagasse

This is a source of dry roughage in ruminant diets. It has good palatability but low digestibility for cattle and buffalo. However, it is extensively used as fuel in the sugar factories. Bagasse can be used as a source of dry roughage with fodders in TMR. This product can be handled in the form of compressed bale to reduce its volume.

Sugar beet pulp

Like sugarcane bagasse, this is also a by-product of the sugar beet industry. Due to its high energy content and high fermentation rate, it is used as an energy source as pellets. Its production is limited to NWFP, as it is not grown in other provinces. Silage from this product has been successfully prepared and fed to livestock on a limited scale. There is a need to introduce this product to farmers and guide its best use in combination with other feeds.

Fodder Preservation

It is a common practice in temperate countries to preserve fodders in the form of hay or silage. During shortages of fodder, these preserved fodders can be fed to animals.

Hay Making

Hay is grass or legume that has been cut, dried, stored and used as animal feed, particularly for grazing ruminants. Hay is especially palatable for young growing calves, and can be fed when there is not enough pasture or rangeland. It is also fed during times when animals are unable to access pasture, such as when kept in a stable or farm.

Commonly used plants for hay include mixes of grasses such as ryegrass, timothy, brome, fescue, orchid grass, Bermuda and other native grasses depending on region. Many types of hay includes legumes such as alfalfa, clovers and berseem. Oat, barley and wheat plants are occasionally made into hays, although usually as straw, a harvest byproduct where only stems are dried and baled after grain harvest. Straw is used for animal bedding and generally is considered poor animal fodder.

After harvest, hay can be raked into rows as it is cut, then turned periodically to dry, particularly if a modern swather is used. During drying, which can take several days, the process is usually speeded up by turning the cut hay over with a hay rake or spreading it out. However turning the hay too often or too roughly can cause dry leaf matter to fall off and reduce its nutrient value to animals. Drying can be speeded up by mechanized processes such as use of hay conditioners or by use of dessicants sprayed onto the hay to speed moisture evaporation.

Hay must be kept dry in storage or it may rot. The moisture content of stacked hay must be kept lower than 22% to avoid a risk of spontaneous combustion. Hay is best stored under a roof when resources permit. It is frequently placed inside sheds or stacked inside a barn to maintain its quality and color. Care must be taken that hay stored inside is never exposed to sources of heat or flame as it is highly flammable.

Modern mechanized hay production usually uses a number of machines. While small operators use a tractor to pull various implements for mowing and raking, larger options use specialized machines such as mowers or swathers, which are designed to cut the hay and arrange it into a windrow in one process. Balers are usually pulled by a tractor, with larger balers requiring more powerful tractors. The first balers produced rectangular bales small enough for a person to lift, usually 70 to 100 pounds each. However, to save labor and increase safety, loaders and stackers were developed to mechanize transport of small bales from the field to haystacks.

Silage Making

Due to seasonal fluctuation, animals are subjected to irregular supply of fodder which results in heavy monetary losses through decreases in production. A solution to this problem is preservation of green fodder by silage making. This method has not been very popular with farmers in the past, but with introduction of larger commercial farms its importance is increasing. Silage preparation techniques make feeding of animals easier and also saves labor and machinery costs on cutting and chaffing of fodder at the farm. Generally summer fodders are cereals with less CP, but higher sugar contents making them more suitable for silage making. Winter fodders are mostly legumes with high moisture and CP contents, and less sugars, making them more suitable for hay making.

Silage is high moisture fermented forage preserved by anaerobic fermentation, controlled largely by lactic acid bacteria. It can be a major form of forage fed to dairy animals during fodder shortage and is prepared by cutting fodder crops and ensiling them during the period when green fodder is available in excess. All fodder crops can be preserved in the form of silage but maize, sorghum, millet and Mott grasses are the best fodders to ensile. Bacteria ferment sugars and convert them to lactic acid, which preserves fodder and protects them from putrefying bacteria. Because legumes have low sugar contents and are rich in CP, they should be ensiled by mixing with other material containing low CP and high sugar, or be supplemented with molasses.

