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Nutritional Management for Buffalo Production*

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ABSTRACT : The buffalo (*Bubalus bubalis*) is an important contributor to milk, meat, power, fuel and leather production in many developing countries. Buffaloes can be categorized into Asian and Mediterranean buffaloes. Asian buffalo includes two subspecies known as Riverine and Swamp types. Riverine (water buffalo) and Swamp buffaloes possess different genetics (50 vs. 48 chromosomes, respectively), morphology (body frame, body weight, horn shape and skin color) and behavior (wallowing in mud or water) and thus, are reared and used for different purposes. Low per head milk yield, poor reproductive performance (seasonal breeding behavior, anestrous, and longer calving interval) and low growth rate in buffaloes have been attributed to insufficient supply of nutrients. In many parts of Asia, where the buffalo is an integral part of the food chain and rural economy, irregular and inadequate availability of quality feedstuffs and their utilization are hampering the performance of this unique animal. Balanced nutrition and better management can enhance buffalo productivity. Many efforts have been made in the last few decades to improve nutrient supply and utilization in buffaloes. Recent research on locally available feed resources such as crop residues, and industrial by-products, dietary addition of micronutrients, use of performance modifiers and use of ruminally protected fat and protein sources have shown significant potential to improve growth, milk yield and reproductive performance of buffaloes. However, a number of issues, including establishment of nutrient requirements for dairy and beef, development of buffalo calf feeding systems, nutritional management of metabolic and reproductive anomalies, and understanding and exploitation of the buffalo gut ecosystem, need to be addressed. Extensive coordinated research and extension efforts are required for improved buffalo nutrition in developing countries. (**Key Words :** Buffalo, Nutrition, Feeding)

INTRODUCTION

The buffalo (*Bubalus bubalis*) is an important contributor to milk, meat, power, fuel and leather production in many developing countries. Buffaloes could be categorized into Asian and Mediterranean buffaloes. Asian buffalo have two subspecies known as the Riverine and Swamp types. The River (water buffalo) and Swamp buffalo possess different genetics (50 vs. 48 chromosomes, respectively), morphology (body frame, body weight, horn shape and skin color) and behavior (wallowing in mud or water) thus are reared for different purposes. Riverine buffaloes are generally larger in size, heavier with curled horns and are mainly found in India, Pakistan and in some countries of western Asia. They are primarily used for milk and meat production (Sarwar et al., 2002a, b). Swamp buffaloes are stocky animals with marshy land habitats and are mainly found in South East Asian countries. They are primarily used for draught power but are also used to produce meat and small quantity of milk.

Global buffalo population is estimated to be 177 million (FAOSTAT, 2006). Out of which nearly 170 million are in Asia (more than 95%) and the remaining are found in Africa (3.92 million) and South America (1.3 million). Australia and Mediterranean countries also have significant buffalo population (FAOSTAT, 2006). In Asia, majority of the buffaloes are reared in a mixed cut and carry, tethering and grazing system on communal pasture land. In South Asia, there are emerging semi-commercial and commercial-size dairy operations around the peri-urban areas. Buffaloes under such farming arrangements are reared in total confinement system (Sarwar et al., 2002a, b).

Buffalo has inherent ability to produce milk with high milk fat contents ranging from 6 to 8.5%. Because of its higher milk fat contents, buffalo milk is preferred over cow milk and fetch better price in South Asian milk markets (Sarwar et al., 2002a, b; Khan et al., 2008a). In other

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countries including Mediterranean region, the buffalo milk is mainly used to produce cheese.

Buffaloes are better converter of poor-quality fibrous feeds into milk and meat. Terramoccia et al. (2000) reported better degradation of both crude protein (CP) and protein-free dry matter (DM) in buffaloes than in cattle. Other workers have also demonstrated a better digestive ability of buffaloes than cattle to utilize poor quality roughage (Bartocci et al., 1997; Agarwal et al., 2009).

