Journal of Animal and Veterinary Advances 9 (11): 1570-1574, 2010
ISSN: 1680-5593

Effects of Sodium Bicarbonate, Magnesium Oxide and Dried Sugar Beet Pulp in Diets of Dairy Cows on Milk Yield, Milk Composition and Rumen Fluid and Some Blood Parameters

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Abstract: The objective of this study was to evaluate the effect of buffering agent ($NaHCO_3$ and MgO) or substituting Dried Sugar Beet Pulp (DSBP) with barley on milk yield, composition of milk, some blood parameters and ruminal fermentation in cows. In the experiment, four lactating Holstein cows with similar age, lactation period and milk yield were utilized. Cows with second phase of lactation were selected. Treatments consisted of control (40% Barley), control+1% $NaHCO_3$ ($NaHCO_3$), control+1% $NaHCO_3$+0,5% MgO (MgO) and barley substituted with DSBP. All diets were calculated to be isocaloric and iso-nitogeneous. The experiment was a 4×4 Latin square design. While milk yield was significantly higher in animals fed diets containing $NaHCO_3$+MgO compared with animals fed control, compositions of milk were not significantly different among the groups. Addition of $NaHCO_3$, $NaHCO_3$ + MgO significantly increased ($p<0.05$) acetic acid concentrations but did not affect blood parameters. In conclusion addition of $NaHCO_3$ or $NaHCO_3$ + MgO increased milk yield but did not affect composition of milk. An increase in ruminal acetic acid concentrations and acetic/propionic acid ratio due to buffering agent is an important finding. It must be revaluated the use of supplements in feeding diets since they decrease propionic acid level.

Key words: Sodium bicarbonate, magnesium oxide, dried sugar beet pulp, milk yield and composition, rumen fluid, blood parameters

INTRODUCTION

Feedstuff production is not enough to meet the requirement in Turkey. Approximately 16-17 tons of forage dry matter are produced from pastures and ranges each year. These amounts are 20-25% of the annual forage requirement. The Southeastern Anatolia between production and need has tried to be full with creal crop residues such as straw (Saricicek and Okuyan, 1993). Thereby, in order to fulfill animal's nutrient requirement, more concentrate feed has to be fed resulting in an increase in feed cost. Turkey is one of top sugar beet producing countries. Sugar beet by products such as wet or DSBP have high cellulose digestibility and thus are very cheap energy source for ruminant in Turkey (Deniz *et al*., 2001).

Ruminal pH is normally buffered by bicarbonate ions of saliva. Lowering percentage of forage in ration causes a decrease in chewing and rumination that stimulate secretion of saliva on the other hand it increases acid formation in the rumen. While concentrations of VFA increase, ruminal pH decrease as a result of rapid degradation of carbohydrate in concentrate feed in the rumen leading a significant alteration of ruminal bactria population.

Number of lactic acid bacteria thus, lactic acid production increase in the rumen resulting in acidosis (Coskun, 1998; Orskov, 1990). Sodium bicarbonate and MgO are the agents most commonly used against acidosis. These agents can be included 0.5-2.5% in diets (Coskun, 1998).

The response of animal to these agents depends on forage/concentrate ratio of diet, feed intake and amounts of buffer in diet. The aim of this study was to evaluate the effects of buffers ($NaHCO_3$ and MgO) and substitution of barley with DSBP on milk yield, milk composition, rumen fermentation and some blood parameters in dairy cows.

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MATERIALS AND METHODS

This research was carried out in a dairy farm. Four Holstein cows with similar age, lactation period and milk yield were utilized. Cows with second phase of lactation were chosen. Chemical compositions of feed used in the experiment were analyzed as described by Weende (Akkilic and Surmen, 1979) system. Treatments consisted of control (40% Barley), control+1% $NaHCO_3$ ($NaHCO_3$), control + 1% $NaHCO_3$ + 0.5% MgO (MgO) and barley substituted with DSBP. All diets were calculated to be isocaloric and iso-nitogeneous (Table 1). To determine the amount of $NaHCO_3$ and MgO, literature values were used (Senel, 1992; Worley *et al*., 1986; Erdman *et al*., 1980, 1982).

