Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(4): 916-922

Received: 17-05-2018
Accepted: 19-06-2018

Hunny Sharma
M.V.Sc. Scholar, NDRI, Karnal, Haryana, India

Ravi Prakash Pal
Ph.D. Scholar, NDRI, Karnal, Haryana, India

Shahid Hassan Mir
Ph.D. Scholar, NDRI, Karnal, Haryana, India

Veena Mani
Principal Scientist NDRI, Karnal, Haryana, India

Lamella Ojha
Ph.D. Scholar, NDRI, Karnal, Haryana, India

Correspondence
Ravi Prakash Pal
Ph.D. Scholar, NDRI, Karnal, Haryana, India

Effect of feeding buffer on feed intake, milk production and rumen fermentation pattern in lactating animals: A review

Hunny Sharma, Ravi Prakash Pal, Shahid Hassan Mir, Veena Mani and Lamella Ojha

Abstract
The dairy industry is under pressure to fulfil the increasing demands of milk and milk products. For this reason, dairy farms are growing in size and utilizing state-of-art technologies in an attempt to improve their productivity and efficiency. Additionally, dairy entrepreneurs face the challenge of maintaining the quality of milk. Higher concentrate mixture is required to maintain the production of lactating animals. Feeding high concentrates to high producing animals often upset the rumen environment and compromising the productivity of animals. Different feed additive is used to prevent the occurrence of sub-acute rumen acidosis, among them buffers are commonly used. Studies have shown that buffers not only maintain the rumen homeostasis but also increase the productivity of animals. The literature pertaining to the effectiveness of supplementation of dietary buffer on feed intake, milk production and rumen fermentation pattern in lactating animals is being presented in this review.

Keywords: Buffer, feed intake, lactating animal, milk production, rumen acidosis

Introduction

Nutrition is a key factor influencing the performance, health and welfare of cows (Poppi *et al*., 2000) [51]. However, milk quantity and composition (especially fat content) are subject to the change in the nutrition plan, thus providing producers means to adjust to the changing market demands on a short-term basis (Chalupa and Sniffen, 1996) [8]. Therefore, cows with a high genetic potential for milk production receiving diets lacking in specific nutrients (e.g. energy, protein, vitamins or minerals) would result in suboptimal production responses. To prevent this from happening, producers provide dairy cows with highly digestible diets containing a high proportion of readily fermentable carbohydrates (Plaizier *et al*., 2008) [50], ensuring the cow's energy requirements are met. The high energy content of the provided diets will ensure maximum productivity but can lead to severe consequences resulting in reduced productivity and eventually reduced the profitability of the farm. Since ages ruminants have evolved to digest and metabolize predominantly forage diets (Van Soest, 1994; Krause *et al*., 2006; Dryden, 2008) [61, 41, 16]. Therefore, dairy cows with high concentrate diets (with limited amounts of effective fibre) often result in metabolic disorders, of which sub-acute rumen acidosis (SARA) is the most common and has substantial financial implications. SARA is a great concern to dairy farmers as it is associated with various undesirable disorders such as reduced dry matter intake and fibre digestion (Calsamiglia *et al*., 2008) [6], milk fat depression, laminitis (Nocek, 1997) [47], liver abscesses and even death can occur (Plaizier *et al*., 2008) [50]. Enemark *et al.* (2002) [20] reviewed the literature on aetiology of rumen acidosis, its pathogenesis, occurrence, significance, diagnostics and prophylaxis with special attention to subclinical rumen acidosis and concluded that the resulting metabolic acidosis appears to be reflected in urine. In an attempt to manage and alleviate SARA, feed additives are added to dairy cow diets, of which buffers are the most common compounds used. These can be provided through endogenous production (via saliva) and/or through dietary buffers of which sodium bicarbonate is the compound most commonly used in the industry (Chalupa *et al*., 1996) [9]. Though, buffers have shown to be very effective in preventing SARA. Mineral buffers are regularly added to diets in an attempt to prevent acidosis, especially in diets where the fibre content is too low. Buffers may prevent an overgrowth of acid tolerant *Lactobacilli*, preventing the potential reduction in rumen pH (Enemark, 2008) [19].

However, buffers should not be used on a routine basis to compensate for suboptimal feeding management. Buffers are compounds that neutralize excess acid within the cow's digestive system. Technically, buffers and alkalizers are different (Hutjens, 1991) [34]. Buffer (eg. Sodium bicarbonate and sodium sesquicarbonate) maintains the acidity level, or pH, within a narrow range when either an acid or a base is added, in contrast, an alkalizer eg. magnesium oxide and magnesium hydroxide, raises the pH in direct proportion to the amount added.

