

14

Improving buffalo milk

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Abstract: Buffalo are the second largest source of milk supply in the world; world production of buffalo milk exceeds 75 million metric tons per year and is increasing steadily at about 3% per year. Dairy cattle produce 84% of the total milk in the world with an average fat and protein content of 4% and 3.5%, respectively, while the average fat content of buffalo milk is about 8% and the protein content in buffalo milk ranges from 4% to almost 4.5%. Thus, in terms of energy-corrected milk, buffalo milk accounts for about twice the food contribution implied by the volume of buffalo milk produced yearly.

Physiologically, buffalo are capable of breeding throughout the year and having a calf every year. However, oestrus detection in buffalo is a problem; while irregular oestrus, and anoestrus lasting three or four months, are rarely seen in modern Western dairy herds, it is a common problem in small, rural buffalo herds, which makes up the majority of the buffalo production in most of the world.

There are several important herd management factors that should be considered to improve milk production in buffalo. These include managing the nutritional status of the dam around calving, pre- and post-partum hygiene, good milking management, balanced feeding throughout the year, oestrus detection and artificial insemination, and finally managing thermal stress and improving housing.

Buffalo milk can be utilized for manufacture of a wide variety of dairy products. Because of the differences in compositional and physicochemical properties between buffalo and bovine milk, processing technology and equipment designed for cow's milk may not be suitable for buffalo milk processing. Modifications must be considered for making certain products.

Key words: buffalo, management, milk, composition, products.

14.1 Introduction

World milk production has doubled in the last few decades and it is noteworthy that currently buffalo supply about 12% of the total world milk production. Table 14.1 shows buffalo distribution and milk production among the major buffalo farming countries. India and Pakistan have produced, respectively, 60% and 30% of the world's buffalo milk. In India, buffalo milk contributes 55%, and in Pakistan 75%, of their total milk production (Högberg, 2004). The Food and Agriculture Organization of the United Nations estimates that the world's milk production from buffalo is about 75 million metric tons yearly, most of which is produced in Asia and the Pacific nations (73 million metric tons) by low-producing animals (FAO, 2007). Probably a large portion goes unreported as buffalo milk is largely handled by small rural family farms for their own use. For comparison, the FAO estimates the world's milk production from cows at 460 million metric tons, about six times that of buffalo production. Buffalo milk is used in much the same way as cow's milk. It is high in fat and total solids, which gives it a rich flavor. Many people prefer it to cow's milk and are willing to pay more for it. The demand for buffalo milk in India (about 60% of the milk consumed and over 80% in some states) is reflected in the prices paid for a liter of milk: about 130 paisa for cow's milk compared with about 200 paisa for buffalo milk. Although the two milks are roughly nutritionally equivalent, customers are willing to pay 54% more for buffalo milk. In the US, buffalo milk and its products are also considered as specialties. In Egypt the severe mortality rate among buffalo calves is due in part to the sale of buffalo milk, which is in high demand, thus depriving calves of proper nourishment. This also occurs throughout India and Pakistan where in the Bombay area alone an estimated 10,000 newborn calves starve to death each year because of lack of milk (Kay, 1974; Jainudeen, 2003).

There are two species of buffalo: the African Buffalo (*Syncerus*), which are wild, and the Asian Buffalo (*Bubalus*), which for the most part are domesticated (*Bubalus bubalis*). Within the Asian Buffalo there are two distinct types: swamp and river buffalo (Toll and Halnan, 1976). Swamp buffaloes tend to be indigenous to those parts of Asia in which there is not a large base of consumers of fresh drinking milk or milk-based products. This covers Indonesia northwards to China. River buffaloes tend to be found in those countries where milk plays a more

Table 14.1 Number of domestic buffalo and milk production among major buffalo farming countries

Country	Number ($\times 1000$)	Milk ($\times 1000$ tons)
India	92,090	35,340
Pakistan	21,213	16,456
China	20,818	2,300
Nepal	3,419	729