Low milk yield, poor reproductive performance (seasonal breeding behavior, anestrous, and longer calving interval) and low growth rate have been reported in buffaloes (Singh and Mehra, 1990; Qureshi et al., 2002; Sahoo et al., 2004; Wynn et al., 2009). In many parts of Asia, irregular and inadequate availability of quality feedstuffs and their utilization are the main causes of poor performance of buffaloes. In South-east Asia, the buffaloes are mainly fed cereal straws that are highly lignified and contain low contents of both fermentable protein and carbohydrates. Many efforts have been made in the last few decades to improve the nutrients supply and utilization in buffaloes with varying degree of success. Recent research on locally available feed resources such as cereal straws and corncobs, ensiling fodders, use of industrial and agriculture by-products, dietary addition of fermentation modifiers, vitamins, and usage of ruminally protected dietary protein and fat sources have shown significant potential to improve both growth and milk yield in buffaloes. Use of metabolic and fermentation modifiers, manipulations of rumen microorganisms in buffaloes could also play a significant role in improving its productivity.

The objective of this review is to summarize existing feeding practices and current research in nutritional management of buffaloes.

Protein and energy requirements of buffaloes

Buffaloes like other domesticated ruminants meet their protein and energy requirements from fermentation end-products (microbial protein and volatile fatty acids). In recent past, comparative studies on the digestive physiology and nutrient requirements of buffalo with other species such as cattle and sheep have been reported (Bartocci and Di Lella, 1994; Puppo et al., 2002). A greater ruminal degradation of both fiber and protein was noticed in buffaloes than in cattle and sheep. This unique ability to better ferment fiber in buffaloes could be the result of adaptation because for years they have been fed on low quality high fibrous feeds (Sarwar et al., 2005a). Particularly in Aisa and elsewhere, energy and protein demands of buffaloes are being mainly met by feeding them low-quality roughages, agricultural crop-residues and industrial by-products which contain high levels of lingo-cellulosic materials, low levels of fermentable carbohydrate and protein. Although feeding fresh-green fodder (legumes and grasses) through "cut and carry system" is still contributing significantly to the nutrition of south Asian buffaloes, however, weather extremes limit the use of green fodders to certain seasons. Thus, during extreme fodder scarcity periods (May to June and November to December) in India and Pakistan, buffaloes are completely switched to cereals straws to meet their energy and protein demands (Khan et al., 2006c). Current research work on the subject is summarized below.

Quality and level of dietary protein

The scientific data to explain protein requirements and their utilization from different sources at various physiological stages in buffaloes is scarce. In contrast to high producing western dairy cattle where much attention has been paid to develop energy and protein standards and nutrient requirement models, no such planned effort has been made to establish protein or energy needs in buffaloes. Conflicting results have been reported by various workers on the level of protein required in buffalo diets during lactation and growth (Verna et al., 1994; Campanile, 1997; Terramoccia et al., 2000; Puppo et al., 2002). Protein concentrations used in lactating buffalo diets can be equal to or below 12% on DM basis, since these concentrations have little influence on the quantity and quality of milk produced (Verna et al., 1992; Verna et al., 1994). Sivaiah and Mudgal (1978) suggested the administration of 166 to 126 g of digestible CP/100 g of milk protein produced, while according to Rai and Aggarwal (1991), the concentration of CP on DM should be between 11 and 14%. A linear increase in fiber digestibility, greater microbial counts and a linear reduction in N retention was observed in buffalo bulls with increasing level of ruminally degradable protein (RDP) (Javaid et al., 2008). In this study, ruminal ammonia, blood urea N (BUN) and urinary N excretion were higher in bulls fed diets containing increasing level of RDP. They concluded that no deleterious effects had been noticed on ruminal parameters and digestibility of nutrients when 82% RDP (of total 16% dietary CP) was fed to buffalo bulls. Nisa et al. (2008) reported that the DM and NDF intakes were decreased while their total tract apparent digestibility in lactating buffaloes was increased when RDP contents were increased from 50 to 82% in the dietary CP. Dietary RDP/RUP did not affect the CP digestibility in lactating buffaloes. Milk yield and milk constituents (fat and protein) yields were greater in buffaloes fed 50% RDP than those fed higher levels of RDP. Lower conception rate and a linear decrease in N balance and milk yield of buffaloes with increasing level of RDP:RUP was observed.