The experiment was a 4×4 Latin square design with 15 day of initial adaptation period. The experiment consisted of 4 periods with 20 days adaptation and 7 days sampling period, a total of 27 days. Nutrient requirements of animals were determined using NRC (1988) values. Cows were milked twice a day and amounts of milk measured for each milking to determine daily milk yield during each sampling period. About 1% of milk were sampled at each milking. Then, 0.5% saturated $HgCl_2$ was added into milk to stop fermentation just after sampling.

Approximately 10 mL blood from *V. jugularis* and 100 mL rumen fluid from rumen were collected 3 h post-feeding from each animal for each period. Ruminal pH were determined immediately after sampling. Ruminal NH_3-N concentrations were determined after necessary treatments were done (Demirel and Bolat, 1996) as soon as possible. A dublicate of rumen fluid were taken into tubes (3 mL) and stored at -20°C for VFA analysis. Serum were drawn from blood and stored at -20°C for analysis. Milk samples were analyzed for Dry Matter (DM), Crude Protein (CP), ash (Akkilic and Surmen, 1979) and fat (Kurt *et al*., 1993). Concentration of lactose in milk samples were calculated with an equation described by McDowell and McDaniel (1968) as follows:

Table 1: Composition of concentrate feed mix used in the experiment (%)

Ingredients	Control	$NaHCO_3$*	$NaHCO_3$ + MgO*	DSBP
Barley	40.00	40.00	40.00	-
DSBP	-	-	-	40.00
Wheat	2.00	2.00	2.00	2.00
Corn	22.85	22.85	22.85	23.00
Cottonseed meal	9.25	9.25	9.25	10.00
Wheat bran	8.25	8.25	8.25	8.00
Molasses	2.25	2.25	2.25	2.10
Limestone	1.60	1.60	1.60	1.00
$NaHCO_3$	-	1.00	1.00	-
MgO	-	-	0.5	-
Salt	1.00	1.00	1.00	1.00
Vitamin[a]	0.15	0.15	0.15	0.15
Mineral[b]	0.15	0.15	0.15	0.15
ME (Cal kg^{-1})	2502.40	2502.40	2502.40	2502.70
CP (%)	16.08	16.08	16.08	16.01
Ca (%)	0.90	0.90	0.90	0.60
P (%)	0.70	0.70	0.70	0.60

a: Premix provided per kg of diet: Vit A 5.000.000 IU; Vit. D_3 1.000.000 IU; Vit. E, 25.00 mg; b: Suplied (per kg of diet): Mn, 40.000.000 mg; Fe, 50.000.000 mg; Zn, 40.000.000 mg; Cu,10.000 mg; I, 500 mg; Co, 100 mg; Se, 100 mg; *: $NaHCO_3$ and MgO were added to feed mixes after feed mix was prepared

$$\text{Lactose (\%)} = \text{Solid matte (\%)}-(\text{CP\%}-0.7\times \text{ash\%})$$

While milk yields corrected for Solid Matter (SCM) were calculated according to Tyrell and Reid (1965) milk yields corrected for 4% fat (4% FCM) were calculated according to Jurgensen (1982) using following formulas:

$$\text{SCM (lb)} = 12.3\ (F) + 6.56\ (SNF)-0.0752\ (M)$$

$$\text{4\% FCM (kg day}^{-1}) = MY\ (0.4+0.15 \times FY)$$

Where:

F = Fat yield lb day^{-1}
M = Milk yield lb day^{-1}
MY = Milk yield kg day^{-1}
FY = Fat yield kg day^{-1}

While DM, ash, CP and Ether Extract (EE) concentrations of feedstuff were analyzed with a method described by Weende (Akkilic and Surmen, 1979), Crude Fiber (CF) contents were determined with the method of Crampton and Maynard (Akkilic and Surmen, 1979). Serum total protein, glucose levels were determined by Chema Protein (Total)® and Chema Glucose FL (Fast)® kits using spectrophotometry. Serum Ca, P and urea levels were analyzed by an auto analyzer. Volatile Fatty Acid (VFA) concentrations of rumen fluid were determined using HPLC. Rumen ammonia-N levels were analyzed using thedistillation unit of Kjeldahl apparatus (Deniz and Tuncer, 1995).

