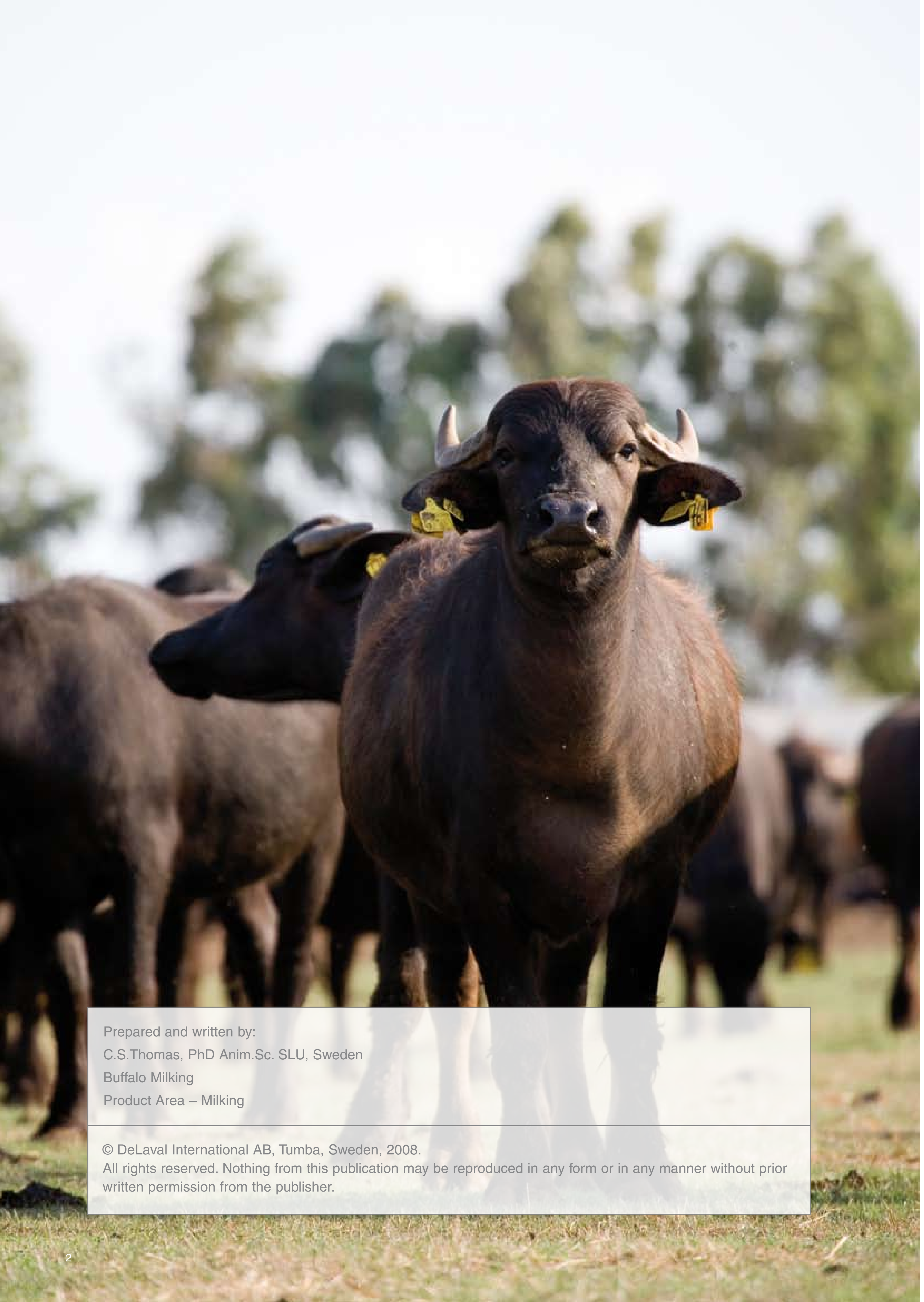
DeLaval

Efficient dairy buffalo production



Prepared and written by:
C.S.Thomas, PhD Anim.Sc. SLU, Sweden
Buffalo Milking
Product Area – Milking

Preface

World milk production has doubled in the last few decades. The last few years have also witnessed a consistent increase in the organized production of milk and meat from buffalo. Buffalo milk, its dairy derivatives, and buffalo meat, are cherished and relished by young and old alike. Buffalo farming is now an almost worldwide phenomenon. Apart from its growth in the traditional bastions, it is also gaining a foothold in other regions of the world where buffalo rearing was never a traditional activity.

In spite of the immense potential of buffalo farming, we seem to know very little about the humble buffalo, its productive capabilities and limitations. This handbook, developed from an original text written by Mikaela Ståhl Högberg and Ole Lind: *Buffalo Milk Production*, provides an overview of dairy buffalo production, its scope and its limitations. It describes how improvements in processes and practices – breeding, feeding, milking and management – can have a consequent positive bearing on buffalo productivity. By increasing awareness of both the potential and the limitations of buffalo milk production, efforts can be focused on developing effective programmes that could help this species to optimize productivity. It is sincerely hoped that this handbook will provide an illuminating perspective on all aspects of buffalo farming.

While researching this project, I was assisted and encouraged by many individuals. I owe my gratitude to them all. In particular, I would like to thank Dr Ole Lind, DeLaval, Sweden, Prof. Kerstin Svennersten-Sjauna, SLU, Sweden and Prof. Rupert M. Bruckmaier, University of Bern, Switzerland.

C. Santosh Thomas

List of contents

1. Introduction to dairy buffalo production

Water buffalo have been responsible for more than ten percent of world milk production for several years, but the potential of these animals has seldom been appreciated or recognised. One of the main reasons for this is that those who have a stake in rearing buffalo are generally poor and underprivileged, and not able to project the impact this beast has on their livelihood and well-being.

The word "buffalo" evokes a mixed response in North America, a large section of Europe, and in many other parts of the world where buffalo have never been considered a domesticated species. This animal has been identified as a zoo animal or a wild beast. However it is among the most gentle of the domesticated dairy species, which is obvious in India and the sub-continent where it is common to see small children handling large herds of buffalo.

Over time buffalo rearing has shifted from the backyard to commercial farms and large business enterprises. The immense popularity of buffalo milk and meat products has ensured that buffalo production has followed in the path of the dairy cattle industry. However for this species to perform optimally under the pressure of intensive production systems, buffalo breeds have to be improved, with clear focus on the desired output. This has not yet happened. Buffalo, although potentially excellent for both milk and meat production, still languish in obscure conditions of poor nutrition, breeding, management and welfare.

This animal is called the water buffalo because of its natural instinct to wallow in ponds of water and muddy pools.

Buffalo wallowing in a pool on a hot summer day.

Domestication – an historical perspective

Studies of human settlement down the ages show that domestication of animals is intrinsic to any progressive civilisation. Archaeological findings and historical data point to the fact that buffalo were first domesticated around 2 500 BC in the Indus Valley: present day India and Pakistan (Chantalakhana and Falvey, 1999). Around 600 AD, Arab traders brought water buffalo from Mesopotamia towards the Near East: modern day Syria, Israel and Turkey.

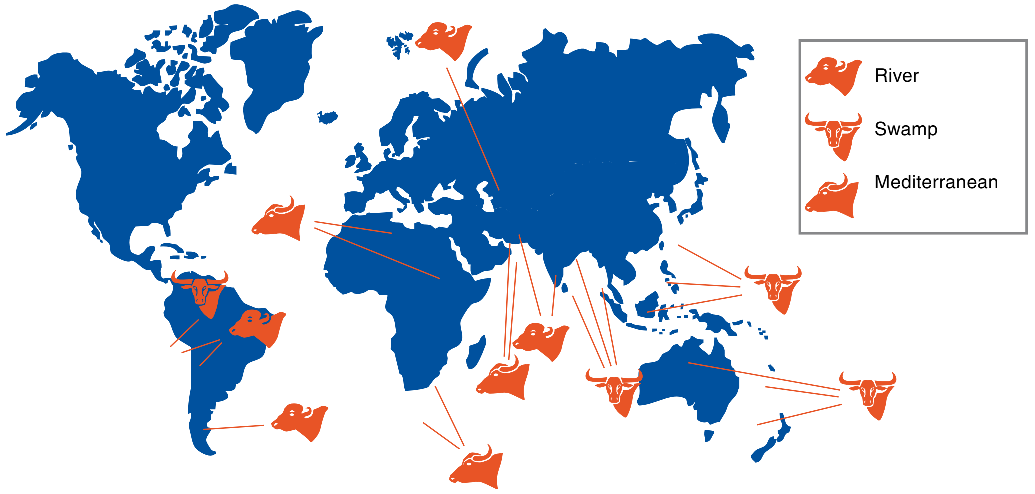
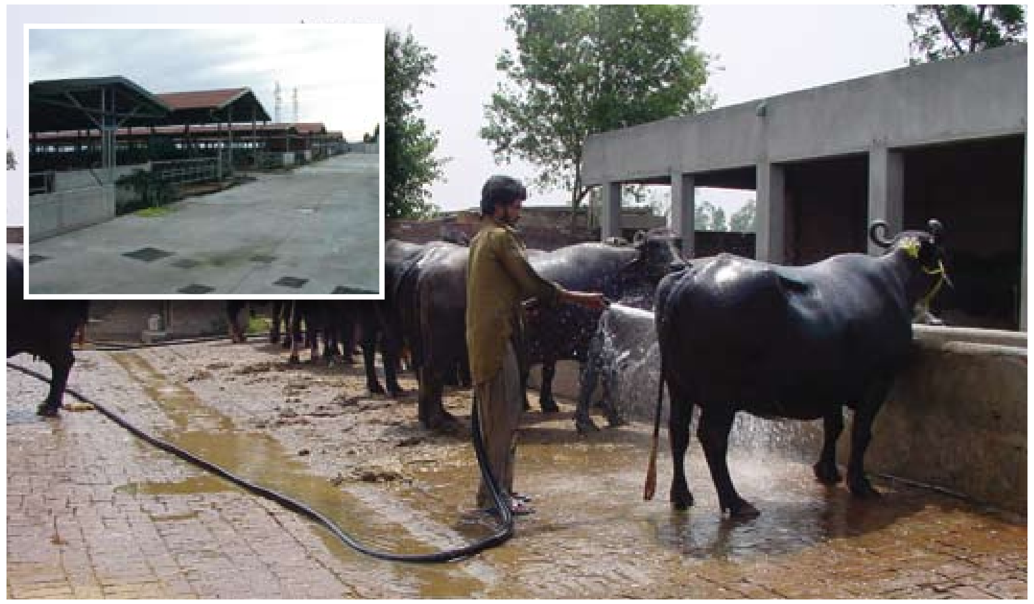


Figure 1: Distribution of domesticated buffalo in different parts of the world.

During the Middle Ages the animal was brought to Europe by pilgrims and crusaders. Buffalo are now found in Italy, Hungary, Romania, some Balkan countries, Greece and Bulgaria. The domestic water buffalo has also been introduced into South America, the United States and Australia (BSTID, 1981).

World milk production has doubled in the last few decades and it is noteworthy that in the last few years, buffalo have supplied about 12% of the total world milk production. 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 (FAO, 2004).



Buffalo farms in Mumbai city

Global distribution of domesticated buffalo

Dairy buffalo production has been a tradition in parts of the world like the Caucasian countries, Asia and Egypt, where fresh buffalo milk, dahi (cultured sour milk), ghee (butter oil) and yoghurt are popular. In Italy the dairy buffalo industry is flourishing thanks to the popularity of buffalo mozzarella cheese. Because of the market for mozzarella, buffalo farming is a profitable enterprise and is carried out in an organised manner with modern equipment. In South American countries like Brazil and Argentina, buffalo are reared for both milk and meat. In recent years, buffalo milk and milk products, especially mozzarella cheese, have become immensely popular and dairy buffalo production has found its way into non-traditional areas with the number of buffalo farms mushrooming even in the UK and USA (Palmer, 2005). In India as well as Pakistan, in the vicinity of all the major cities like Mumbai, Calcutta, and Karachi, one can find a large number of buffalo farms of varying herd sizes. In Mumbai alone, there are more than 200000 buffalo in downtown districts and probably another 100000 in suburban areas. Some of these farms have herd sizes of more than 1000 buffalo, and on average these herds have more than 100 buffalo (Vidya, 2004). 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 two percent of the buffalo farms in those two countries.

Figure 2: Domesticated buffalo

Domesticated buffalo

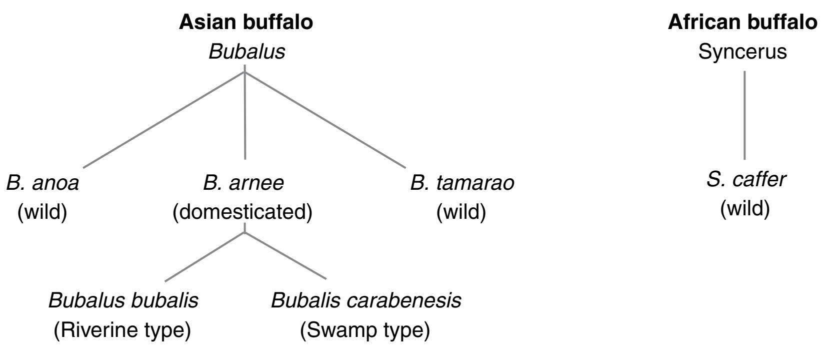
Riverine type
(50 diploid chromosomes) Breeds such as Murrah, Nili Ravi, Jaffrabadi, Mediterranean.

Swamp type
(48 diploid chromosomes) For example Carabaos.

Population

There are 170 million buffalo in the world today: 97% in Asia, 2% in Africa – mainly in Egypt, and 0.2% in Europe – mainly in Italy (FAO, 2004). India has 56%, Pakistan 14% and China 13% of the world buffalo population. Nearly 98% of water buffalo in Asia and the Pacific region are raised by small farmers owning less than two hectares of land and fewer than five buffalo (Chantalakhana and Falvey, 1999). Buffalo contribute 72 million tonnes (Mt) of milk and three Mt of meat annually to world food, much of it in areas that are prone to nutritional imbalances. In addition they are a major source of draught power, and that is why buffalo have been called the "live tractor of the East" (Cockrill, 1967). So it is surprising that very little resource and international effort has gone into developing this species. Similarly the systems and programmes to improve buffalo are not yet effective even though there is abundant genetic variety of this species.

World buffalo *(Adapted from Mahadevan, 1992.)*



Classification and breeds

The domestic water buffalo *Bubalus bubalis*, belongs to the family *Bovidae*, sub-family *Bovinae*, genus *bubalis* and species *arni* or wild Indian buffalo (Chantalakhana and Falvey, 1999). Buffalo are classified into two distinct classes: swamp buffalo and river buffalo.

Swamp buffalo

Swamp buffalo are found in China, Thailand, the Philippines, Indonesia, Vietnam, Burma (Myanmar), Laos, Sri Lanka, Kampuchea and Malaysia. They are mainly used as draught animals, particularly in rice cultivation. Swamp buffalo produce relatively small quantities of milk – 1.0 to 1.5 litres per day – so they are not heavily used in milk production (Chantalakhana and Falvey, 1999). The swamp buffalo might however be used in meat production (BSTID, 1981). The name 'swamp' has probably arisen from their preference for wallowing in stagnant water pools and mud holes (Subasinghe et al., 1998).

River buffalo

Riverine breeds of the Indian sub-continent are mainly raised for milk production. Their milk yield is about six to seven litres per day. Twelve of the 18 major breeds of buffalo are kept primarily for milk production. The main milk breeds of India and Pakistan are the Murrah, Nili-Ravi, Surti, Mehsana, Nagpuri and Jaffrabadi (Chantalakhana and Falvey, 1999). The river buffalo prefers, as its name reveals, to wallow in clear, running water (Subasinghe et al., 1998).

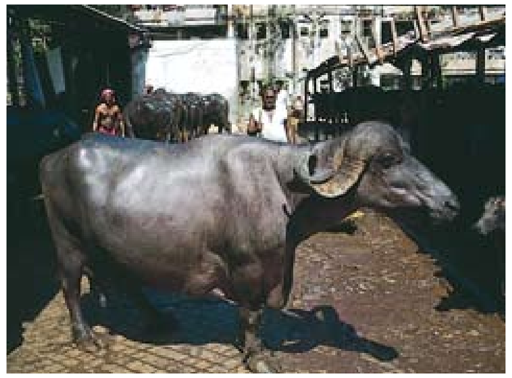
The most important breed for milk production in India is the Murrah. Murrah buffalo originate from the area around Delhi, and the breed has been spread from that area to other parts of India. The breeds Surti and Nili-Ravi are believed to have developed from the Murrah through geographical isolation. The Nili-Ravi buffalo were two different breeds (Nili and Ravi) but are now considered to be a single breed. The Kundi breed is also of importance in milk production. Traditionally the buffalo breeds in Europe have been of the local Mediterranean type and the breeds in Caucasia, the Caucasian type. The most important breed in Bulgaria is the Bulgarian Murrah, which is the result of cross breeding between the local Mediterranean buffalo and the Indian Murrah, followed by upgrading with Indian Murrah. Cross breeding local buffalo with high yielding elite buffalo has now started in several countries.

1) Swamp buffalo.

2) Jaffrabadi and Murrah, two of the riverine breeds of buffalo.

Typical body weights and milk production of popular buffalo breeds

Murrah
Weight: male – 550 kg, female – 450 kg
Production: 1 800 to 2 500 kg in 300 days



Jaffrabadi
Weight: male – 800 kg, female – 600 kg
Production: 2 000 to 2 200 kg in 300 days

Mediterranean
Weight: male – 600 kg, female – 500 kg
Production: 2 000 to 2 800 kg in 300 days

Mehsana
Weight: male – 500 kg, female – 400 kg
Production: 1 800 to 2 000 kg in 300 days

Nili-Ravi
Weight: male – 700 kg, female – 550 kg
Production: 1 800 to 2 400 kg in 300 days

Beheri (Egypt)
Weight: male – 450 kg, female – 350 kg
Production: 1 800 to 2 000 kg in 300 days

Utility of buffalo

Work

The water buffalo is an important beast of burden in Asian farming. It is widely used to plough, level land, plant crops, puddle rice fields, cultivate field crops, pump water, haul carts, sleds and shallow-draft boats. It is also used to carry people, thresh grain, press sugar cane, haul logs, and more. Buffalo have an advantage over other draught animals in wet or muddy areas, with their large hooves. Their legs can withstand wet conditions better than cattle. However they are not as fast as cattle, horses or mules. This puts them at a disadvantage in dryer areas (BSTID, 1981).

Meat production

Buffalo have been used as draught animals for centuries. This has lead to exceptional muscular development: some animals can weigh more than 1 000 kg. Though buffalo are a major source of meat, they have not been used solely for meat production until recently. Most buffalo meat is derived from old animals so not surprisingly the meat is considered to be of poor quality. However this is not true of meat from younger animals. Buffalo meat from animals properly reared and fed, is tender and palatable. Buffalo are lean animals. In general, a buffalo carcass has a higher proportion of muscle and a lower ratio of bone and fat than a cattle carcass (BSTID, 1981).

Milk production

Buffalo are the second largest source of milk supply in the world. In 2004, according to statistics from the United Nations' Food and Agriculture Organisation (FAO) the world production of buffalo milk was 75.8 million tonnes (Mt). Trends in world milk production over the five years to 2004 indicate that the volume of buffalo milk is increasing steadily at about three percent per year (see Table 1). 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. The average fat content in buffalo milk is about 7 to 8% while protein content in buffalo milk ranges from 4.2 to 4.5%. So in terms of energy corrected milk, buffalo milk is making a greater food contribution than the actual volume of buffalo milk suggests.

Table 1: Trends in world buffalo milk production – a comparison with other dairy species.

Parameters (%)	Year 2000	2001	2002	2003	2004
Increase in world cow milk	2	1	2	2	0
Cow milk of total world milk	85	85	85	84	84
Total world cow milk (Mt)	488 057 837	494 618 011	505 222 503	514 035 351	513 312 002
Increase in world buffalo milk	3	4	3	4	1
Buffalo milk of total world milk	12	12	12	12	12
Total world buffalo milk (Mt)	67 417 389	70 414 905	72 288 775	75 372 769	75 833 191
Increase in world sheep milk	-3	4	-3	2	1
Sheep milk of total world milk	1	1	1	1	1
Total world sheep milk (Mt)	7 198 400	7 459 725	7 250 519	7 393 335	7 438 527
Increase in world goat milk	2	3	1	1	0
Goat milk of total world milk	2	2	2	2	2
Total world goat milk (Mt)	11 065 482	11 456 111	11 560 801	11 708 274	11 716 286
Increase in world camel milk	3	5	0	4	0
Camel milk of total world milk	0	0	0	0	0
Total world camel milk (Mt)	426 085	430 268	433 278	434 000	434 450
Total world milk (Mt)	564 453 649	574 165 193	584 379 020	596 755 876	608 943 729
Increase in world milk		1.69	1.75	2.07	2.00

(FAO, 2004)

Table 1: Trends in world buffalo milk production – a comparison with other dairy species.

Buffalo in a loose housing barn.

India is the world's largest producer of milk but unlike other milk producing nations, the milk is produced by a large number of farmers (about 70 million) located in some 500 000 remote villages. The families of the milk-producing farmers are mostly poor and under-privileged. Therefore, the additional income every year through the sale of surplus milk is vital to their well-being and economic security (Manorama India Yearbook, 1998).

The riverine breeds produce more milk than the swamp types, as they have been selected specially for their milk production. The average milk yield of the riverine breeds Murrah, Nili-Ravi and Surti are 2 000 to 2 100, 1 800 to 2 000 and 1 600 to 1 800 kg per lactation respectively, according to Subasinghe et al. (1998). However, reports of higher milk yields, especially in Murrah buffalo, are not unusual. A lactation yield of 3 775 kg by a Murrah buffalo was reported by Basu et al. (1979). Today this figure is even higher in some cases.

Buffalo milk

Buffalo milk is high in total solids, fat, proteins and vitamins compared to cow's milk. Buffalo milk also contains less cholesterol and more tocopherol, which is a natural anti-oxidant. The peroxidase activity is two to four times higher in buffalo milk than in cow's milk, which means that buffalo milk has better natural keeping qualities (Chantalakhana and Falvey, 1999). Buffalo milk appears to be whiter than cow's milk because it lacks the yellow pigment carotene, a precursor of vitamin A. But buffalo milk contains even more vitamin A than cow's milk.