Mechanism involved in regulation of acid-base balance in dairy cattle

Regulation of acids and bases in the body are controlled through slight changes in hydrogen ion concentration, which may depress or accelerate chemical reactions in cells. High hydrogen ion concentration leads to acidosis. To prevent acidosis, the body has defence mechanisms: acid-base buffer systems (bicarbonate buffer system), respiration regulation, and kidney excretion (Guyton, 1971) [28]. Feeding high concentrate rations to dairy cattle not only result in higher milk production but also a higher risk of acidosis due to acid production in the rumen. There are three primary systems that regulate the hydrogen ion concentration in the fluids to prevent acidosis or alkalosis: (1) the chemical acid-base buffer system of the body fluids, which immediately combines with acid or base to prevent excessive changes in hydrogen ion concentration, (2) the respiratory centers, which regulate the removal of CO_2 (and therefore, H_2CO_3) from the extracellular fluid and (3) the kidneys, which can excrete either acid or alkaline urine, thereby reducing the extracellular fluid hydrogen ion concentration toward normal during acidosis or alkalosis (Guyton, 1986) [29]. Buffers are defined as a combination of a weak acid and its salt, which assist in maintaining rumen pH. Alkalizing agents neutralize the acid and increase pH (Goering and Van Soest, 1970) [27]. Buffers have been fed to sustain milk fat levels and feed consumption. They inhibit dramatic drops in rumen pH and thus work to sustain the critical balance of acetic and propionic acid.

Effect of buffers on feed intake in the ruminant

Because buffers have the ability to stabilize rumen pH there is more efficient cellulose digestion and increased rumen turnover, resulting in greater feed intake and decreased rumen fill. Miller *et al*. (1990) [46] reported that cows fed high and low fill diets with and without 1.5% sodium bicarbonate exhibited no production responses although dry matter intake increased slightly on buffered diets. Erdman *et al.* (1980) [21] studied digestibility parameters where an increase in ADF apparent digestion increased from 36% to 45.1% and 46.8% for 1.0% NaHCO3, and 0.8% MgO, respectively. Many other studies support findings that buffers increase dry matter intake (Kilmer *et al*., 1980) [40]. In contrast, Ehrlich and Davison (1997) [18] found intake to decrease with cows fed 4% sodium bentonite when fed sorghum-based diets. Apparent dry matter digestibility was decreased when 0.6 and 1.2% sodium bentonite was added to the diet (Fisher and Mackay, 1983) [24]. Similarly, ADF digestibility was also decreased for cows supplemented with 1.2% sodium bentonite. Kennelly *et al.* (1999) [39] reported that cellulose or ADF digestibility was not changed when animals supplemented with sodium bicarbonate. Hasan *et al*, (2001) [31] reported that dry matter intake (DMI) of the lactating animal was increased with increasing DCAD of ration which resulting in greater milk production. Due to high metabolic rate and the tendency for cellular environment become acidic, positive DCAD is given to obtain better performance in lactating animals (Hasan *et al.,* 2001) [31]. Paton *et al*. (2006) [48] found that sodium bicarbonate addition in a ration of cattle did not change dry matter intake (DMI) of animals. Tucker *et al.* (1994) [60] reported that natural sodium sesquicarbonate fed for an entire lactation increased DMI per unit of metabolic body weight at 4 months of postpartum. Bougouin *et al.* (2018) [4] did not observe any change in DMI of cows given high starch or high fibre based rations with or without supplementation with 1% sodium bicarbonate.

Effect of buffers on nutrient digestibility in the ruminants

McKinnon *et al*. (1990) [44] conducted a trial to see the effect of bicarbonate supplementation on milk production and acid-base balance in lactating dairy cows and found that the apparent digestibilities of DM, CP and ADF for cows and heifers were not significantly influenced by treatment. Kennelly *et al*. (1999) [39] reported that supplementation of $NaHCO_3$ in cows fed a high- or low-forage diet did not affect intake of DM, CP, and NDF. Solorzano *et al.* (1989) [58] studied the effect of sodium bicarbonate supplementation with sodium sesquicarbonate supplementation in lactating cows and observed an increase in intake of nutrients and nutrient digestibility in both the groups when compared with control thus indicating that sodium sesquicarbonate was as effective as sodium bicarbonate**.** Dschaak *et al*, (2010) [17] reported that supplementation of $NaHCO_3$ or zeolite did not change digestibilities of DM and nutrients (OM, CP, NDF, and ADF). Supplementation of zeolite in finishing diets of beef steers did not change DM digestibility (Cole *et al*., 2007) [11]. Johnson *et al*. (1988) [37] found that the addition of synthetic zeolite decreased digestibilities of DM and OM but they suggested that lower digestibilities could be attributed to consumption of the indigestible synthetic zeolite. Johnson *et al.* (1988) [37] showed that the addition of sodium bicarbonate did not affect apparent digestibilities of DM and OM. The addition of 0.95% bicarbonate **(**Bougouin *et al.,* 2018) [4] and 0.8% bicarbonate (Pereira and Armentano, 2000) [49] to diets did not influence nutrient digestibility. Meschy *et al*. (2004) [45] using a meta-analysis approach and (42 diets, 40 studies) found that the adding buffer at concentrations ranging from 0.5 to 2.5% of DMI had no effect on DM digestibility, but improved fibre digestibility.