Source: adapted from Jainudeen (2003).

important part in the human diet. They range from India through Pakistan into the Middle East, through the Caucasus and into the Balkans. River buffalo are primarily a triple-purpose animal, producing milk, meat and draft power, while the swamp buffalo are kept mainly for meat and draught. Buffaloes vary greatly in size. The single greatest reason for this variation is environmental. In areas where animal feed is scarce the animals tend to be smaller than in those areas where forage is more plentiful. Typically, adult females can range anywhere between 350 kg high in the Himalayas to 800 kg in Bulgaria and Italy (Cockrill, 1974).

Twelve of the 18 major breeds of water buffalo are kept primarily for milk production (although males may be used for draft and all animals are eventually used for meat). The main milking breeds of India and Pakistan are the Murrah, Nili/Ravi, Surti, Mehsana, Nagpuri, and Jafarabadi. The buffalo of Egypt, Eastern Europe (Bulgaria, Romania, Yugoslavia, and some parts of the former USSR) and Italy are used primarily for milk production and there are also herds used principally for this purpose in Iran, Iraq, and Turkey (Cockrill, 1974). Buffalo milk is commercially more viable than cow milk for the manufacture of both fat-based and fat-free milk products, such as butter, ghee and milk powders, because of its lower water content and higher fat content. By virtue of the greater opacity of casein micelles, coupled with higher levels of colloidal proteins, calcium and phosphorus, buffalo milk is more densely white and has superior whitening properties as compared to cow milk (Cockrill, 1974). Therefore, unlike cows' milk (which is pale and creamy-yellow in color) and cow milk fat (which is golden yellow in color), buffalo milk is distinctively whiter. Processed buffalo milk and cream are intrinsically whiter and more viscous than their cow milk counterparts, because of conversion of greater levels of calcium and phosphorus into the colloidal form. Buffalo milk is, therefore, more aptly suitable for the production of tea and coffee whiteners than cow milk. Higher innate levels of proteins and fat render buffalo milk a more economically attractive alternative to cow milk for the production of casein, caseinates, whey protein concentrates and a wide range of fat-rich dairy products (Cockrill, 1974).

14.2 Chemical composition

Buffalo milk contains less water, more total solids, more fat, slightly less lactose, and more protein than cow's milk (see Table 14.2). It seems thicker than cow's milk because it generally contains more than 16% total solids compared to 12–14% for cow's milk (Addeo *et al.*, 1977). In addition, its fat content is usually 50–60% (or more) higher than that of cow's milk. Although the butterfat content is usually 6–8%, it can range as high as 12% in the milk of some well-fed dairy buffalo herds in the US, but the butterfat content can run well below 5% in the milk of swamp buffalo of East Asia.

Because of its high butterfat content, buffalo milk has considerably higher energy value than cow's milk. Phospholipids are lower but saturated fatty acids are higher in buffalo milk. Studies have shown that digestibility is not adversely

Table 14.2 Physicochemical properties of buffalo and bovine milk

	Buffalo	Bovine
<i>Gross composition (%)</i>		
Fat	7.3	3.7
Lactose	4.4	4.8
Protein	4.5	3.4
Total solids	17.2	12.7
Ash	0.9	0.7
Titrateable acidity	0.16	0.15
pH	6.8	6.7
<i>Protein profile (g/100 ml)</i>		
α_{s1} -casein	1.6	1.3
α_{s2} -casein	0.25	0.35
β -casein	1.4	1.0
κ -casein	0.45	0.3
β -lactoglobulin	0.4	0.3
α -lactalbumin	0.14	0.13
<i>Fatty acid profile (%)</i>		
C4	3.9	3.3
C6	1.6	1.0
C8	0.8	1.3
C10	1.6	3.0
C12	2.0	3.1
C16	33	28
C18:0	12	15
C18:1	25	28
C18:2	1.5	1.9
CLA ^a	0.6	0.5
<i>Selected minerals (mg/100 ml)</i>		
Calcium	180	120
Magnesium	20	13
Sodium	45	50
Potassium	100	140
Phosphate	88	75
Chloride	64	120
Zinc	0.4	0.3
Iron	0.08	0.04
Copper	0.01	0.01
<i>Selected vitamins</i>		
Vitamin A (IU/100 ml)	3200	1500
Tocopherol (mg/100 ml)	33	31
Thiamine (μ g/100 ml)	35	30
Riboflavin (μ g/100 ml)	160	170
Ascorbic acid (mg/100 ml)	6.7	2.0