From the published data it can be concluded that supplementing buffalo diets with RUP can increase the efficiency of N utilization by increasing the flow of N and amino acids to the small intestine, supplying more amino acids for milk yield. Higher level of RDP in buffalo ration causes excessive ruminal NH_3 production in rumen which ultimately results in an increase blood urea. Increase in ruminal NH_3 and blood urea decreases dry matter intake (DMI) and reduces conception rate in buffaloes, similar to those observed in dairy cattle (Dhali et al., 2006). Furthermore, excessive supply of protein and/or imbalance supply of RDP and RUP in buffalo ration could cause negative energy balance associated with metabolic disposal of excessive N escaping from the rumen.

Treatment of crop residues

The roughages are eaten by buffaloes less voluntarily because of their slow passage through alimentary canal (Sarwar et al., 2004a, 2005b). Only limited use can be made of straws in buffalo nutrition if fed without any treatment. Animals spend more energy in chewing and digesting such roughages than they gain from them. Often the digestibility of poor roughage is limited not due to the lignification only but also due to the low N content. Physical (particle size reduction), biological (pre-feeding fermentation, addition of fibrolytic enzymes), and chemical treatment have been extensively explored to improve the utilization of crop residues in buffalo diets (Khan et al., 2008b).

Among various chemicals (acids and alkalis) employed for the treatment of cereal straws, ammonia (NH_3) and alkali have shown good results (Mehra et al., 2001). Decreased neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin contents of ammoniated straws have been reported (Sarwar et al., 1994). Ammoniation can break the linkage between hemicellulose and lignin and make the hemicellulose fraction partially soluble to NDF solution. The soluble hemicellulose would be highly digestible by ruminal micro-organisms. Moreover, after being ammoniated, treated straws have increased N content relative to untreated straws. It can also improve palatability and intake in buffaloes (Nisa et al., 2004a). However, in urea treated fibrous crop residues about 70% of ammonia (NH_3) released from urea by the action of urease escapes to the environment. This often renders the ammoniation process uneconomical and causes environmental pollution (Sarwar et al., 2004a, b). Organic and inorganic acids (Dass et al., 2004; Sarwar et al., 2004a; Khan et al., 2006a; Khan et al., 2006b) have been used to increase the N retention in urea treated fibrous material. Corn steep liquor (CSL) is a concentrated thick and complex mixture of carbohydrates, amino acids, peptides, organic compounds, inorganic ions, and *myo*-inositol phosphates derived from wet corn milling (Nisa et al., 2004a). However, CSL has low pH because of its high lactic acid contents that limit its direct feeding to ruminants. The low pH and fermentable sugars of CSL and acidified molasses can possibly enhance fermentation and thus N retention (fiber bound and water soluble fractions) in ammoniated straw better than merely adding acids to reduce the pH of ensiled urea treated wheat straws for N capture (Nisa et al., 2004a; Nisa et al., 2004b). Significantly higher intake, digestibility, and milk yield have been reported in buffaloes fed ammoniated wheat straw or corncobs ensiled with acidified fermentable sugar sources than otherwise (Sarwar et al., 2005a; Khan et al., 2006a; Nisa et al., 2006).

Urea molasses blocks

Although the cellulosic feedstuffs are the primary basal feed for buffaloes, seasonal shortages do occur during weather extremes and drought and flood situations, which adversely affect the buffalo productivity. A combination of urea, molasses and minerals in the form of solid blocks has been extensively prepared and fed to buffaloes. These blocks, as a source of fermentable carbohydrates and nitrogen, are preferred over ammoniation of crop residues because they are easy to ship and safe to handle by farmers. In many studies (Singh and Mehra, 1990; Sahoo et al., 2004), the supplementation of urea molasses block (UMB) to buffaloes fed straw based diets has increased the growth and supported moderate milk production.