Influence of buffers on acid-base balance in the ruminant
Rumen pH

Rumen pH did not change on the addition of 1.5% sodium bicarbonate in postpartum cows fed a 60% concentrate ration on a dry matter basis (Erdman *et al.*, 1980) [21]. They reported that magnesium oxide has more effect on pH stability than sodium bicarbonate. In the similar trial, fistulated cows supplemented with combined 0.8% magnesium oxide and 1.0% sodium bicarbonate on a similar diet exhibited an increase in rumen pH from 6.03 to 6.28 (Erdman *et al.*, 1980) [21]. Harrison *et al*. (1989) [30] found that supplementation of sodium sesquicarbonate or sodium bicarbonate (1.2%) in steers fed with 60% concentrate mixture remained at a rumen pH above 5.5. In contrast, those animals were not receiving buffers in ration experienced extreme drops in rumen pH to 4.0. Cruywagen *et al*. (2007) [14] compared the effects of Acid Buf and sodium bicarbonate on rumen pH. They reported the Acid Buf treatment to maintain a significantly higher minimum rumen pH (5.42) when compared to a control treatment (5.19) and also found the time that ruminal pH was below 5.5 to be shorter for the Acid Buf treatment (4 h) when compared to the other treatments, *viz.* 7.7 h for the sodium bicarbonate treatment and 13 h for the control treatment. Beya (2007) [1] reported that Acid Buf ingested at 90 g/cow per day had a greater effect on rumen pH and on the prevention of sub-acute rumen acidosis than sodium bicarbonate ingested at a level of 180 g/cow per day. Jasaitis *et al*. (1987) [36] reported the buffering capacities of mineral buffers to be highest when compared to all feedstuffs of which carbonate buffers generally have higher buffering capacities than phosphate buffers. This attributes to sodium bicarbonate being the most preferred buffer as it has been proved to be beneficial in preventing post-prandial decreases in rumen pH (Russell & Chow, 1993) [54]. Wohlt *et al*. (1987) [63] reported that much of the buffering capacity of sodium bicarbonate occurs between pH 4 to 6, which is in disagreement with Russell (1998) [53] who reported sodium bicarbonate's buffering capacity to become limited when the pH is below 6.0. Ruminal pH characteristics (mean, maximum, minimum, hours, and area under a threshold pH of 5.8 or 5.5) were not affected by the addition of sodium bicarbonate in the ration of cattle (Paton *et al*., 2006) [48]. Although neither method of delivering sodium bicarbonate (SB) reduced the total time each day that pH was below the pH thresholds used to indicate subacute ruminal acidosis, the number of long (> 4 h) continuous bouts of acidosis (pH ≤ 5.8) was reduced ($P \leq 0.01$) when SB was mixed into the ration compared with the control. Ruyet and Tucker, (1992) [42] conducted an experiment to see the effect of ruminal buffers: temporal effects on buffering capacity and pH of ruminal fluid from cows fed concentrate and sorghum silage in a ratio of 68:32. Ruminal fluid was incubated with either $NaHCO_3$, a natural sodium sesquicarbonate, a multi-element buffer or MgO (7.1 g/ L of ruminal fluid), or no buffer for 48 h and found that $NaHCO_3$ and sodium sesquicarbonate increased both ruminal fluid pH and buffering capacity sharply whereas multi element buffer only increased pH and buffering capacity moderately. Cattle also exhibit changes in fecal and urinary pH when supplemented with buffers. Erdman *et al*. (1980) [21] reported that supplementation of 0.8% magnesium oxide and a combination of 0.9% magnesium oxide plus 1.0% sodium bicarbonate in 60% concentrate diet of early postpartum cows increased fecal pH from 5.95 to 6.44 whereas urinary pH did not change. Ghorbani *et al*. (1989) [25] reported that cows supplemented with 1.0% sodium bicarbonate in averaging 180 d postpartum exhibited an increase in urine pH from 8.05 to 8.15. They also revealed that urine pH continued to fall for approximately 2 and 4 h post feeding on buffer and control diets, respectively. Ration of ruminants without supplementation of a buffer resulted in decrease urine pH. Ruminant animals excrete alkaline urine except when fed high concentrate diets. The most acid in urine is in the NH^{4+} ion form, which contributes to lower pH (Scott, 1970) [57]. Limestone was reported to be a successful buffering agent by Wheeler (Wheeler and Noller, 1977) [62] when it was observed to increase the pH of the lower gastrointestinal tract and feces. These studies demonstrate a negative correlation between fecal starch and fecal pH. Enemark *et al.* (2002) [20] reviewed the diagnostic rumen acidosis, its aetiology, pathogenesis, occurrence, significance, diagnostics and prophylaxis with special attention to subclinical rumen acidosis (SARA) from their studies concluded that resulting metabolic acidosis appears to be reflected in urine.