Processed milk products

Buffalo milk is used for a variety of different milk products such as butter, butter oil (clarified butter or ghee), soft and hard cheeses, condensed or evaporated milks, ice cream, yoghurt and buttermilk. The properties of buffalo milk make it very suitable for processing. For example, it takes eight kilograms of cow's milk to produce one kilogram of cheese, while it takes only five kilograms of buffalo milk (BSTID, 1981). In India, 28% of the total milk production is converted into ghee and about 20% is converted into products such as dahi (curd), khoa (dehydrated milk) and a variety of milk sweets (Chantalakhana and Falvey, 1999).

Characteristics and behaviour

Genetics

Although the river buffalo is the main dairy animal in some countries, it is a primitive animal compared to the developed dairy breeds among cattle like the Holstein-Friesian and Jersey. Many generations of selective breeding have produced cattle with almost predictable productive and reproductive traits. This has not been the case among the buffalo breeds as most of these animals are reared by landless and marginal farmers, with the animals reproducing naturally (Chantalakhana and Falvey, 1999). However there is no reason why buffalo breeds could not be developed in the same way as cattle.

Buffalo have a number of anatomical and physiological similarities with the other species in the Bovidae family. Cattle have 60 diploid chromosomes, river buffalo have 50 and swamp buffalo have 48. While the two types of buffalo can be mated to produce a fertile offspring which has 49 diploid chromosomes, buffalo cannot be successfully mated with any other species in this family (Mahadevan, 1992).

Appearance

The swamp buffalo is slate grey, droopy necked and ox-like. It has massive backswept horns (BSTID, 1981). There are no clear differences between breeds of swamp buffalo, except for body size (Subasinghe et al., 1998). The riverine buffalo is usually black or dark grey, with tightly coiled or drooping straight horns (BSTID, 1981). They are generally large in body size. There are greater differences between riverine breeds than between the breeds within the swamp type (Subasinghe et al., 1998). The body weight of a female buffalo of Murrah breed ranges from 430 to 500 kg, according to Ganguli (1981).

Nutrition and life cycle

Buffalo are grazers (Pathak, 1992) and they graze a wider range of plants than cattle do (BSTID, 1981). They utilize low-grade roughage more efficiently than cattle do. Buffalo have slower ruminal movements, a smaller rate of outflow from the rumen and higher bacteria population in rumen fluid. This leads to a longer exposure of the feed and consequently a more complete digestion. The rumen of a buffalo also has a higher production of volatile fatty acids than the rumen of cattle. This might be one of the factors contributing to the higher fat content in buffalo milk (Ganguli, 1981).

The buffalo has an exceptionally long productive life. A normal healthy female buffalo could have as many as nine to ten lactations (Ganguli, 1981).

Heat tolerance

Buffalo are less tolerant of extremes of heat and cold than various breeds of cattle. The body temperature of a buffalo is lower than that of a cow in spite of the fact that its black skin absorbs much heat and its skin has only one-sixth the density of sweat glands that a cow skin has. This explains why buffalo like to wallow in water when the temperature and humidity are high (BSTID, 1981). Regulation of body temperature in this way influences feed intake, reproduction and milk production.

Dairy temperament

A comparative study of temperament was done among Murrah buffalo, crossbred cows and Red Sindhi (Indian breed) cows. The results of this study showed that these buffalo had a higher percentage of docile animals (Nayak and Mishra, 1984). Almost 50% of this group of Murrah buffalo were docile. About 7% of the group were aggressive. The rest were classed as restless or nervous animals. However in another study by Roy and Nagpaul (1984), Murrah buffalo were compared with Karan Swiss and Karan Fries dairy cows (two Indian breeds of crossbred cows). It was found that the buffalo had higher temperament score (more aggressive temperament) than the dairy cows. The temperament scores for all three groups decreased with increasing parity between the third and fifth lactation (Roy and Nagpaul, 1984).

Buffalo in a loose housing barn.

The different temperaments of buffalo affect concentrate intake, milking behaviour and milk production (Nayak and Mishra, 1984). Docile buffalo are preferred over nervous and aggressive animals, as the docile animals are easier to milk, handle and manage. They also produce more milk of relatively better quality than that from aggressive buffalo (Nayak and Mishra, 1984; Gupta et al., 1985).

In a comparison between docile, restless, nervous and aggressive Murrah buffalo, it was found that the docile individuals had a higher rate of concentrate intake, shorter let-down time, slightly longer milking time, higher daily milk yield, higher milk flow rate and a higher percentage of milk fat than the other groups of buffalo (Nayak and Mishra, 1984).

Maintenance behaviour
It was found in a study by Thind and Gill (1986), that buffalo were eating the most after morning and evening milking, and also eating moderate amounts around noon and midnight. Ruminating behaviour was most intense after each peak of eating behaviour. Some variations between the seasonal periods were seen. The buffalo took water three times during a 24-hour period in the cooler seasons, and four times during a 24-hour period during the warmer seasons. In a study by Schultz et al. (1977), on average 27% of the time was spent on feeding, 39% on ruminating and 34% on resting (while lying or standing). A similar study on grazing buffalo found 37 to 54% of their time was spent on feeding, 28% on ruminating and the remaining time on resting, walking and wallowing (Bud et al., 1985).

Another behavioural study on Murrah buffalo under the loose-housing system was made by Odyuo et al. (1994). The results from this study showed that buffalo spent significantly more time on eating, idling (other behaviours than eating, ruminating or sleeping) and walking during daytime, and significantly more time on ruminating and sleeping during the night time. Peaks in eating behaviour in lactating buffalo were observed around 4:00, 9:00, 13:00, 15:00, and 19:00. Ruminating behaviour was lowest during the hours around noon and highest during early morning and late evening. The highest peaks of sleeping behaviour were seen around 3:00 and 23:00. Idling time peaked around noon.

Behaviour in mechanised management
Integrating various aspects of dairy buffalo management together, such as improved housing, nutrition, breeding and milking, is known to produce remarkable improvements in buffalo productivity (Sastry and Tripathi, 1988). Better animal welfare will be reflected in the normal behavioural activities and milk production. In dairy cattle it has been established that restricting normal feeding leads to behavioural abnormalities like tongue rolling (Redbo et al. 1996). The rhythm of the various buffalo activities like feeding, lying, standing and ruminating was not disturbed by the mechanisation of different farm activities like concentrate feeding, manure handling, water feeding and milking (Thomas et al., 2005). However, using a shower to cool the animals before milking, and again during the hottest parts of the day, was found to improve feeding behaviour in the daytime (ibid).

Limitations in buffalo milk production

The limited application of systematic programmes for breed improvement through selective breeding at the village level has been the main bottleneck in the development of buffalo production. In general, a dairy cow is considered to be efficient if the age at first calving is about 24 to 30 months. The calving interval should be about 12 to 13 months, with a lactation length of about 300 days, a 60 to 90 day dry period, and milk production of between 6 000 to 7 000 kg per lactation. As an example, in Sweden the average milk produced per recorded dairy cow was 8 794 kg, with 4.1% fat and 3.4% protein or 8 939 kg ECM (energy corrected milk, Sjaunja et al., 1990). Age at first calving among the herds reported was around 29 months with calving intervals at about 13.2 months (Swedish Dairy Association, 2003).

One could argue that the buffalo has its own species-specific productive and reproductive traits. In general buffalo are usually aged around 40 to 60 months at first calving (Ganguli 1981). However, there are indications that productive traits can be improved. As an example, Mediterranean breeds and swamp buffalo calved earlier than those of the Indian subcontinent (Rao and Nagarcenkar, 1977).

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 ranged from 60 to 200 days (Wahid, 1973). Average lactation length ranged from 252 to 270 days. As a result of these factors the productive life of a buffalo is only 39% of its total life, compared to 52% in developed dairy breeds (Ganguli, 1981; Sastry, 1983).

In most of the buffalo milk-producing countries of Asia, 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, others have suggested the early summer decline in milk production could be due to heat stress and shortage of 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.

Buffalo have developed survival mechanisms to seek water for immersion in these conditions, but extreme heat or cold significantly affect their milk production and reproductive efficiency (Sastry, 1983). In addition to climatic influences, poor nutrition and management also affect breeding and production.

Breeding to improve milking characteristics

Heritability of the partitioning of milk in the udder has been established for decades and dairy cattle have been bred for higher cisternal fraction, smaller teat dimensions, and high milk flow rates (Johansson et al., 1952). It has been postulated that there could be further selection on udder storage capacities in dairy cattle. Animals will be selected for more frequent milking, to suit recent developments in automatic milking in parts of the world like Europe. In countries like Australia and New Zealand where cattle are on pasture, they will be selected for larger udder storage capacities and longer milking intervals (Knight, 2001). Although buffalo in India have been selected for milking characteristics, it possibly has not been done from a machine milking perspective. Apart from this, limited application of advanced breeding techniques like artificial insemination has hampered the process of breed improvement in buffalo (Sastry, 1983).

Contemporary innovations in buffalo production

Changes in breeding, feeding and management can bring about notable improvements in the productive and reproductive performance of buffalo (Sastry, 1983). An obvious though neglected target has been finding out why the first calving occurs at such a high 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 and seasonality. 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, important management factors to consider in improving milk production are managing nutritional status around calving, pre- and post-partum hygiene, good milking management, balanced feeding, heat detection and artificial insemination, managing thermal stress and improving housing (Ganguli, 1981; Sastry, 1983).

In the following chapters some practical aspects related to improving dairy buffalo production are discussed in more detail.

Buffalo are said to be seasonal breeders. However, this is not entirely true as buffalo are polyestral animals and may breed all year round. The buffalo's reputation as a difficult breeder is because of its inherent susceptibility to environmental stress, which causes anoestrus and sub-oestrus. These conditions are responsible for prolonged inter-calving periods, resulting in great economic losses for the buffalo dairy industry. Susceptibility to heat stress also affects feed intake and in turn the nutritional balance, and this also inhibits reproductive efficiency.

Males

Bulls reach sexual maturity at two to three years of age. Semen is produced all year round but it is highly affected by heat stress and low quality feed. The buffalo bull seems to be most fertile in spring, when the volume of ejaculate and sperm concentration is highest. Sperm vitality is also much higher in spring than at other times of the year. Corresponding values are lowest in summer time. Heat stress may have a negative effect on libido.

Females

Wild or feral female buffalo reach sexual maturity at two to three years of age. Domesticated buffalo that are cared for and fed properly may reach puberty earlier. Puberty is highly affected by management factors. Size is more important than age, and a Murrah heifer should weigh around 325 kg at insemination or mating and 450 to 500 kg at her first calving. The age of puberty in buffalo is 36 to 42 months in India. It is comparatively late compared to other countries like Italy, where the age at first calving is between 28 to 32 months on average (Borghese and Mazzi, 2005).

Delayed puberty in both male and female buffalo is common in India. This is due to neglect of calves during their growing period. Buffalo have the potential to gain 400 to 800 gm daily after about four to six months of age, and can attain the 300 to 450 kg body weight suitable for breeding at about 24 months of age. However in a majority of dairy buffalo calving occurs at four to six years of age. This is mainly due to an inadequate supply of feed and nutrients during the growing phase (Ranjan and Pathak, 1992).

The reproductive cycle of a buffalo

The oestrus cycle varies between 21 and 29 days depending on breed. The total duration of oestrus is usually 24 hours but varies from 12 to 72 hours. The most reliable sign of oestrus is frequent urination. The signs of oestrus are much less pronounced in buffalo than in cattle. Many buffalo show oestrus only at night time, and then it is difficult to detect. A lactating animal may have a slight decrease in milk yield when in heat, although it is seldom as pronounced as in cattle. The buffalo may be more restless and be difficult to milk (Bhikane and Kawitkar, 2000).

- Age at puberty: 36 to 42 months
- Length of oestrus cycle: 21 days
- Duration of heat: 12 to 24 hrs
- Time of ovulation: 10 to 14 hrs after end of oestrus
- Period of maximum fertility: last 8 hrs of oestrus
- Gestation period: 310 days
- Period of involution of uterus: 25 to 35 days

Reproductive performance in buffalo

The reproductive efficiency of a species is determined by many different processes, which result from interaction among genetic and environmental factors. The processes involved, individually or together, include age of puberty or maturity, pattern of oestrus cycle and oestrus behaviour, length of breeding, ovulation rate, lactational anoestrus period, post-partum anoestrus, inter-calving period and reproductive life span. A combination of these traits is used to measure breeding efficiency or breeding performance in farm animals (Agrawal, 2003). Reproductive efficiency in buffalo is reported to be alarmingly low, causing severe economic losses to milk producers (Ranjan and Pathak, 1992).

Some of the difficulties observed with buffalo reproductive performance

1. The first post-partum heat varies greatly with season, breed and individual. It has been reported to appear within less than 60 days in some cases and over 230 in others. Average post-partum oestrus in the Murrah breed of India has been reported to be 100 days. The first post-partum oestrus is not always fertile, especially if it comes very near partus.
2. At birth buffalo have fewer primordial cells in the ovary than cattle have.
3. Compared to cows, buffalo suffer from higher atresia of follicles – 20 000 versus 100 000 (Bhosrekar, 2005).
4. Buffalo have a high proportion of silent oestrus and short duration oestrus. This is one of the most important problems in buffalo reproductive efficiency. It is even more problematic during the hot and humid months when it is compounded by thermal stress. Short and silent oestrus is the main reason why heat is often undetected in buffalo.
5. A large number of buffalo suffer from post-partum anoestrus, a complete absence of oestrus cycle and no signs of heat. This is one of the most common causes of buffalo infertility.

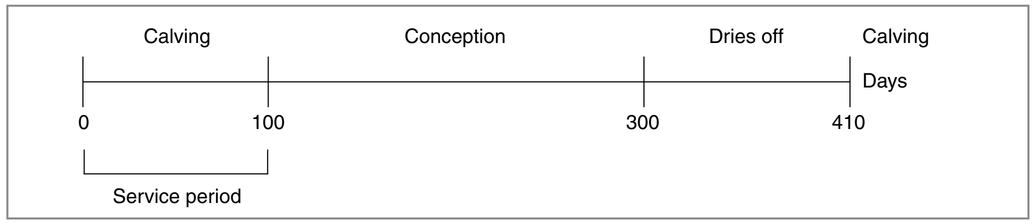
Reasons for poor reproductive performance

1. Climate affects both production and reproduction in all farm animals. However as buffalo are very susceptible to extreme conditions of heat and cold they show a tendency towards better performance during the cool months. In India 70 to 80% of buffalo conceive between July and February. In Italy the usual calving season is from September to December. In India it is reported that a lower number of services are needed during the July to February breeding season than in the March to June season (Agrawal, 2003). Buffalo are sexually activated by decreased daylight.
2. As mentioned earlier buffalo have poor thermal tolerance on account of an under developed thermo regulatory system and are unable to get rid of excess body temperature. If their housing is not designed to take care of this special species-specific requirement for adequate shade and ventilation, it will affect production and reproduction (Ramesh et al., 2002).
3. Nutrition plays a major role in the reproductive performance of buffalo, as with other farm animals. However there is a strong possibility that the consequences of poor nutrition are often interpreted as seasonality of breeding in buffalo. Under feeding, over feeding or unbalanced feeding, as well as deficiencies in minerals, vitamins or trace elements will cause reduced fertility in buffalo just as in other farm animals. A poor body condition score at calving affects fertility, characterised by prolonged post-partum intervals, reduced conception rates, and more services per conception. A very low protein diet can cause cessation of oestrus (Agrawal, 2003).
4. One of the reasons buffalo suffer from long post-partum anoestrus is because their natural behaviour of rolling in dirty water pools, and unhygienic shed conditions, cause buffalo to suffer from a high incidence of endometritis. The loose broad uterine ligaments and rolling in water cause torsion of uterus cases in buffalo. Buffalo also suffer from uterine prolapse and retention of the afterbirth. All these lead to uterine infections, delayed involution of the uterus and endometritis in buffalo resulting in the need for repeat breeding.

Hygiene during calving is very important for preventing endometritis in buffalo.

Approaches for improving reproductive efficiency

1. Providing the right kind of housing for buffalo to suit their natural behavioural requirements is important for their optimum performance. Free stall as well as tied systems work well for buffalo. However it is important that the housing provides sufficient shelter from both heat and extreme cold. During summer they have to be protected from extreme heat while in winter they have to be protected from extreme cold as well (Ramesh et al., 2002).
2. Showers or foggers with fans or wallowing tanks should be made available to buffalo during the hottest part of the day. Thermal ameliorative measures such as sprinkling and cooling are known to increase comfort levels and feed intake in buffalo (Sastry and Tripathi, 1988; Thomas et al., 2005).
3. Balanced feeding with mineral supplements, plenty of green fodder, and concentrate as per each animal's specific need, is necessary to bring buffalo into normal reproductive cycles.
4. Regular testing of all buffalo and bulls for infectious reproductive diseases like brucellosis and regular culling of infected animals are crucial for good reproductive health in the herd. Attending cases of difficult birth and retained placenta in time and maintaining good hygiene during parturition are also crucial to prevent reproductive disorders such as endometritis.
5. Wall charts, breeding wheels, herd monitors and individual buffalo records are important oestrus detection aids. See Appendix 1. The key to successful use of these inexpensive management aids is to accurately record every heat, beginning with the first heat after calving, and to make daily use of the information to identify those buffalo that are due to return to oestrus (Ramesh et al., 2002).



(Ståhl Högberg and Lind, 2003)

Figure 3: Calving interval.

Table 2. Inter-calving period in buffalo

Table 2: Inter calving period in buffalo.

Breed/Country	Gestation period (Days)	Age at first calving (Months)	Services per conception	Calving interval (Days)
Egypt	315		1.8 (AI)	452
Egypt	315		1.42	400
Iraq		37		408
Mediterranean/Bulgaria	315–318	37		434
Mediterranean/Italy	308–312	39		425
Mediterranean/Rumania	315	39		433
Murrah/Bulgaria	312	38		436
Murrah/India	307–314	38	1-3.5	334–537
Murrah/Nepal		52.3		594
Nili-Ravi/Pakistan	308	43–48		528
Native/Nepal		44.5		570

(Ståhl Högberg and Lind, 2003)

Breeding buffalo

Calving interval

Regularity in conception and a short calving interval are most important to achieve a high lifetime milk production. Calving interval in buffalo is highly dependant on management, climate and nutrition. It is therefore shorter in some regions and longer in others (see Table 2). In order to shorten the calving interval the female should be serviced again as soon as possible after calving, after providing a sufficient period of rest (see Figure 3). Weaning of calves at birth has been shown to decrease the service period in comparison to unweaned buffalo. A shorter service period will lead to a shorter calving interval – a calving interval of less than 410 days is recommended.

Natural mating

Except for a very small percentage of the world's buffalo, most are bred through natural mating. In most cases at the village level and in the home tracts of buffalo there is no information on the buffalo bull or on the dam's milk yield, and this information is seldom considered while breeding. This has been one of the major reasons for the diversity in both the productive and reproductive traits of buffalo. Even in Italy where buffalo production is more advanced, 95% of buffalo are bred naturally.

In Italy as well as in Egypt and India, one bull is maintained for 30 females. However as this method persists on the farms it is crucial to avoid the spread of venereal diseases which cause infertility and sterility in both sexes. In recent years these problems have shown an increasing pattern in buffalo herds in India (Ingawale and Dhoble, 2004).

Having a breeding bull with the dams all the time enhances the chances of fertile mating. This bull seldom misses a female in heat. However, to be able to calculate the time of calving it is advisable to keep some sort of record of expected heat. The observant farmer will soon learn how his buffalo behave when in heat and when to expect conception and calving. The females can be teased with a bull twice a day around expected oestrus. A breeding bull can be put into service from three years of age. In Italy, it is recommended that a breeding bull on a large farm should be exchanged after a maximum of five years. One bull, if managed correctly, can serve 20 to 25 females. On a smaller farm, the bull should be exchanged more often to avoid inter-breeding. If the bull shows signs of loss of interest in the females or is otherwise ill, he should be taken out of service immediately. In order to perform best, bulls must be fed high quality feed and be protected from heat and cold stress in the same way as the rest of the herd. Bulls should not be used for service more than twice a week.

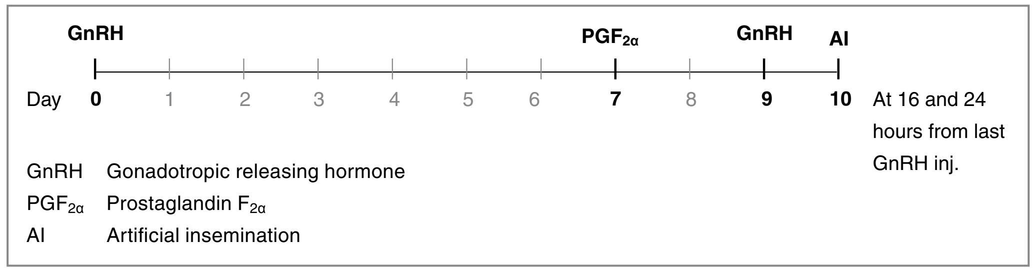
Artificial insemination (AI)
Genetic improvement of dairy animals to improve productivity has been the centre of focus of many advanced dairy countries. Using genetically superior animals can improve the reproductive efficiency of dairy species. With the help of AI improved genes are transmitted to a large number of offspring, and the interval between generations is reduced.

Buffalo generally have more difficulty conceiving by artificial insemination than cattle do. Reports from the National Dairy Research Institute, Karnal, India, show that the conception rate for first insemination is around 40% and the conception rate for third insemination is around 77%. Even in Italy only about 2 500 buffalo are inseminated per year specifically for progeny testing.

Although intensive research is going on at various universities and institutions around the world, breeding programmes for buffalo are not readily available for the common farmer. In the state of Gujarat in India, the National Dairy Development Board has a breed improvement programme called Dairy Herd Improvement Programme Actions (DIPA). The genetic gain of buffalo is being improved through selective mating of both sire and dam, to breed sires with the desired genetic traits. A progeny testing programme is being followed, producing 100 completed first lactation records of progeny per bull. Twenty bulls are put to test every year, with 2 000 doses of frozen semen from each bull being distributed to the selected villages, and 5 000 doses being stored until the test results are available.

Oestrus synchronization for fertility enhancement in buffalo
In order to solve these breeding and infertility problems and to enhance buffalo fertility, oestrus/ovulation synchronization can be adopted as an integral part of breeding. Ovulation synchronization trials have been successfully carried out in coastal Andhra Pradesh, in the districts of Guntur, Vijaiwada and Vishakapattanam in India. More than 400 buffalo from 24 villages were synchronized with the following protocol.