RESULTS AND DISCUSSION

Chemical composition of forage and concentrate feedstuff used in the experiment are shown in Table 2. Daily milk yield, composition of milk, forage intake, 3 h post-feeding ruminal pH, NH_3-N, total VFA, acetic acid, propionic acid, butyric acid, lactic acid, acetic/propionic acid ratios, serum total protein, glucose, urea, Ca and P levels are shown in Table 3. Chemical composition of forage and concentrate feedstuff used in the experiment are shown in Table 2. Chemical composition of diets were similar except diet containing DSBP. While concentrations of ash and CF were higher, concentrations of EE and NFE were less in DSBP diet compared with other diets resulted from the substitution of barley with DSBP. Because CF

Table 2: Chemical compositions of forage and concentrate used in the experiment (%)

Items	DM	Ash	OM	CP	EE	CF	NFE
Sainfoin (Forage)	89.18	7.04	82.14	13.35	1.45	27.10	40.24
Control	87.54	8.75	78.79	15.93	1.34	5.63	55.89
$NaHCO_3$	89.23	9.52	79.71	16.12	1.98	5.25	56.36
$NaHCO_3$+MgO	88.94	9.36	79.58	16.51	1.84	5.91	55.32
DSBP	88.52	10.97	77.55	16.26	0.82	9.12	51.35

Table 3: Forage intake, milk yield, composition of milk, ruminal fermentation and some blood parameters of cows

Items	Control	$NaHCO_3$	$NaHCO_3$+MgO	KSPP	p-value
Forage intake (kg DM day^{-1})	13.36	13.02	13.20	14.58	NS
Milk					NS
Milk yield (kg day^{-1})	10.37^{b}	11.03^{ab}	11.44^{a}	10.67^{ab}	NS
Fat corrected milk yield (kg day^{-1})	10.94	11.06	11.57	10.77	NS
Solid corrected milk yield (kg day^{-1})	10.87	11.17	11.31	10.65	NS
Solid matter (%)	8.97	9.05	8.58	8.40	NS
Fat (%)	4.35	4.04	4.08	4.08	NS
Protein (%)	4.07	4.07	3.97	3.79	NS
Lactose (%)	5.41	5.49	5.07	5.09	NS
Ash (%)	0.73	0.74	0.65	0.68	NS
Rumen Fluid					
PH	6.89	6.99	6.87	6.77	NS
NH_3-N (mg/100 mL)	12.28	12.93	9.56	13.14	NS
Total VFA (x mmol L^{-1})	92.47^{bc}	101.40^{a}	99.70^{ab}	87.27^{c}	*
Acetic acid (mmol L^{-1})	50.26^{b}	65.22^{a}	62.64^{a}	50.38^{b}	**
Propionic acid (mmol L^{-1})	26.81^{a}	22.73^{b}	23.31^{b}	20.34^{c}	**
Butyric acid (mmol L^{-1})	15.40	13.44	13.75	16.54	NS
Lactic acid (mmol L^{-1})	8.13	7.89	5.10	6.07	NS
Acetic/Propionic acid	1.88^{c}	2.87^{a}	2.71^{ab}	2.49^{b}	**
Serum					
Total Protein (g/100 mL)	8.41	8.59	8.83	8.85	NS
Urea-N (mg/100 mL)	13.25	19.75	18.00	17.75	NS
Glucose (mg/100 mL)	74.77	81.96	59.51	64.88	NS
Ca (mg/100 mL)	6.75	8.18	7.28	7.58	NS
P (mg/100 mL)	5.23	6.58	5.30	5.35	NS