Blood pH and respiratory gases

Blood pH is crucial for animal survival with fatal levels outside the range of 7.0-7.8; normal pH is 7.4 (Guyton, 1971) [28]. The efficiency of the respiratory system to supply sufficient CO_2 to steady blood pH is evident in the difficulty many researchers experience in detecting pH differences. A study by Schneider *et al*. (1986) [56] found cows subject to heat stress experienced blood alkalosis at a pH of 7.44 probably due to hyperventilation and a decrease of pCO_2. The difference compared with the normal level of 7.40 was statistically significant; however, the difference was only of 0.04 units. Huntington and Britton (1979) [33] were successful in finding reduced blood pH in lambs fed 90% concentrate diets where pH declined from 7.44 to 7.20. When comparing sodium compounds, a study by Bigner *et al*. (1997) [2] reported sodium bicarbonate and sodium propionate were equally effective in raising blood bicarbonate concentration and blood pH to 7.4 in acidotic dairy cows. Diets with salt were ineffective at correcting acidosis with a blood pH of 7.34. McKinnon *et al*. (1990) [44] found that buffer supplementation elevated ($P<0.05$) blood pH in cows, but not in heifers, when compared to either the control or NH_4Cl rations. Bicarbonate levels were reduced ($P<0.05$) by NH_4Cl supplementation in both trials when compared to the two buffered rations. Sulzberger *et al*. (2016) found that oral supplementation of clay (act as buffer) in Holstein cows after a grain challenge did not significantly change blood gas parameter but significantly changed ($P \leq 0.001$) rumen pH, fecal pH, base excess, and blood HCO_3^-, as well as blood pH ($P \leq 0.001$). Hu *et al*. (2007) [32] found that relationships between feed intake and acid–base status of lactating dairy cows as manipulated by dietary cation–anion difference (DCAD). A database was developed from 16 studies of DCAD (ranging from −19.1 to 72.7) effects on DMI and production of lactating dairy showed that adjusted DMI increased as blood HCO_3^-concentrations (quadratic, $P<0.001$; $R2 = 0.83$), blood pH (linear, $P<0.001$; $R2 = 0.82$) increased. Blood gas analysis is a valuable tool to diagnose acidosis in dairy animals because it provides a good assessment of acidosis while being less invasive than rumen pH analysis (Gianesella *et al.,* 2010) [26].

Effect of buffers on rumen fermentation in ruminant

Mao *et al.* (2017) [43] conducted an experiment to see the effect of supplementation of sodium bicarbonate buffer @ 70 mg/ 1000 mg substrate (concentrate and roughage; 70:30) on rumen fermentation, levels of lipopolysaccharide and biogenic amine, and composition of rumen microbiota under *in vitro* conditions. They reported that bicarbonate group had higher ($P<0.001$) pH, total gas production and total VFA concentration; higher proportions of acetate, propionate, valerate and total branched-chain VFA and a lower proportion of butyrate. Total gas production, pH, a concentration of TVFA and proportions of acetate, propionate, butyrate, valerate and total branched-chain VFA were also affected ($P<0.001$) by incubation time ($P<0.001$) and the interaction between incubation time and bicarbonate supplementation whereas NH_3-N concentrations remained unaltered. Bougouin *et al.* (2018) [4] studied the effect of 1% bicarbonate addition in lactating cows fed high dietary starch (23.1%) or low starch (5.9%) rations. They observed an increase in rumen pH with increased bicarbonate addition, but no effect was seen on CH_4 emissions and other rumen characteristics i.e total VFA and protozoa. They found these results consistent with the effect of bicarbonate addition on methanogenesis and on nutrient digestibility whatever the diet. Kawas *et al.* (2007) [38] reported that the addition of bicarbonate in lamb's diet can increase the rumen VFA concentrations and alter their molar proportion toward a higher proportion of acetate which was in support of findings of Coppock (1982) [12] in lactating cows. Similar findings have been observed by Kennelly *et al.* (1999) [39], who used bicarbonate in high-concentrate diets of lactating cows. Cabrita *et al.* (2009) [5] showed that dietary buffers increased the completeness of biohydrogenation pathways, with a concomitant decrease in almost all biohydrogenation intermediates, including rumenic acid. Ghorbani *et al.* (1989) [25] compared the effect of supplementation of 1% sodium bicarbonate with sodium sequicarbonate to lactating cows on rumen fermentation and acid-base balance. They found no differences due to treatment on means molar percentage of isobutyrate, isovalerate, or total VFA. Supplementation of sesquicarbonate in lactating animals increased the molar percentage of acetate and decreased molar percentage propionate which resulted in higher acetate: propionate ratio as compared with the cows fed $NaHCO_3$. However, the molar percentage of butyrate and valerate decreased in cows supplemented with sodium sesquicarbonate when compared with those fed the control diet. No differences were detected for blood pH, pCO_2, or HCO_3^- among treatment.