Figure 4: Oestrus synchronization with GnRH



(Bhosrekar, 2005)

It was reported by Bhosrekar (2005), that more than 700 buffalo were screened. Those having reproductive problems like endometritis, cystic degeneration of ovaries, adhesions etc. and poor body score were excluded from the synchronization programme. The buffalo included in the programme were vaccinated against foot and mouth disease (FMD), Haemorrhagic Septicaemia (HS) and Black Quarter (BQ) and were dewormed before the start of the

ovulation synchronization programme. The above-mentioned protocol was followed and buffalo were inseminated on the predetermined dates.

Most of the buffalo were of graded Murrah type (crossbred with local breeds) and suffering from post-partum anoestrus ranging from 110 to 300 days. One hundred percent of the buffalo came in heat and were inseminated as scheduled 16 and 24 hours after the last GnRH injection. On the first AI after synchronisation, the conception rate ranged from 19 to 29%. However on the second and third AI the conception rate improved to give an overall 77.3% conception rate from three inseminations.

Bhosrekar (2005) also reported another trial, of subcutaneous norgestomet implants in buffalo and cow heifers aged between four to six years, with well developed genital organs but not showing oestrus. The trial population of 75 buffalo and cattle heifers were in the areas of the Vishakapattanam dairy of Andhra Pradesh and the Kolar milk union of Karnataka in India. All the heifers came in heat and were inseminated. A twelve day protocol was followed.

Figure 5: Oestrus synchronization with Norgestomet

(Bhosrekar, 2005)

On first AI after synchronization the conception rate obtained was 48%. These trials have shown farmers a way forward for breeding management. Oestrus synchronization in heifers has helped to reduce the age at first calving. Feed supplementation is important too: two kilograms of mineral mixture were distributed to the farmers to feed the participating buffalo and heifers during the trial period.

Recording buffalo production
Replacing good milking buffalo with their own daughters instead of purchasing new buffalo from the market has some advantages. First, the spread of diseases is limited compared to selling and purchasing on the market. Next, the farmer has full control over his herd. He knows the history of each buffalo and can make more accurate decisions concerning the future. He will know whether the buffalo has had any diseases or problems with fertility. The buffalo will already know the farmer and will therefore be easier to handle, which is most important when it comes to machine milking. High milk yield, ease to milk, short let down time, high conception rate, and temperament, are some of the selection criteria which are desirable in a good breeding buffalo.

When creating a breeding programme it is important to keep records of the buffalo (see Appendix 2, Breeding records). History, milk yield of mother, peak yield, lactation length, and services per conception, are all parameters that it is important to track. When breeding for a higher milk yield it is especially important to register milk production correctly at regular intervals. The International Committee for Animal Recording (ICAR) has put up some basic rules for milk recording which are similar in all countries:

- All buffalo in the herd must be recorded.
- Milk yield should be recorded once a month.
- Lactation yield is calculated by summing the average yield of two consecutive tests multiplied by the number of days between tests.
- Lactation duration should be 270 to 310 days.

3. Housing and management of buffalo

Buffalo are highly productive animals and are able to perform even under very poor conditions of nutrition and management. However if they are provided with better conditions their productive efficiency could be improved. In this context several aspects need consideration, starting with housing, calf and heifer management, health care and information management.

Housing and management in backyard farms
In India most buffalo are reared in the backyard of the home, so much so that the buffalo is like a family member and is very well taken care of. The buffalo in turn has a close affinity for people. It is usually the lady of the house who takes care of these animals. The buffalo are tied up for the night in small shelters very close to the farmer's house. The shelters are cleaned early in the morning and the buffalo are then fed concentrates: home-made mixes of oil cakes and wheat bran. The calf is allowed to suckle to stimulate milk let down. Buffalo are hand milked and towards the end of milking some milk is left behind for the calf, which is then allowed to suckle again. There is very little awareness of pre- and post-milking hygiene. The animals are then fed around eight to ten kg of green fodder and in seasons of scarcity they are fed the same quantity of wheat straw. Around 09:00 to 10:00 they are set free to go and drink water in the common village pound, and they wallow in these tanks. For a couple of hours during midday and the afternoon they are tied up under shady trees and are again fed eight to ten kg of forage. Towards evening they are again taken to the shelters, fed concentrates, milked and then fed some roughage towards the late evening.

Housing and management in organised buffalo farms in the Indian subcontinent
In all the major cities of north India where large-scale buffalo production exists, owners of these farms have been in this business for the past two to three generations. In these organised dairy farms the routines are similar to the backyard farms, except the animals are not let out for wallowing. Usually one farm hand takes care of about ten buffalo. These animals are usually housed in tied up housing, in a head-to-head or tail-to-tail system, with a high raised manger in which the animals are fed. There would be a centrally located water trough where the animals are brought to drink water, and they will also be washed here once or twice a day. Animals are fed roughage two or three times a day and usually all the concentrate in the ration is fed twice a day during milking. The barns are washed and cleaned with water twice a day and manure is picked up and dumped into manure pits outside the barns. All these farm activities are very labour intensive.

Buffalo farms in cities like Mumbai have a perennial problem of limited space to house buffalo. Consequently non-lactating buffalo are seldom maintained at these farms. In Mumbai it is considered necessary for economic viability to average milk production of 8 kg per buffalo per day. All animals producing below 3 kg milk per day are examined for pregnancy status and all non-pregnant buffalo are sold off, usually for slaughter.

A few producers have salvage farms 100 to 150 km away: pregnant buffalo are transported and reared there until calving, after which they are transported back. Very little effort goes into identifying oestrus and improving conception rates. One buffalo bull is maintained for 30 to 40 buffalo and this bull is paraded among the buffalo twice a day to identify those in oestrus. As a consequence there is usually a 40 to 50% buffalo replacement rate. Most calves on these farms die, bringing calf mortality to an alarming 90%. Even apart from this the cost of production is very high. The demand for water, feed, fodder, and the removal of milk and dung from the farms results in a big influx of large and small trucks in and out of Mumbai. These trucks are estimated to require more than 100 000 litres of fuel per day. A similar situation prevails in several other huge cities in India as well as in Pakistan.

In contrast to this some buffalo farmers have moved out of the cities and relocated in larger farms in rural areas, where they can produce fodder and make optimum use of manure, improving their profits by 30 to 40%. These farms have adapted improved technology in feeding and milking and they have also been able to bring down the replacement rate to about 10 to 15% while restricting calf mortality to around 10%.

Management of dairy buffalo in backyard farms in India.




Large-scale dairy buffalo production around major cities of India.


Loose housing barn in Sangli, India.

Tied up barn in Yavatmal, India.

Organised buffalo farm in Latina, Italy.

Organised buffalo farm in Vermont, USA.

Housing and management of organised farms in Italy and other developed countries

In developed dairy countries like Italy buffalo are usually maintained in loose housing barns. However in areas with an extremely cold winter climate, barns should be designed in such a way that all animals can be housed in heated enclosures. Barn layout is thoughtfully planned for milking, feeding and movement of animals. Since labour is scarce and expensive most of the farm activities are mechanised. In most farms total mixed rations are fed from a feed mixer wagon, and there are common water troughs in every enclosure. Animals are usually grouped based on their stage of lactation and fed based on their productivity. However there are several farms that practise individual concentrate feeding combined with in-parlour feeding, using the Alpro™ feeding systems very effectively. Several farms have low cost barns with a large paddock area that is able to be cleaned every month, using a tractor. Several other farms have installed hydraulic manure scrapers which clean barns twice a day.

Improved housing and management of buffalo

Production performances of Murrah buffalo in tied up housing and in loose housing were studied, and the result proved beyond doubt that loose housing was more profitable, with increased yields (Jagatjit Singh et al., 1993). Giving the animals some protection from hot and cold seasons has provided some valuable information. In winter, curtains helped lactating buffalo to produce about 500 gm more milk daily than animals kept in an open shed (Gill et al., 1975). A higher conception rate of 80% was obtained in animals given showers in addition to wallowing facilities. This may also prevent early calf mortality (Raizada and Pandey, 1972).

In areas where loose housing cannot be practised buffalo should be tied up in a conventional half-walled shed through the daytime (after milking) from April to June. Over-herding of buffalo in the shed should be avoided, with a maximum 25 buffalo in a floor space of 25 ft x 50 ft. The animals should be let out into an open paddock or yard overnight, for exercise and to provide opportunity for natural breeding behaviour. They also need to be able to wallow for half an hour daily in clean water. Care should be taken to empty and disinfect the wallowing tanks at least once every weekday otherwise they can spread a variety of contagious diseases.

With proper management buffalo farming is indeed profitable. By deciding at birth whether a calf should be a milk producer or not, proper care of the calves is easier and less costly. The farmer can then focus on the future milk producers and cull the others. No matter how good the genetic potential, no animal will perform well if it is not cared for and fed properly. Bull calves from high yielding dams can be kept at the farm for future breeding. They can also be sold to breeding stations for progeny testing.

Housing in warm and temperate regions

As discussed, housing for water buffalo should protect against thermal stress – particularly from direct exposure to sun, heavy rains and cold weather. It must allow good ventilation.

Housing may therefore be different in different areas of the world, due to differences in climate. But all housing should allow enough space for each buffalo. The outdoor yard should preferably be covered with grass or maybe concrete, in order to prevent it from becoming an unhygienic mud hole in rainy periods.

Buffalo may appear to be misplaced in a hot and humid environment as they are more or less dependent on water for their cooling. This is not entirely true. Buffalo protected from direct sunlight do very well even during hot and humid days, partly because of their ability to lose heat through the respiratory tract. But note that high milk production requires a high feed intake, and that leads to higher metabolic heat production. High yielding buffalo thus have a disadvantage over lower yielding animals, and need more cooling facilities. If buffalo are not provided with proper shelters, wallows or cool showers, their feed intake and growth rate declines, and there could even be loss of body weight. Water intake increases and in the case of lactating buffalo there could be a drop in milk production. There is also a marked reduction in fertility.

Guidelines to consider for good management

1. The feeding, watering and milking place should always give shade and protection from heavy rains, either by trees or by a roof.
2. Cool water either from a clean river or served in an earthen pit, helps the animals to maintain their temperature. Drinking bowls are used extensively for buffalo as an efficient way to provide clean, cool, fresh water at all times. Water troughs should always be placed in the shade.
3. A paddock with trees gives very cheap and effective protection from sun. However, the trees may need to be protected from the buffalo also.
4. In hot humid climates it is better not to have walls. Walls may lead to inadequate ventilation, favouring bacteria and mould growth which makes the stable unhygienic. To protect the interior from sunshine (or heavy rain), curtains made from straw, textile or other suitable material can be used.
5. If possible provide buffalo with a wallow. However, the wallow should be one with clean water and not far from the farm. Spending time walking in the sun to and from the wallow costs more than it saves.
6. Showering the buffalo with cool water for three minutes twice a day has proven to be an efficient way for them to get rid of excess heat.
7. In tied up systems it is advisable to provide partitions between buffalo. This helps to reduce the number of cases of teat trampling and other udder injuries. Partitions are also useful while milking buffalo with bucket milking machines or in a pipe-line milking system.

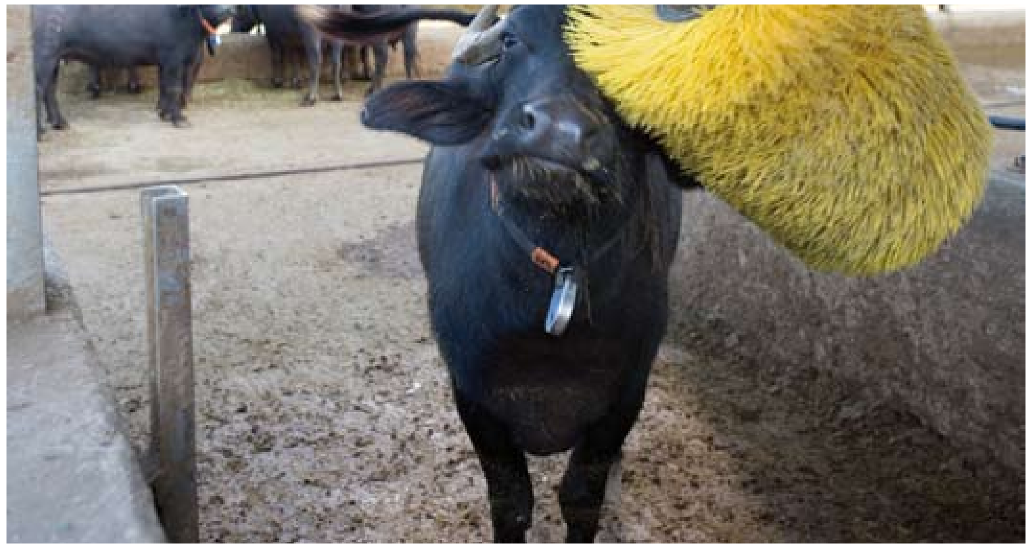
Thermal ameliorative measures to improve comfort levels of buffalo

The comfort or thermo neutral zone is described as the environmental temperature range in which no apparent demands are made upon physiological thermoregulatory mechanisms (Schein and Hafez, 1969). This temperature range is from 2 to 21°C for Bos taurus and 10 to 27°C for Bos indicus. But buffalo are more sensitive than cattle to direct solar radiation and high ambient temperatures. There are several reasons for this.

1. The dark body colour which absorbs heat well when the animals are exposed to sunlight.
2. The relatively fewer number of sweat glands per unit area of skin, which is unfavourable for high heat loss by sweating.
3. The thick epidermal layer of skin, which protects against heat loss by conduction and radiation.

Buffalo under a shower for cooling in Italy.

Cooling system at a buffalo farm in India.



Buffalo using the swinging cow brush.

Cattle have much more efficient thermoregulation mechanisms with their greater density of sweat glands which enable much more heat dissipation through sweating. In spite of their limitations buffalo adapt and thrive in hot and humid tropical and sub-tropical climates, principally due to the semi-aquatic behaviour by which a buffalo seeks water to immerse its body as a means of reducing the heat load (Mahadevan, 1992). Buffalo are known to have a higher water turnover rate than both Bos taurus and Bos indicus cattle (Siebert and MacFarlane, 1969). They are also less efficient users of water per unit of dry matter intake, have higher urine outputs and a lower percentage of kidney reabsorption of water (Moran et al., 1979).

Buffalo become more restless, nervous and aggressive during hot-dry and hot-humid climatic conditions. The percentage of restless, nervous and aggressive buffalo increases with increasing atmospheric temperature. During dry, hot and humid seasons almost all nervous and aggressive buffalo and more of the docile buffalo need oxytocin injections for milk letdown (Pathak, 1992). Buffalo seem to tolerate cold better than is commonly supposed. However, cold winds and rapid drops in temperature appear to have caused illness, pneumonia and even death (BSTID, 1981).

A study on the effect of certain summer management practises on lactating Murrah buffalo indicate that there is a definite increase in yield of about 20 to 25% by providing cooled drinking water and showering the animals during the afternoons (Radadia et al., 1980). A distinct improvement in the summer breeding of buffalo following managerial changes in farm practises has been reported (Roy et al., 1968). A higher conception rate, of 80%, was obtained in animals given showers in addition to wallowing facilities. Showers may prevent early embryonic mortality. This study further established that there is no quiescence of reproduction rhythm during summer. Buffalo heifers whose age at puberty coincides with onset of summer can also be located in heat and can conceive during summer (Raizada and Pandey, 1972). Resting animals under a tree instead of the hot sun could also prevent pre-natal mortality.

Housing in cold regions

The shelter should protect the animals from rain, snow and strong wind. It may be a simple construction with a roof and three walls. This system will allow the buffalo to go outside to graze when the weather allows it. There should be a feeding area inside the shelter in case of several days with bad weather. A separate heated milking area is advisable. Dry and clean bedding is important in cold weather to maintain animal health. In places with an extremely cold climate such as in Caucasia and the Balkans, with several winter months with a temperature below freezing, a heated barn may be necessary.

Pens for calves

Calves should be kept in individual pens for the first month. The pens should be easy to keep clean, with shelter from direct sunlight, rain, snow and draught. Keeping the calves in separate pens makes it easier to check what they eat, that they are growing properly, and to detect illnesses. Also, naval suckling is avoided and diseases are less likely to spread.

Individual pens are recommended for young buffalo calves.

The calves should have access to fresh and clean water at all times. Preferably, the buckets for milk and water should be outside the pen, in a steady holder within easy reach for the calf, but so the calves cannot splash liquid on the bedding. Humid bedding will facilitate growth of germs and parasites. The pen should contain a holder for hay and concentrate. These holders should be placed above the ground so that the calf cannot step or defecate in them.

Overall health control

Buffalo should be checked daily for injuries and illnesses. Wounds and open sores are a perfect growing place for all kinds of bacteria. It is easy to keep control over milking buffalo since they are studied closely twice a day. But apart from looking at the udder at milking the farmer or milker should observe the whole animal. Heifers, calves and bulls should be checked too, not just milking animals.

Lameness and large injuries are easier to detect than small scratches. Lameness can be caused by injuries in the hooves and legs as well as back pains. Touch the animal carefully all over the body, to locate the injury.

Large as well as small injuries must be taken care of. Bleeding sores may require veterinary attention although this is quite rare. Wounds should be carefully cleaned, and the best way is to use clean water and mild soap. Cleaning should be done very gently with clean hands and cloths. Chemicals such as ethanol and iodine might hurt. Never attend to wounds during milking! It is best to take the animal to a sick box or undisturbed area to attend to any wounds.

Looking at the faeces is an easy way to detect internal defects. This is easy in the milking place when one pail of faeces can be related to one buffalo. If the faeces look different from usual, the milker/farmer should be observant. If the buffalo is not eating properly or otherwise seems dull and unfit it might be a sign of some kind of illness.

Buffalo enjoying shade trees.

If an animal has some or all of the above mentioned symptoms it is advisable to measure the rectal temperature. Normal rectal temperature is 38º to 39ºC. If it is above that, the animal may have some sort of infection and a veterinarian should be called. The quicker a wound or an infection is taken care of, the less likely the risk of more buffalo becoming ill.

Parasites
In the tropics and subtropics, parasites, ticks and mosquitoes can be a big problem. Internal parasites may cause malfunction of the digestive tract and thereby decrease feed utilization. Ticks and mosquitoes cause discomfort and damage to the skin that in turn can lead to inflammatory processes.

Chemicals and drugs to fight parasites should be used both to prevent disease and to treat it. A disadvantage with chemicals and drugs is that they often leave traces in the milk. Some may be harmless and undetectable, yet others may influence processing of the milk and/or leave traces dangerous for human consumption.

Chemicals against parasites should be sprayed on the animals. Care must be taken not to spray in the eyes or genital area. The chemical should be applied with a sponge on the face and around the genitals. Dip baths, which are used for sheep, are most unsuitable for buffalo. The buffalo will see the dip baths as wallows and this has at least two disadvantages:

1. They may enjoy wallowing in the dip, and be difficult to get out. This prolonged immersion in the dip may harm their skin.
2. Buffalo natural behaviour is to defecate in their wallow, which would make the dip bath extremely unhygienic.

Vaccination programmes
There are a number of vaccines available for common diseases. Most vaccination programmes are more efficient if applied to young calves, with boosters given at regular intervals. This is further evidence of the advantage of recruiting calves at the farm.

Buffalo are sensitive to the same diseases as cattle. Diseases strike harder on animals in poor condition. In order to protect the animals, they should be properly vaccinated and de-wormed at regular intervals. It is important to include all animals at the farm in a veterinary control programme in order to minimize risks of disease outbreaks. In Italy, all controlled animals are checked at six month intervals for tuberculosis, brucellosis and leukosis. Infected animals are immediately taken out of production and culled.

Feeding

Buffalo are, like cattle, ruminants. This means that they utilize micro-organisms in the rumen to digest the feed. Feed eaten by ruminants is of vegetable origin. The ruminant is an expert in converting cellulose and other fibrous materials into high quality milk and meat. Their digestive capacity is greater than the non-ruminant. Ruminants "chew the cud", that is they regurgitate partly digested food to the mouth to chew it again, thus helping to breakdown this plant material.

Feed enters the rumen when swallowed by the animal. The rumen is an anaerobic environment, e.g. no oxygen is present. The feed is exposed to microbes such as bacteria, protozoa and fungi. These microbes attack the feed particles and by enzymatic action the components are broken down and used for their own metabolism, growth and propagation. The feed is masticated, regurgitated and exposed to microbes in the rumen. Large particles will become smaller and eventually be transported to the reticulum and further on. How long a specific feed particle will stay in the rumen depends on size, palatability and the fibre content of the feed. Buffalo have slower rumen movement than cattle, which leads to a slower rate of ingesta outflow. The pH of the rumen content is similar to that of cattle, and it is affected in the same manner. Normal pH is between six and seven, depending on feed and time of feeding.

Feed components can be divided into protein, energy (carbohydrates), fat, minerals and water. The breakdown and utilization of the different feed components are reviewed below.

The waste end products of the microbial attack are methane and carbon dioxide that are eructated. Volatile fatty acids (VFA) of which acetic, propionic and butyric acids are the predominant ones, are together with ammonia, absorbed through the rumen wall and transported via the blood to, for example, the liver and udder where they serve as building material for chemical compounds such as glucose, protein and fat. Most ammonia is utilised directly by the rumen microbes to synthesize proteins.

Ruminants are dependent on the function of the rumen microbes. Therefore, it is important to keep the rumen environment healthy. The easiest and best way is to feed a high amount of good quality roughage and a smaller amount of good quality concentrate.

