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ORIGINAL ARTICLE

Variation in dietary cation-anion differences (DCAD) of feed ingredients in relation to milk fever disease in dairy cattle

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Milk fever is an important disease that affect lactating cow due to the shortage of calcium circulation after parturition. Incidence of milk fever can be minimized by changing diet acidity/alkalinity before parturition to enhance Ca release of bone, and minimizing it excretion through several regulatory mechanisms. However, cow's regulatory mechanisms are inadequate in its ability to satisfy the increased metabolic requirement of calcium. Many formulas have been suggested in literature for calculating Dietary Cation-Anion Differences (DCAD) in attempts to acidify diets to minimize the incidence of milk fever. Thus, selection of feed ingredients, and used formula (DCAD below 0 mEq/kg) are important when formulating diet to reach appropriate acidification of the cows' blood. The aim of current study is to characterize and to measure DCAD of different feed ingredients (Listed in: National Research Council (NRC, 2001)) using the most used equations reported in the literature which are highly correlated with the incidence of milk fever. Tabulated DCAD values showed that the ability of most forages to cause acidification of the cow is not possible and few feed ingredients possessed mild-strong acidic effect. However, using ingredients with acidic effect have nutritional and economic limitations especially in dairy diets. This screening study showed that mostly used feed ingredients in Jordan possess alkaline effect. The magnitude of $DCAD^1$ ((Na^++ K^+) + (Cl^-)), $DCAD^2$ ((Na^++ K^+) + (Cl^-+ S^{-2})) and $DCAD^3$ ((Na^++ K^+) + (Cl^-+ 0.6S^{-2})) of different feed ingredients mainly used in Jordan ranged from 93.5 - 592.7 mEq/kg, 31.2 - 349.5 mEq/kg, and 56.1 - 446.8 mEq/kg, respectively. Thus, incorporation of acidifying ingredients is necessary when feeding dry cows without compromising feed intake when cows fed under Jordanian conditions. Several nutritional strategies have been suggested to acidify complete diet, and positively enhance Ca releasing from bones to decrease the possibility occurring milk fever in dairy cows.
Key words: dietary cation-anion difference; milk fever; cattle; feed ingredients

Introduction

Milk fever (hypocalcaemia) is considered as a serious disease in dairy cattle, and it occurs when cows are unable to compensate for the high demand in Ca required for milk production and satisfy its own needs after parturition (Charbonneau et al., 2006). Dairy cattle responses at this period by triggering endocrine and physiological changes that involves stimulating the secretion of parathyroid hormone and afterwards increase the concentration of 1, 25 $(OH)_2D_3$ (Thilsing-Hansen et al., 2002). Consequently, parathyroid hormone directly stimulates renal reabsorption mechanisms for calcium to minimize the losses through urination, and will stimulate processes to enhance intestinal absorption of calcium, and mobilization of calcium from bone (NRC 2001). However, cow's regulatory mechanisms are limited in its ability to satisfy the increased metabolic requirement by the rate, by which calcium can be mobilized from bone reserves (DeGaris & Lean, 2009). This condition has been reported to be more pronounced in older cows, and in cows fed on alkalogenic diets, and thus make them more exposed to the risk of milk fever (Ramberge et al., 1984).

Nutritionist attempts to lower DCAD (Dietary Cation-Anion Difference) in cows before calving to trigger physiological mechanism that induce compensated metabolic acidosis condition (Thilsing-Hansen et al., 2002). Cows compensate metabolic acidosis by regulating calcium elimination from the body through increasing urinary excretion of acids (Vagnoni & Oetzel, 1998), maintaining blood pH by bone accepting hydrogen ion in replace of Ca (Lemann et al., 2003) and retaining calcium in blood by reducing its excretion in urine (Charbonneau et al., 2006). Consequently, these regulatory mechanisms enhance more calcium to be retained in the blood. Many formulas have been suggested in literature for calculating DCAD for different feed ingredients and complete diets for dairy cows. Using the preferred equation ((Na^++ K^+) + (Cl^-+ S^{-2})) by many nutritionists, it is common to attempt to bring DCAD less than zero mEq/kg diet (NRC, 2001). To achieve this DCAD level, extra intake of anionic salt must be fed for at least 10 days before birth (Thilsing-Hansen et al., 2002). However, feeding anionic salts have been associated with low dry mater intake because of its low palatability (Goff & Horst, 1997). Reduction of feed intake and negative energy balance just before calving is undesirable and may lead to risk of ketosis and fatty liver syndrome. Thus,

careful selection of feed ingredients is important when formulating diet to reach appropriate acidification of the cow with minimal usage of anionic salts especially in farms with limited feed ingredient choices such as Jordan.
The objectives of this study were: to compare alkalinity/acidity of feed ingredients using different DCAD equations mostly used in literature; to screen acidic feed ingredients that have potential to reduce the incident of milk fever in cows fed under Jordanian conditions.