^a Conjugated linoleic acid (Guo, 2003).

Source: based on Guo (1993) and Sahai (1996).

affected by this. Because of the high fat content, the buffalo's total fat yield per lactation compares favorably with that of improved breeds of dairy cattle; it is much higher than that of most of the indigenous cows of Asia and the Pacific regions.

Normally the protein in buffalo milk contains more casein and slightly more albumin and globulin than cow's milk. Several researchers have claimed that the biological value of buffalo milk protein is higher than that of cow's milk, but this has not been clinically proven (Patel and Mistry, 1997). The proteins of buffalo milk, in particular the whey proteins, are much more heat stable than those of cow's milk. Dried milk products prepared from buffalo milk exhibit higher levels of undenatured proteins when processed under similar conditions (Patel and Mistry, 1997), due probably to the milk's higher total solids. The mineral content of buffalo milk is nearly the same as that of cow's milk except for phosphorus, calcium, and iron, which occur in roughly twice the amounts in buffalo milk. Buffalo milk tends to be lower in salt. There is a significantly lower water content and a higher fat content in buffalo milk than in cow's milk, with almost 45% more milk solids in buffalo milk. Because of this, buffalo milk is better suited for the manufacture of fat-based milk products, such as butter, ghee, and milk powder. And even with almost twice the fat content of cow's milk, buffalo milk has only a fraction of the cholesterol (0.65 mg g^{-1} vs. 3.13 mg g^{-1}) (see Patel and Mistry, 1997). Buffalo milk contains relatively higher levels of conjugated linoleic acid (CLA) than cow's milk. This may make buffalo's milk a more nutritionally wise and health-conscious choice for dairy product consumers. However, the energy density of buffalo milk is much higher than that of cow's milk.

Buffalo milk also lacks the yellow pigment carotene, precursor for vitamin A, and its whiteness is frequently used to differentiate it from cow's milk in the market. Despite the absence of carotene, the vitamin A content in buffalo milk is almost as high as that of cow's milk. Apparently the buffalo converts the carotene in its diet to vitamin A (Patel and Mistry, 1997). The two milks are similar in B complex vitamins and vitamin C, but buffalo milk tends to be lower in riboflavin.

14.3 Milk products

Buffalo milk, like cow's milk, can be utilized for the manufacture of a wide variety of dairy products such as cream, butter, butter oil (clarified butter or ghee), UHT cream, ice cream, yogurt and some cheeses without changing the equipment or processing strategies. However, processing technology and equipment designed for cow milk product manufacture are often not adequately suited for buffalo milk processing due to the differences in compositional, physicochemical and functional properties between buffalo and bovine milk. The following considerations need to be taken into account in buffalo milk product processing (Sahai, 1996):

- Buffalo milk variations are greatly affected by age, stage of lactation, season, and breed.
- Buffalo milk has higher total solids, fat content and calcium level. These will affect processing and yield of certain products.
- Casein micelles are larger and there is a higher level of calcium in buffalo milk than in cow milk. Buffalo milk's rennet clotting time is much less and its curd tension is higher than that of cow milk.
- The buffering capacity, pH and viscosity of buffalo milk are higher than those of cow milk.
- The fermentation and/or ripening process of buffalo milk is generally slower.
- Butter made from buffalo milk is harder than that of cow milk due to its higher levels of saturated fatty acids.