Silage fodders are preserved in closed structures called silos, that can be of different shapes and sizes depending upon choice and availability of resources. There are many types of silos and their shape and size depends upon the weather conditions and amount of fodder to be ensiled. These can be built above or below the surface of the ground. Some of the common types of silo are pit silos, bunker silos, bag silos and tower silos, some of which could be easily adopted in Pakistan.

Pit and bunker silos

These are pits or trenches with concrete walls and floor that are filled and packed with tractors and loaders. These can be above the ground (bunker silo) or below the ground level as pits (pit silo). The filled trench is covered with a plastic sheet to make it air tight. They are inexpensive and especially well suited to very large operations. These can also be adopted for smaller operations by making smaller trenches and, once filled, ensiled material can be withdrawn manually. These are cheaper structures and suitable for Pakistani conditions.

A small size pit silo can be prepared simply by digging a pit with a slope in the middle so that a tractor can easily move in it for pressing the fodder. It can be lined with a plastic sheet so that soil does not mix with the fodder. Chaffed fodder is added and pressed continuously with a tractor. On completion, the pit can be covered with the same plastic sheet. Similarly, a bunker silo with two parallel thick walls (13-18 inches) are constructed with a concrete floor. The level of the floor should be raised in the middle so that effluent will drain. After filling with fodder, the ensilage can be covered with plastic sheet to maintain anaerobic conditions.

Tower silos

These are cylindrical structures and can be made of many materials. Wood staves, concrete staves, cast concrete and steel panels have all been used and have varying cost, durability and air tightness. Tower silos are usually unloaded from the top. An advantage of tower silos is that the silage tends to pack well due to its own weight, except at the top. In Pakistan, such silos have not yet been constructed as it involves a larger investment and needs mechanization in filling and emptying the silos.

Bag silos

These are heavy weight plastic bags, usually around 6-8' in diameter, and of variable length as required for the amount of material to be stored. They are packed using a machine made for this purpose and sealed on both ends. The bag is discarded in sections as it is torn off. Bag silos require little capital investment, except for the packing machine. Because they can be used as a temporary measure when growth or harvest conditions require more space, though some farms use them every year, they are becoming popular with farmers.

Method of silage making

For preparation of silage, fodder is cut and kept in the field for a period of 5-6 hours to evaporate some moisture. It is best if the fodder is chopped before putting it into the silo. Ideally the moisture should be around 65% for making silage. Hence wilting of fodder for few hours in the sun is necessary. For filling the pit, spread a layer of 2 feet thickness of chopped fodder and press it to reduce air. Spread a second layer over it and continue to 4 or 5 layers. Finally, put dry grass on the upper layer and cover it with clay or a plastic sheet.

In maize growing areas, maize plants after harvest are not effectively used and is usually burned as fuel. However if it is cut immediately after removing the corn ears, it can be used for silage preparation. At this stage the plant is quite mature and the sugar content is low. Hence for preparation of good silage it is better if some molasses (at 1-2% of fodder weight) is added. Silage from such crops is successfully prepared and fed to livestock in the country.

Checking silage quality

- pH of silage should be 3.5 to 4.5.
- The concentration of lactic acid in high moisture silage should be 5-9%, especially in high moisture silage.
- No fungal colonies should be visible.

- Aroma should be good and free from NH_3 and butyric acid.
- Should be greenish in color.

Silage is most often fed to dairy cattle because they respond well to it. Initially (for few days) animals may not relish the taste. To help them develop a taste for silage, it is best to mix in green fodder for the first week. Once a taste is developed, 20-34 kg of silage along with other fodders may be fed per animal per day.

Advantages of silage include:

- The nutritional value of silage remains the same throughout the feeding period.
- Silage can be made in most kinds of weather.
- It provides succulent feed during scarcity period of green fodder.
- It preserves some vitamins.
- Once the silage is prepared there is no further cost.
- Nutritive value of ensiled forage could be increased by adding suitable additives.
- This method is especially useful for larger farms as the labor cost is saved by avoiding daily expenditure on cutting and chaffing of fodder.