Materials and methods

Dietary Cation-anion Differences was calculated based on the strong ion model that are mostly used in literature (DeGaris & Lean, 2009). These equations are selected in this study based on meta-analysis studies that showed strong ion models are correlated and predicted milk fever incidence (Charbonneau et al., 2006; Lean et al., 2006). The following equation was used to calculate mil-equivalent of each ion:

$$mEq = \frac{(\%\, ion in feed \times 10000 \times Valence)}{Atomic\ weight}$$

Strong ion models used to calculate DCAD of feed ingredients mostly used in dairy cattle nutrition listed in NRC (2001) are as the following:

$DCAD^1(mEq/kg) = (Na^+(mEq/kg) + K^+(mEq/kg)) - (Cl^-(mEq/kg))$

$DCAD^2(mEq/kg) = (Na^+(mEq/kg) + K^+(mEq/kg)) - (Cl^-(mEq/kg) + S^-(mEq/kg))$

$DACD^3(mEq/kg) = (Na^+(mEq/kg) + K^+(mEq/kg)) - (Cl^-(mEq/kg) + 0.6S^-(mEq/kg))$

Results and discussion

Table 1 shows a list of feed ingredients, and their calculated dietary DCAD (mEq/kg) using different equations. Tabulated values of DCAD shown in table 1 can provide a useful tool of nutritionist to calculate DCAD of complete feed and to compare DCAD of different feed ingredients when macro mineral analysis of different feed ingredient is not analyzed. Although minerals are considered the most variable of the nutrients commonly determined in feed ingredients (Berger, 1996), using stochastic programming in feed formulation software can provides assurance of meeting the requirement of animals to a great probability when the variation in nutrient concentration is known (Peña et al., 2009). For the same feed ingredient listed in table 1 and as expected, using DCAD values was highest for $DCAD^1$ and it was the lowest for $DCAD^2$ (because of including the acidifying sulfur in the equation) and was intermediate for $DCAD^3$ (because of including fraction of sulfur). The coefficient 0.6 was included in $DCAD^3$ based on the proportional efficiency of sulfate salts lowering urine pH in contrast to Cl salts (Goff et al., 2004). Until now, the suitable equation form used to predicate the incidence of milk fever is still unclear. However, DeGaris & Lean (2009) concluded that both $DCAD^2$ and $DCAD^3$ equations were equivalent in predicting milk fever risk although table 1 shows big differences between $DCAD^2$ and $DCAD^3$ for many same feed ingredients. This difference between $DCAD^2$ and $DCAD^3$ is critical when interpreting the results as nutritionists are looking for a narrow DCAD when formulating diets for dairy cattle during dry period to reduce the risk of milk fever incidence. For instance, a meta-analysis study obtained from twenty-two published studies showed that reducing dietary $DCAD^3$ from +300 to 0 mEq/kg in non-lactating dairy cows reduced dietary dry matter intake by 11.3%, reduced the incidence of milk fever by 13.2% (from 16.4 to 3.2%) and urine pH from 8.09 to 7.01 (Charbonneau et al., 2006).

Table 1. List of feed ingredients and their calculated dietary cation-anion difference (DCAD) (mEq/kg, dry basis) using strong ion model equations.

	Ingredient	*$DCAD^1$	**$DCAD^2$	***$DCAD^3$
1	Alfalfa	466.3	304.1	369.0
2	Almond hulls	670.3	645.3	655.3
3	Apple pomace	195.6	152.0	169.4
4	Bakery byproduct meal	82.1	-5.2	29.7
5	Bread wastes	163.4	57.4	99.8
6	Cereal by product	146.4	84.0	109.0
7	Cookie by product	75.0	-6.1	26.3
8	Barley grain rolled	115.2	40.4	70.3
10	Barley silage headed	474.9	368.9	411.3
11	Beet sugar pulp	329.6	142.5	217.3
12	Bermudagrass Costal, hay, early head	345.3	45.9	165.7
13	Bermudagrass titfon-85, hay, 3-4 wk growth	266.6	29.6	124.4
14	Blood meal, ring dried	165.3	-315.0	-122.9
15	Blood meal, batch dried	165.3	-315.0	-122.9
16	Brewer grains, wet	125.5	-111.5	-16.7
17	Brewer grains, dried	90.7	-115.1	-32.8
19	Canola Meal, mech, extracted	379.8	-75.6	106.6
21	Citrus pulp dried	284.8	222.5	247.4
23	Corn distiller grains with solubles, dried	338.5	64.0	173.8