Ensiling legumes and grasses

The critical constraint in profitable buffalo production is the inadequacy of quality forage (Touqir et al., 2007). In Asia, due to low per acre yield and minimum area under fodder production, the available fodder supply is much less than actually needed. Low per acre fodder yield coupled with two important fodder scarcity periods (one during summer and other during winter months) further aggravates the fodder availability situations (Khan et al., 2006a, b, c). Constant supply of forage for buffaloes could be achieved by ensiling when the fodders are abundantly available (Sarwar et al., 2005a). Ensiling multi-cut high yielding legumes (Lucerne, Berseem) and grasses (corn, sorghum, barley, oat, millet, mott (*Pennisetum purpureum*) and jambo fodders) offer a good promise to bridge the escalating gap between supply and demand of fodder for buffaloes. However, because of continuous use of fresh green fodders over the years through the "cut and carry system", dairy farmers in south Asia believe in a strong myth that feeding silage could hamper buffalo productivity (Khan et al., 2006c). Recently few studies (Nisa et al., 2005; Khan et al., 2006c; Touqir et al., 2007) have successfully fed grasses and legumes silages to lactating buffaloes without hampering their productivity. Touqir et al. (2007) reported that the jambo grass and mott grass ensiled with 2% molasses for 30 days could safely replace the conventional fresh grass fodder (75% DM) in the diet of lactating *Nili* buffaloes without affecting nutrient digestibility and milk yield. Similar results were reported when Mott grass (Nisa et al., 2005), berseem and lucerne silages (Sarwar et al., 2005b) were replaced for conventional fresh fodders in the diets of lactating *Nili* buffaloes. Khan et al. (2006c) reported that intake, total tract apparent digestibility, milk yield and its composition was not affected when fresh oat grass fodder DM (75%) was replaced with its silage in lactating buffaloes.

Berseem and lucerne are highly nutritious, high yielding and abundantly available multi-cut legumes in Asia. However, these leguminous fodders have high buffering capacity (due to high protein and mineral content), and high moisture content that led to slow pH decline during ensiling and caused heavy nutrient losses (Yahaya et al., 2004). These fodders could be best ensiled after lowering their moisture content either through wilting or ensiling them with cereal straws and by supplementing with a fermentable carbohydrate source. Touqir et al. (2007) reported that the berseem and lucerne could be ensiled with wheat straw to increase their DM to 30% along with 2% molasses for buffaloes.

Nutritional strategies to improve reproduction

Fertility in water buffalo is considerably lower than that in cattle (Drost, 2007). Delayed first calving age, longer calving interval, seasonal estrous behavior and poor estrus expression in buffaloes have been reported by many authors (Qureshi et al., 2002; Patro et al., 2003; Rakshe, 2003). It has been demonstrated that manipulation of nutritional and environmental factors could reduce the age of first calving and calving interval in buffaloes (Qureshi et al., 2002; Drost, 2007). Delayed age at first calving is not a characteristic of the species, but is dependant on the nutritional management of the growing animals (Zicarelli, 2006). Delayed age at first calving in buffaloes could be reduced if they are fed to achieve higher body weight gain (Qureshi et al., 2002). Pre-weaning and post-weaning feeding strategies greatly affect the early growth rate, age at first conception and calving in buffaloes. Therefore, to ensure a good growth in buffalo, heifer management needs to start from birth. Zicarelli (2006) described that the time required by the new-born for doubling its weight at birth in the majority of the domestic species including buffalo was indirectly correlated to the protein, fat and ash content of the milk, to the lactose/fat ratio and to the energetic value but directly correlated to the lactose content and the fat/protein ratio of the milk. Moreover, he mentioned that the buffalo calf represented an exception because, despite more concentrated milk, for doubling the weight at birth, it takes more time than the bovine calf. Buffalo heifers that showed a daily gain of 631 g per day reached puberty at 598 days, while a daily gain of 441 g per day postponed puberty to 658 days (Borghese et al., 1994). Age at puberty is also affected by dietary energy level. Heifers fed with high level of energy (5.56 MFU/d) had better daily gain of 562 vs. 465 g than heifers fed with lower energy level (4.42 MFU/d), and reached puberty 30 days earlier (Borghese et al., 1994). Zicarelli et al. (2005) concluded that more energy dense diets were required for buffaloes than in cattle to improve growth rate similar to cattle and to reduce the age at first calving in buffalo. Qureshi et al. (2002) described that higher serum urea levels because of excessive CP intake and poor body condition because of lower energy intake were the key factors for lower reproductive efficiency in *Nili-Ravi* buffaloes.