Improving the Quality of Dry Roughages

Chemical Treatment of Straws

Forages constitute an important, and considerable, proportion of the diet of most ruminants. Ruminants derive energy from the fermentation of the carbohydrates, which are the main components of plant cell walls. The extent to which these carbohydrates are digested is variable. Generally, straws and crop residues are poorly digested and are commonly referred to as low quality feeds. These low quality feeds are abundant and therefore is of considerable interest for utilizing them as ruminant feeds.

Cereal straws are important part of livestock feeding in Pakistan as they provide DM and energy to the ruminants. Annual straw production is about 36 million tonnes in Pakistan, with wheat and rice straw making up the major proportion. In spite of the immense importance of straw in livestock feeding, the utility of straw is low due to its low digestibility and low CP content. If the nutritional value of straw is increased, it can be a better source of energy and protein for livestock.

Chemical treatment of low quality feeds, particularly with alkalis such as NaOH, can substantially enhance degradation of cell wall polysaccharides by rumen microorganisms. This improvement in nutritional value is known and chemicals have been applied to cereal straws and other low quality crop residues with varying degrees of success. Efforts have been made to improve digestibility, and in some cases digestibility and CP level, through chemical treatment. In this connection, sodium hydroxide was used (Das and Kundu, 1994) which resulted in improved digestibility by breaking lignocellulosic bonds, but its use remained low due to high costs of chemicals and environmental pollution. The other compound used for this purpose is anhydrous ammonia (Brit and Huber, 1976) which improved digestibility and increased the nitrogen content. But due to non-availability of ammonia gas in the market, and its transportation in specialized containers, its use is limited. Fertilizer grade urea has been used for this purpose (Cheema et al. 1991 and Ali et al. 1992), as urea is converted into ammonia during incubation. Urea is commonly available and farmers are familiar with its handling.

Extensive research and extension work has been carried out by government agencies to introduce this technique to farmers. However in spite of their best efforts, adoption rates have remained low.

Feeding Total Mixed Rations

One way to combat the shortage of green fodders is to use TMR. The term TMR may be defined as "The practice of weighing and blending all feedstuffs into a complete ration which provides adequate nourishment to meet the needs of dairy cows." Each bite consumed contains the required level of nutrients (i.e., energy, protein, minerals, vitamins) needed by the cow. Advantages of a TMR include:

- The dairyman has more control over the feeding program.
- All forages, grains, protein supplements, minerals and vitamins are thoroughly mixed preventing the cow from sorting for individual ration ingredients.
- Completely blended feeds, coupled with grouping cows, permits greater flexibility in feeding exact amounts of feed to nourish cows in particular stages of lactation and at various levels of milk production.

However there are also some disadvantages that include:

- Special mixing equipment must have the capability to blend all feed ingredients.
- The mixer, preferably mobile, must be able to accurately weigh each ingredient.

Ideally a TMR is the mixture of fodder and concentrate feeds thoroughly mixed. However, due to a lack of appropriate machinery for cutting, chaffing and above all the mixing of this material, true TMR's are rare in Pakistan. Instead wheat straw is mixed with concentrate ingredients such as cottonseed cake, brans and hulls. Such practices are more common in peri-urban areas where there is shortage of fodder availability.

The University of Veterinary and Animal Sciences (Lahore) has introduced a feed package which is comprised of wheat straw mixed with concentrate ingredients and compressed into a bale. This feed package has the following characteristics:

1. Is a complete balanced feed with all the nutrients.
2. It needs less space for storage.
3. It is easy to feed and requires less labor.
4. It is highly suitable when there is shortage of fodder.
5. It can be easily transported by rail or road.

Year Round Fodder Supply

Through improving the sowing program, availability of fodder year round is possible. Table 4 is the sowing program of various fodder crops which will be helpful in providing the fodder though out the year thereby decreasing the shortage of fodder.