24	Corn Gluten feed, dried	373.5	99.1	208.8
25	Corn gluten meal, dried	108.4	-428.1	-213.5
26	Corn grains cracked	93.5	31.2	56.1
27	Corn grains, ground, dry	93.5	31.2	56.1
28	Corn grain, steam-flacked	93.5	31.2	56.1
29	Corn grain, rolled, high moisture	100.2	37.8	62.8
30	Corn grain, ground, high moisture	100.2	37.8	62.8
31	Corn grain and cob, ground	118.6	56.2	81.2
32	Corn grain and cob, high moisture	107.4	51.2	73.7
33	Corn Hominy	185.9	111.0	140.9
34	Corn silage immature <25% DM	252.2	164.9	199.8
35	Corn silage, normal 32-38% DM	229.4	142.1	177.0
36	Corn silage, Mature >40% DM	237.7	175.3	200.3
37	Cotton seed with lint	280.8	137.3	194.7
38	Cotton seed hulls	288.4	244.8	262.2
39	Cotton seed meal, solvent, 41% CP	430.1	180.6	280.4
40	Fats and oil, Calcium Soaps	0.0	0.0	0.0
45	Feathers meal	159.0	-708.1	-361.3
46	Feathers meal with some viscera	46.3	-1045.3	-608.7
47	Fish byproducts Anchovy, meal, mech	394.0	-92.6	102.1
48	Fish byproducts Menhaden, meal, mech	259.4	-464.2	-174.7
49	Grasses, cool season, pasture intensively managed	710.0	585.3	635.2
50	Grasses, cool season, hay, all samples	390.4	259.4	311.8
51	Grasses, cool season, hay, immature<55% NDF	551.8	402.1	462.0
52	Grasses, cool season, hay, Mid-maturity 55-60% NDF	320.0	170.3	230.2
53	Grasses, cool season, hay mature >60% NDF	326.3	220.3	262.7
54	Grasses, cool season, silage	482.3	351.4	403.8
55	Grasses, cool season, silage immature <55% NDF	628.1	497.1	549.5
56	Grasses, cool season, silage mid-maturity 55-60% NDF	543.7	412.7	465.1
57	Grasses, cool season, Silage mature>60 NDF	389.6	264.9	314.8
58	Grass-legume mixture, hay, immature < 51% NDF	528.1	353.4	423.3
59	Grass-legume mixture, hay, mid maturity 51-57% NDF	413.7	245.3	312.7
60	Grass-legume mixture, hay, mature>0.57 %NDF	377.7	196.8	269.2
61	Grass-legume mixture, silage, immature <51% NDF	540.9	372.4	439.8
62	Grass-legume mixture, silage mid-maturity 51-51% NDF	552.6	396.6	459.0
63	Grass-legume mixture, silage mature > 57%	431.6	412.8	420.3
64	Grass-legume mixture (12-15% hemicellulose) hay, immature< 47% NDF	672.0	503.6	570.9
65	Grass-legume mixture, hay, mid maturity 47-53% NDF	652.9	503.2	563.0
66	Grass-legume mixture, hay, mature >53% NDF	314.9	140.2	210.1
67	Grass-legume mixture, silage immature < 47% NDF	244.2	144.4	184.3