Buffalo are the second largest (after cows) source of milk in the world. They are of great economic importance in India in preparing 'toned' milk – a mixture of buffalo milk and milk made by reconstituting dry skim-milk powder. The richness of buffalo milk makes it highly suitable for processing if proper processing technologies are exploited. To produce 1 kg of cheese, a cheese maker requires 8 kg of cow's milk but only 5 kg of buffalo milk. To produce 1 kg of butter requires 14 kg of cow's milk but only 10 kg of buffalo milk. Because of these high yields, processors appreciate the value of buffalo milk.

As a specialty product, buffalo cheese is highly prized for its pure white appearance and smooth texture. In many countries it is among the most desirable cheeses (Mozzarella and Ricotta in Italy, Gemir in Iraq, the salty cheeses of Egypt, and Pecorino in Bulgaria, for example). In Venezuela all the cheese produced from the small La Guanota milking herd in the Apure River basin (about 100 kg a day) is bought by the Hilton Hotel Caracas and sells for twice the price of cheese made from cow's milk (Falvey, 1999).

Cheeses, including buffalo milk cheeses, are becoming increasingly popular throughout the world. Demand is rising at a rate that is among the highest for any food product. Cheese offers particular benefit to areas where refrigeration is not widely available, where transporting high-protein foods to remote areas is difficult, and where seasonal fluctuations affect milk supplies. Buffalo milk may make cheesemaking profitable on an even smaller scale than conventional dairying; it is more concentrated than cow's milk and requires relatively less energy to transport and process (an increasingly important factor where fuels are limited) (Falvey, 1999). Although much in demand for making soft cheese, buffalo milk is less desirable for making hard cheeses such as Cheddar or Gouda. During cheesemaking, buffalo milk produces acid more slowly than cow's milk, retains more water in the curd, and loses more fat in the whey. However, some of these problems can be eliminated by reducing the calcium content of the buffalo milk through ionic exchange with sodium chloride (Czulak, 1964; Czulak *et al.*, 1969). Ultrafiltration also appears to help reduce some of the typically observed problems during cheese making with buffalo milk (Patel and Mistry, 1997).

14.4 Dairy management and milk production

The characteristics of the dairy buffalo so closely approximate those of the dairy cow that successful methods of breeding, husbandry, and feeding for milk production for the cow can be applied equally to the dairy buffalo (Jainudeen, 2003). Buffalo are generally very docile and easy to handle. They rarely show aggression to people but can be very aggressive to one another. In general the husbandry of buffalo is not dissimilar to that of cattle. However, buffalo have not been systematically bred for uniform udders and teat size; therefore it is difficult to milk buffalo using modern milking machines (Aliev, 1969, 1970; Alim, 1982). Nevertheless, thousands of buffalo are machine milked in Bulgaria and Italy, so machine milking can be adapted to buffalo and vice versa. Buffalo in the research herd at Ain Shams University in Egypt have adapted well to machine milking (Badran, 1992). Machine milking is a standard practice at the university's buffalo farming operation. The calves are separated from their dams immediately after birth and no problems of milk letdown have been observed (Badran, 1992). However, milk letdown is often an issue in small rural milking farms and some buffalo dams have problems with milk letdown without a calf around. Frequently, a calf is kept with the cow and is tied to her foreleg at milking time. In India, Burma, and other Asian countries a dummy calf may be provided at milking (Kay, 1974).