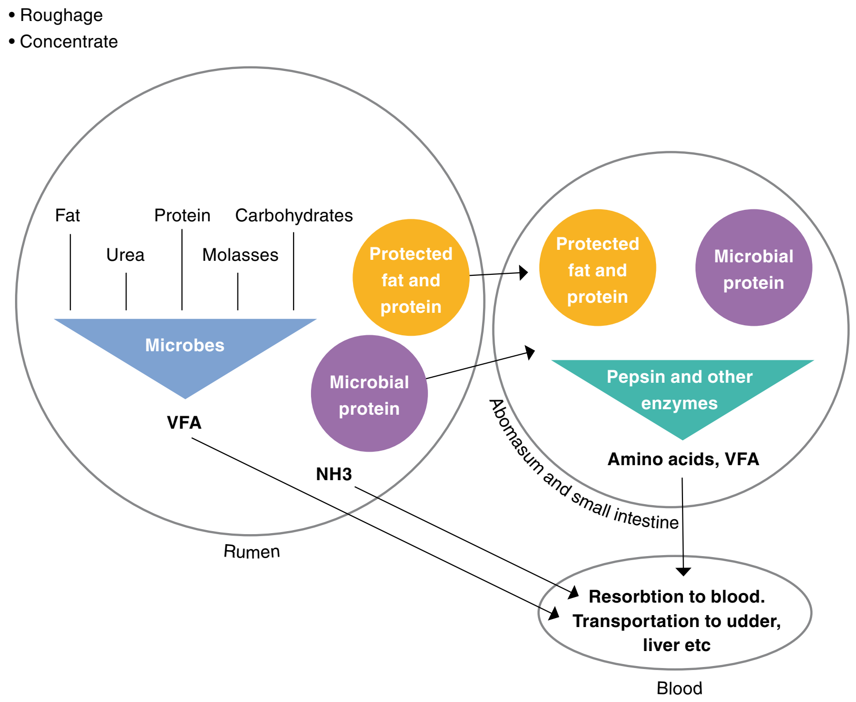


Figure 6: Feed degradation in the ruminant animal. (Adapted from Ståhl Högberg and Lind, 2003)

Protein

Almost all protein is attacked by the microbes and utilized in their metabolism and incorporated in the microbial mass. Microbial protein is of high quality and is absorbed as amino acids after being digested by gastric enzymes in the abomasum.

Ammonia which is absorbed by the rumen wall and transported by the blood to the liver, is converted to urea. When there is protein deficiency, urea can be utilized by the rumen microbes as a non-protein nitrogen source to build protein. In this way nitrogen is circulated and efficiently used by the animal.

Protein can be protected to withstand microbial attack. It is then called "by-pass protein". By-pass protein is only degraded in the abomasum and small intestine where it undergoes enzymatic attack similar to that of mono-gastric animals. By-pass protein is commercially available in some ready made concentrates and is usually given to high producers.

Carbohydrate

Carbohydrates are the main sources of energy for ruminants. Carbohydrates are the components of starch and fibres. Fibre is a common name for cell-wall components such as cellulose, hemi-cellulose and lignin. Starch can be degraded by animal gastric enzymes, whereas fibres cannot. Ruminants can utilize fibres to a larger extent than mono-gastric animals because of the ruminal microbes. However, lignin (wood-fibre) is not utilized. It is generally believed that buffalo utilize fibre more efficiently than cattle do. The efficiency of fibre digestion is five to eight percent higher in buffalo than in cattle.

Fat

Fat is required in small amounts for the ruminant. However, whatever fat is present in the feed undergoes microbial attack and degradation. Unsaturated fatty acids are to a large extent saturated. This is one of the reasons for the milk and body fat of the ruminant being of equal composition, largely independent of the type of feed given. If the fat can in some form be protected from ruminal degradation, and instead be utilized in the lower intestinal tract, it may be used as an additional energy source. However, it may then unfavourably alter milk fat composition. Too much unprotected fat in the diet depresses the ability of the microbes to ferment fibres, negatively influencing energy utilisation.

Nutrient requirements
In order to utilize animal, feed and economic resources as efficiently as possible, one must know the nutrient requirements of the animals. If an animal is wrongly fed this may lead to diseases, loss of production and thereby economic losses. By knowing what a specific animal needs, proper advice concerning purchase, cultivation and feeding systems can be given. Requirements for buffalo are more or less the same as for cattle, so nutrient requirement tables for dairy cattle may be used as a guide. A farmer must observe the animals and change the feeding system, with guidance from an extension officer, if the feed seems unsuitable.

Energy
Sources of energy are predominantly carbohydrates like fibre and starch, and fat to a lesser extent. For buffalo, fibre in the form of roughage is the most important and cheapest energy source. When calculating feed ratios for buffalo the term metabolizable energy (ME) is used. This means the amount of energy that can be used by the animal for maintenance, growth, lactation etc. The gross energy (GE) of the feed is the amount present in the feed when it enters the animal. Much of the energy is then converted into heat which is lost through thermal regulation. Energy is also lost in the faeces and urine as well as in the methane and carbon dioxide gases.

Energy is measured in calories (cal) and joules (J) (1 cal equals 4.18 J). It is most common to use the term Megacalories (Mcal) or Megajoules (MJ) which means a million cal or J. Another measurement is Total Digestible Nutrients (TDN). The unit for TDN is kg or gram.

The energy ratio in the feed may be increased by adding fat in protected form, thus transferring its digestion from the rumen to the intestinal tract. Feeding of protected fat has been proven to increase nutrient utilization. Feeding of unprotected fat in similar amounts has been shown to adversely affect nutrient utilization.

Protein
Protein is required for growth, tissue repair and milk production. Good sources of protein are leguminous forage, grain and oilseed cakes. Protein requirements are measured in Crude Protein (CP) in kg or gram (CP = nitrogen x 6.25).

Minerals and vitamins
Minerals are essential for many body functions. The macro-minerals calcium (Ca) and phosphorus (P) are especially important in milk production. They are also vital for the skeleton and the function of nerve impulses. Phosphorus is the mineral included in the body's energy metabolism, ATP. When considering Ca and P requirements for the animal it is equally important to consider the ratio in which they are given. The Ca:P ratio should be 2:1 since there is an antagonist relationship between the two minerals concerning uptake from the small intestine.

Vitamins are essential for total body function. Most vitamins are synthesized by the animal or its rumen microbes. Such vitamins, B, C and K (and to some extent D) do not need to be fed. Vitamin B is synthesized by ruminal microbes, vitamin K by intestinal microbes and vitamin C in the tissues. Vitamin D is formed when the precursor, found on the skin on animals and on grass, is exposed to UV rays, so in tropical countries vitamin D deficiency is rare. Vitamins A and E are not synthesized in the animal but must be supplied. Vitamin A is found in silage, fresh grass, dark green leaves, peas and carrots. Cereals are a source of vitamin E.

Mineral and/or vitamin mixture should always be supplied in order to fully meet the requirements. Animals which do not receive a ready made concentrate mixture with a mineral and vitamin supplement, must be fed a supplement in the form of "lick stones" to which the animals have free access, or fed a powder individually once or twice a day. Vitamins may be included in the mineral feed, but vitamins are sensitive and may be destroyed if exposed to sunlight. Care must therefore be taken to store vitamin supplements correctly.

Water
Water is essential for most body functions, such as body temperature control, milk production and maintaining blood plasma volume. Thermal regulation of the animal is the most water consuming process. The animal receives water in three different ways:
- drinking water
- water in feed
- metabolic water = water made from feed degradation.

Drinking water is the most important water source and should be of good hygienic quality. The water available in feed is highly dependent on the dry matter in feed. Straw, hay and cereals include little water, whereas silage and fresh grass may contain as much as 70% or more.

The water requirements of buffalo depend on:
- diet (dry matter)
- environment (humidity, temperature)
- physiological function (growth, pregnancy, lactation).

Generally, buffalo require more water than cattle under the same circumstances and should have access to clean cool water ad libitum.

Restricted water intake leads to a decrease in dry matter intake and thus negatively affects milk production and growth.

Salinity of water is seldom a problem in dairy buffalo feeding. A salt content of up to five grams per litre of water can be used for buffalo. However, temporary diarrhoea may be caused by water approaching the higher levels.

Feedstuff
The main diet for buffalo is roughage such as grass, legumes and straw. The roughage can be fed either fresh as pasture or in a cut-and-carry system, or conserved as hay or silage. Roughage is often complemented with grains, concentrate and agro-industrial by-products such as oilseed cakes, sugar cane tops etc.

Roughage should form the base of the feed ration and contribute to meeting at least the total maintenance requirements. Grains and concentrate should be fed only to meet additional requirements such as growth, pregnancy and milk production. Too much non-fibrous feed will alter the rumen environment. In the long run this could lead to serious problems in feed digestion causing loss of appetite, weight loss and a drop in milk yield. This is especially important for animals under stress, for instance from high growth rate or high milk yield. The roughage should be of good quality – of both nutritional quality and hygienic quality. This cannot be emphasized enough.

Types of roughage
The most common roughage is grass (of various species). However lucerne, berseem and clover are herbaceous legumes which have an advantage over grass as they are nitrogen fixing. This means that the plants will (with the help of bacteria) fix air-nitrogen and thus they are less dependent on the nitrogen content of the soil. These plants contain more protein than grass under the same circumstances. Lucerne (or alfalfa) has several advantages. It contains elevated amounts of calcium, vitamin E and caroteen which are of major importance for milk production.

There are also tree legumes which can be used as high quality feed, e.g. Leucaena leucocephala, Gliricida spp., Sesbania and others. However as many of the tree legumes contain anti-nutritional compounds which may depress digestibility as well as decrease feed intake, they should not be fed as the sole source of roughage. A maximum ratio of 50% tree legumes in the total diet can be considered a safe level. Since buffalo are strict grazers, the trees should be pruned and the branches or leaves given to the buffalo. Pruning with regular intervals of six to ten weeks increases re-growth of the leaves.

Straw provides lower quality roughage. Straw from rice, barley, wheat, sorghum etc. is widely used in feeding ruminants, but its protein and energy content is low. Rice or paddy straw has a high silica content in the cell walls which makes it difficult to digest.

Harvesting roughage
In the beginning of the growth season, the protein and energy content of grass is high and the lignin content low. Thus, the grass is of high quality. With maturity the protein and sugar content decreases and the cell walls become lignified. The growth pattern is the same for legumes although it is a little slower. It is therefore important to harvest roughage in the optimal period and to conserve it for use in dry seasons.

Pastures should not be over or under grazed. Over grazing leads to insufficient forage in the later season and the soil will be more vulnerable to erosion and permanent damage. In the case of under grazing, the pasture is not utilized efficiently. The grass will grow more quickly than the animals can eat it. Thus the grass will age, and its nutrient composition will change unfavorably to high lignin and low protein content.

In many areas, grass is not harvested even if not grazed and is left as "standing hay". However, this standing hay has a very low nutritive quality, close to that of straw.

Treatment of roughage
Chaffing, grinding and pelleting are ways to improve the digestibility of straws by making the nutrients available to the rumen microbes. Chemical treatments with alkali or ammonia are effective ways of improving quality. Ammonia treated, chaffed straw may even substitute for green forage for low milk producing buffalo.

Concentrate
The term concentrate means that a high amount of nutrients are concentrated in a small amount of dry feed. The most typical concentrates for tropical countries are different types of oilseed cakes. Oilseed cakes are derived as by-products of oil produced for human use. The remainder is pressed together to form a cake. The cakes have a relatively high energy content, but are mostly used because of their high protein content.

Other types of feed which can be classified as concentrate are molasses and urea. Urea can be used by the microbes as a source of nitrogen. The use of urea also requires an easily fermented energy source, such as molasses, for the micro-organisms. There should be an appropriate balance between protein and energy in the rumen for the efficient and proper growth and multiplying of the micro-organisms. Care should be taken to ensure that the quality of the concentrate is up to standard.

Grain
Barley, wheat, oat, rye, maize and sorghum grains are excellent feed for ruminants, given in balanced amounts. However, since they are used for human consumption their use as animal feed should be carefully considered.

Voluntary intake
The definition of voluntary intake is the amount of feed an animal can eat per day. It is commonly expressed in kg of dry matter or in percent of live weight.

After having considered the nutrient requirements of the animal and the feed stuff to be used the proper feeding regime can be calculated. However, one must take into consideration how much the animal can eat. There is a physical limit as to how much feed the animal can eat in one day.

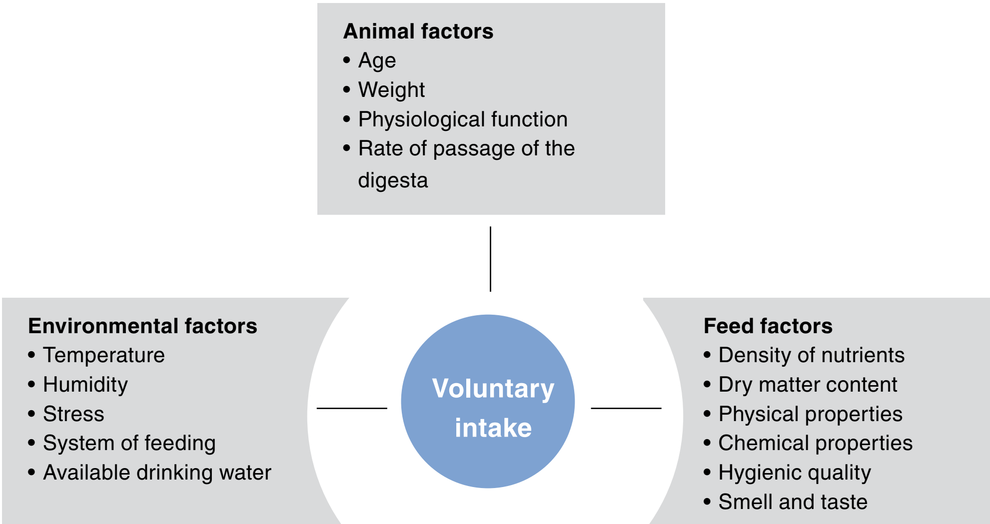


Figure 7: Factors affecting voluntary intake. (Adapted from Ståhl Högberg and Lind, 2003)

A high producing lactating buffalo can eat more than a low producing one. Similarly a growing heifer may eat more than a dry buffalo. As pointed out before, feed intake decreases with high environmental temperature and humidity. Individual feeding usually results in higher feed intake, since there is less competition for feed and a more relaxed atmosphere.

A rough estimate of voluntary intake for a buffalo heifer is 2.2 to 2.5% of its live weight per day, if provided with a small portion of straw, a large portion of green feed and some concentrate. A milk producing buffalo should be able to consume up to three percent of its live weight in good quality feed. Too high a ratio of straw in the diet reduces voluntary intake. A protein content of less than six percent also reduces intake of that feed.

Practical feeding of the lactating buffalo

Lactating buffalo should be given the best feed the farm can offer. Producing milk is one of the most energy demanding biological processes. Weight loss is common in high producing animals during the first month of lactation because they can not consume a sufficient amount of energy. A popular term is that the animals are milking off the fat. It is therefore important that the buffalo is in good health status at partus. In Table 6, examples of various feeding regimes for lactating buffalo are given. A well balanced ratio of protein, energy, vitamins and minerals in a palatable and tasty feed is the best way of increasing milk production and live weight, as well as improving health and fertility.

Traditional feeding patterns for buffalo all over the world are subject to seasonal forage and crop production, which affects the level of milk production. Forage is insufficient during the dry season and abundant during the rainy season. Shortages are overcome by conserving forages as hay or silage.

Formulating feed ratios for milk producing buffalo

Formulating feed ratios for milk producing buffalo starts with theoretical calculating of the requirements. As there are no standardized international tables for dairy buffalo requirements, the calculations in Table 3 are based on dairy cattle nutrient requirement tables (NRC, 1988).

It is important to know the buffalo live weight. This is most accurately done by weighing the animals three times in one week and calculating the average. However, this requires an animal scale and is very time consuming. Weighing the animals once is good as a guide. Once the weight is known, requirements for maintenance can be extracted from Table 3. Milk yield should also be known, as well as fat percentage. Recommendations are to use at least three days of milk records to calculate the average yield and fat percentage. For simplicity, the yield is then calculated as four percent fat corrected milk (shown in Table 3). Total requirements are gained by summing the requirements for maintenance and for milk production. The requirement for milk production is based upon the calculation of fat corrected milk (FCM) using the formula:

4% FCM, kg = 0.4 x (milk yield, kg) + 15 x (milk yield, kg x fat%/100)

Table 3: Nutrient requirements of buffalo

Requirements for live weight (kg)	Energy (ME in Mcal)	TDN (kg)	Total crude protein (g)	Calcium (g)	Phosphorus (g)
450	13.0	3.4	341	18	13
500	14.2	3.7	364	20	14
550	15.3	4.0	386	22	16
600	16.3	4.2	406	24	17
Requirements for milk yield per kg 4% fat corrected milk					
	1.24	0.32	90	2.73	1.68

Table 3: Nutrient requirements of buffalo

(Tables 3 to 9 are all adapted from Ståhl Högberg and Lind, 2003)

For a buffalo weighing 550 kg and yielding 7 kg of milk with 7.2% fat per day, the amount of 4% fat corrected milk comes to 0.4 x 7+15 x (7 x 0.072) = 10.36 kg per day.
Nutrient requirements for this animal could be calculated as follows:

Table 3a: Nutrient requirements of a buffalo weighing 550 kg and yielding 7 kg of 7.2% fat milk

Requirements for live weight (kg)	Energy (ME in Mcal)	TDN (kg)	Total crude protein (g)	Calcium (g)	Phosphorus (g)
Maintenance req.	15.30	4.0	386.0	22.0	16.0
Req. for 10.36 kg FCM	12.85	3.32	932.4	28.28	17.4
Total req. per day	28.15	7.32	1318.4	50.28	33.4

Table 3a: Nutrient requirements of a buffalo weighing 550 kg and yielding 7 kg of 7.2% fat milk

If the animal seems to be too fat at the time of weighing, the maintenance requirements may be reduced by ten percent. Similarly, if the animal is too skinny, ten percent may be added to the maintenance requirements. The feeding regime of the buffalo can then be decided. Primarily, crops grown on the farm should be included in the diet. For optimal economic feeding regimes the feed should be analyzed at a laboratory for dry matter content, energy and crude protein, and for calcium and phosphorus. The example in Table 4 uses feedstuff analyses from NRC's tables (1988) for dairy cattle.

Table 4: Examples of nutrient content of common feedstuffs used for feeding buffalo

Feed name live weight (kg)	Energy (ME in Mcal)	TDN (kg)	Total crude protein (g)	Calcium (g)	Phosphorus (g)
Alfalfa hay	2.36	0.63	200	15.4	2.2
Napier grass	2	0.55	87	6	4.1
Rape fresh	3.16	0.81	164		
Oats	2.73	0.6	140	2	2
Sorghum fresh	2.36	0.63	88	4.3	3.6
Sorghum silage	2.14	0.58	62	3.4	1.7
Maize silage	2.67	0.7	81	2.3	2.2
Wheat straw	1.51	0.44	0	1.8	1.2
Rape seed	2.93	0.76	390	7.2	11.4
Cotton seed cake	2.71	0.71	448	1.9	1.2
Wheat bran	2.67	0.7	171	11.8	3.2
Molasses	2.67	0.7	103	11	1.5
Urea	0	0	281	0	0

Table 4: Examples of nutrient content of common feedstuffs used for feeding buffalo

Taking the previous example: the 550 kg buffalo yielding 7 kg milk with a fat percentage of 7.2 giving 4% FCM of 10.36 kg, the daily requirements are:

28.15 Mcal of metabolizable energy,
7.32 kg TDN,
1.32 kg crude protein,
50.28 g calcium and
33.40 g phosphorus (Table 5).

The corresponding estimated feed intake would be 550 x 0.03=16.50 kg dry matter (DM). In this example, forage should cover the energy requirements of 15.3 Mcal.

It is important to note that silage should not form the sole source of roughage because it has a high amount of easily fermentable carbohydrate and a physical structure which does not really stimulate rumen contraction. As a rule of thumb, the amount of silage in a diet should not exceed 30% of the total dry matter intake if concentrate is also given. If the diet is solely made from roughage the silage ration may be increased to 60%. On the other hand, alfalfa hay contains much too much protein and therefore it is important to give a mixture of silage, hay and perhaps straw.

In this example the maintenance requirements can be met by giving 5 kg wheat straw and 5 kg maize silage on a dry matter basis. Alfalfa hay of 2 kg and 8 kg of wheat straw would also provide the requirements, but it is not likely that the buffalo would eat it, because of its texture.

We need to provide another 12.85 Mcal for the milk production. This can be provided by increasing the amount of forage if it is of good quality, or it may be provided by concentrate. However, the costs for different fodder should be taken into account. If the farm can produce sufficient forage of good quality it is probably wiser to increase the amount of home grown forage in the diet instead of purchasing expensive concentrate.

In accordance with Table 5, dry matter from 4 kg maize silage together with 5 kg alfalfa hay and 5 kg wheat straw gives a balanced diet containing the necessary nutrients. Only phosphorus needs to be added. The Ca:P ratio should be approximately 2:1, so another 22 g P needs to be provided in this diet. It is also clear in this example that the buffalo should be able to produce milk without being fed any concentrate. The total amount of dry matter comes to 14 kg here, and we had calculated on 16.5 kg. To increase the dry matter intake some of the wheat straw may be replaced by some maize silage and/or alfalfa hay (Table 6).

Making silage.

Table 5: Diet calculation for milk yield up to 10 kg of 7.2% fat milk

Table 5: Diet calculation for milk yield up to 10 kg of 7.2% fat milk

Feed name live weight (kg)	Energy (ME in Mcal)	TDN (kg)	Total crude protein (g)	Calcium (g)	Phosphorus (g)	DM (kg)
Total requirement per day						
7 kg of 7.2% fat milk	28.15	7.32	1 318.4	50.28	33.4	16.5
Availability of nutrients through roughages						
Maize silage	10.68	2.8	324	9.2	8.8	4
Alfalfa hay	11.8	3.15	1 000	77	11	5
Wheat straw	7.55	2.2	0	9	6	5
Diet content						
	30.03	8.15	1 324	95.2	25.8	14
Deficiency/surplus						
	1.88	0.83	5.6	44.92	-7.6	-2.5

Table 6: Examples of feeding regimes for a lactating buffalo weighing 550 kg

Table 6: Examples of feeding regimes for a lactating buffalo weighing 550 kg

Milk yield (7% fat)	4% FCM	Kg dry matter of roughage	Kg dry matter of concentrate
4 kg	5.8 kg	3.5 alfalfa hay + 3.2 maize silage + 4 wheat straw **or**	2 wheat bran
5 kg	7.40 kg	2 alfalfa hay + 4 maize silage + 4 fresh sorghum	
7 kg	10.15 kg	5.3 alfalfa hay + 5.5 maize silage **or**	
		4.5 alfalfa hay + 5 maize silage + 2 wheat straw **or**	
		3.5 alfalfa hay + 5.5 maize silage **and**	2 wheat bran
9 kg	13.05 kg	5.6 alfalfa hay + 5.5 maize silage + 3 wheat straw **or**	
		4.5 alfalfa hay + 5.5 maize silage **and**	2.5 wheat bran
10 kg	14.50 kg	6 alfalfa hay + 7 maize silage **or**	
		9 alfalfa hay + 3 maize silage **and**	1 cotton-seed-cake
12 kg	17.40 kg	7 alfalfa hay + 5 maize silage + 2 wheat straw **and**	1.5 wheat bran
15 kg	21.75 kg	7.5 alfalfa hay + 6 maize silage **and**	2.2 wheat bran + 0.5 molasses + 0.3 urea
		or 8 alfalfa hay + 6 maize silage **and**	2.5 wheat bran + 0.5 molasses
		or 13 maize silage **and**	3 cotton seed cake

Including urea in the diet may be a cheap and good way to “help up” a low protein diet. One must remember, however, that a source of highly soluble carbohydrates such as molasses must be included in a urea diet. The maximum level of urea should correspond to less than 25% of the crude protein. An alternative is to feed ready made urea-molasses blocks.