Table 4. Year-round Green Fodder Availability Calendar for Irrigated Areas

Crops	Sowing time	Harvesting time	Fodder Production (t/ha)
Sorghum	From 3rd week of March to mid- September.	May to December	50-70
Sorghum + Cowpeas	From 3rd week of March to mid- September.	May to December	40-60
Millet	From 3rd week of March to mid- September.	May to December	45-65
Millet + Cowpeas	From 3rd week of March to mid- September.	May to December	40-60
Maize	From 3rd week of March to mid- September.	May to December	50-70
Maize + Cowpeas	From 3rd week of March to mid- September.	May to December	50-70
Sorghum Sudan grass hybrid	From mid- Feb. to mid-March	Mid-April to December	100-120 (Total of 4-5 cuttings)
Mott grass	From mid- Feb. to August	Mid-April to Dec. (Perennial crop)	80-150 (Total of 5-6 cuttings)
Berseem	From September to November.	Mid-December to mid-May.	80-100 (Total of 5-6 cuttings)
Berseem + Oats	From September to November.	Early December to mid-May.	100-120 (Total of 5-6 cuttings)
Lucerne	From December to November.	Perennial crop available around the year	65-90 (Total of 6-7 cuttings)
Lucerne + oats	From Sep. to November.	Perennial crop available all year.	70-100 (Total of 6-7 cuttings)
Oats	From Sep. to December.	From early Dec. to end of April.	60-8

Long Term Strategies

Fodder Seed Production

Lack of improved fodder crops is one of the major limiting factors in fodder crop production in Pakistan. It is estimated that only 5-10% of the area of fodder crops is grown with improved seed. Improved seed production involves a number of interlinked systems, being agro-climatic conditions, specific crop adaptation to environment, socio-economic and political factors including prices and marketing, crop management and production. Unfortunately, there is neither private nor government sector involvment in the fodder crop seed business as is the case with wheat, cotton and vegetables. Only 10% of fodder seed is produced locally, and requirements are met either by importing seed from other countries and by purchasing from the under standard non-certified seed, or produced by the farmers without any consideration of seed production guidelines.

Total fodder crop seed requirements of Pakistan is about 58963 tonnes. Out of which 9692 is imported from USA, Holland, France, Argentina, South Africa, Australia, India, Egypt and Iraq. It is estimated that the fodder seed market of Rs. 3007 million exists and there is great potential for domestic fodder crop seed production. Recently a number of private seed companies have entered into fodder seed production in the country. For example, Jalandar Seed Company based at Arifwala; Younas Seed Corporation, Vehari; Pak Agro Mianwali, and Green Gold Faisalabad are involved in domestic fodder crop seed production. Domestic fodder seed production should be encouraged by providing incentives to seed growers. Some suggestions for fodder seed production/improvement are:

- The private sector should be encouraged and facilitated for production of quality fodder crop seed.

- Seed production pockets of fodder crops should be identified and developed. For example, Quetta is the best place for lucerne seed production and the Sheikhupura area is best for berseem seed production.

- Improved seeds of high yielding fodder varieties should be produced at government, agricultural and livestock farms till the seed industry is established or seed production is taken up by seed corporations or private sector.

Improving the Nutritional Quality of Fodder by Introducing Leguminous Fodder Crops

Summer fodders are predominantly cereal in nature with CP contents that do not exceed 8-9%, a level that cannot meet requirements of lactating animals. Farmers have to supplement these fodders with concentrate, which is an extra fiscal burden.

One possibility to increase the CP contents of summer fodders is to mix some leguminous fodder with the cereals. However available legume fodders, such as cowpeas, jantar and guar, are not very suitable as intercrops. For example, the stems of janter and guar become woody while it is difficult to cut a fodder crop with cow peas. Hence there is need to introduce suitable legume crops which not only fit into the summer fodder system, but also improves the quality of fodder.

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Summary

The dairy sector is a critical part of the food production system, as well as providing fertilizer, income and employment in rural areas. Although Pakistan's milk production is about 6% of the global milk production, and production has increased by six fold in the last 50 years, future growth is not assured. More than 60% of milk comes from buffaloes, and more than 80% of the milk is produced by rural subsistence producers. While Pakistan has been meeting its demand for milk from domestic production, the gap between demand and supply is increasing as growth in consumption is about 7% while growth in supply is only about 4%. Presently 97% of milk produced in rural area are not linked to a potential market, and nearly 15% of milk produced is spoiled or wasted.