The lactation length is on average 300 days for the Murrah breed, and about 20 days shorter for the river and swamp buffalo (Aliev, 1969). Milk yields typically range from 1500 to 1800 kg for the first lactation with a steady increase to a peak during the fourth. This peak level is usually maintained through the ninth lactation, at about 16 years of age (Kay, 1974; Lall and Narayanan, 1991). Modern dairy cows in the US will continue to be productive members of the herd for 10 or more lactation cycles, with average milk yields of 8800 kg of milk or more (different breeds produce within a range of around 4000 to over 10,000 kg of milk per annum). However, average herd life for the higher production breeds is only four years due to problems associated with infertility, diseases, lameness, or production (NRC, 1988). Some animals, despite their high genetic potential, simply fail to produce economic levels of milk to justify their feed costs. Just as with dairy cows, buffalo herd life is strongly correlated with production levels (Lall and Narayanan, 1991). Lower production cows live longer than high production cows, but are arguably less profitable because of higher feed cost to maintain high production levels. However, the vast majority of buffalo milk is produced by smallholder farms and the buffalo are also draft animals, unlike dairy cattle in the US. Therefore, it is not uncommon for small family farms to keep lower producing buffalo because of the high cost of replacing them (Falvey, 1999).

In countries like India and Egypt, the milk yield of dairy water buffalo is generally higher (680–800 kg) than for local cattle (360–500 kg) (Badran, 1992). However, since selection for exceptional milk production is not conducted systematically, large variations in yield occur between individual animals, and

milk production of buffalo falls short of its potential. Nonetheless, some outstanding yields have been recorded. One Indian government farm reported average yields for milking buffalo from 4 to 7 kg per day in lactations averaging 285 days. Daily yields of 12 kg have been reported for some Bulgarian buffalo cows and a daily production of over 20 kg has been reported for some remarkable animals in India. A peak milk yield of 31.5 kg in a day has been recorded from a champion Murrah buffalo in the All India Milk Yield Competition conducted by the Government of India (Lall and Narayanan, 1991). At Caserta, Italy, a herd of 1600 machine-milked, pedigreed dairy buffaloes has produced average yields of 1500 kg during lactations of 270 days (5.5 kg per day per buffalo). In Pakistan and India averages of 6.8 kg and 6.3 kg per day are common for Nili/Ravi buffalo cows and Murrah buffalo cows during lactations averaging 282 days (Williamson and Payne, 1965; Cady *et al.*, 1983).

Swamp buffalo of Southeast Asia are generally considered poor milk producers. They are mainly used as draft animals, but it may be that their milk potential has been underestimated due to the poor quality of feed; most subsist on whatever they can graze on while working and don't receive any supplemental feed. In the Philippines, swamp buffalo cows with nursing calves have produced 300–800 kg of milk during lactation periods of 180–300 days (Falvey, 1999). In Thailand, swamp buffaloes selected and reared for milk production have yielded 3–5 kg per day during 305-day lactations. As with cattle, the percentages of fat, protein, and total solids decrease as the milk yield increases (NRC, 1988).

14.5 Feeding management

India, Pakistan and most Asian countries have limited feed resources for feeding their buffalo stock (Whyte and Mathur, 1965a, 1965b). The available resources are essentially tropical pasture, straw and crop residue, all generally low in protein (Jainudeen, 2003). As buffalo are capable of surviving on very little, they are often fed very little. The energy and protein requirements for lactating buffalo are on the order of 100 times higher than for maintenance (1.28 g/kg body weight vs. 126.6 to 166.34 g/kg body weight during lactation). There is no physiological need to feed concentrate to maintain butterfat content in buffalo milk, since buffalo release excess fat into the milk and store only a minimum in body tissues (Jainudeen, 2003), although there is ample evidence to suggest that feed supplements do improve milk yield. Like dairy cattle, buffalo fed supplements show better body condition, shorter calving intervals and higher milk yields (Jainudeen, 2003). Even a simple block lick of urea and molasses supplies fermentable energy and macro- and micro-minerals to make rumen microflora and fauna more efficient in fermenting and digesting the low quality roughage available as feedstock. However, there are several physiological factors that contribute to the buffalo's ability to utilize poor quality roughage and crop residue better than cows. Among these are the buffalo's large rumen volume,

very high rate of salivation, slower passage of digestate through the reticulo-rumen, slow rumen motility and high cellular activity. The buffalo's physical and physiological characteristics make it better suited than the native cows as a dairy animal in these regions of the world (Williamson and Payne, 1965).