Controlling the animals’ intake of feed is a good practice. Low yielders tend to eat more than they require and at the same time it is difficult for the high yielders to eat enough. It is therefore vital that the feed is analyzed and the milk yield known, in order to provide the correct nutrient requirement for each animal.

Practical feeding of the calf

Calf mortality can be very high in some countries. In India it is often 30 to 40% before three months of age, and in Italy the figures may be higher. This is caused by malpractice such as negligence, limited milk feeding, injuries and diseases. By increasing the amount of feed to the calf's requirements and by following sound calf management practices as outlined here, mortality can be decreased.

Colostrum is the most important and most suitable feed for the newborn calf. It contains all the nutrients needed along with the vital antibodies. It is crucial for the survival of the calf that it receives colostrum during the first 12 hours of its life, the earlier the better. The calves should be given colostrum as long as the mother provides it, e.g. three to four days. Any surplus colostrum can be frozen and then thawed and carefully heated to 39°C before feeding. If no freezing facilities are available colostrum can stay fresh for a couple of days if it is cooled in a hygienic container. Colostrum can be fermented with living lactic acid culture. Fermented colostrum can be kept for at least a week and up to two weeks if cooling facilities are available.

If the calf is not allowed to suckle its mother it should be provided with colostrum as soon as possible after birth. If it is not possible to feed the calf directly after milking the buffalo, colostrum should be cooled in order to maintain hygienic quality. When it is time to feed the calf, the milk should be carefully heated to no more than 39°C. Colostrum must never be boiled. Boiling the milk destroys the antibodies which are needed for the calf.

The natural eating behaviour of the calf is to suckle its mother often, and to consume a small amount of milk at each suckling period. It is best for the calves reared under artificial conditions if their eating behaviour can be as "natural" as possible. Colostrum should be fed to the calf several times a day, preferably more than twice a day, at equal intervals.

The calf should be trained to drink from a bucket. The easiest way to do this is to dip clean fingers into the milk and then allow the calf to lick and suck the fingers. The hand is then gradually drawn into the milk in the bucket while the calf is still suckling. Once the calf has learnt to drink it is easy to feed. The calf may need assistance for five days. There are special nipples that can be put in the bucket. Once the calf suckles those, it will need less assistance from the trainer.

Table 7: Nutrient requirements of pre-ruminant calves

Age (d)	Daily gain (kg)	DCP (g)	TDN (g)	ME (Mcal)	Ca (g)	P (g)	Vit A (1 000 IU)	Vit D (IU)
0–15	0.20	80	400	1.5	2.5	1.5	1.5	200
16–30	0.30	90	500	1.7	3.0	2.0	1.5	250
31–60	0.30	125	800	2.4	3.5	2.5	1.7	250
61–90	0.35	150	1 000	3.6	4.0	3.0	2.0	260

Table 7: Nutrient requirements of pre-ruminant calves

After the colostrum period, whole milk should be provided to the calf until 15 days of age at a level of 1/8th to 1/10th of the calf's body weight (see Table 7). Milk replacer can be fed along with the whole milk provided that it has a certain composition of nutrients. It is not advisable to completely substitute whole milk with milk replacer. Milk and/or replacer should be offered to the calf on at least two occasions per day. The milk and/or replacer should be served at body temperature (38-39°C).

At two weeks of age, the calf should be introduced to good quality green feed and concentrates, as a calf starter (Table 9). This stimulates the rumen to grow and function properly.

By following the feeding schedule in Table 8 and ensuring the feed contains the nutrient requirements listed in Table 7, a daily gain of 0.35 kg can be expected in Murrah calves.

Table 8: Feeding schedule for calves

Age (days)	Whole milk (l)	Skim milk (l) /milk replacer	Calf starter (g)	Hay (g)
0–14	4*	–	–	–
15–21	3.5	–	50	300
22–28**	3.0	–	300	500
29–35	1.5	1.0	400	550
36–42	–	2.5	600	600
43–49	–	2.0	700	700
50–56	–	1.5	800	800
57–63	–	1.0	1000	1000
64–70	–	–	1200	1100
70–77	–	–	1300	1200
78–84	–	–	1400	1400
85–91	–	–	1700	1900

first 3 to 4 days, feed colostrum.ensure a smooth and gradual change to milk replacer*

Table 8: Feeding schedule for calves

An alternative method is to rear calves with foster mothers. In Italy, 40% of calves are reared by suckling an old and less productive buffalo or even a cow. This has several advantages, particularly that little labour is required to feed the calf and the calf will secure its own nutrient intake. Calf starters similar to those mentioned in Table 9 can also be used to feed buffalo calves.

Table 9: Calf starter mixture

Table 9: Calf starter mixture

Feed source	Amount
Crushed barley	50%
Groundnut cake	30%
Wheat bran	8%
Skim milk powder	10%
Mineral mixture	2%
To increase palatability, add, per 100 kg of starter	
Molasses	5–10 kg
Salt	500 g

Buffalo calves fed with stovers of maize, bajra and oat cannot meet their nutrient requirements and are often in negative energy and protein balance. However, feeding the calves treated stovers with a urea-molasses-salt complex both enhances the palatability of the stovers as well as the digestibility and nutrient value. Buffalo male calves weighing 150 to 200 kg have been proven to increase their intake of treated stovers compared to untreated ones, thus increasing weight gain and improving nitrogen balance and health.

See DeLaval 2002, Efficient Calf Management.

Practical feeding of the heifer

The heifer is a future milk producer and has to be given a fair chance to produce well. She must have an average daily gain of at least 500 grams per day in order to reach the optimum size for calving within a reasonable time (500 kg at 32 to 40 months). Unfortunately, many farmers consider heifers to be unproductive and hence they are not properly fed. Since lack of feed is often a reality, it is not possible to feed all animals in the herd with high quality feed. The following advice could be considered as a rule of thumb, bearing in mind that the quantity and quality of feed varies with the season. Furthermore, the condition and growth rate of the heifer should be checked regularly to see that she has the appropriate growth rate. If not, her feeding schedule should be adjusted.

Heifers should be fed seasonal green feed of about 4 to 7 kg dry matter (DM) together with some straw and concentrate or grain per day. If the green feed is leguminous the ration of green feed and concentrate or grain can be reduced and the amount of straw increased. However it is important to feed the heifers a small amount of grain or concentrate, not less than 0.5 kg per day, to help both them and their rumen to become accustomed to this type of feed prior to partus.

If available, ammonia treated straw could be given along with low quality green feed and concentrate. Silage could be given to heifers, but it is often a very valuable feed saved for milk producing animals. However, a few months before partus the heifer should slowly be introduced to the feed she will have as a milk-producing buffalo.

Maximum voluntary intake for the heifer is obtained at approximately 1 to 1.5 kg DM of straw together with 3 kg DM of green feed and 1 kg concentrate.

Straw fed to appetite is not enough to keep or increase the body weight of growing buffalo. Straw fed to growing stock should preferably be ammoniated and further supplemented with green feed or hay and some kind of concentrate to give the best result.

Practical feeding of the dry buffalo

Feeding the dry buffalo is concerned with preparing for partum and high milk production. In the last two months of gestation the buffalo has increased requirements for nutrients for foetal growth. Experiments with Murrah buffalo has shown that the best economical way of feeding dry buffalo two months before calving is at 125 percent of the recommended level for cattle (NRC, 1988). By giving the dry buffalo a little more than she needs, her chance of building up body reserves and being in good physical condition is improved.

5. Milking management of buffalo

In dairy buffalo production world-wide, milking is one activity that is considered to be sensitive and labour intensive. In general buffalo are known to be difficult to milk. A number of researchers from different parts of the world have reported the problem of disturbed milk ejection and rapid termination of lactation when calves die or if the usual milker is replaced (Sastry and Tripathi, 1988). In a survey in India on prevailing milking practices, it was reported that most farmers have experienced these problems with their buffalo. In order to overcome the problems, 65% of the farms surveyed used concentrate feeding during pre-stimulation to improve milk let down, while 13% used injectable oxytocin to induce milk ejection (Varma and Sastry, 1994). Although not documented it is a well known practise in large buffalo herds, to use oxytocin injections to achieve milk let down. One of the disadvantages of this is that continuous oxytocin treatment could lead to addiction (Bruckmaier, 2003). To avoid these treatments and their side-effects, it is necessary to understand the factors that influence the efficient extraction of buffalo milk, such as milk accumulation, storage of milk, and milk ejection.

Much work has been done on the milking management of dairy cattle, sheep and goat, but comparatively little research data is available on the milking management of buffalo (Sastry and Tripathi, 1988). DeLaval has been conducting research at different levels in different parts of the world to develop machine milking techniques that suit the species-specific requirements of buffalo. DeLaval was the first to supply milking machines to buffalo farmers in Italy. In the past decade DeLaval has been the major supplier of milking machines to buffalo farmers in India, Egypt and Europe.

In most developed dairy countries where there is milk production, machine milking has been successfully practised for more than 30 to 40 years. In India today more and more buffalo farms all over the country have started using machines to milk their buffalo herds. There are many farms where herds of 300 to 500 buffalo are now machine milked (Thomas et al., 2004). Soon there will be a major shift towards machine milking in large and small buffalo farms all over India, because of the advantages and convenience of machine milking buffalo. This change will be driven by several important factors. It is more economical to machine milk buffalo in commercial dairy herds. Apart from the economic benefit, other benefits include ease of operation (ergonomics) as the milker does not have to sit crouched under buffalo, improved milking hygiene, and improved milk quality.

Machine milking of buffalo in a parlour on a large commercial farm.

Machine milking with a bucket milking machine on a small family farm.

Anatomical and physiological differences between cattle and buffalo with respect to milking

Udder structure, teats and machine milking

Several factors have a bearing on the complete removal of milk and stripping yields during machine milking. These factors include teat length, teat thickness, teat canal length, effective diameter of the teat canal during milking, the minimum and maximum biological force that keeps the teat canal closed, and the stiffness of the teat when full of milk prior to milking.

Figure 8: Bowl shaped udders in Murrah buffalo.

In buffalo the variation in udder shapes is much greater than in dairy cows, because most buffalo are not selectively bred. Buffalo udder shapes can be classified as rounded, bowl shaped and cup shaped. Bowl shaped udders are found on 65% of Indian Murrah buffalo. This udder shape is more desirable than others as these udders extend forwards and backwards rather than downwards (Sastry and Tripathi, 1988).

Buffalo have much longer teats than dairy cattle. The front teats are, on average, 5.8 to 6.4 cm long, with a diameter of approximately 2.5 to 2.6 cm. The hind teats tend to be 6.9 to 7.8 cm long and their diameter 2.6 to 2.8 cm (Thomas et al., 2004). Among Indian Murrah buffalo the different teat shapes can be classified as bottle shaped, conical and cylindrical: 60 to 80% have cylindrical teats, 15 to 30% have conical teats and just 3 to 8% have bottle shaped teats.

The epithelium of the streak canal is thicker and more compact in buffalo than in cattle. The sphincter muscle around the streak canal is thicker in buffalo than in cattle. More force is therefore required to open the streak canal. The teat sphincter tonus has been reported to be at least 400 mm Hg negative pressure in buffalo (the tension falls slightly after calf suckling and hand milking). The length of the streak canal in buffalo ranges from 1.9 to 5.5 cm compared to 0.5 to 1.5 cm in cattle (Thomas et al., 2004). These are some of the major causes of buffalo being categorised as “hard milkers”.

Cylindrical shaped teats are the most desirable but they should not be more than 5 cm long with a diameter of not more than 2.5 cm.

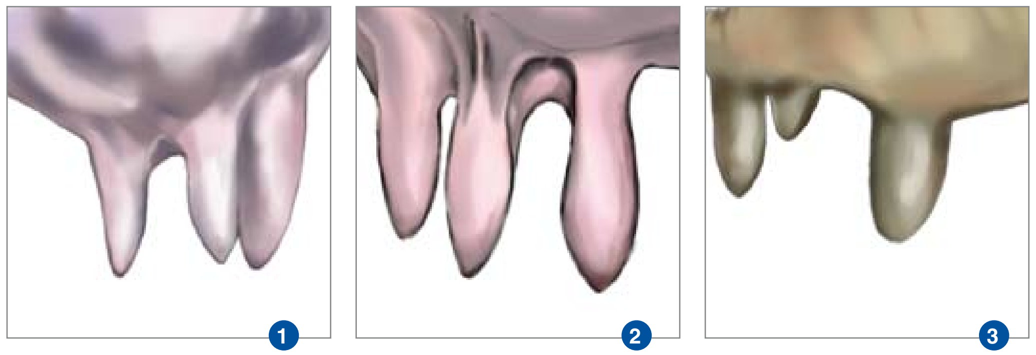


Figure 9: Buffalo teats

1) Conical shaped teats.

2) Bottle shaped teats.

3) Cylindrical shaped teats.

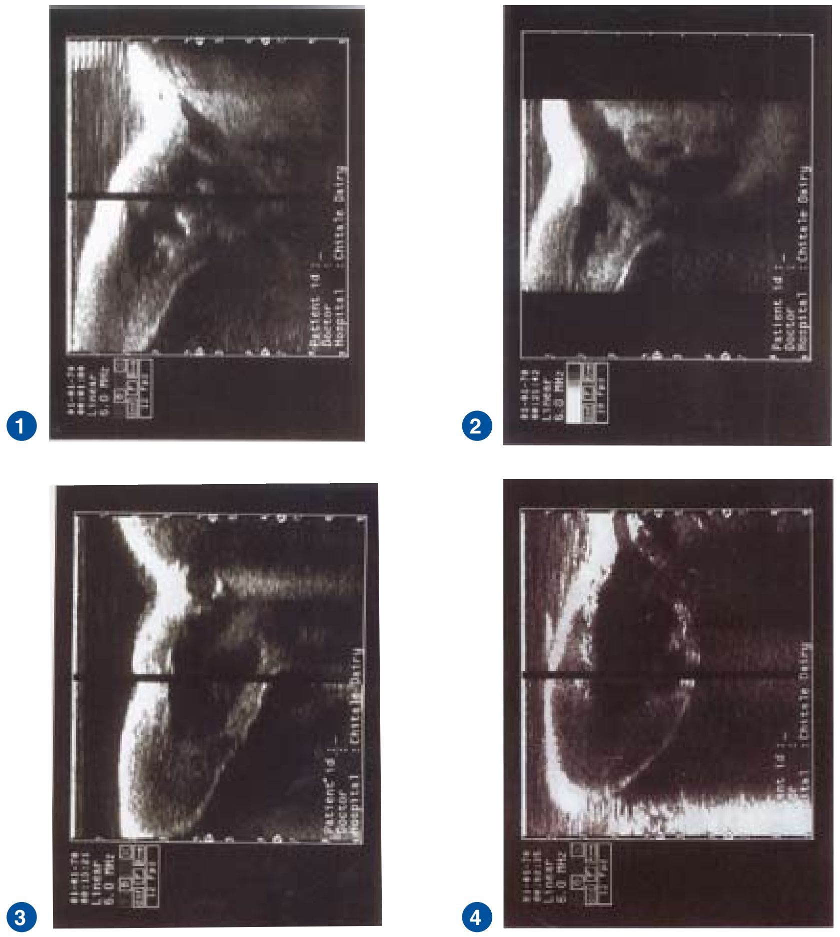
Ultrasound cross-section of a buffalo udder:

1) Fore udder cistern

2) Hind udder cistern

3) Fore teat cistern

4) Hind teat cistern.



Milk accumulation and storage in buffalos

In most mammalian species the mammary gland consists of secretory and ductal tissue. Among the prominent dairy species of cattle, goats and sheep, as milk secretes it is transferred within the gland via the ducts into a large cistern that drains out from a single orifice for each lobule (cluster of alveoli). As a consequence, a relatively large portion of the secreted milk is stored as the cisternal fraction of milk in these species. The cisternal area of the mammary gland in dairy species is referred to as two separate cavities, the teat and gland cisterns. Of the total milk secreted in 10 to 12 hours in cows, the cisternal fraction has been reported to be between 20 to 40% while in goats and sheep, the cisternal cavities are relatively larger than in cows. However recent studies on buffalo where the cisternal and alveolar fractions were measured separately revealed that in buffalo 95% of the milk secreted between milking is stored in the secretory tissue (Thomas et al., 2004).

The rate of milk secretion and the process of milk removal are both influenced by the size of the cistern. In both sheep and cattle, it is evident that animals with large cisterns are better producers of milk and are well adapted to milking routines with longer milking intervals and short stimulation. It is also reported that animals with small cisterns are more susceptible to the short-term autocrine inhibition of milk secretion where the presence of milk in large quantities in the secretory tissue leads to reduced milk secretion. This effect is less intense if the milk is accumulated in the cisternal area and not in close proximity to the secretory tissue. In buffalo the cisternal area is relatively much smaller than in cattle, sheep and goats, so it is possible that if large portions of milk remain in the secretory tissue, not extracted, it could lead to an immediate drop in milk yield. It is therefore crucial to empty the udder of buffalo efficiently during milking.

Milk ejection

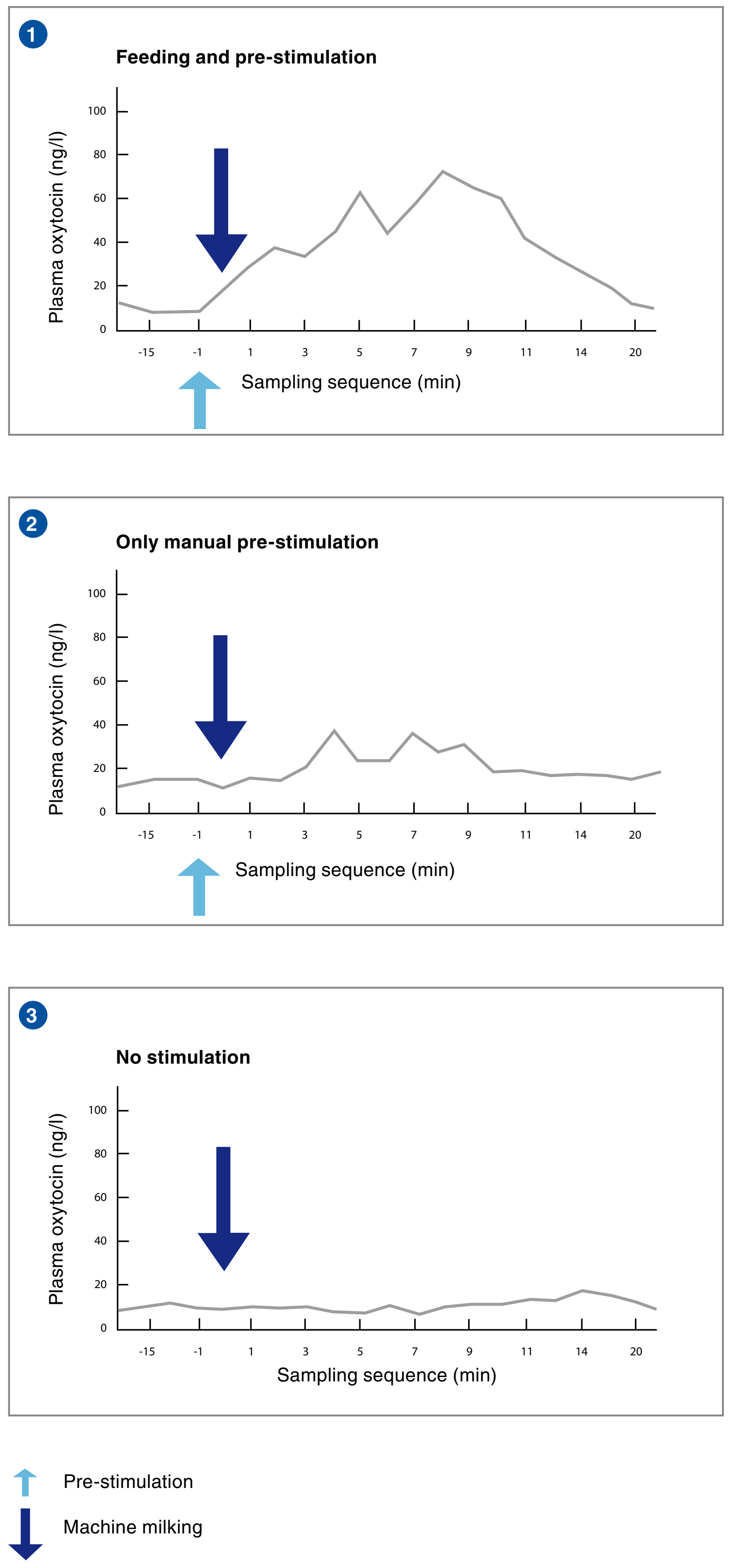


Figure 10: Milk ejection. The effect of different pre-milking actions on the milk ejection hormone, oxytocin.

1) With feeding and pre-stimulation.

2) Manual pre-stimulation only.

3) No stimulation.

(Developed from Thomas et al., 2004)

Milk ejection and milk removal

Milk ejection in mammals is a process that is controlled by the maternal instincts of the lactating animal. It is a complex process involving a number of interactions between the mother and her young. The lactating animal's eyes and ears recognise a calf as it approaches for suckling, and she identifies her own calf by smelling it. When the infant or young one suckles the teat, this triggers milk ejection. The teats are densely supplied with nerves and have a large numbers of receptors that are sensitive to touch, pressure and temperature. The stimulus received by the teats is conducted via the spinal cord to the pituitary gland causing the release of oxytocin, the milk ejection hormone. As a consequence of increased blood levels of oxytocin, myoepithelial cells surrounding the secretory tissue in the udder contract and milk is expelled out into the cisternal area. However milk ejection can be easily disturbed by stress, pain or any other perceived threat situation that is part of the fight or flight mechanism in mammals.