x: Total VFA consist of acetid, propionic and butiryc acids: $^{a-c}$Values with different letter in the same line indicate significant difference ($p<0.05$)

digestibility of DSBP is very high (Deniz *et al*., 2001), this difference in CF contents of diets is not very important. Although, it was not statistically significant, the highest forage intake was observed in animals fed DSBP diet (Table 3).

Some researchers have indicated that DSBP increased feed intake by increasing palatability of diet (Tyrell and Reid, 1965; Jurgensen, 1982). While amount of concentrate given was fixed, animals had free access to forage in this study. Even though there was little variation among animals and periods, forage/concentrate ratio was generally 2:1.

Daily milk yiels were 10.37, 11.03, 11.44 and 10.67 kg day^{-1} for control, $NaHCO_3$, NaHCO + MgO and DSBP diets, respectively ($p<0.05$). Daily milk yield was significantly higher in animals fed $NaHCO_3$ + MgO supplemented diet compared with animal fed control diet ($p<0.05$) but similar with other groups (Table 3). Solid corrected and fat corrected milk yields were similar among treatments.

Similar to the results, many studies reported an improvement in milk yield (Erdman *et al*., 1980; West *et al*., 1991; Schneider *et al*., 1986; Tucker *et al*., 1993; Rogers *et al*., 1985) but only one study indicated a decrease in milk yield with buffer supplementation (Aslam *et al*., 1991). Schneider *et al*. (1986) fed diets containing 38% silage, 62% concentrate supplemented with 1% $NaHCO_3$, 0.73 NaCI and 1.3 or 1.8% potasium to 19 kg daily milk producing cows. Addition of $NaHCO_3$ into diet significantly increased milk yield, fat corrected milk yield, fat content of milk. In another study, Fisher and Mackay (1983) supplemented control diet with 180 g $NaHCO_3$. Cows fed $NaHCO_3$ supplemented diet had significantly higher milk yield and fat corrected milk yield but less lactose in milk compared with cows fed control diet. Concentrations of milk fat and protein did not differ between treatments.

About 3 h post-feeding ruminal pH values were similar among treatments, ranging from 6.77-6.99. Considering the 2:1 forage/concentrate ratio of diets, these pH values are in normal range. Addition of buffers into diets increased ruminal pH when animals were fed diets low in fiber (Kilmer *et al*., 1981; Thomas *et al*., 1984).

Neither buffering agents nor source of carbohydrate did not significantly affect ruminal NH_3-N concentrations (Table 3). All ruminal NH_3-N values were above the levels (5-7 mg dL^{-1}) required for optimal microbial protein synthesis in the rumen (Deniz and Tuncer, 1995). Kilmer *et al*. (1981) have reported that dairy cows fed 0.8% $NaHCO_3$ supplemented diets had significantly higher

ruminal NH_3-N concentrations compared with control group. It was speculated that this increase in ruminal NH_3-N concentrations resulted from increased ruminal protein degradation due to increased pH. On the other hand, Stokes *et al*. (1986) fed cows with diets containing 0.7% $NaHCO_3$ or 0.7% $NaHCO_3$ + 0.28% $MgSO_4$ only animals fed diet supplemented with 0.7% $NaHCO_3$ had significantly greater ruminal NH_3-N concentrations compared with other groups. DePeters *et al*. (1984) have reported that supplementing control diet with $NaHCO_3$ above 0.25% of DM did not increase in fact decreased ruminal NH_3-N concentrations.