68	Grass-legume mixture, silage, mid maturity 47-53% NDF	410.2	248.0	312.9
69	Grass-legume mixture, silage, mature < 53% NDF	552.5	359.2	436.5
70	Grass-legume mixture (10-13.5% hemicellulose) hay, immature< 44% NDF	460.1	335.4	385.3
71	Grass-legume mixture, hay, mid maturity 44-50% NDF	511.9	349.8	414.6
72	Grass-legume mixture, hay, mature>50% NDF	515.4	353.2	418.1
73	Grass-legume mixture, silage immature< 44% NDF	589.5	389.9	469.8
74	Grass-legume mixture, silage, mid maturity 44-50% NDF	571.6	415.7	478.1
75	Grass-legume mixture, silage, > 50% NDF	552.2	390.0	454.9
76	Legume forage, pasture, intensively managed	656.0	462.7	540.0
77	Legume forage, hay, all samples	442.6	286.7	349.1
78	Legume forage, hay, immature<40% NDF	512.6	306.8	389.1
79	Legume forage, hay, mid maturity 44-46% NDF	463.2	269.8	347.2
80	Legume forage, hay, mature, > 46% NDF	482.0	338.5	395.9
81	Legume forage, silage, all samples	585.2	435.5	495.4
82	Legume forage, silage, immature, < 40% NDF	632.8	445.7	520.5
83	Legume forage, silage, mid maturity, 40-46 % NDF	603.9	429.2	499.1
84	Legume forage, silage, mature, > 46% NDF	607.3	432.6	502.5
86	Meat meal	340.5	22.4	149.6
87	Meat and bone	445.6	202.3	299.6
91	Oat hay, headed	353.0	265.6	300.6
92	Oats silage, headed	465.5	347.0	394.4
93	Pea nut meal, solvent	322.4	122.8	202.7
94	Potato by product meal	325.5	256.9	284.3
95	Rice bran	389.2	270.7	318.1
96	Rye, annual, silage	622.1	497.3	547.2
98	Sorghum grain, dry rolled	107.6	39.0	66.5
99	Sorghum grain, steamed flacked	107.6	39.0	66.5
100	Sorghum silage	287.0	212.2	242.1
101	Sorghum hay, Sudan type	289.4	208.3	240.8
102	Sorghum silage, Sudan type	512.3	418.8	456.2
103	Soybean hulls	376.4	301.6	331.5
104	Soybean meal expellers, 45% CP	531.4	319.3	404.1
106	soybean meal, solvent, 44% CP	548.5	261.5	376.3
107	Soybean meal, solvent, 48% CP	592.7	349.5	446.8
108	Soybean seed, whole	502.0	308.6	386.0
109	Soybean seed, whole roasted	496.3	296.7	376.6
111	Sunflower meal, solvent	367.2	123.9	221.2
115	Wheat bran	309.8	178.9	231.3
116	Wheat grain, rolled	101.2	7.6	45.1
117	Wheat hay, headed	356.2	275.1	307.6
118	Wheat middling	337.8	225.5	270.4
119	Wheat silage, early headed	379.4	273.4	315.8
120	Wheat straw	279.4	210.7	238.2
121	Whey wet, cattle	778.3	61.0	347.9

*$DCAD^1 = (Na^+ + K^+) - (Cl^-)$, **$DCAD^2 = (Na^+ + K^+) - (Cl^- + S^-)$, ***$DACD^3 = (Na^+ + K^+) - (Cl^- + 0.6S^-)$