In dairy cows hereditary traits like milk ejection have been improved by selective breeding and the large volume of milk produced by these animals further influences quick milk ejection. Thus modern dairy cows are conditioned to respond to stimuli like feeding during milking, the presence and touch of the milker, and the sound of the milking machine.

Buffalo have not been selectively bred to the extent that dairy cattle have been, hence the maternal instinct remains dominant in them and they can be easily disturbed by even small changes in milking routines. Since buffalo have very little milk in their cisterns prior to milk ejection, if they are disturbed and milk ejection is inhibited it results in more than 95% of the secreted milk remaining in the secretory tissue. Thus it is possible that if buffalo are repeatedly disturbed during milking, milk secretion could be inhibited and milk yield affected.

In a short-term experiment different pre-stimulation treatments were studied to evaluate their influence on milk ejection. (Figure 10:1-3. Thomas et al., 2005). The treatments evaluated were: manual pre-stimulation and feeding during milking, manual pre-stimulation without feeding, and direct machine milking without manual pre-stimulation. Buffalo responded best to manual pre-stimulation and feeding during milking. Their normal milking routine, with manual pre-stimulation and in-parlour feeding, resulted in good milk ejection and oxytocin release.

From this study it is evident that buffalo are easily disturbed by even small changes in the milking routines. It is therefore crucial to introduce machine milking gradually, along with good milking procedures, to buffalo who have not previously been machine milked. DeLaval has researched techniques for conditioning buffalo to machine milking and we have observed that it takes about five to seven days to completely accustom buffalo to machine milking and to obtain normal milk yields (Lind et al., 1997).

Efficient milking of buffalo

The presence or absence of cisternal milk in the different dairy species is important when machine milking. In sheep and goats the large cisternal fraction of milk is available for a comparatively longer time at the start of machine milking, so a lack of pre-stimulation does not have a critical influence on milk removal. In dairy cows machine milking without pre-stimulation can cause a temporary reduction in milk flow (bimodal milk flow) or a total interruption in milk flow after the cisternal fraction is extracted. The consequence of this can be milking on empty teats until the alveolar milk is available. In sheep, goats and cattle emptying of the large cisternal fraction during machine milking can stimulate the flow sensitive receptors situated in the teat canal and cistern, possibly resulting in a complete and better ejection.

Buffalo have longer teats and long teat canals than dairy cows, and it is important to take this into consideration in machine milking (Thomas et al., 2004). This is one of the reasons why a different vacuum level has to be used when machine milking buffalo. In the absence of cisternal fraction of milk the teats of buffalo are empty, and thus during machine milking they may be similar to the teats of dairy cattle towards the end of milking. In the absence of the cisternal fraction, if the milking unit is applied prior to milk ejection, the empty teats are exposed to vacuum. Vacuum suction causes the teat canal and milk ducts to collapse, preventing further milk flow. This may be painful for the animal and could lead to inhibition of milk ejection.

However, milking with the DeLaval milking system for buffalo that has Duovac™ as part of the milking unit, minimises the impact of milking on empty teats. Duovac is a milk flow controlled milking system which synchronises with each individual animal's milk ejection and milk flow pattern (Figure 11).

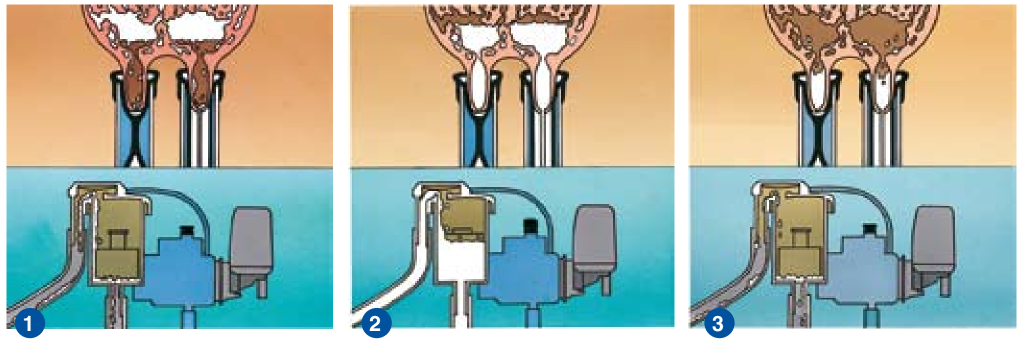


Figure 11. The milking process using Duovac™.

(DeLaval, 2001, Efficient Milking)

When the Duovac milking unit is applied, machine milking commences on low vacuum. When milk flow from the udder increases to above a certain set level, e.g. 200 ml/min., the vacuum automatically increases to the normal milking vacuum and stays that way until the milk flow falls below that set level, i.e. 200 ml/min., towards the end of each milking (Figure 12). In this way the Duovac system gently stimulates let down, and is gentle on the teats after the peak flow.

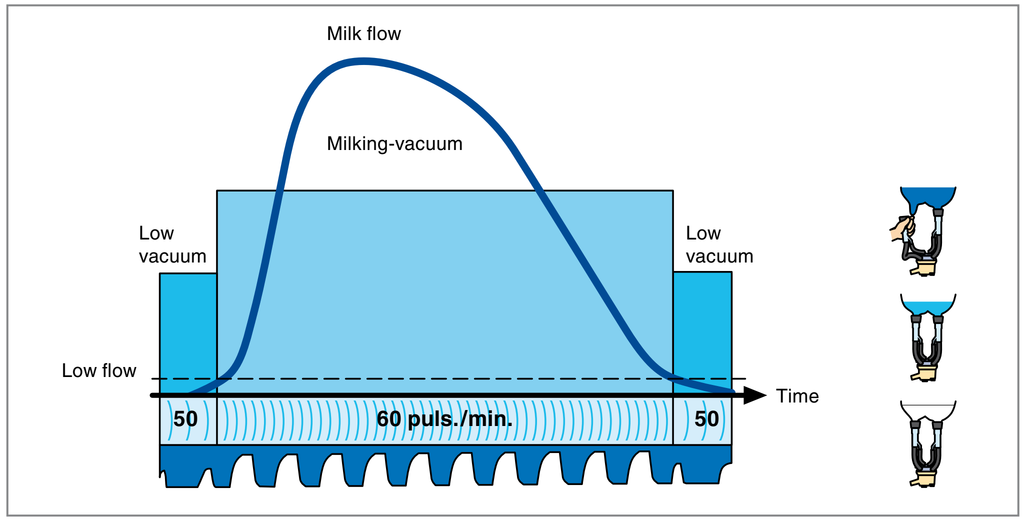


Figure 12. Principle of operation of the Duovac™

1) Low flow with low vacuum

2) High flow with milking vacuum

3) Low flow with low vacuum

This milking system is ideally suited to the physiology of buffalo milk ejection and milk flow. Since prior to milk ejection buffalo teats are usually empty, milking them using Duovac is not stressful for the animals. In addition by using an electronic pulsator the pulsation ratio can be modified: in the initial low vacuum phase during Duovac milking the massage time can be increased so that the teats are massaged longer while there is no milk in the teats. This is beneficial to the animal as it causes minimum accumulation of tissue fluids at the teat tip.

In another short research project designed to optimise milking routines in buffalo with respect to milk ejection, milk flow and milking efficiency, 24 buffalo in four groups were studied (Thomas et al., 2005). Milk yield, stripping yield, milking time and milk flow during machine milking were recorded. There were five treatments (randomised design): direct machine milking (no pre-stimulation), one minute manual pre-stimulation, three minutes manual pre-stimulation, reduced vacuum during early milking (Duovac), and intravenous oxytocin injection. Figure 13:1-5, tactile stimulation and milk flow, shows some of the observations from this study.

Tactile stimulation and milk flow

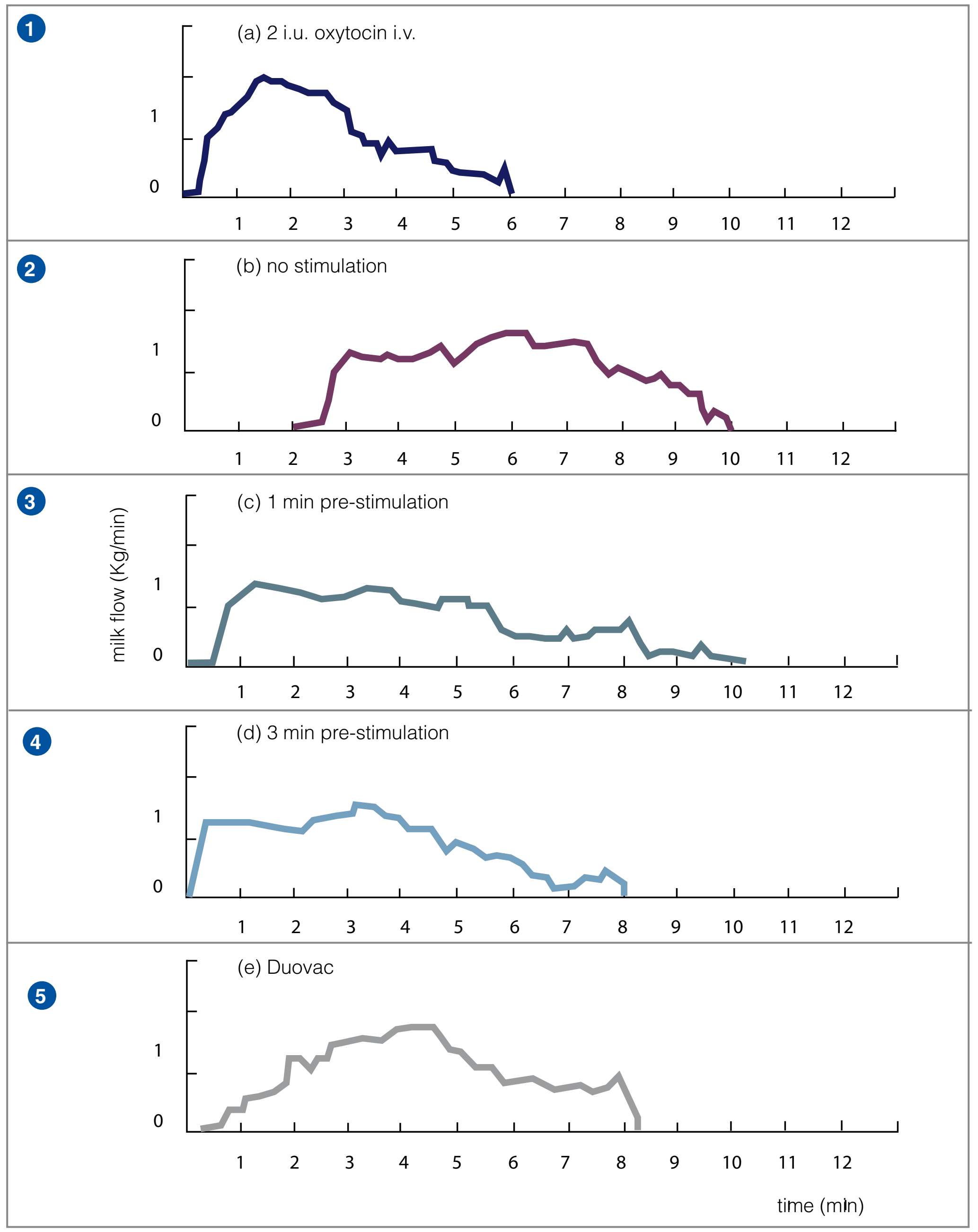


Figure 13: Tactile stimulation and milk flow. (Thomas et al., 2005)

1) Milk flow in buffalo begins only after an active milk ejection.

2) Cisternal milk fraction is not visible in milk flow curves so pre-stimulation is needed.

3) Inadequate stimulation results in disturbed milk ejection.

4) Tactile pre-stimulation in machine milking is more efficient at low vacuum (Duovac).

5) Low vacuum milking (Duovac) avoids cluster climb and obstruction of milk flow.

Machine stripping with Alfadast

Alfadast

Long teat canals in buffalo necessitate stripping. The DeLaval Alfadast system provides an excellent solution for machine stripping buffalo, which is otherwise a tedious manual task.

Good milking routine for buffalo

An appropriate milking routine is important for hygienic and production reasons as well as to create a comfortable and stress free environment for animals and milkers. It is easier to maintain good hygiene and to facilitate buffalo acceptance of relief milkers if a consistent milking routine is followed. With dairy cows it has been demonstrated that the practicing of a regular strict milking routine results in increased milk production.

The routine outlined here can be followed by both hand and machine milkers in stanchion barns or where milking is carried out in flat barns. In the case of hand milking in such barns, points six to nine are omitted. Routine checks of the milking machine should be done before each milking session according to the manufacturer's recommendations.

Buffalo milking routine

1. Start by tying (if not already tied) and feeding the buffalo.
2. Remove dung from the floor.
3. Wash hands with soap and dry them.
4. Clean the teats with special towels and massage teats thoroughly.
5. Foremilk the buffalo by hand into a strip cup, checking the appearance of the milk.
6. Apply the cluster gently. Check tube alignment.
7. Check the buffalo every now and then to make sure that she is comfortable with the machine.
8. Palpate the udder to check that it feels empty.
9. Remove the cluster gently.
10. Dip the teats in a suitable disinfectant solution.
11. Clean all the equipment in the milking room.
(Ståhl Högberg and Lind, 2003)

When machine milking, it is important that the milking machine is nearby and ready to be applied to the udder at the right time (after pre-milking). Thus, each buffalo must be cleaned, massaged and pre-milked and then have the machine applied directly. It must be emphasized that it is not possible to clean the udders on all the buffalo first and then apply the machines to the first buffalo. The oxytocin release has just a short duration (a few minutes).

1) Milking buffalo in a tandem parlour means that the buffalo can be released one by one.

2) Bucket milking in a small parlour.

Pre-milking

Pre-milking routines are as important when milking buffaloes as when milking cows. It is important to use a smooth and comfortable milking technique. The "knuckling" or "stripping" method is used in the wrong belief that it overcomes resistance in the teat sphincter. These milking methods might cause elongation and damage to the teats. A much more comfortable and appropriate method is the "full hand" technique. This technique imitates the calf's suckling and is therefore a better stimuli (DeLaval Efficient Milking, 2001).

Machines for milking buffalo

Since the udder and teats in buffalo are different from those in cattle, milking machines for cattle have to be modified to suit buffalo. Results from recent studies in India indicate that it is possible to reduce the cluster weight and the frequency of liner slip by applying an appropriate combination of liner design and cluster weight. It is not only the total weight of the cluster that is important, but also the distribution of its weight on the udder. 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 depend upon vacuum levels and pulsation rates among other factors. Studies on Egyptian buffalo revealed that a vacuum of 51 kPa and a pulsation rate of 55 cycles per minute 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.). The higher vacuum level, however, caused a significant increase in somatic cell counts. The highest milk yield within an acceptable time was found when using 56 kPa and 65 cycles/min. In all trials a pulsation ratio of 50:50 was used.

Studies in Pakistan indicated that the pulsation rate and ratio should be 70 cycles/min. and 65:35 respectively for Nili-Ravi buffalo.

In Italy, the majority of farms use the same machines for both buffalo and cattle. It is a simple "cattle machine" with one vacuum level operating at approximately 40 cm Hg.

In India, recent trials have been made with milking with Duovac from DeLaval. Successful milking was done with a vacuum level of 55 kPa, 70 cycles/min. pulsation rate and pulsation ratio of 65:35 for milk flows above 0.2 kg/min. For milk flows under 0.2 kg/min. the respective data was 38 kPa, 48 cycles/min. and the same pulsation ratio.

Milking with machines

In order to obtain all the advantages with machine milking the correct technique must be used. Both milkers and buffalo must be familiar with the machines. If the buffalo are scared or feel uncomfortable they will withhold their milk and thereby yield less. This in turn will lead to economic loss for the farmer and eventually he will lose his faith in machine milking.

Introducing machine milking

The concept of machine milking should be introduced slowly by people with whom the buffalo are familiar and feel comfortable with, under the supervision of an expert. The procedure noted here for introducing buffalo to machine milking is recommended by DeLaval. It is applicable for a whole herd where neither animals nor people are familiar with machine milking. A successful introduction should be possible by carefully following these steps:

- Training personnel. Training of milkers should be done by a person from the milking machine company. This person will have good knowledge of the biology of milking, and of machine milking, as well as of the design, function and maintenance of the milking equipment. The training should include introduction procedures, the milking routine, handling the machine, cleaning and maintenance as well as certain aspects of the day-to-day servicing of the machine.

- Installation of the milking machine in the barn and any other modifications to 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 habituate heifers than older buffalo to machine milking. Older buffalo may have been hand milked by a certain routine for several lactations and may respond negatively to a change in routine. Heifers on the other hand are not accustomed to any specific routine and are more likely to accept machine milking just as well as hand milking. Furthermore their udders and teats are more uniform and not damaged by previous milking. Liner slip and other negative effects of machine milking are therefore less pronounced in heifers. Note that heifers should not be hand milked but directly introduced to the machine. They may get accustomed to the noise of the vacuum pump etc. by participating in the milking routines prior to partus.

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

- Milk the old and selected animals as usual by hand but let the vacuum pump run during milking. This will accustom the animals to the noise. Put the pump on before actual milking, but after the buffalo have been tied up, as the animals may be startled by the sudden noise.

  Repeat the procedure (usually two to four times) until all buffalo are accustomed to the noise. It is better to repeat this procedure once or twice more until all buffalo are comfortable, rather than rushing into the next step.

- 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 is carried out. This will allow the buffalo to get used to the ticking sound of the pulsator. It will give them a chance to look at the machines and smell them and maybe even to taste them. Make sure though, that they do not chew on them!

  Move the machines to the next buffalo in order of being milked. This accustoms the buffalo to machines being moved around. The procedure should be repeated (usually two to four times) until all the animals have accepted the presence of the machines. At this stage all buffalo should be well accustomed to the new routine.

If some buffalo are still showing signs of nervousness or stress, it is recommended to repeat the above mentioned steps until the animals are calm. Buffalo that after this procedure have still not accepted being milked by machines, should be returned to hand milking. One or two frightened or uncomfortable buffalo might cause major disturbances in the whole herd.

Be consistent with the milking routine, including pre-milking preparation, right from the beginning of this introduction to machine milking. The regular milker should carry out machine milking during the introduction period. 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 the best ways to calm an animal.

These first sessions of machine milking usually require more time than those following. However, this time is well worth spending to ensure calm and easy-milking buffalo for the future.

Mastitis

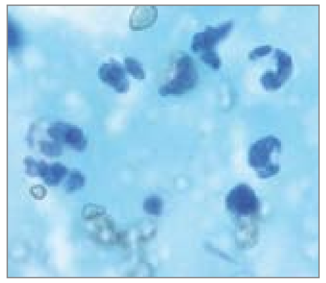
Mastitis, inflammation of the mammary gland, is a common disease in dairy animals. The disease causes great economic losses both for farmers and for dairies.

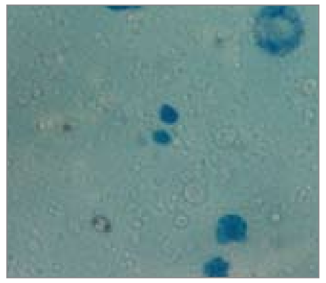
Mastitis may be caused by several factors. Most common is bacterial infection. Good hygiene practice is the most efficient way of preventing the disease from developing and spreading. Mastitis may also be caused by trauma such as injuries on the udder or the teat. Sores are a perfect way of entry for bacteria.

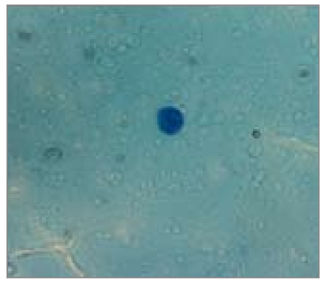
The most common bacteria causing mastitis in buffalo are Staphylococcus (Staph. epidermis and Staph. aureus), Streptococcus (Str. dysgalactia and agalactia) and Coryonebacterium spp. This is not very different from the incidence of respective bacteria in cattle mastitis. There is, however, a difference in bacteriology of the mastitis due to the kind of farm the buffalo come from. On modern farms the most common bacteria causing mastitis is often Staph. aureus. On traditional farms, Streptococcus faecalis, Escherichia coli and Clostridium perfringens are the most prevalent.

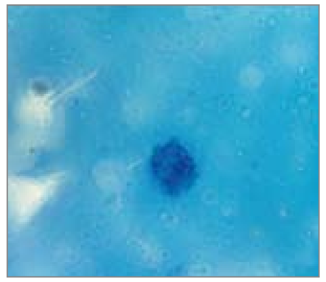
Different types of bacteria cells in buffalo milk

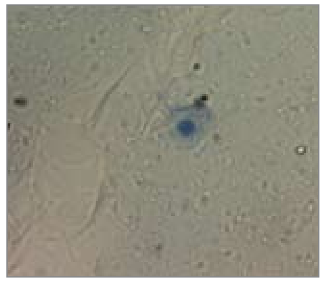
Bacteria cells in buffalo milk photographed by Anika Rickberg, SLU, Uppsala, from cell smears prepared by C.S. Thomas.


Leucocytes


Lymphhocytes


Monocytes


Macrophage


Epithelial cells


Cell fragments

Prevailing recommendations for hygiene, milking routines and herd management should be followed regardless of whether milking is carried out by hand or machine. Machine maintenance is important, with two basic requirements being regular servicing of milking machines so they continue to operate with appropriate vacuum levels; and regular liner replacement.

Mastitis risk on traditional buffalo farms is often linked to lack of even the most simple hygiene routines. The bacteria which cause mastitis on traditional farms, faecal and soil bacteria, indicate clearly that standards of hygiene could be improved.

Mastitis seems to be more frequent in animals with high milk yield, whether individuals, herds, breeds or species. This may have to do with the higher stress that the udder is exposed to when yielding more milk. It is quite clear however, that buffalo are less susceptible to mastitis than cattle. There might be both anatomical and physiological reasons for this.
An Indian study cited in Ståhl Högberg and Lind (2003) compiled data on the incidence of mastitis in cows as well as in buffalo, see Table 10.

Table 10: Incidence of mastitis in India

Table 10: Incidence of mastitis in India
(% of animals)

	Buffalo	Cows
Sub-clinical mastitis	24.4%	43.9%
Clinical mastitis	24.8%	54.7%

Mastitis can be clinical or sub-clinical. There is an important difference between these two. Sub-clinical mastitis may not even show. The observant milker may see slight changes in the milk such as the appearance of flakes, when fore milking into the strip cup. Sub-clinical mastitis shows up in the California mastitis test (CMT) and with increased counts of somatic cells in milk.