One of the most important finding of this study was that both $NaHCO_3$ and $NaHCO_3$ + MgO supplementations increased concentrations of acetic acid and decreased concentrations of propionic acid in the rumen. Concentrations of acetic acids were 50.26, 65.22, 62.64 and 50.38 mmo L^{-1} for control, $NaHCO_3$, $NaHCO_3$ + MgO and DSBP diets, respectively ($p<0.05$). The concentrations of propionic acids were significantly greater in the rumen of cows fed control diet compared with those fed other diets. These changes in concentrations of acetic and propionic acids caused by buffering agents were reflected at acetic acid/propionic acid ratios. Thus, acetic acid/propionic acid ratios were the highest in cows fed diets supplemented with buffering agents followed by DSBP ($p<0.05$). It has been reported that $NaHCO_3$ and MgO supplementation of diets increased acetic acid concentrations and decreased propionic acid concentrations via increasing rate of passage from rumen (Thomson *et al*., 1978; Harrison *et al*., 1975). Use of artificial saliva at 4 and 8% as buffering agents increased rate of liquid passage thus decreased concentration of propionic acid (Harrison *et al*., 1975). Similar to the results, many researchers (Erdman *et al*., 1980; West *et al*., 1987; Staples *et al*., 1988) have reported that buffering agents increased acetic acid, decreased propionic acid concentrations in the rumen thus caused a high acetic/propionic acid ratios in dairy cows. About 3 h post-feeding serum total protein, urea, glucose, Ca and P levels were similar among treatments (Table 3).

Serum total protein levels were 8.59, 8.83 and 8.85 g mL^{-1} for $NaHCO_3$, $NaHCO_3$ + MgO and DSBP, respectively. These values were a little above the levels known as normal (6.0-8.5 g mL^{-1}) in the literature. However, serum total protein levels of control were in the range of normal levels (8.41 g mL^{-1}). Serum urea levels (6.0-36.0 mg dL^{-1}) were in agreement with the values reported in the literature (Altintas and Fidanci, 1993; Imren and Sahal, 1990). Even though serum glucose levels were in the range of normal levels (Altintas and Fidanci, 1993; Imren and Sahal, 1990) it was over (81.96 mg dL^{-1}) normal levels in animals fed diet supplemented with $NaHCO_3$. Serum Ca levels were 7.28, 7.58 and 6.75 mg dL^{-1} for $NaHCO_3$+MgO, DSBP and control diets, respectively. These values were at lower edge of normal Ca levels reported for cows (Altintas and Fidanci, 1993; Imren and Sahal, 1990). However, serum Ca levels of animals fed diet supplemented with $NaHCO_3$ were in the range of normal values. Serum P levels were in agreement with the values reported in the literature.

Similarly, Rogers *et al*. (1985) have reported that 1.2% $NaHCO_3$ supplementation did not affect serum total protein, glucose, Ca and P levels. Addition of $NaHCO_3$ into diet increased serum Ca levels about 1.2 mg dL^{-1} (Kilmer *et al*., 1980). This increase was thought to be caused by the increase in absorption of Ca in the intestine due to alteration of intestinal pH which was revealed as an increase in blood. Tucker *et al*. (1988) have reported that addition of 1.4% $NaHCO_3$ did not alter serum Ca levels. In contrast, Staples *et al*. (1988) noted an increase in serum Ca levels but not P levels by addition of $NaHCO_3$.

CONCLUSION

Addition of $NaHCO_3$ or $NaHCO_3$ + MgO increased milk yield but did not affect composition of milk. An increase in ruminal acetic acid concentrations and acetic/propionic acid ratio due to buffering agent is an important finding. It must be revaluated the use of supplements in feeding diets since they decrease propionic acid level.

REFERENCES

Imren, H.Y. and M. Sahal, 1990. Veteriner iç hastaliklari. Aydogdu Ofset Matbaacilik Ambalaj Sanayi ve Tic. Ankara.

Senel, H.S., 1992. Ruminant Rasyonlarinda Sodyum Bikarbonat'in Kullanilmasi. Klasis Otel/Silivri, Mayis, pp: 21-33.