Effect of buffers on milk production and milk composition

Rindsig *et al*. (1969) [53] studied the effects of sodium bentonite at 5 or 10% of a pelleted concentrate to cows fed milk fat-depressing diets and found milk production significantly increased at the 5% level only. In contrast, a study by Fisher and Mackay (1983) [24] compared the feeding of sodium bicarbonate and sodium bentonite. There was a trend of decreased dry matter digestibility and milk production with the addition of sodium bentonite, however differences were not significant from the control diet. Erdman *et al.* (1980) [21] found an increase in production when 0.8% MgO and 1.5% sodium bicarbonate were fed in combination on a 60% concentrate diet. Schneider *et al.* (1986) [56] also found a production increase for cows fed 1.0% sodium bicarbonate compared with cows fed salt or potassium chloride. Cassida *et al.* (1988) [7] found that supplementation of sodium sesquicarbonate 0.75% of the ration DM in early lactation dairy cows fed corn silage-based diets was effective in improving milk fat percentage, milk fat yield, and 4% FCM yield. Tucker *et al*. (1994) [60] reported similar milk yield throughout lactation from cows fed natural sodium sesquicarbonate and control cows, and the shape of the lactation curves also similar to control. Acid Buf (the skeletal remains of the seaweed *Lithothamnium calcareum*) is another buffer proven to be effective when supplemented to potentially acidotic dairy rations. Cruywagen *et al*. (2004) [13] reported an inclusion of Acid Buf at 0.3% of the dietary dry matter (or 80g/day) to be sufficient in order to optimize milk output and efficiency of feed into milk. In another study, Cruywagen e*t al*. (2007) [14] compared Acid Buf with sodium bicarbonate in terms of their effects on milk yield and composition. They reported the "Acid Buf" treatment to have resulted in significantly higher daily milk yield of 31.6 L/cow, compared to 27.6 and 29.1L/cow for the control and sodium bicarbonate treatments, respectively. They also reported higher milk fat content for the Acid Buf treatment (42.1 g/kg) when compared to the control (38.6g/kg) and sodium bicarbonate (41.8 g/kg) treatments, although the difference was only significant when comparing the Acid Buf treatment with the control treatment. Beya (2007) [1] suggested Acid Buf (at 90 g/cow per day) to be a more effective buffer compared to sodium bicarbonate (at 180 g/per cow per day). The literature on the efficiency of Acid Buf is rather limited, but thus far it has proved to be effective in potentially acidotic dairy rations. Clark *et al.* (2009) [10] fed sodium sesquicarbonate @ 1.0 and observed singnificant increase in milk production, 4% fat-corrected milk, fat, protein, and solids-not-fat than did control cows. Cabrita *et al.* (2009) [5] did not observe any change in milk yield on supplementation of buffer containing sodium bicarbonate and magnesium oxide**.** Bougouin *et al.* (2018) [4] did not observe any change in milk yield in cows kept on high starch and high roughage based rations with supplementation of 1% sodium bicarbonate**.**

Milk fat

The primary reasons buffers are fed are to alleviate milk fat depression and encourage feed intake. High concentrate rations favor a rumen environment that supports propionate rather than acetate production. Rindsig *et al*. (1969) [53] observed cows supplemented with sodium bentonite at 5 and 10% of a pelleted concentrate had increased acetate and decreased propionate in the rumen. Esdale and Satter (1972) [23] found cows continually infused with 9-12 moles of sodium bicarbonate increased A: P from 1.1 to 2.8. Logically, milk fat would be increased if acetate levels increased. Some studies do not support this theory. Rearte *et al*. (1984) [52] reported that supplementation of 1.9% $NaHCO_3$ to rotationally grazed, lactating Holsteins did not change milk fat or VFA proportions. On the other hand, Erdman *et al*, (1982) [22] reported that many studies have shown an increase in milk fat when cows are supplemented with buffers. Likewise, it has been shown that the acetate to propionate ratio (A: P) can be increased through buffer supplementation (Erdman *et al*., 1982) [22]. Kennelly *et al*. (1999) [39] found cows fed 75% concentrate diets increased A: P from 1.31 to 2.0 when supplemented with sodium bicarbonate. In accordance, However, milk fat content has not typically correlated with a higher A: P among these studies. Reasons could stem from the many environmental, physiological, genetic, and feed-type situations dairy cattle encounter. For instance, Donker and Marx (1980) [15] found no change in milk fat percentage even though cows increased milk production, forage intake, and weight gain compared with control cows. Priorities of fat use could have shifted towards tissues rather than milk production in this case. Perhaps the physical condition of the cow was favored in some instances when buffers supplementation in lactating animal increased acetate while milk fat levels did not change (Kennelly *et al.*, 1999) [39]. Solorzano *et al.* (1989) [58] reported an increase in milk fat which was comparable to the cows fed sodium bicarbonate. These cows were kept on with 60 concentrates: 40 roughage diet**.** Supplementation of buffer [mixture of 0.75% sodium bicarbonate ($NaHCO_3$), 0.75% potassium bicarbonate (KHCO3) and 0.66% ammonium chloride (NH4Cl)] in ration of lactating cows did not change milk fat (McKinnon *et al.*, 1990) [44]. Iwaniuk *et al.* (2015) [35] conducted an experiment to see the effect of cation source: sodium sesquicarbonate when replaced 0, 33, 67, and 100% of the supplemental potassium carbonate (150 mEq/kg of DM DCAD) and found better performance in terms of milk yield and milk fat% and feed efficiency in lactating cows.