Zicarelli (1997) reported that a variable number of buffalo cows became acyclic due to sudden climatic variation such as a fall in temperature, exposure to cold wind, heavy rain associated with low temperature, or hot weather without any possibility of bathing or sheltering from the sun. Higher oxidative stress during summer is the primary cause of reproductive failure in buffaloes. Kahlon and Singh (2003) indicated that supplementation of α-tocopherol to anestrous buffalo heifers mitigated the effects of oxidative stress to improve their antioxidant status. They explained that the oral supplementation of α-tocopherol at 3,000 mg per week per animal in anestrus heifers declined erythrocytic superoxide dismutase and glucose-6-phosphate dehydrogenase activities significantly but led to non-significant increase in erythrocytic glutathione peroxidase activity. Similarly, Nayyar et al. (2002) reported that anoestrus buffalo heifers supplemented with vitamin E at 3,500 IU/week had increased vitamin E level in the plasma and 80% buffaloes showed estrus within 133 days of supplementation. The post partum estrus interval was reduced from 63 to 35 days in Egyptian buffaloes by supplementing 4,200 mg of vitamin E in combination with 4.2 mg Se from the last month of pregnancy till first month post partum (Ezzo, 1995). Panda et al. (2006) concluded that vitamin E supplementation at 1,500 IU/d in dairy buffaloes might be practiced from 60 days prepartum to 30 days postpartum in order to have higher plasma α-tocopherol level and better total antioxidant status at parturition. Vitamin E supplementation at 1,000 IU from 30 to 60 days postpartum decreased postpartum estrus interval, days open and services per conception suggesting that the supplemental dose might be reduced from 1,500 IU to 1,000 IU from 30-60 days postpartum in buffaloes.

El-Barody et al. (2001) reported that the buffaloes receiving niacin supplementation had shown a shorter interval from calving to detected estrus, required fewer services per conception, shorter uterine involution and days open as compared with the control group. They explained that energy status was generally considered to be the major nutritional factor that influenced reproductive process in buffaloes. Overall in ruminants, poor nutrients supply resulted in a low ovulation rate associated with decreasing

LH pulse frequency, probably due to inadequate hypothalamic GnRH secretion (Rhind et al., 1989). In cattle, a strong correlation between negative energy balance in early lactation and resumption of ovulation has been shown (Canfield and Butler, 1990). Furthermore, long term restriction of feed intake induced anestrus in cattle due to insufficient circulating LH which probably suppresses follicle growth and oocyte maturation. El-Barody et al. (2001) indicated that the beneficial effect of niacin supplementation on feed utilization resulted in an increased DMI and affected the energy mobilization by increasing the ME intake. Because DMI is the major limiting factor for the production of milk by high yielding animals, it seems likely that the key element dictating an early ovulation in dairy animals supplemented with niacin is the better nutrient intake during the first few weeks after calving. This has potentially a two-fold effect on ovarian recrudescence in the dairy buffaloes. First, it is likely that the enhanced nutrient availability to the animal may stimulate the ovary or other parts of the hypothalamic-pituitary-ovarian axis. In addition, greater nutrient intake reduces the energy deficit and may avoid stimulation of gonadotropin secretion, which could accompany severe nutrient depletion. They concluded that the supplementation of niacin at 6 g/head daily improved the productive and reproductive performance of buffaloes. Sarwar et al. (2007b) reported that feeding 1.5% of sodium bicarbonate (SB) to early lactating buffaloes during summer reduced services per conception. They explained that lactating buffaloes had higher metabolic rate that tended to make the cellular environment acidic due to more CO_2 production. A high SB diet, due to high Na content, is alkalogenic in nature and reduces the extent of that acidity and thereby increases cellular glucose uptake and DM intake (Block, 1994). Sarwar et al. (2007b) attributed better reproduction response in buffaloes fed SB to their higher DM intake. Javaid (2007) reported that increasing RUP in the diets of buffalo linearly decreased the fertility in buffaloes fed iso-nitrogenous diets. Excess intake of CP, associated with increasing serum urea levels, might had led to delayed postpartum ovarian activity in *Nili-Ravi* buffaloes (Qureshi et al., 2002).