Acute mastitis is detected very easily. The udder is sore, swollen, hot and red. The buffalo is in pain when the inflamed quarter is touched. An inflamed quarter should be milked by hand very carefully, not forcing the milk out. This may be quite difficult, since the milk is thick (more like jelly) and may contain blood. The milk should not come into contact with any containers used for milking, nor animals or the floor. It should be discarded. The milker should carefully wash his hands before touching any other quarter, animal or equipment. Never milk an inflamed quarter with a machine!

Buffalo have a powerful defence against mastitis because of the anatomy of the teat. This starts with the teat skin, since buffalo teat skin is less sensitive than that of cow teats to chapping and sores. Inside the streak canal, the epithelium is thicker and more compact than in cattle. This gives extra resistance against the penetration of bacteria through the epithelium.

Furthermore, the keratin layer of the streak canal is thicker. The importance of the keratin layer is that it contains bactericidal and bacteristatic lipids and cationic proteins. The cationic proteins are inhibitory to the growth of Streptococcus agalactica and Staphylococcus aureus.

The sphincter of the streak canal is, as mentioned before, tighter than in cattle. It is also supplied with more nerve fibres and a richer blood vessel system than in cattle. This will help in maintaining a tight closure of the duct, limiting entry of bacteria into the mammary gland.

Testing for mastitis by checking somatic cell count with CMT.

Measuring somatic cell count with DeLaval cell counter DCC.

When the udder becomes infected or inflamed, the natural defence system goes into action to eliminate the infection or inflammation. Blood leukocytes, especially the phagocytes, migrate through the alveolar epithelium to the milk in order to remove the invading pathogens. Neutrophils are the most active leukocytes in this process. Lymphocytes and macrophages are also important in the udder defence system. Neutrophils, lymphocytes and macrophages together with epithelial cells are present in normal milk. In buffalo milk, several studies have revealed that the amount of neutrophils in total somatic cells (SCC) can be from 22-88% with an average of 56%. Lymphocytes are in the order of 10-54% (mean 28%). The occurrence of macrophages in buffalo milk is less than in cattle milk (8% vs. 30%). This massive attack by neutrophils is a powerful defense by the udder against invading pathogens.

Cell counts in milk from healthy buffalo varies between 50 000 and 375 000 per ml. This is comparable to cattle milk and the difference therefore lies in the differential cell count as described above. Studies indicate that the concentration and functional efficiency of phagocytes are superior in buffalo compared to cattle.

Mastitis disease is cured by antibiotics. Treating buffalo in the dry period with antibiotics in order to prevent the disease has been shown to be very effective. However, this can not be recommended since bacteria are known to develop resistance to antibiotics. Instead good methods for preventing the disease should be practiced. With training to detect mastitis during the early phase, spread of the disease can be prevented.

Mastitic milk

Machine milking has both been praised as the solution to mastitis problems and been cursed as the cause of mastitis. None of these extremes are completely true.

As stated previously, incorrect use of milking machines or milking with machines in poor condition may cause trauma to the teats. This in turn may lead to injuries like sores or chapping. The sores are readily invaded by pathogenic organisms and the disease becomes a fact. If a buffalo has got an infected quarter already, machines may aid in transmitting pathogens to the other quarters or to another buffalo. A fluctuating vacuum may cause milk to be pressed into the teat again, thus invading the teat with pathogens.

The machines themselves may also be a source for pathogens. Old liners and rubbers are easily cracked, and in these cracks micro-organisms are less susceptible to washing and detergents and may survive the cleaning. All these factors may easily be eliminated by good hygiene practices and by maintaining the equipment in good condition.

6. Buffalo lactation, milk yield and milk composition

Lactation in buffalo

Each lactation begins with the birth of a calf, and the initial yield is a reliable indicator of the animal's genetic potential. The highest yield is reached after five to six weeks of lactation and maintained for some weeks. Thereafter the yield decreases until the end of lactation. Lactation ends as the dry period starts.

In buffalo, the highest lactation milk yield is seen in the fourth lactation, after which it declines. The shape of the lactation curve depends on factors such as feed, management, milking frequency and diseases. The length of lactation and yield for various breeds is shown in Table 11. The optimum lactation length in Murrah buffalo has been reported to be 262 to 295 days.

In Italy it is recommended to keep a lactation length of 270 days in controlled herds. ICAR recommends a lactation length of 305 days, similar to that for controlled cattle.

Table 11: Lactation length and milk yield

Table 11: Lactation length and milk yield

Breed	Lactation (days)	Milk yield (kg/lactation)	Type of herd/country
Murrah	294 average	1 764 average	Military farm / India
Murrah	294 first lactation	1 590	Research Inst. / India
Murrah	385 first lactation	1 770 ± 102	University farm / India
Murrah	272 (average)	1004	Research Center / Nepal
Native / Nepal	223 (average)	489	Research Center / Nepal
Nili-Ravi	250 – 327	1 586 – 1 855	Unknown / India
Surti	238 – 350	1 086 – 2095	Unknown / India
Surti	305 recalculated	1 043	University farm / India
Purnathadi	243	1 224 ± 306	Household/India
Mediterranean		964 – 1 279	Rumania
Mediterranean	270	2 100	Italy / Private farms
Mediterranean	270	2 100	Italy / Research Institute
Mediterranean		1 488 – 1 700	Bulgaria
Caucasian		1 100 – 1 445	Azerbaijan
Iraq	255	1 342	Breeding station / Iraq
Egyptian	217	1 227	Egypt
Egyptian	260 – 360	1507 – 1 939	Breeding station / Egypt
Murrah		945 – 1 113	Brazil
Murrah	237	1 573	China
Nili-Ravi	261	1 873	China
Swamp	235	441	China
50% Murrah	276	1 096	China
75% Murrah	270	1 153	China
87.5% Murrah	291	1 540	China

(Ståhl Högberg and Lind, 2003)

Factors affecting lactation and milk yield

Lactation and milk yield depend on both genetic and non-genetic factors. The genetic influence is from species, breed, and individual animals. Further, it is affected by the ability to reproduce – that is by fertility and the calving interval. Improvements in these factors may result from breeding and selection.

The non-genetic factors are management, amount and quality of feed, and the farmer's skill in detecting heat and illnesses. Factors which are outside the farmer's control such as climate, temperature and humidity also influence lactation and milk yield.

Buffalo in a field near Naples, Italy.

Feeding is the most important factor for increasing and sustaining the milk yield. Sufficient amounts of energy, protein, minerals and water must be provided in order to achieve maximum yield. See chapter 4 section on: Practical feeding of the lactating buffalo.

Calving interval is closely related to lactation length and milk yield. The longer the calving interval, the longer the lactation and the higher the lactation yield. However, total lifetime yield will be substantially less than that of a buffalo with shorter calving intervals. (See chapter 2 section on: Breeding buffalo).

Milking. The anatomy of the udder and physiology of milk ejection in buffalo is quite primitive compared to that of dairy cows (see chapter 5: Milking). When a buffalo is being machine milked for the first time it is important to ensure that the udder is emptied efficiently. Even in dairy cows it is known that milk ejection is inhibited or disturbed when they are milked in unfamiliar surroundings, and then it is only possible to extract the cisternal milk (Bruckmaier et al., 1993). Repeated occurrence of inhibition of milk ejection and high residual milk fractions could result in a reduction in the secretory activity in the mammary gland.

Reproductive efficiency. Studies on reproductive efficiency indicate that Riverine breeds of buffalo reach puberty around six months earlier than Swamp breeds. However pre-weaning and weaning nutrition is important in promoting growth and achieving puberty in all breeds: animals that have a higher daily gain reach puberty in a shorter time. Because of the weight differences between breeds, heifer weight at first conception can vary from 250 to 400kg. Heifers bred with a good early management system conceived at a younger age than a control group (Barile, 2005).

The weight of the heifer at calving seems to affect milk yield. Studies on Murrah (cited in Ståhl Högberg and Lind, 2003) indicate that buffalo heifers should weigh about 400 to 500 kg at the time of calving in order to reach maximum milk production.

Dry period

Buffalo should be dried off approximately two to three months before expected calving. The dry period is valuable to the buffalo, she may rest and the udder tissue recuperates and reconstitutes itself.

In high yielding herds (above 10 kg per day on average) the buffalo should be dried off when the daily yield falls below 2.5 kg, even if it is still more than three months to expected calving. An alternative to drying off is to use the buffalo as a foster mother to newly born calves. One buffalo may serve one newborn calf, or two older calves which also receive additional feed. Care should be taken to dry the foster mother off completely no later than two months before calving.

In herds which are hand milked and where the yield is low, it is difficult to set a lower limit in kg. Instead, the two months limit is recommended.

Differences in milk composition

Milk from buffalo differs from that from cattle. The biggest difference is with respect to fat. In cattle, the milk contains between 3 to 5% fat, depending on feed and breed. In buffalo milk the average fat content is usually 7 to 8% but may be as high as 13%.

Table 12: Composition of buffalo and zebu cattle milk

Table 12: Composition of buffalo and zebu cattle milk

Breed/Country	Water (%)	Fat (%)	Protein (%)	Lactose (%)	S.N.F. (%)
Egyptian	82.4	7.9	4.2	4.8	9.9
Mediterranean/Italy	81.9	7.9	4.3		10.2
Caucasian	82.7	7.6	4.1	5.0	9.8
Chinese	76.8	12.6	6.0	3.8	10.6
Murrah/India	82.7	7.1	4.6	3.6	10.2
Murrah/Bulgaria	81.8	8.0	4.5	4.8	10.2
Zebu cow	86.6	4.2	3.6	4.9	9.2

(Ståhl Högberg and Lind, 2003)

Buffalo milk fat has a higher melting point than that of cattle, due to its higher proportion of saturated fatty acids (77:23, saturated:unsaturated). Buffalo milk fat contains higher proportions of butyric, palmitic and stearic acids and a lower content of caproic, caprylic, capric and lauric acids than does cow milk (Ganguli, 1974). Phospholipids and cholesterol are lower in buffalo milk. It is also less susceptible to oxidative changes compared to cows' milk.

Table 13: Proportion of fatty acids in normal buffalo milk

Table 13: Proportion of fatty acids in normal buffalo milk

Fatty acids	C4:0	C6:0	C8:0	C10:0	C12:0	C14:0	C14:1	C16:0	C17:0	C18:0	C18:1	C18:2	C18:3
%	4.83	2.41	2.41	3.38	2.90	13.21	0.8	32.86	4.82	11.10	20.21	1.0	1.0

(Ståhl Högberg and Lind, 2003)

Fat in buffalo milk has characteristic differences from fat in cow's milk. The fat globules in buffalo milk have an average diameter of 2.80 µm (Martini et al., 2003), smaller than those in cow milk, which have an average diameter of 3.0-5.0 µm (Alais, 1984). In buffalo milk 91% of fat globules range from 2.1 to 4.0 µm and the size is positively correlated to the proportion of unsaturated fatty acids (Martini et al., 2003).

The content of protein, lactose and ash is somewhat higher in buffalo milk than in cattle milk. Buffalo milk contains more Vitamin A than cow milk, and only traces of carotene. This makes the milk look very white, as opposed to cattle milk which has a slight yellow shade.

The different types of casein found in bovine milk are also found in buffalo milk, although in slightly different proportions.

Table 14: Distribution of casein in buffalo and in bovine milk,% of total casein

Table 14: Distribution of casein in buffalo and in bovine milk,% of total casein

Type of casein	α_{s1}	α_{s2}	β	κ
Buffalo	30.2	17.6	33.9	15.4
Bovine	38.4	10.5	36.5	12.5

(Ståhl Högberg and Lind, 2003)

When making a general comparison to cow milk it can be said that buffalo milk contains significantly more total solids, higher levels of the important minerals like calcium and phosphorus, substantially less cholesterol, more of the natural anti-oxidant tocopherol and more vitamin A.

Table 15: Comparison of cow and buffalo milk

Table 15: Comparison of cow and buffalo milk

Traits	Cow	Buffalo
Total solids (%)	13.10	16.30
Fat (%)	4.30	7.90
Protein (%)	3.60	4.20
Lactose (%)	4.80	5.00
Tocopherol (mg/g)	0.31	0.33
Cholesterol (mg/g)	3.14	0.65
Calcium, Ca (mg/100 g)	165.00	264.00
Phosphorus, P (mg/100 g)	213.00	268.00
Magnesium, Mg (mg/100 g)	23.00	30.00
Potassium, K (mg/100 g)	185.00	107.00
Sodium, Na (mg/100 g)	73.00	65.00
Vitamin A, incl.carotene (I.U.)	30.30	33.00
Vitamin C (mg/100 g)	1.90	6.70

(Chantalakhana and Falvey, 1999)

New born buffalo calves need colostrum

Composition of colostrum

During approximately the first three days of lactation the buffalo secretes colostrum. Colostrum is vital for the newborn calf and its composition reflects the calf's need. Colostrum contains the important proteins, the immunoglobulins, which are the newborn calf's source of antibodies. The iron and copper content of colostrum is markedly higher than that in normal milk.

Table 16: Composition of colostrum

Table 16: Composition of colostrum

	Water (%)	Fat (%)	Total protein (%)	Lactose (%)	Vitamin A (µg/kg)
Buffalo	68	15	13.6	3.1	–
Bovine	73	9.55	9.59	7.54	1.8

(Ståhl Högberg and Lind, 2003)

Alterations in milk composition

There are several factors that influence the composition of milk within a species: primarily stage of lactation, milk yield, season, feeding, nutritional level and completeness of milking. Milk composition can be altered both before and after milking. If change occurs inside the udder it is mostly due to a disease or to treatment of the disease by antibiotics or another type of medication. Changes in feed can alter the composition of milk, but these changes are seldom extreme, usually falling within normal intervals. The season of the year can also affect milk composition, although these changes are mostly due to differences in feeding during different seasons.

A study on Nili-Ravi buffalo in Pakistan showed the influence on fat percentage of stage of lactation, with fat percentage increasing steadily from 5.5% in the first month of lactation to 7.5% in the tenth month of lactation. It was reported by Ganguli (1974) that the percentage of fat in buffalo milk varied from 6.37 to 8.10%, and protein from 3.78 to 4.65%.

In Brazil it has been reported that the percentage of fat in buffalo milk was around 5.95% and protein content around 4.2% (Tonhati and Cerón-Muñoz, 2002).In Italy it has been reported that there is an improvement in the percentages of fat (8.07%) and protein (4.69%). This improvement has been mainly attributed to selective breeding for higher fat and protein, and to improved feeding and nutrition (Italian Breeders' Association A.I.A., 2005).

Feedstuff

A rule of thumb is that roughage increases fat content in milk, whereas concentrate depresses it. This depends on the differences in production of volatile fatty acids (VFA) in the rumen from the different carbohydrate sources. Feed rich in fibre results in a higher proportion of acetic acid, increasing the fat content of the milk. Feed rich in concentrate results in a higher proportion of propionic acid which is unfavorable for milk fat synthesis. If too much concentrate is given, levels of milk fat may be reduced.

Higher energy diets seem to give better coagulation properties in the milk. Long-chain fatty acids increase when the energy concentration in feed is low.

Glucosinolates in Brassica spp. are hydrolyzed by the ruminal microbes into thiocyanates, iso-thiocyanates and some other products. Thiocyanate is then excreted in the milk. Extremely high feeding levels with Brassica spp. may lead to undesirable levels of thiocyanate in the milk. Thiocyanate may cause thyroid enlargement in animals as well as in the humans ingesting it. Common feedstuffs of Brassica spp. are mustard fodder and mustard oil cake. Even 15 days after withdrawal of mustard feed, circulatory high levels of thiocyanate may be secreted in the milk.

Disease and medication

Mastitis changes the milk composition dramatically. If antibiotics are applied to cure mastitis, they will be excreted in the milk. Controlling external parasites with medication such as diazinon affects milk yield as well as composition. The chemical may be detected in the milk up to 48 hours after dermal application.

7. Buffalo milk industry

Biting into stretchy mozzarella

Tradition and habits of buffalo milk consumption are quite diverse in different parts of the world. There is however an increasing demand for buffalo milk and buffalo milk products. Dairy buffalo milk production has increased to account for up to 13% of world milk production in recent years and there is a steady consistent growth in the buffalo population in most of the buffalo milk producing countries.

Table 17: Trends of growth in buffalo populations and milk production

Table 17: Trends of growth in buffalo populations and milk production

Country	Buffalo population		Buffalo milk production		Type of buffalo
	Year 2006 1 000 heads	Average growth in 5 years (%)	Year 2006 (tonne)	Average growth in 5 years (%)	
Argentina	200	NA	NA	NA	River
Bulgaria	7,132	-10%	NA	NA	River
Brazil	1,174	1%	NA	NA	River
Colombia	60	NA	NA	NA	River
Venezuela	100	NA	NA	NA	River
China	22,813	0%	2,850,000	1%	Swamp
Egypt	3,920	2%	2,300,000	2%	Mediterranean
India	98,805	1%	52,100,000	4%	River
Iran, Islamic Rep of	580	4%	232,432	1%	Mediterranean
Italy	205	2%	215,228	9%	Mediterranean
Nepal	4,203	3%	926,850	4%	River
Pakistan	28,400	4%	21,136,000	4%	River
Sri Lanka	314	0%	26,730	1%	River
Turkey	105	-8%	38,058	-12%	Mediterranean

(FAO, 2006; World Buffalo Association, 2005; Colombian Buffalo Breeders Association, 2006; REU Technical series 67, 2005; FAO, 2007.)

There is also consistent growth of three to five percent in buffalo milk production worldwide, which compares well with the other popular milk producing species.

Table 18: Trends in species wise milk production from 1996 to 2005

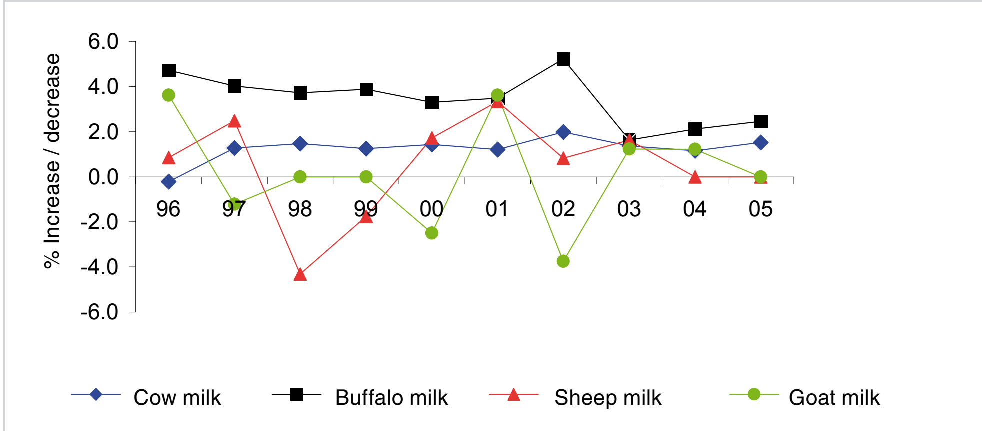


Table 18: Trends in species wise milk production from 1996 to 2005

Buffalo milk

Buffalo milk differs substantially from milk from other dairy species.

Table 19: Average composition of milk from some prominent dairy species

Species	Water	Fat	Protein	Lactose	Ash
Friesian cow[1]	87.92	3.40	3.13	4.86	0.69
Gir cow[2]	86.44	4.73	3.32	4.85	0.66
Crossbred cow[3]	86.54	4.50	3.37	4.92	0.67
Buffalo[4]	82.76	7.38	3.60	5.48	0.78
Goat[5]	87,10	4.25	3.52	4.27	0.86
Sheep[6]	81.00	7.90	5.80	4.50	0.80
Camel[7]	86.50	3.10	4.00	5.60	0.80

Bos taurus[1], *Bos indicus*[2], *Bos Taurus x Bos indicus*[3], *Bubalus bubalis*[4], *Capra hircus*[5], *Ovis aries*[6], *Camelus dromedarius*[7]. *(Aneja et. al., 2002)*

Table 19: Average composition of milk from some prominent dairy species

The milk processing industry values the superior whitening property of buffalo milk, which makes it very suitable for producing skim milk powder. The high proportion of milk solids in buffalo milk not only make it ideal for processing into valuable dairy products, but also contribute to some extent to energy saving during processing. Yoghurts made from buffalo milk are naturally thick set, which reduces the need to add additional milk proteins or gelling agents.

Buffalo milk has a higher casein concentration and the casein index (casein content/protein content x 100) is higher than 80%, which is higher than that of cow or goat milk (Alais, 1984). Buffalo milk is known to have superior renneting ability and curd firmness, properties which are important in the production of mozzarella cheese. The high casein content of buffalo milk is known to influence curd firmness (Storry and Ford, 1982).

Buffalo milk in an open tank.

Buffalo milk fetches a good price all over the world. Margins per kg raw milk from buffalo are higher than for cow milk in the major buffalo milk producing countries. This is evident from the 2007 prices for raw milk and milk products from buffalo milk and the corresponding raw milk prices from dairy cows in these countries.

Table 20: Price of buffalo milk in main buffalo markets of the world, 2007

Table 20: Price of buffalo milk in main buffalo markets of the world, 2007

Country	Cost of production (€/ Kg)	Raw milk price of BM* (€/ Kg)	Raw milk price of CM* (€/ Kg)	Milk Product	Milk Product Price (€/ Kg)
India	0.26	0.55 [1)]	0.33	Paneer (fresh cheese)	1.6
Pakistan	0.30	0.77 [2)]	0.40	Paneer (fresh cheese)	2.2
Egypt	0.37	0.41	0.25	Mozzarella	3.0
Italy	0.50	1.00	0.32	Mozzarella	12

**BM: Buffalo Milk, CM: Cow milk, [1)] raw buffalo milk sold in Mumbai city , [2)] raw buffalo milk sold in Karachi*

Buffalo milk products

In regions where buffalo have been breeding for centuries several milk products based on buffalo milk have evolved. The qualities of buffalo milk such as high total solids content, superior whiteness and viscosity, give buffalo milk preference over cow milk for the preparation of several Indian dairy products as well as specialised cheeses. Buffalo milk is used to produce unique products worldwide like mozzarella, yoghurts, ice creams, dahi, ghee and paneer. A brief description of some popular buffalo milk products follows.