Bougouin *et al.* (2018) [4] found that supplementation of 1% bicarbonate in ration of lactating animals reduced milk concentrations of C4:0, *iso* C18:0, and some isomers of CLA (*trans*-10, *trans*-12, *trans*-7, *trans*-9, and *trans*-12, *cis*-14) whereas milk concentrations of *cis*-9, *trans*-11 CLA, *cis*-9 20:1 ($P \leq 0.05$), total PUFA, and total CLA were increased. On contrary, Cabrita *et al.* (2009) [5] observed a decrease in almost all rumen biohydrogenation intermediate concentrations and a greater C18:0 concentration, suggesting a more complete RBH with dietary buffer addition.

Milk protein

Tucker *et al*. (1994) [60] reported an increase in milk protein when sodium bicarbonate was fed to cows during middle and late lactation (9-44 wk). Sodium bicarbonate may have 13 increased microbial utilization of protein. However, other studies have found no changes (Ehrlich and Davison 1997) [18]. Tucker *et al*., (1994) [60] fed natural sodium sesquicarbonate for an entire lactation in dairy cows and observed that milk protein content was 0.09 percentage units higher for naturally occurring sodium sesquicarbonate (NOSS) during the entire lactation *(P*< .001). This difference did not appear in mid lactation and was most apparent during late lactation. The influence of dietary buffers on milk protein content is not as well defined as the effect on milk fat content.

Conclusions

Dietary buffer supplementation in high producing lactating animals maintains ruminal homeostasis by resisting any change in pH. Buffer supplementation tends to increase rumen acetate: propionate ratio and fibre digestibility thereby increasing fat percentage and milk production, respectively. Buffers also tend to increase the dry matter intake of animals which help to maintain the high productivity in lactating animals. Buffer supplementation may thus serve as an effective and economical tool for the dairy farmers to fulfil the increasing demands of milk and milk products.

Reference

1. Beya MM. The effect of buffering dairy cow diets with limestone, Acid Buffer or sodium bicarbonate on production response and rumen metabolism. MSc (Agric) thesis, University of Stellenbosch. South Africa, 2007.
2. Bigner DR, Goff JP, Faust MA, Tyler HD, Horst RL. Comparison of oral sodium compounds for the correction of acidosis. Journal of Dairy Science. 1997; 80:2162-2166.
3. Blummel M, Makkar HPS, Becker K. *In- vitro* gas production: a technique revisited. Journal of Animal Physiology and Animal Nutrition. 1997; 77:24-34.
4. Bougouin A, Ferlay A, Doreau M, Martin C. Effects of carbohydrate type or bicarbonate addition to grass silage-based diets on enteric methane emissions and milk fatty acid composition in dairy cows. Journal of dairy science. 2018; 101(7):6085-6097.
5. Cabrita ARJ, Vale JMP, Bessa RJB, Dewhurst RJ, Fonseca AJM. Effects of dietary starch source and buffers on milk responses and rumen fatty acid biohydrogenation in dairy cows fed maize silage-based diets. Animal feed science and technology. 2009; 152(3-4):267-277.
6. Calsamiglia S, Cardozo PW, Ferret A, Bach A. Changes in rumen microbial fermentation are due to a combined effect of type of diet and pH. Journal of animal science. 2008; 86(3):702-711.
7. Cassida KA, Muller LD, Sweeney TF. Sodium Sesquicarbonate for Early Lactation Dairy Cows Fed Corn Silage-Based Diets. Journal of Dairy Science. 1988; 71(2):381-387.
8. Chalupa W, Sniffen CJ. Protein and amino acid nutrition of lactating dairy cattle-today and tomorrow. Animal Feed Science and Technology 1996; 58(1-2):65-75.
9. Chalupa W, Galligan DT, Ferguson JD. Animal nutrition and management in the 21st century: dairy cattle. Animal feed science and technology. 1996; 58(1-2):1-18.
10. Clark JH, Christensen RA, Bateman IIHG, Cummings KR. Effects of sodium sesquicarbonate on dry matter intake and production of milk and milk components by Holstein cows. Journal of dairy science. 2009; 92(7):3354-3363.
11. Cole NA, Todd RW, Parker DB. Use of fat and zeolite to reduce ammonia emissions from beef cattle feedyards. American Society of Agricultural and Biological Engineers. In International Symposium on Air Quality and Waste Management for Agriculture, 16-19 September 2007, Broomfield, Colorado, 2007, 41.
12. Coppock CE, Grant PA, Portzer SJ, Charles DA, Escobosa A. Lactating dairy cow responses to dietary sodium, chloride, and bicarbonate during hot weather. Journal of dairy science. 1982; 65(4):566-576.
13. Cruywagen CW, Swiegers JP, Taylor SJ, Coetzee E. The effect of Acid Buf in dairy cow diets on production response and rumen parameters. Journal of Dairy Science. 2004; 87(1):46.
14. Cruywagen CW, Taylor SJ, Beya MM. The effect of buffering dairy cow diets with limestone, Acid Buf or sodium bicarbonate plus limestone on production response and rumen parameters. Journal of Dairy Science. 2007; 90:561-561.
15. Donker JD, Marx GD. Sodium bicarbonate in diets for milking Holstein cows. Journal of Dairy Science. 1980; 63:931-935.
16. Dryden GM. Animal nutrition science. Cabi. 2008.
17. Dschaak CM, Eun JS, Young AJ, Stott RD, Peterson S. Effects of supplementation of natural zeolite on intake, digestion, ruminal fermentation, and lactational performance of dairy cows. Professional Animal Scientist. 2010; 26:647-654.
18. Ehrlich WK, Davison TM. Adding bentonite to sorghum-based supplements has no effect on cow milk production. Australian Journal of Experimental Agriculture. 1997; 37:505-508.
19. Enemark JM. The monitoring, prevention and treatment of sub-acute ruminal acidosis (SARA): A review. The Veterinary Journal. 2008; 176(1):32-43.
20. Enemark JMD, Jorgensen RJ, Enemark PS. Rumen acidosis with special emphasis on diagnostic aspects of subclinical rumen acidosis: a review. Veterinarija ir zootechnika. 2002; 20(42):16-29.
21. Erdman RA, Botts RL, Hemken RW, Bull LS. Effect of dietary sodium bicarbonate and magnesium oxide on production and physiology in early lactation. Journal of Dairy Science. 1980; 63:923-930.
22. Erdman RA, Hemken RW, Bull LS. Dietary Sodium Bicarbonate and Magnesium Oxide for Early Postpartum Lactating Dairy Cows: Effects of Production, Acid-Based Metabolism, and Digestion1. Journal of Dairy Science. 1982; 65(5):712-731.