Metabolic and fermentation modifiers

Generally the metabolic modifiers are defined as compounds which are fed, injected, or implanted in animals to improve nutrient utilization, feed efficiency, rate of gain, milk yield and its composition. Fermentation modifiers are the products that are used in feed to manipulate rumen fermentation for better feed utilization. Both metabolic (Somatotropin β-Agonists estrogenic and androgenic implants; conjugated linoleic acid; chromium, carnatine, magnesium, niacin, manganese, selenium betaine, vitamin A, D, and E) and fermentation modifiers (methane inhibitors, proteolysis and deamination inhibitors, defaunation agents, microbial enzymes, buffer agents, ionophores, probiotics, yeast cultures, mold fermentation extracts and non-ionic surfactant) have been extensively used in dairy and beef cattle to improve the feed utilization and productive response. However, their effect on buffaloes has rarely been demonstrated in the literature. Injecting 250 mg of bST in lactating buffaloes did not affect blood metabolites such as glucose, triglycerides, total proteins, albumin, globulin and electrolytes like sodium and potassium (Mishra and Shukla, 2004). However, a significant decrease in BUN concentration was noticed in buffaloes receiving bST injection. Average milk yield was 25% more in bST injected animals than those of control animals. Usmani and Athar (1997) reported no negative effect of bST injection on the reproductive response of buffaloes. Sarwar et al. (2007c) also investigated the influence of bST administration at the rate of 250 mg per animal fortnightly in mid lactating buffaloes. Significantly higher feed consumption and milk yield was noticed in buffaloes receiving bST injection compared to control.

Niacin functions as a coenzyme for the pyridine nucleotide electron carriers NAD (H) and NADP (H). Consequently niacin plays a critical role in mitochondria respiration and the metabolism of carbohydrate, lipids and amino acids (Kumar and Dass, 2006). In ruminants, niacin is synthesized by rumen microorganisms and its synthesis has been considered to be adequate for their optimum performance (Hungate, 1966). But, other research findings suggested that microbial production of niacin in the rumen does not meet requirements of growing calves (Girard, 1998) and oral administration of niacin has resulted in an increased microbial protein synthesis and volatile fatty acids (Flachowsky, 1993). Dass and Kumar (2005) demonstrated that supplementation of niacin had a stimulating effect on rumen fermentation in buffaloes with enhanced synthesis of microbial protein and VFAs. They further stated that positive effect of niacin supplementation on rumen protozoa number had also been confirmed. Furthermore, the supplementation of niacin in the diet of buffaloes had improved the rumen fermentation by decreasing the concentration of ammonia-N and increasing protein synthesis (Kumar and Dass, 2006). Oral administration of niacin has resulted in an increased microbial protein synthesis and higher weight gain in growing animals (Flachowsky, 1993). However, Kumar and Dass (2006) reported that supplementation of niacin at 100 and 200 ppm in the diet of buffalo calves had no significant beneficial effect on their growth and nutrient utilization.

The use of biological feed additives, particularly live yeast cultures (*Saccharomyces cerevisiae*), has been extensively used to enhance nutrient utilization in ruminant animals (Francia et al., 2008). However, the extent of response is often influenced by the basic diet of the host animal and the strain of yeast. Kumar et al. (1994) described that the inclusion of yeast culture in a high concentrate diet of buffalo calves increased microbial populations and altered fermentation in the rumen. Kumar et al. (1997) reported that inclusion of yeast in the diet of buffalo calves fed a high roughage diet significantly increased the total number of rumen bacteria which in turn probably resulted in changed VFA production with higher acetate to propionate ratio. Francia et al. (2008) reported that the inclusion of *S. cerevisiae* and *A. oryzae* in a calf starter improved total tract apparent digestibility of DM, OM, CP, NDF and gross energy. They described that the positive effects of these additives may be related to stimulation of growth of cellulolytic bacteria, which led to increased hay intake and fiber digestibility.