The reasons for low, and inconsistent, growth in milk production are low animal productivity, poor transportation and marketing infrastructure, and limited access to veterinary services and feeds. There is a critical need for intervention and changed practices by government, feed industry and dairy producers in order to facilitate increased productivity of the dairy sector.

In general, government and NGO involvement in the dairy sector is modest at both the macro and micro level. For example, there is a need for better structural policies related to the dairy sector, as well as involvement in improving the infrastructure that is critical to transporting inputs to dairy farms and facilitating shipment of milk and milk products to markets. Government should also take a more active role in regulating production and marketing of milk and milk products to assure that dairy farmers receive a fair price for milk, and that dairy products sold to consumers are safe.

The feed compounding industry, which is critical to growth of the dairy sector and increased per animal productivity, should make better efforts to provide timely and up to date information to their dairy farmer clients, perhaps in meetings with groups of farmers relative to nutrition and management of dairy animals. Facilitating farmer access to computer software programs to, for example, create nutritionally balanced rations would increase animal productivity and make better use of scarce feed resources.

A primary reason for low animal productivity in the dairy industry is a lack of nutritionally high quality feeds due to high prices that result from competition with other animal industries, primarily poultry farms, as well as non-food uses such as ethanol production. However dairy animal productivity could be increased by farmers, even in the absence of higher supply of nutritionally high quality feeds, if the current nutritional knowledge base on dairy animals were used. An important feeding practice that could also increase animal productivity, and make better use of feed resources, would be use of totally mixed rations (TMR). This concept, common in most dairy areas of the world, is little used due to lack of knowledge of its existence or a belief that expensive equipment and/or large numbers of animals are required to support it. In fact this is not the case as even the smallest farmers can create TMR's using hand mixers.

Past efforts to increase dairy production have relied to some extent on introduction of animals with higher milk production potential. However a lack of nutritionally high quality feeds has generally prevented these animals from expressing their genetic potential. As a result, the need for large numbers of dairy animals with very low productivity (that are required to produce sufficient milk to meet the national need), has not changed. As the availability of nutritionally high quality feeds to the dairy industry is likely to be even more limited in the future, due to high prices and higher value uses, it is critical that available feed resources be used efficiently, primarily by assuring animal health by providing effective preventative veterinary care, making use of current nutritional knowledge in formulating least cost diets and using nutritionally effective diet preparation and delivery systems.

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Handbook of
Dairy Nutrition
Pakistan

Growth in the dairy industry, of late has been very significant in the Asia Subcontinent. Pakistan is the fifth largest milk producer in the world and countries like Bangladesh, Nepal and Sri Lanka are fast catching up with milk production in order to become self sufficient. A significant change forthcoming is the commercialization of dairy and there is increasing thrust for dairy development by respective Governments in these countries. Entrepreneurs are investing in good animal breeds and are keen on total animal care covering aspects like health, nutrition and reproduction. Favourable economic improvements are also accelerating dairy development. Milk as a commodity will be heavily in demand in these regions for nutrition to the growing populations.

This project of developing four handbooks on dairy nutrition is undertaken by the American Soybean Association – International Marketing (ASA-IM), for Bangladesh, Nepal, Pakistan and Sri Lanka. It is aimed at providing overall guidance to improve milk production in the regions with special emphasis to nutrition as this aspect is one of the major factors that can drive growth in the dairy industry. Among a variety of feed stuffs that are used for dairy feeds, the handbooks have focused on soy products as a dependable and consistent source of protein and energy for dairy feeds in the modern era.

The handbooks are prestigious outcomes of elaborate field and desk work of the editors, country authors and personnel of the ASA-IM-Asia Subcontinent. They are designed to improve knowledge and technology base for most people engaged in the dairy industry. It is also hoped that the different handbooks will serve as cross-reference material for countries in the region to facilitate learning from each others experiences. As a result of this project, we look forward to specific improvements in nutrition, increased usage of quality ingredients and scientifically formulated balanced feeds in the dairy industry and will be open to take this forward.

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