23. Esdale WJ, Satter LD. Manipulation of ruminal fermentation I.V. Effect of altering ruminal pH on volatile fatty acid production. Journal of Dairy Science. 1972; 55:964-970.
24. Fisher LJ, MacKay VG. The investigation of sodium bicarbonate or bentonite as supplements in silages fed to lactating cows. Canadian journal of animal science. 1983; 63(4):939-947.
25. Ghorbani GR, Jackson JA, Hemken RW. Effects of sodium bicarbonate and sodium sesquicarbonate on animal performance, ruminal metabolism, and system acid-base status. Journal of Dairy Science. 1989; 72:2039-2045.
26. Gianesella M, Morgante M, Cannizzo C, Stefani A, Dalvit P, Messina *et al*. Subacute ruminal acidosis and evaluation of blood gas analysis in dairy cow. Veterinary medicine international, 2010.
27. Goering HK, Van Soest PJ. Forage Fiber Analyses (apparatus, reagents, procedures and some applications. Agriculture Handbook. ARS, USDA Washington DC, 1970, 379.
28. Guyton AC. Medical Physiology. 4th edition. Chapter 37: Regulation of acid-base balance. W.B. Saunsers *Co*., Philadelphia, PA, 1971.
29. Guyton AC. Textbook of Medical Physiology. WB Saunders, Philadelphia. 1986; 298-299.
30. Harrison JH, Riley RE, Loney KA. Effect of type and amount of buffer addition to grass silage-based total mixed rations on milk production and composition. Journal of Dairy Science. 1989; 72:1824-1830.
31. Hasan ZU, Sarwar M, Iqbal Z, Bilal MQ, Chatha ZA. Dietary cation anion balance in the ruminants II – effects during midlactation and dry period. International Journal of Agricultural Biology. 2001; 3:143-148.
32. Hu W, Murphy MR, Constable PD, Block E. Dietary Cation-Anion Difference Effects on Performance and Acid-Base Status of Dairy Cows Postpartum. Journal of dairy science, 2007; 90(7):3367-3375.
33. Huntington GB, Britton RA. Effective dietary lactic acid on rumen lactate metabolism and blood acid base stasis of lambs switched from low to high concentrate diets. Journal of Animal Science 1979; 49:1569-1576.
34. Hutjens MF. Feed additives. Vet Clinics North Am.: Food Animal Practice. 1991; 7:525.
35. Iwaniuk ME, Erdman RA. Intake, milk production, ruminal, and feed efficiency responses to dietary cation-anion difference by lactating dairy cows. Journal of Dairy Science, 2015; 98(12):8973-8985.
36. Jasaitis DK, Wohlt JE, Evans JL. Influence of feed ion content on buffering capacity of ruminant feedstuffs *in vitro*. Journal of Dairy Science. 1987; 70:1391-1403.
37. Johnson MA, Sweeney TF, Muller LD. Effects of Feeding Synthetic Zeolite A and Sodium Bicarbonate on Milk Production Nutrient Digestion, and Rate of Digesta Passage in Dairy Cows1. Journal of Dairy Science. 1988; 71(4):946-953.
38. Kawas JR, Garcia-Castillo R, Garza-Cazares F, Fimbres-Durazo H, Olivares-Saenz E, Hernandez-Vidal *et al*. Effects of sodium bicarbonate and yeast on productive performance and carcass characteristics of light-weight lambs fed finishing diets. Small Ruminant Research. 2007; 67(2):157-163.
39. Kennelly JJ, Robinson B, Khorasani GR. Influence of carbohydrate source and buffer on rumen fermentation characteristics, milk yield, and milk composition in early-lactation Holstein cows. Journal of Dairy Science. 1999; 82:2486-2496.
40. Kilmer LH, Muller LD, Wangsness PJ. Addition of Sodium Bicarbonate to Rations of Pre-and Postpartum Dairy Cows. Journal of dairy science. 1980; 63(12):2026-2036.
41. Krause KM, Oetzel GR. Understanding and preventing subacute ruminal acidosis in dairy herds: A review. Animal Feed Science and Technology. 2006; 126(3-4):215-236.
42. Le Ruyet P, Tucker WB. Ruminal Buffers: Temporal; Effects on Buffering Capacity and pH of Ruminal Fluid from Cows Fed a High Concentrate Diet. Journal of dairy science. 1992; 75(4):1069-1077.
43. Mao S, Huo W, Liu J, Zhang R, Zhu W. In- vitro effects of sodium bicarbonate buffer on rumen fermentation, levels of lipopolysaccharide and biogenic amine, and composition of rumen microbiota. Journal of the Science of Food and Agriculture. 2017; 97(4):1276-1285.
44. McKinnon JJ, Christensen DA, Laarveld B. The influence of bicarbonate buffers on milk production and acid-base balance in lactating dairy cows. Canadian Journal of Animal Science, 1990; 70(3):875-886.
45. Meschy F, Bravo D, Sauvant D. Analyse quantitative des réponses des vacheslaitières à l'apport de substances tampon. INRA Productions Animales. 2004; 17:11-18.
46. Miller TK, Hoover WH, Poland Jr WW, Wood RW, Thayne WV. Effects of Low and High Fill Diets on Intake and Milk Production in Dairy Cows. Journal of dairy science. 1990; 73(9):2453-2459.
47. Nocek JE. Bovine acidosis: implications on laminitis. Journal of Dairy Science. 1997; 80:1005-1028.
48. Paton LJ, Beauchemin KA, Veira DM, von Keyserlingk MA. Use of sodium bicarbonate, offered free choice or blended into the ration, to reduce the risk of ruminal acidosis in cattle. Canadian journal of animal science. 2006; 86(3):429-437.
49. Pereira MN, Armentano LE. Partial replacement of forage with non-forage fiber sources in lactating cow diets. II. Digestion and rumen function. Journal of Dairy Science. 2000; 83(12):2876-2887.
50. Plaizier JC, Krause DO, Gozho GN, McBride BW. Subacute ruminal acidosis in dairy cows: The physiological causes, incidence and consequences. The Veterinary Journal. 2008; 176(1):21-31
51. Poppi DP, France J, McLennan SR. Intake, passage and digestibility. In: Feeding systems and feed evaluation models. Eds. Theodorou, M.K. & France, J., CAB International Publishing, Oxon, U.K, 2000, 35-52.
52. Rearte DH, Kesler EM, Stringer WC. Forage growth and performance of grazing dairy cows fed concentrates with or without sodium bicarbonate. Journal of Dairy Science. 1984; 67:2914-2921.
53. Rindsig RB, Schultz LH, Shook GE. Effects of the addition of bentonite to high-grain dairy rations which depress milk fat percentage. Journal of Dairy Science. 1969; 52:1770-1775.
54. Russell JB, Chow JM. Another theory for the action of ruminal buffer salts. Decreased starch fermentation and propionate production. Journal of Dairy Science. 1993; 76:826-830.
55. Russell JB. The importance of pH in the regulation of ruminal acetate to propionate ratio and methane