Dietary cation anion difference (DCAD) is the difference between certain dietary minerals nominated as cations (Na, K) and anions (Cl, S) on the basis of charges they carry and is usually measured as milliequivalents of (Na+K)-(Cl+S) per kilogram of DM (Sarwar et al., 2007a). Animal productivity is influenced more by the difference between these cations and anions than their individual effects when fed as a sole independent mineral source. Recently, Shahzad et al. (2008a) reported that a diet having 330 mEq/kg DM DCAD has promoted feed consumption, water intake and resulted in greater milk yield and milk fat in early lactating buffaloes. They explained feeding more dietary cations than anions counteracted the ruminal and blood acids and increased the feed consumption in early lactating buffaloes. Enhanced feed intake and weight gain has also been reported in growing buffalo male calves fed 330 DCAD level (Shahzad et al., 2007b). Occurrence of hypocalcemia was reduced by feeding diet containing -110 DCAD level, for last four to six weeks before parturition (Shahzad et al., 2008b). The slight metabolic acidosis induced by low DCAD diet improves calcium absorption from intestine and mobilization from bones. Similar results in cattle were previously demonstrated by Block (1994).

High nutrients demand of lactating cattle in early lactation is usually satisfied by high concentrate diet, which generally results in low acetate to propionate ratio (Anderson et al., 1999). This leads to decreased feed consumption because of ruminal acidosis and thus low milk yield and milk fat content (Kennelly et al., 1999). There are various way and means to increase DMI in lactating animals and one of the most promising is supplementing of sodium bicarbonate. Sarwar et al. (2007b) reported that feeding 1.5% of sodium bicarbonate to early lactating buffaloes during summer not only increased DMI, water intake, milk yield and milk fat % but also reduced services per conceptions. They explained that high sodium bicarbonate diet had the tendency to increased ruminal pH, which might have shifted the fermentation pattern in favor of acetate and butyrate production. It might have resulted in increased *de novo* fatty acid synthesis which accounts for about 60% of bovine milk fat and hence increased milk fat content.

Nutritional management of calves

To have good dairy replacement stock and higher body weight gain in buffalo, an efficient calf-feeding system is crucial because it determines the future income and sustainability of a buffalo enterprise. However, buffalo calf nutrition and feeding management is the most neglected area in both buffalo husbandry and research. Wynn et al. (2009) reported higher mortality and morbidity losses in buffalo calves and attributed this to poor colostrum and feeding management of calves. In south Asia, although calves are generally separated from their dams at birth, however, they are allowed to suckle limited amount of milk for few weeks directly from dam's teat at each milking. Then the calves are usually milk weaned between 4 to 12 weeks of their age. Main determinants of milk weaning in buffalo calves are the price of milk, dam's milk let down behavior and sex of the calf. Direct teat suckling is commonly used as a stimulus for milk let down under conventional farming in India and Pakistan. In many cases, especially in rural areas, female calves are weaned later than male calves. In contrast to this system, Mediterranean buffalo calves are separately fed limited amount of milk or milk replacer using bucket or teat for first few weeks of life before weaning. The Mediterranean buffalo calves also receive some amount of concentrate to ensure their early rumen development. Early mortality in buffalo calves in south Asia was higher than those reported in Mediterranean buffalo calves (Khan et al., 2007; Ranjhan, 2007). Ranjhan (2007) explained that mortality in buffalo calves could be reduced if the calves are separated from their dams at birth, fed good quality colostrum within few hours of their birth and then milk in proper amounts using artificial nipples. Scientific data regarding growth and physiological response of buffalo calves to various dietary attributes during pre-weaning and post-weaning is scarce to draw solid conclusions. Sporadic attempts have been made to examine the influence of weaning age (Palladino et al., 1993; Cutrignelli et al., 2003), dietary energy and protein level in starter diets (Luccia et al., 2003; Zicarelli et al., 2007), supplementation of yeast cultures (Kumar et al., 1997; Francia et al., 2008) on the performance of buffalo calves with contrasting conclusions. In most of the studies where growth and physiological response of buffalo calves to various dietary treatments were assessed used the term "buffalo calf" for animals having body weight ranging between 40 to 220 kg. Thus at the first instance, it is highly essential to develop and use proper scientific terminology based on the physiology, body weight and age of buffalo calves. Then the extensive coordinated research efforts are required to establish the pre-weaning and post-weaning nutritional regimens and feeding management systems for calves reared for two distinct purposes i.e. milk and meat production.

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