Akkiliç, M. and S. Sürmen, 1979. Yem Maddeleri ve Hayvan Besleme Laboratuvar Kitabi. Ankara Üniversitesi Basimevi, Ankara, pp: 85-125.

Altintas, A. and U.R. Fidanci, 1993. Evcil hayvanlarda ve insanlarda kanin biyokimyasal normal degerleri. A.Ü. Vet. Fakültesi Derg., 40: 173-186.

Aslam, M., W.B. Tucker, J.F. Hogue, R.K. Vernon and G.D. Adams, 1991. Controlled ruminal infusion of sodium bicarbonate 2: Effects of dietary and infused buffer on ruminal milieu. J. Dairy Sci., 74: 3496-3504.

Coskun, B., 1998. Yem Katki Maddeleri. S.Ü. Veteriner Fakültesi Yayin Ünitesity, Konya, Turky, pp: 198-199.

DePeters, E.J., A.H. Fredeen, D.L. Bath and N.E. Smith, 1984. Effect of sodium bicarbonate addition to alfa hay-based diets on digestibility of dietary fractions and rumen characteristics. J. Dairy Sci., 67: 2344-2355.

Demirel, M. and D. Bolat, 1996. Kurutulmus seker pancari posasi katkili karma yemlere üre ve niasin ilavesinin rumen sivisi ve kan parametreleri üzerine etkisi. Turk. J. Vet. Anim. Sci., 20: 211-214.

Deniz, S. and S.D. Tuncer, 1995. Bitkisel protein kaynaklarinin formaldehit ile muamele edilmesinin süt verimi ve kompozisyonu ile bazi rumen ve kan metabolitleri üzerine etkisi. Turk. J. Vet. Anim. Sci., 19: 17-22.

Deniz, S., M. Demirel, S.D. Tuncer, O. Kaplan and T. Aksu, 2001. Degisik sekillerde üretilen seker pancari posasi silajinin kuzu ve süt inegi rasyonlarinda kullanilma olanaklari. Kaliteli seker pancari posasi silajinin elde edilmesi. Turk. J. Vet. Anim. Sci., 25: 1015-1020.

Erdman, R.A., R.L. Boots, R.W. Hemken and L.S. Bull, 1980. Effect of dietary sodium bicarbonate and magnesium oxide on production and physiology in early lactation. J. Dairy Sci., 63: 923-930.

Erdman, R.A., R.W. Hemkin and L.S. Bull, 1982. iertary sodium bicarbonate and magnesium oxide for early postpartum lactating dairy cows: Effects on production, acid-base metabolism and digestion. J. Dairy Sci., 64: 712-718.

Fisher, L.J. and V.G. Mackay, 1983. The effect of sodium bicarbonate, sodium bicarbonate plus magnesium oxide or bentonite on the intake of corn silage by lactating cows. Can. J. Anim. Sci., 63: 141-148.

Harrison, D.G., D.E. Beever, D.J. Thoms and D.F. Osbourn, 1975. Manipulation of rumen fermentation in sheep by increasing the rate of flow of water from the rumen. J. Agric. Sci. Camb., 85: 93-101.

Jurgensen, M.H., 1982. Animal Feeding and Nutrition. 5th Edn., Low Kendall/Hunt Publishing Company, Dubuque, Iowa.

Kilmer, L. H., L.D. Muller and T.J. Snyder, 1981. Addition of sodium bicarbonate to rations of postpartum dairy cows: Physiological and metabolic effects. J. Dairy Sci., 64: 2357-2369.

Kilmer, L.H., L.D. Muller and P.J. Wangsness, 1980. Addition of sodium bicarbonate to rations of pre-and postpartum dairy cows. J. Dairy Sci., 63: 2026-2036.

Kurt, A., S. Çakmakçi and A. Çaglar, 1993. Süt mamülleri muayene ve analiz metodlari rehberi. Atatürk Ü. Ziraat Fakültesi Yayin No. 18, Erzurum. Atatürk Ü. Ziraat Fakültesi Basimevi. pp: 112-118.