production *in -vitro.* Journal of Dairy Science. 1998; 81:3222-3230.
56. Schneider PL, Beede DK, Wilcox CJ. Responses of lactating cows to dietary sodium source and quantity and potassium quantity during heat stress. Journal of Dairy Science. 1986; 69:99-110.
57. Scott P. Aspects of renal function in ruminants. Rowett Research Institute Annual Report. 1970; 26:98.
58. Solorzano LC, Armentano LE, Grummer RR, Dentine MR. Effects of sodium bicarbonate or sodium sesquicarbonate on lactating Holsteins fed a high grain diet. Journal of Dairy Science. 1989; 72:453-461.
59. Sulzberger SA, Kalebich CC, Melnichenko S, Cardoso FC. Effects of clay after a grain challenge on milk composition and on ruminal, blood, and fecal pH in Holstein cows. Journal of Dairy Science. 2016; 99(10):8028-8040.
60. Tucker WB, Hogue JF, Aslam M, Lema M, Le Ruyet P, Shin IS *et al*. Controlled Ruminal Infusion of Sodium Bicarbonate. Influence of Infusion Dose on Systemic Acid-Base Status, Minerals, and Ruminal Milieu. Journal of Dairy Science 1993; 76(8):2222-2234.
61. Van Soest PJ, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 1991; 74: 3583-3597.
62. Wheeler WE, Noller CH. Gastrointestinal tract pH and starch in feces of ruminants. Journal of Animal Science. 1977; 44:131-135.
63. Wohlt JE, Jasaitis DK, Evans JL. Use of Acid and Base Titrations to Evaluate the Buffering Capacity of Ruminant Feedstuffs *in Vitro*. Journal of Dairy Science. 1987; 70(7):1465-1470.