14.6 Factors that influence the yield and composition of buffalo milk

Presently, there are 18 recognized breeds of buffalo. All vary in milk yield and composition. However, just as with cow's milk, buffalo milk composition is affected by many factors including breed, age, stage of lactation and feeding regime. Table 14.3 shows the gross composition of milk from different buffalo breeds. Buffalo allowed a dry period of 50 days or shorter between oestrus and breeding produce less milk in the following lactation (Williamson and Payne, 1965). And just as with cow's milk, gross composition of buffalo milk changes with lactational age, with increasing protein and fat, while lactose decreases with advancing lactation (Lall and Narayanan, 1991). Even the composition of the milk fat and protein changes with advancing stage of lactation (Table 14.4). Large milk fat globules increase in percentage, short chain fatty acids decrease while long chain and unsaturated fatty acids increase, and the concentration of cholesterol increases because of the breakdown of the epithelial cells that line the mammary ducts of the udder (Hofi *et al.*, 1977).

A buffalo is capable of breeding throughout the year and having a calf every year. They carry their calf for 10 months; twin calves and calving difficulties are very rare. Buffalo are very hardy and tolerant of weather conditions (Tailor and Jain, 1993). They are extremely disease resistant. Calves especially rarely suffer from pneumonia or non-nutritional scours. Lameness and clinical mastitis are also rare in adults (Kay, 1974; Saini *et al.*, 1994). Milk yields in buffalo herds are usually recorded over a period of 305 days from calving. Where feeding is adequate and the incidence of disease is controlled, animals will frequently continue to give satisfactory daily yields well beyond this period.

A serious handicap in the development of superior milking characteristics of the buffalo is that artificial insemination (AI) often presents particular difficulties. Oestrus detection in buffalo is a problem; irregular oestrus, and anoestrus lasting three or four months, are rarely seen in modern Western dairy herds.

Table 14.3 Comparative gross composition (%) of buffalo's and cow's milk

Animal	Total solids	Protein	Fat	Lactose
Murrah buffalo	17.96	4.36	7.45	4.83
Swamp buffalo	18.34	4.13	8.95	4.78
Indian native cow	12.15	3.25	3.60	4.59
Modern US dairy cow	12.50	3.40	3.50	5.00

Table 14.4 Changes in chemical composition (%) of commingled water buffalo milk during a year

Component	Jan	Feb	Mar	Apr	May	Jun
pH	6.79 ± 0.01	6.76 ± 0.01	6.82 ± 0.01	6.98 ± 0.01	6.88 ± 0.01	6.85 ± 0.01
Total solids	18.45 ± 0.04	18.20 ± 0.09	18.48 ± 0.03	16.39 ± 0.01	17.51 ± 0.03	16.61 ± 0.02
Fat	7.63 ± 0.03	6.58 ± 0.03	7.07 ± 0.06	6.68 ± 0.03	6.90 ± 0.01	6.80 ± 0.01
Crude protein	5.37 ± 0.11	5.23 ± 0.03	5.25 ± 0.02	4.65 ± 0.06	5.12 ± 0.04	4.59 ± 0.37
Lactose	4.50 ± 0.08	4.73 ± 0.04	4.59 ± 0.10	4.49 ± 0.06	4.56 ± 0.03	4.50 ± 0.07
Ash	0.92 ± 0.01	0.92 ± 0.03	0.92 ± 0.01	0.91 ± 0.05	0.91 ± 0.02	0.91 ± 0.03
Component	Jul	Aug	Sept	Oct	Nov	Dec
pH	6.82 ± 0.01	6.89 ± 0.01	6.91 ± 0.01	6.91 ± 0.01	6.78 ± 0.03	6.83 ± 0.03
Total solids	17.29 ± 0.08	17.78 ± 0.01	17.79 ± 0.01	17.98 ± 0.02	18.47 ± 0.01	18.40 ± 0.03
Fat	6.57 ± 0.06	7.02 ± 0.03	7.40 ± 0.01	7.60 ± 0.01	7.97 ± 0.06	7.37 ± 0.06
Crude protein	4.70 ± 0.09	5.14 ± 0.10	5.11 ± 0.13	5.10 ± 0.07	4.98 ± 0.26	4.94 ± 0.02
Lactose	4.60 ± 0.08	4.49 ± 0.02	4.55 ± 0.04	4.66 ± 0.06	4.69 ± 0.01	4.70 ± 0.03
Ash	0.92 ± 0.01	0.92 ± 0.04	0.92 ± 0.03	0.92 ± 0.01	0.92 ± 0.02	0.92 ± 0.05