Urinary pH is considered as a practical mentoring measurement to metabolic acidosis to reduce the incidence of milk fever during dry period (Goff et al., 2004). Forage ingredients are relatively low in energy content and considered the recommended feed ingredients for feeding dairy cattle during the dry period. In the three used DCAD equations, all forage feed ingredients did not show any negative DCAD (i.e. acid inducing effect) (Table 1). Thus, the ability of forage to cause acidification of the cow is not possible. However, few feed ingredient possessed mild-strong metabolic acidosis effect based on DCAD[2] equation (such as bread wastes (-5.2 mEq/kg), cookie by product (-6.1 mEq/kg), blood meal derived product (-315.0 mEq/kg), dried and wet brewer grains (-111.5 and -115.1 mEq/kg, respectively), canola meal (-75.6 mEq/kg) , dried corn gluten meal (-428.1 mEq/kg), feather meal without (-708.1 mEq/kg) and with viscera (-1045.3 mEq/kg), fish by products (range from -92.6 and -464.2 mEq/kg)) and DCAD[3] equation (such as blood meal derived product (-122.9 mEq/kg) , dried and wet brewer grains (-16.7 and -32.8 mEq/kg, respectively), dried corn gluten meal (-213.5 mEq/kg), feather meal with viscera (-608.7 mEq/kg), and fish by-products Menhaden (-174.7 mEq/kg).
In Jordan, few ingredients choices are available to the producers for dairy cattle such as: corn silage, alfalfa, wheat straw, corn, barley, wheat bran, and soybean meal. Based on the three equations mostly used by nutritionist, the magnitude of DCAD[1], DCAD[2] and DCAD[3] of different feed ingredients mainly used in Jordan ranged from 93.5 - 592.7 mEq/kg, 31.2 - 349.5 mEq/kg, and 56.1 - 446.8 mEq/kg, respectively. Forages are expected to be the dominant ingredients in dairy diet before calving (due to relatively lower energy demand for dry cow and their cheap prices). Feeding forages have been reported to increase the risk of milk fever due to high cations level (Barnouin & Chassagne, 1991). Furthermore, concentrate feeding to dry cow has been reported to make cow to lose appetite around calving and to absorb less calcium than is required (Allen & Davies 1981; Braak et al., 1986). As shown above, absence of ingredients that possess mild-strong metabolic acidosis effect in Jordan may expose dairy cattle to the risk of milk fever. To best of our knowledge, there are no statistics regarding clinical or subclinical milk fever occurrence in dairy cattle in Jordan. However, milk fever is reported to occur at the rate of 5-10% (Bushinsky, 1996) and can reach as 34% in individual herds (Houe et al., 2001). With limited feed ingredient choices available for feeding dairy cattle during dry period, feed ingredients (with minimal usage of anionic salts) that have mild-strong metabolic acidotic effect is required to reduce the incidence of milk fever. However, the few feed ingredients with mild-strong metabolic acidosis effect mentioned above are not available in Jordan (i.e. considered as industry byproducts or raw materials that does not existed in enough quantities). Furthermore, their inclusion in the diet may have some nutritional limitations that must be taken into consideration when formulating diet for dairy cattle before calving. For example, corn gluten meal is lack of lysine and the proportion metabolizable lysine is very low (Sauvant et al., 2004), thus, including large quantities of corn gluten meal to acidify complete diet before parturition may compromise utilization of metabolizable lysine in cattle. Including feather meal in cattle at high level has been reported to be associated with reducing intake (Leme et al., 1978). Blood meal has been reported to be lack in Sulphur-rich amino acids (Klemesrud et al., 2000) and isoleucine (Maiga et al., 1996). Feeding other mild-strong acidic feed ingredients such as bakery wastes, fish meal, brewer grains has been reported to possess some nutritional and cost constrains that limits their inclusion in feed (Stallings, 2009). Several nutritional strategies have been adapted to acidify complete diet to stimulate compensated metabolic acidosis in dairy cattle. Goff & Horst (1997) showed that feeding diets low in potassium and sodium is effective in reducing the risk of milk fever. Certain anionic salt has been reported to be more palatable than another anionic source. Sulfate salts have been reported to be more palatable than chloride salts (Goff & Horst, 1996). Between mostly used anionic salts, magnesium sulfate has been reported to be the most palatable and calcium chloride is the least palatable (Oetzel, 1991). However, chloride has been shown to possess larger acid activity (by 1.6 times) compared to sulfate (Goff et al., 2004). Commercially, adding sweetener to anionic salts is used to mask bad palatability of anionic salts. Combination of previous strategies can be used together to acidify diet. In theory, using binding agents that binds to cations and encapsulation of anionic salt can be potential alternatives to minimize the risk of milk fever. Further research must be conducted to investigate combined strategies to reduce incidence of milk fever.

Conclusions

Calculated DCAD values showed that the ability of most forage to cause acidification of the cow is not possible. However, few feed ingredients possessed mild-strong metabolic acidosis effect, but they have limitations when included in dairy diets during dry period. Several nutritional strategies have been suggested to acidify complete diet to stimulate compensated metabolic acidosis in dairy cattle raised under Jordanian conditions.

References

Allen, W.M., Davies, D.C. (1981). Milk fever, hypomagnesaemia and the 'downer cow' syndrome. Brit. Vet. J, 137, 435–441.
Barnouin, J., Chassagne, M. (1991). An aetiological hypothesis for the nutrition–induced association between retained placenta and milk fever in the dairy cow. Ann. Rech. Vét, 22, 331–343.
Berger, L.L. (1996). Variation in the trace mineral content of feedstuffs. Prof. Anim. Sci, 12, 1–5.
Braak, A.E., van't Klooster, A.T., Malestein, A., Faber, J.A. (1986) Effects of low and high calcium intake prepartum on calcium mobilization rate around parturition in dairy cows. The Vet. Quart, 8(1), 12–23. https://doi.org/10.1080/01652176.1986.9694013
Bushinsky, D.A. (1996). Metabolic alkalosis decreases bone calcium efflux by suppressing osteoclasts and stimulating osteoblasts. Amer. J. Physiol, 271, 216–222.
Charbonneau, E., Pellerin, D., Oetzel, R.G. (2006). Impact of lowering dietary cation–anion difference in nonlactating dairy