McDowell, R.E. and B.T. McDaniel, 1968. Interbreed matings in dairy cattle 1. yield treats, feed efficiency type and rate of milking. J. Dairy Sci., 51: 767-777.

NRC., 1988. Nutrient Requirements of Dairy Cattle. 6th Rev. Edn., National Research Council Acadmic Science, Washington, DC, USA.

Orskov, E.R., 1990. Energy Metabolism: Energy Nutrition in Ruminants. Elsevier Applied Science, New York, pp: 11-18.

Rogers, J.A., L.D. Muller, C.L. Davis, W. Chalupa, D.S. Kronfeld, L.F. Karcher and K.R. Cummings, 1985. Response of dairy cows to sodium bicarbonate and limestone in early lactation. J. Dairy Sci., 68: 646-660.

Sariçiçek, B.Z. and M.R. Okuyan, 1993. Süt Ineklerinin Beslenmesinde Kaba Yemin Yeri ve Önemi. Yem Magazin Dergisi, Mayis, pp: 10-13.

Schneider, P.L., D.K. Beede and C.J. Wilcox, 1986. Responses of lactating cow to dietary sodium source and quantity and potassium quantity during heat stress. J. Dairy Sci., 69: 99-110.

Staples, C.R., S.M. Emanuele, M. Ventura and D.K. Beede, 1988. Effects of new multielement buffer on production, ruminal environment and blood minerals of lactating dairy cows. J. Dairy Sci., 71: 1573-1586.

Stokes, M.R., L.L. Vandemark and L.S. Bull, 1986. Effect of sodium bicarbonate, magnesium oxide and a commercial buffer mixture in early lactation cows fed hay crop silage. J. Dairy Sci., 69: 1595-1603.

Thomas, J.W., R.S. Emery, J.K. Breaux and J.S. Liesman, 1984. Response of milking cows fed a high cocantarate, low roughage diet plus sodium bicarbonate, magnesium oxside, or magnesium hydroxide. J. Dairy Sci., 67: 2532-2545.

Thomson, D.J., D.E. Beever, M.J. Latham and M.E. Sharpe, 1978. The effect of inclusion of mineral salts in the diet on dilution rate, the pattern of rumen fermentation and the composition of the rumen microflora. J. Agric. Sci., 91: 1-7.

Tucker, W.B., J.F. Hogue, M. Aslam, M. Lema and P.L. Ruyet *et al*., 1993. Controlled ruminal infusion of sodium bicarbonate. 3. Influence of infusion dose on systemic acid-base satatus, minerals and ruminal milieu. J. Dairy Sci., 76: 2222-2234.

Tucker, W.B., Z. Xin and R.W. Hemken, 1988. Influence of dietary calcium chloride on adaptive changes in acid-base status and mineral metabolism in lactating dairy cows fed a diet high in sodium bicarbonate. J. Dairy Sci., 71: 1587-1597.

Tyrell, H.F. and J.T. Reid, 1965. Prediction of the energy value of cows milk. J. Dairy Sci., 48: 1215-1223.

West, J.W., B.G. Mullinix and T.G. Sandifer, 1991. Changing dietary electrolyte balance for dairy cows in cool and hot environments. J. Dairy Sci., 74: 1662-1674.

West, J.W., C.E. Coppock, D.H. Nave, J.M. Labore, L.W. Greene and T.W. Odom, 1987. Effects of potassium carbonate and sodium bicarbonate on rumen function in lactating holstein cows. J. Dairy Sci., 70: 81-90.

Worley, R.R., J.A. Paterson, K.P. Coffey, D.K. Bowman and J.E. Williams, 1986. The effects of corn silage dry matter content and sodium bicarbonate addition on nutrient digestion and growth by lambs and calves. J. Anim. Sci., 63: 1728-1736.