Source: Guo (2003).

Large-scale dairy buffalo production is a greater reality in India and Pakistan than anywhere else in the world, even though it represents less than 2% of the buffalo farms in those two countries. Further, because most buffalo milk still comes from small farms, there is a lack of organization around selective breeding programs for the best milking characteristics (Chantalakhana, 1999; Falvey, 1999). AI is still practiced only to a very limited extent for buffalo breeding and herd management: in Italy for 2.5% of the buffalo, in Egypt and Iran for 0.5%, and in Romania for 0.1% of animals. In the large cooperative and state farms in Bulgaria, AI is used on 80% of the buffalo. In most other countries it is not used at all. The low use of AI has slowed down the implementation of selection schemes for genetic improvement of milk and meat productivity. Research trials conducted in Italy have indicated that artificial insemination is feasible and successful in buffalo using techniques to synchronize oestrus and boost fertility (Mason, 1974). Where there has been selection over a number of generations combined with improved nutrition, controlled environmental conditions and protection from disease, high lactation yields from individuals and small herds of animals have been achieved (Lall and Narayanan, 1991). It was estimated as far back as the 1960s that the milk requirements for all of India could be met by about half the present number of cows and buffalo, with further savings of available feedstocks that are presently being wasted on uneconomic animals if India were to adopt a nationwide program using modern animal husbandry practices including AI to produce improved animal stocks (Whyte and Mathur, 1965a, 1965b; Nanda and Nakao, 2003).

14.7 Factors to consider for improving milk production and reproductive capacity of buffalo

Buffalo account for about 80 million metric tons of milk and three million metric tons of meat annually to world food supplies, much of it in parts of the world that are prone to nutritional imbalances. In addition they are a major source of draft power in much of the undeveloped world, which is why buffalo have been called the 'live tractors of the East' (Cockrill, 1970). Therefore, it is surprising that very little resources and scientific effort have gone into developing superior buffalo breeds similar to that of cattle, even though there is abundant genetic variety of this species. Sound breeding programs may also produce good quality milk.

Buffalo are the second largest source of milk supply in the world. In 2004, according to statistics from the United Nations' Food and Agriculture Organization (FAO), the world production of buffalo milk was 75.8 million metric tons. Trends in world milk production over the five years from 2000 to 2004 indicate that the volume of buffalo milk is increasing steadily at about 3% per year. While dairy cattle produce 84% of the total milk in the world it has to be noted that this volume is with an average fat and protein content of 4% and 3.5%, respectively (FAO, 2007). The average fat content in buffalo milk is about 7.5%

to almost 9%, while protein content in buffalo milk ranges from 4% to almost 4.5%. Thus, in terms of energy-corrected milk, buffalo milk accounts for about twice the food contribution suggested by the actual volume of buffalo milk produced yearly.