cows: a meta–analysis. J. Dairy Sci, 89, 537–548.
DeGaris, P.J., Lean, I.J. (2009). Milk fever in dairy cows: A review of pathophysiology and control principles. Vet. J, 176, 58–69.
Goff, J.P. Horst, R.L. (1996). Comparison of sulfuric acid with hydrochloric acid as a source of acidifying anions. Proceedings, Midwest section of the ADSA/ASAS, Abstract #274.
Goff, J.P., Horst, R.L. (1997). Effects of addition of potassium or sodium, but not calcium, to peripartum rations on milk fever in dairy cows. J. Dairy Sci, 80, 176.
Goff, J.P., Ruiz, R., Horst, R.L. (2004). Relative acidifying activity of anionic salts commonly used to prevent milk fever. J. Dairy Sci, 87, 1245–1255.
Horst, R.L., Goff, J., Reinhardt, T.A., Buxton, D.R. (1997) Strategies for preventing milk fever in dairy cattle. J. Dairy Sci, 80, 1269–1280.
Houe, H., Ostergaard, S., Thilsing–Hansen, T., Jorgensen, R.J., Larsen, T., Sorensen, J.T., Aggar, J.F., Blom, J.Y. (2001). Milk fever and subclinical hypocalcemia – an evaluation of parameters on incidence risk, diagnosis risk factors and biological effects as input for a decision support system for disease control. Acta. Scand, 42, 1–29.
Klemesrud, M.J., Klopfenstein, T.J., Lewis, A.J. (2000). Evaluation of feather meal as a source of sulfur amino acids for growing steers. J. Anim. Sci, 78(1), 207–215.
Lean, I.J., DeGaris, P.J., McNeil, D.M., Block, E. (2006). Hypocalcemia in dairy cows: metanalysis and dietarycation–anion difference theory revisited. J. Dairy Sci, 89, 669–684.
Lemann, J., Bushinsky, D.A., Hamm, L.L. (2003). Bone buffering of acid and base in humans. Amer. J. Physiol. Renal, 285, F811–F832.
Leme, P., Forero, O., Owens, F.N., Lusby, K.S. (1978). Feather meal as a protein source for range cows. Okla. Agr. Exp. Sta. Res. Rep. MP-103, 31–34.
Maiga, H.A., Schingoethe, D.J., Ellison–Henson, J. (1996). Ruminal degradation, amino acid composition, and intestinal digestibility of the residual components of five protein supplements. J. Dairy Sci, 79 (9), 1647–1653.
National Research Council (2001). Nutrient requirements of dairy cattle. Washington, D.C.: National Academic Press.
Oetzel, G.R. (1991). Meta–analysis of nutritional risk factors for milk fever in dairy cattle. J. Dairy Sci, 74, 3900–12.
Peña, T., Lara, P., Castrodeza, C. (2009). Multiobjective stochastic programming for feed formulation. J. Operat. Res. Soc., 60, 1738–1748.
Sauvant, D., Perez, J.M., Tran, G. (2004). Tables INRA–AFZ de composition et de valeur nutritive des matières premières destinées aux animauxd'élevage: 2ème édition. ISBN 2738011586, 306 p. INRA Editions Versailles.
Stallings, C.C. (2009). Limit These Feeds in Rations for Dairy Cattle. Virginia Cooperative Extension. Publication 404–119. Available from: https://pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/404/404–119/404–119_pdf.pdf. Accessed on 10.11.2017.
Thilsing–Hansen, T., Ørgensen, J., Østergaard, S. (2002). Milk fever control principle: A review. Acta. Scand, 43, 1–19.
Ramberg, C.F., Johnson, E.K., Fargo, R.D., Kronfeld, D.S. (1984). Calcium homeostasis in cows with special reference to parturient hypocalcaemia. Amer. J. Physiol, 246, 689–704.
Vagnoni, D.B., Oetzel, G.R. (1998). Effect of dieterycation–anion differences on the acid–base status of dry cows. J. Dairy Sci, 81, 1643–1652.

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