Chai

A large portion of buffalo milk is converted into chai in small tea shops throughout the length and breadth of India and Pakistan. In a typical Indian tea stall or household, chai is usually prepared by boiling loose tea leaves in a vessel with buffalo milk and water. Depending on personal preference, various spices and sugar may be added at this stage. What is understood to be chai in western countries is really what is called masal chai in India. Buffalo milk is preferred to cow milk in making tea due to its superior whitening properties and the higher proportion of total solids in buffalo milk.

Buffalo yoghurt from Italy.

Cream, ghee and butter

Buffalo cream is easier to churn than cow milk cream on account of its higher fat content and the size of the fat globule. These larger fat globules also make it easier to achieve more complete removal of fat from buffalo milk when making skim milk. Butter produced from buffalo milk has better keeping qualities than cow milk butter because of the higher proportion of solid fat, which results in a slower rate of fat hydrolysis and comparatively lower rancidity in storage.

Ghee is the main cooking and frying medium in Indian cooking. Many Indians are vegetarians and ghee is the main source of animal fat in their diets. Sweets and meals cooked in ghee are specially appreciated and are cooked for special occasions. Although ghee from cow milk has a special place in the Hindu culture, buffalo milk is sometimes preferred over cow milk in commercial ghee preparations, again because of its higher fat content. This produces a clean flavour and as it is slower to become rancid it has a longer shelf life (Aneja et. al. 2002).

The texture of buffalo ghee is better than that of cow milk ghee due to its bigger grain size, which in turn may be due to the higher proportion of high melting triglycerides (9 – 12%) compared to 5% in cow milk fat (Patil and Nayak, 2003). Ghee is produced by heat desiccation of butter or cream at 105° to 110°C. The burning and caramelisation of lactose during the long heating process imparts a pleasant cooked flavour to ghee. The cream separated in households or in dairies is often fermented with similar cultures to those used for dahi, giving ghee a characteristic flavour. Ghee from cow milk is distinctly yellow while that from buffalo milk is clear white. After desiccation during storage ghee develops granular crystals that remain dispersed in clear fat.

Dahi

Fermented milk products are an important part of the diet of the people of the Indian subcontinent. Ambient temperatures are usually high in this area and converting milk into fermented milk products is a good way to minimize spoilage. Products like dahi (curd), lassi (stirred curd) and chach (buttermilk) are part of the daily diet of most Indian homes.

Dahi is often mistaken for yoghurt: these are two distinct products in terms of the cultures used to prepare them and the flavours. Dahi is usually made in homes using traditional kitchen recipes. Usually buffalo milk is preferred for dahi because the curd formed is white and thick and has a distinctive flavor. The superior body and texture of buffalo milk dahi could be attributed to the higher total solids content especially fat and protein, the casein micelles and the large fat globules and higher calcium content in the colloidal state (Sindhu and Singhal, 1988).

Milk is boiled and cooled and inoculated with a dahi starter containing a mixed mesophillic culture of Lactococcus lactis subspecies lactis, Lactococcus lactis subspecies cremoris, Lactococcus lactis subspecies diacetylactis and Leuconostoc species grown together. These microorganisms produce a typical flavour in temperatures ranging from 25˚–35°C, and give the dahi a firm body, sweet taste, mildly acidic taste and the typical aroma which is more prominent with buffalo milk (Aneja et. al., 2002).

A very popular dessert called shrikhand, is made with curd placed in a soft porous cotton pouch, which is then hung on a peg to drain for a few hours. Sugar, salt, red chilli powder, black pepper, cumin powder, saffron, cardamom, diced fruit and nuts may then be mixed in for taste. A special Indian preparation called raita is also made from dahi. Grated or small diced cucumber or bottle gourd is added to the dahi, and in some regions small pieces of tomato and onion are also added along with the spices. It is common for people to eat rice mixed with plain yoghurt with or without banana after the main meal.

Fresh buffalo mozarella in a shop in Latina, Italy.

Mozzarella
Mozzarella cheese is synonymous with buffalo and Italy. Buffalo rearing was introduced into Italy in the seventh century, but in the same areas stretched curd cheeses were made from cow's milk as well. It was only in the 1950's that a distinction was made by calling the soft stretched curd from cow milk "Fior di Latte" and that from buffalo milk "Mozzarella".

There is a worldwide increase in mozzarella cheese consumption and Italy exports about 14% of its mozzarella production (Borghese, 2005). The mozzarella manufactured in the region of Campana close to Naples in southern Italy has a DOP (Denomination Origin Protected) registration in the European Union as "Mozzarella di Bufala Campana". Buffalo mozzarella is a stringy textured cheese with the porcelain-white colour typical of buffalo milk, and a very thin rind. It is typically shaped small and round, but is also produced in small bite-sized shapes and plaits. Mozzarella-like fresh cheeses are produced on the farm or in small scale industries in the vicinity of buffalo farms. Along with mozzarella are other products like tereccia, ricotta, crescenza, robiola, caciocavallo, butter and yoghurts.

Fresh mozzarella from buffalo milk is distinctly different from the industrial mozzarella produced from cow milk or mixed buffalo and cow milk. Buffalo mozzarella has a very short shelf life as it produced from natural yeasts and microbes. It has a maximum shelf life of about three to five days without refrigeration. This cheese is very soft and tasty, juicy and creamy. It is rich in milk and flavours and live yeasts and microbes which give it a distinctive taste. The industrial mozzarella which is frequently available in stores and supermarkets is made from cow milk or a combination of cow and buffalo milk. This mozzarella has a much longer shelf life of around 25 to 30 days under refrigeration. However this product is devoid of live yeast and microbes, and is less soft and not juicy. It is usually used in Italian cooking, especially for making pizzas and caprese. In countries like India and Pakistan where there is large scale production of buffalo milk, there is great potential for manufacturing cheeses like mozzarella and ricotta.

Paneer
Cheese making has not such a strong tradition in India compared to the west. However soft cheeses have been prepared in India from time immemorial and paneer is one such cheese. There are products similar to paneer in several parts of the world, such as paneer-khiki in Iran, kareish in Egypt, armavir in the Western Caucasus, zsirpi in the Himalayas, feta in the Balkans and queso criollo, queso pais, and queso llanero in Latin America. Paneer is obtained through heat and acid coagulation of buffalo milk. A typical paneer is marble white in appearance, having a slightly spongy body, close-knit texture and a sweetish-acidic-nutty flavour. According to Indian standards it should contain a maximum of 70% moisture and a minimum of 50% fat in dry matter (Aneja et. al, 2002).

8. Appendices

Appendix 1 – Breeding activity

ID	Date of		Reproductive status		Expected heat	Service		Days			Projected calving	
Cow	Calving	Heat	Status			No.	Sire	Between heats	Open	First service	Interval (months)	Date
3	10 Apr		Open		09 Jun	–	–	–	–	–	–	–
3		11 May	Cycled		01 Jun	–	–	–	31	–	–	–
3		15 Jun	Bred		06 Jul	1	Leo	35	66	66	–	–
3		06 Jul	Bred		27 Jul	2	Duke	21	87	–	–	–
3		27 Jul	Bred	P	17 Aug	3	Duke	21	108	–	13.75	

ID: Identity (name or number)	Current number of inseminations (this becomes “services per conception” when the cow is confirmed pregnant)
Date of latest calving	Sire: identity of bull
Date of latest observed heat	Days between two consecutive observed heats
Indicates the status of the cow: Open = buffalo calved, but has not been observed on heat Cycled = buffalo observed in heat, but has not been inseminated Bred = buffalo inseminated Bred P = cow confirmed pregnant	Number of days between calving and the last insemination. If days open is less than 60 at the time of the first heat place an asterisk* next to it.
	The first service
Indicates the date of the expected return to heat: If the buffalo is open: date of calving + 60 days If the buffalo has cycled or bred: date of heat + 21 days in a month	After a buffalo has been confirmed pregnant, projected calving interval expressed in months is calculated as: Days open + 310 Where: 310 = days of pregnancy 30.4 = average number of days in a month.

Notes

Appendix 2 – Breeding records

By keeping individual breeding records it is easy to keep track of good buffalo, which ones to keep and which to cull.

Buffalo no./name	Last heat date	Serviced date	Name of bull	Expected partus	Last lactation yield	Sex of calf, name of calf if kept	Remarks (culled, sold, dry)

Notes

9. References

Agrawal, K.P., 2003. Augmentation of reproduction in buffaloes. *Proceedings of 4th Asian Buffalo Congress*, New Delhi, India: 121.

Alais, C., 1984. Scienza del Latte. Ed. Tecniche Nuove.

A.I.A., 2005. Milk recording activity: Official Statistics. Associazione Italiana Allevatori, Roma, Italy.

Aneja, R.P., B.N. Mathur, R.C. Chandan, and A.K. Banerjee, 2002. Principles of processing, Section 2. Technology of Indian Milk and Milk Products, *Dairy India Yearbook*. (Ed. and pub. P.R. Gupta), Delhi, India: p. 50.

Barile V.L., 2005. Reproductive efficiency in female buffaloes. Buffalo production and research (Ed. A. Borghese) *REU Technical series* 67, FAO regional office for Europe.

Basu, S.B., D.S. Bhatnagar, R.C. Sharma, P.A. Sharma, M. Gurnani, R. Nagarcenkar and D. Sundaresan, 1979. Murrah buffaloes at NDRI, Karnal. *NDRI. Pub*. No.154.

Bhikane, A.U. and S.B. Kawitkar, 2000. Handbook of veterinary clinicians: India 1768.

Bhosrekar, M.R., 2005. Fertility management of buffaloes. *Dairy Mate*. DeLaval India: 2-3.

Borghese, A, 2005. Buffalo cheeses and milk industry. Buffalo production and research (Ed. A. Borghese) *REU Technical series* 67, FAO regional office for Europe. 185 pp.

Borghese A. and M. Mazzi, 2005. Buffalo populations and strategies in the world. Buffalo production and research, (Ed. A. Borghese) *REU Technical series 67*, FAO regional office for Europe. 19 pp.

BSTID, 1981. Report of an ad hoc panel of the advisory committee on technology innovation. Cited in Thomas, C.S., 2005. Milking management of dairy buffaloes. PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Bud, I., C. Velea, N. Marcu, G. Muresan, M. Vomir and V. David, 1985. Behaviour of dairy buffaloes on pasture. *Natural Abstracts Review 1985*, 55 B:185.

Bruckmaier, R.M., D. Schams and J.W. Blum, 1993. Milk removal in familiar and unfamiliar surroundings: concentration of oxytocin, prolactin, cortisol and β-endorphin. *Journal of Dairy Research* 60:449-456.

Bruckmaier, R.M. and J.W. Blum, 1998. Oxytocin release and milk removal in ruminants. *Journal of Dairy Science* 81:939-949.

Bruckmaier, R.M., 2003. Chronic oxytocin treatments cause reduced milk ejection in dairy cows. *Journal of Dairy Research* 70:123-126.

Chantalakhana, C. and L. Falvey, 1999. Smallholder dairying in the tropics. ILRI (International Livestock Research Institute), Nairobi, Kenya: 462 pp.

Cockrill, W.R., 1967. The living tractor of the east. Alfa-Laval International: 27-28.

Cockrill, W.R. 1974. The husbandry and health of the domestic buffalo. FAO (Food and Agricultural Organization of the United Nations), Rome.

Cockrill, W.R., 1993. *Buffalo Journal 1*.

Colombian Buffalo Breeders Association, 2006. Personal communication.

DeLaval, 2002. Efficient Calf Management.

DeLaval, 2001. Efficient Milking.

El Rafey, M.S., 1962, cited by Addeo F., S. Kuzdal-Savoie, L. Chianese, A. Malorni and C. Sepe, 1981. Buffaloes' milk and milk products. *Dairy Science Abstract*, 30:177-186 (part I); 23:1-241 (part II).

FAO, 2004. http://appsfao.org (accessed 20 December 2004), Food and Agriculture Organization of the United Nations.

FAO, 2006 and 2007. www.fao.org

Ganguli, N.C., 1974. Physico-chemical make-up of buffalo milk in the standardization of techniques of handling, processing and manufacture of products. *XIX International Dairy Congress*, Vol II, 35: 8-374.

Ganguli, N.C., 1981. Buffalo as a candidate for milk production. *International Dairy Federation Bulletin* 137.

Gill, R.S., S.C. Gupte and L.S. Hundal, 1975. Effect of protection from cold on milk production of buffaloes. *Indian Journal of Dairy Science*. 32:122 -125.

Gupta, S.C., M.C. Handa and C. Sahoo, 1985. Dairy temperament of buffaloes in relation to their milking ability. *Indian Journal of Animal Production and Management* 1:116.

Ingawale, M.V. and R.I. Dhoble, 2004. Buffalo reproduction in India: an overview. *Buffalo Bulletin* 23 (1): 4-9.

Jagatjit Singh, R.S. Yadav, B.L. Yadav and S.S. Grewal, 1993. Effect of two housing and feeding systems on feed and water intake in lactating buffaloes in hot and humid season. *Indian Journal of Animal Production and Management* 9, 2-3:79-83.

Johansson, I., N. Korkman and N.J. Nelson, 1952. Studies on the udder evacuation of dairy cows I. The rise in fat percentage during milking. *Acta Agriculturae Scandinavica* 2:43.

Knight, C.H., 2001. A vision of dairy production in the UK. British Society of Animal Science, *Occasional publication* 28:51-57.

Lind, O., K. Ranade and C.S. Thomas, 1997. Experiences from machine milking of buffaloes. *Proceedings of 5th World Buffalo Congress*, Caserta, Italy. (Ed. A. Borghese, S. Failla and V.L. Barile) 916-917

Mahadevan, P. 1992. Distribution, ecology and adaptation of river buffaloes. In: *Buffalo production, production-system approach. World Animal Science*, C6:1–58 (Ed. N.M. Tulloh and J.H.G. Holmes.) Elsevier Science Publishers, Amsterdam, Netherlands.

Manorama India Yearbook, 1998. Cinderella of Indian Agriculture. *Manorama India Yearbook*: 533-536.

Martini, M., S. Spinelli, C. Scolozzi, F. Cecchi, 2003. Studio delle caratteristiche lipidiche del latte di bufale allevate in Toscana: nota II. *Atti II Congresso Nazionale sull'Allevamento del Bufalo*, Monterotondo (RM): 147-151.

Moran, J.B., B.W. Norton and J.V. Nolan, 1979. The intake, digestibility and utilization of low-quality roughage by Brahman cross, buffalo, Banteng and Shorthorn steers. *Australian Journal of Agricultural Research,* CSIRO. 30 (2): 333-340.

NRC, 1988. National Research Council. Nutrient Requirement of Dairy Cattle. p. 38

Nayak, S. and M. Mishra, 1984. Dairy temperament of Red Sindhi, Crossbred and Murrah buffaloes in relation to their milking ability and composition. Indian *Journal of Dairy Science* 37:20-23.

Odyuo, L.T., D.N. Jana and N. Das, 1994. General behaviour of Murrah buffaloes under an intensive management system. *Applied Animal Behaviour Science* 45:293-299.

Palmer, N., 2005. http://www.buffalomilk.co.uk

Pathak, N.N., 1992. Buffalo production, *World Animal Science* C6. (Ed. N.M. Tulloh and J.H.G. Holmes.) Elsevier Science Publishers, Amsterdam, Netherlands.

Patil, G.R. and S.K. Nayak, 2003. Competitive advantages of using buffalo milk for product manufacture. *Proceedings of 4th Asian Buffalo Congress*, New Delhi, India: 183-190.

Ramesh, V., Thanga Thamin Vana and A. Varadhrajan, 2002. Improvement of reproductive performance of buffaloes. *Pashudhan* 17 (01):1-4.

Ranjan, S.K. and N.N. Pathak, 1992. Buffalo production, *World Animal Science* C6. (Ed. N.M. Tulloh and J.H.G. Holmes.) Elsevier Science Publishers, Amsterdam, Netherlands.

Radadia, N.S., R.N. Pal, I.J. Juneja and N.S.R. Sastry, 1980. *Harayana Agricultural University Journal of Research* 10:144.

Raizada, B.C. and M.D. Pandey, 1972. Reproductive performance of buffalo heifers during summer. *Indian Journal of Animal Science*. 42:8-12.

Rao, M.K. and R. Nagarcenkar, 1977. Potentialities of the buffalo. *World Review of Animal Production* 13: 53-62.

Redbo, I., M. Emanuelsson, K. Lundberg and N. Oredsson, 1996. Feeding level and oral stereotypes in dairy cows. *Animal Science* 62: 199-206.

REU Technical series 67, 2005. (Ed. A. Borghese.) FAO regional office for Europe.

Roy, P.K. and P.K. Nagpaul, 1984. Influence of genetic and non-genetic factors on temperament score and other traits of dairy management. *Indian Journal of Animal Science* 54 (6):566-568.

Roy, A., M.D. Raizada, R.B.L. Tewari and M.D. Pandey, 1968. Effect of management on fertility of buffalo cows bred during summer. *Indian Journal of Veterinary Science* 38:554-560.

Sastry, N.S.R., 1983. Monograph: Buffalo husbandry; constraints to successful buffalo farming and overcoming the same through management. Institute of Animal Management and Breeding, University of Hohenheim, Germany, Discipline – Milk Production: 4-6.

Sastry, N.S.R. and V.N. Tripathi, 1988. Modern management innovations for optimising buffalo production. Buffalo production and health: a compendium of latest research information based on Indian studies. *2nd World Buffalo Congress*, New Delhi, India: 38-62.

Schein, M.W. and E.S.E. Hafez, 1969. The physical environment and behaviour. In: Hafez E.S.E. (ed) *The behaviour of domestic animals*, 2nd ed. Williams and Wilkins, Baltimore, Maryland, USA: 65-84.

Shultz, E., T.A. Schultz, J.C. Garmendia and C.F. Chico, 1977. Comparison of cattle and domestic buffaloes fed on tropical forage at three vegetative stages. 1. Behaviour, intake and rumination. *Agronomica Tropical* 27:319-330.

Siebert, B.D. and W.V. MacFarlane, 1969. Body water content and body water turnover of tropical Bos taurus, Bos indicus, Bibos banteng and Bos bubalus bubalis. *Australian Journal of Agricultural Research* 20:613-622.

Sindhu, J.S. and O.P. Singhal, 1988. Quantitative aspects of buffalo milk constituents for product technology. Buffalo production and health: A compendium of latest research information based on Indian studies. *Proceedings of 2nd World Buffalo Congress*, New Delhi, India: 25-28, 263.

Sjaunja, L-O., L. Baevre, L. Junkarinen, J. Pedersen and J. Setälä, 1990. A Nordic proposal for an energy corrected milk (ECM) formula. *ICPMA, 27th Session*, Paris, France.

Stefanon, B., M. Colitti, G. Gabi, C.H. Knight, and J.W. Colin, 2002. Mammary apoptosis and lactation persistency in dairy animals. *Journal of Dairy Research* 69:37-52

Storry, J.E. and G.D. Ford, 1982, cited by Mariani et al. (2001). Some factors affecting the post-clotting development of coagulum strength in renneted milk. *Journal of Dairy Research*. 49:469-477.

Ståhl Högberg, M. and O. Lind, 2003. Buffalo Milk Production. www.milkproduction.com

Subasinghe, D.H.A., N.U. Horadogoda, H. Abeygunawardena and J.A. de S. Siriwardene, 1998. Water buffalo – improved utilisation through new technologies. National Science Foundation, Sri Lanka.

Swedish Dairy Association, 2003. Cattle Statistics. Svensk Mjölk, Eskilstuna, Sweden.

Thind, J.S. and R.S. Gill, 1986. Ingestive pattern of lactating buffaloes kept under loose housing system. Short Communications: 218-223 .

Thomas, C.S., 2005. Milking management of dairy buffaloes. PhD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Thomas, C.S., R.M. Bruckmaier, M.R. Bhosrekar, K. Svennersten-Sjaunja, 2005. Short-term influences of tactile stimulations on milking characteristics in buffaloes. *Mastitis in dairy production, current knowledge and future solutions.* (Ed. H. Hogeveen) Wageningen Academic Publishers, The Netherlands, p. 846.

Thomas, C.S., J. Nordstrom, K. Svennersten-Sjaunja and H. Wiktorsson, 2004. Maintenance and milking behaviours of Murrah buffaloes during two feeding regimes. *Applied Animal Behaviour Science*, 91, 3-4:261-276.

Thomas C.S., H. Nimmervoll, C. Boije, N. Lundeheim and K. Östensson 2004. Occurrence of mastitis in dairy buffaloes under different milking management systems in Sangli district, India. *Buffalo Journal* 3: 289-306.

Thomas, C.S., K.S. Svennersten-Sjaunja, M.R. Bhosrekar and R.M. Bruckmaier, 2004. Mammary cisternal size, cisternal milk and milk ejection in Murrah buffaloes. *Journal of Dairy Research* 71:162-168.

Tonhati, H. and M.F. Cerón-Muñoz, 2002. Milk production and quality and buffalo genetic breeding in the state of São Paulo, Brazil. *1st Buffalo Symposium of Americas*, Belém-Parà, Brazil: 267-280.

Tripaldi, C., G. Catillo , F. Martillotti, M. Angelucci. 1997. Influence of some characteristics of diet on milk quality of water buffalo. *Buffalo Journal* 1:1-13.

Tripaldi C., Terramoccia S., Bartocci S., 2002. Attitudine del latte di bufala alla coagulazione presamica. *Scienza e Tecnica Lattiero-Casearia* 53, 41-52.

Tyrrell, H.F., and J.T. Reid, 1965. Prediction of the energy value of cow's milk. *Journal of Dairy Science* 48:1215-1223.

Varma, A.K. and N.S.R. Sastry, 1994. Milking management of Murrah buffaloes followed in rural India. In: *Proceedings of 4th World Buffalo Congress*, Vol-II, Sao Paulo, Brazil.

Vidya, S., 2004. Personal communication. DOLCOS (Dairy Owners' League and Co-operative Society) Mumbai, India.

Wahid, A., 1973. Pakistani buffaloes. *World Animal Review* 7:22-28.

Wilde, C.J., D.T. Calvert, A. Daly and M. Peaker, 1987. The effect of goat milk fractions on the synthesis of milk constituents by rabbit mammary gland explants and on milk yield in vivo. *Biochemical Journal* 242:285-288.

Wilde, C.J. and M. Peaker, 1990. Autocrine control of milk secretion. *Journal of Agricultural Science* 114:235-238.

Notes

Notes

www.delaval.com

53570959BR/en-200802.