Buffalo are less tolerant of extremes of heat and cold than most cattle breeds. Their body temperature is lower than that of cattle in spite of the fact that their thick black skin (almost three times thicker than a cow hide) absorbs the sun's radiant heat energy very effectively. A buffalo's skin has only one-sixth the density of sweat glands as a cow. This is why buffalo like to wallow in water or mud pools when the temperature and humidity are high (Jainudeen, 2003). Regulation of body temperature in this way influences feed intake, reproduction and milk production. The limited application of AI programs for breed improvement and the overall lack of selective breeding at the village farm level has been the main bottleneck in the development of buffalo production (Nanda and Nakao, 2003). In general, a dairy cow heifer is considered to be efficient if the age at first calving is about 24–30 months. The calving interval should be about 12–13 months, with a lactation length of about 300 days, a 60–90 day dry period, and milk production of between 6000 and 7000 kg per lactation. Compared to buffalo with its own species-specific productive and reproductive traits, a buffalo heifer is on average around 40 to 60 months at first calving (Ganguli, 1981). However, there are indications that productive traits can be improved through selective breeding practices. As an example, Mediterranean breeds and swamp buffalo calved earlier than those from the Indian subcontinent (Rao and Nagarcenkar, 1977). The average calving intervals for Indian and Pakistani buffalo ranged from 15 to 18 months. The dry period has been reported to be 90 to 150 days for the Nili-Ravi breed of Pakistan, while for the Murrah it ranges from 60 to 200 days (Wahid, 1973). The average lactation length ranged from 252 to 270 days. As a result of these factors the productive life of a dairy buffalo is only 39% of its total life, compared to a stunning 52% in developed modern dairy cattle breeds (Ganguli, 1981; Sastry *et al.*, 1988).

In most of the buffalo milk-producing countries of Asia and the Indian subcontinent, it is observed that there are large seasonal variations in breeding and calving in buffalo (Ganguli, 1981). In India and Pakistan, 80% of the buffalo calve during June and December, causing a decline in milk production from March to June. Production starts increasing in June, to peak around September–October before declining again. However, this early summer decline in milk production could be due to heat stress and shortage of high quality forage greens. A dark body, lesser density of sweat glands and thick epidermis make it difficult for buffalo to thrive in extremely hot and dry conditions and these are also the months when the working draft buffalo are in the fields, plowing and cultivating next season's crops. Buffalo have developed survival mechanisms to seek water for immersion in these conditions, but extreme heat and cold significantly affect their milk production and reproductive efficiency (Sastry *et al.*, 1988). In addition to climatic influences, it is clear that poor nutrition and management have an adverse effect on breeding and milk production.

Changes in breeding, feeding and management can bring about notable improvements in the milk production and reproductive performance of buffalo (Sastry *et al.*, 1988). An obvious though neglected target has been finding out why the first calving occurs at such a late age. Close attention from birth to the time heifers reach breedable body size could bring down the age at first calving by six to nine months (Sastry and Tripathi, 1988). It has been shown that balanced feeding could bring buffalo heifers into cycle when they reach 330 kg body weight. There are also cases where heifers have calved at 20 to 24 months (Ganguli, 1981). Calving intervals in buffalo are influenced by the irregular and silent heat period as well as some reported irregularities in reproductive hormones throughout the year. It has been reported that there is seasonal breeding in buffalo due to diminished sexual activity in the period between March and June (Ganguli, 1981). Although buffalo are thought to be seasonal breeders, it has also been reported that they can breed throughout the year if reproduction management is good (Rao and Nagarcenkar, 1977; Sastry and Tripathi, 1988). Thus, it seems clear that there are several important management factors to consider in order to improve milk production in buffalo. These include managing the nutritional status of the dam around calving, pre- and post-partum hygiene, good milking management, balanced feeding throughout the year, oestrus detection and artificial insemination, managing thermal stress and improving housing – all good animal husbandry practices.

14.8 References

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416 Improving the safety and quality of milk

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