DETERMINATION OF DIETARY AND MILK ELECTROLYTES FOR THE EGYPTIAN LACTATING CATTLE FED THE SUMMER AND WINTER DIETS.

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SUMMARY

This study aimed at the dietary cation-anion difference (DCAD) and milk electrolytes determination for lactating Egyptian cows and buffaloes fed the summer and winter diets. Forty heteroparity lactating cattle, twenty cows and twenty buffaloes, at different stages of lactation were used to collect milk samples during summer (with a temperature range of 35-40 °c) and winter (with a temperature range of 18-22 °c). All animals received the diets consisted of concentrate, fodder, and rice straw as 2:1:1 on dry matter basis. In the summer, the fodder was Rayana corn (*Zea mays mexicana*), while, in the winter it was berseem clover (*Trifolium alexandrinum*). The results indicated that the DCAD of the summer and winter diets was 48.64 and 83.61 m Eq/100g DM (on the basis of the equation : $Na^+ + K^+ - Cl^-$), respectively. Slight increase ($P>0.05$) was noticed for 4% fat- corrected milk (FCM) of cows fed the winter diet comparing with those fed the summer diet. However, in the summer 4% FCM of buffaloes significantly ($P<0.05$) decreased by 33.8% comparing with those fed the winter diet. Concerning milk electrolytes, the results indicated that for cow's milk, Na^+/K^+ ratios were 3:1 and 2.6:1, while for buffaloe's milk, these ratios were 1.85:1 and 4.6:1 during the winter and summer, respectively. Milk Cl^- content was 19.75 and 18.33 mg/100g for cow's milk, while, buffaloe's milk contained 17.00 and 24.00 mg/100g during the winter and summer, respectively. This study concluded that buffaloe's milk production was negatively more affected by heat in summer than that of cow. The DCAD of hot-stressed buffaloes should be increased in the summer diets.

***Keywords:** dietary electrolytes, milk electrolytes, cows, buffaloes, milk production.*

INTRODUCTION

It is well known that every aspect of body functioning involves electrolytes. Electrolytes (cations and anions) constitute the bulk of the osmotic apparatus of body fluids and they are an integral part of the buffer system as well as of the structural portion of the pH mechanism.

The cations include Na^+, K^+, Ca^{++} and Mg^{++}, while the principal anions of the body fluid are Cl^-, HCO^-_3, $HPO_4^=$ and $SO_4^=$.

Under normal circumstances the body obtains all of its electrolytes from ingested food or feed and liquids (Reece, 1991).

In field of animal nutrition, the term dietary cation-anion difference (DCAD) means the difference in milliequivalents (mEq) between certain cations (Na^+ and K^+) and anions (Cl^- and $S^=$) per 100g DM of diet (Tucker, *et al.,* 1992; Walker *et al.,* 1998). This DCAD has an essential role either for dry or lactating cows.

It is of interest to report that one of the feeding strategies to prevent milk fever (hypocalcemia) in the period pre-calving is to ingest a diet with a DCAD close to zero (-75.6 to -32.00m Eq/100g DM). This strategy increased post-calving milk yield if the incidence of post-calving metabolic diseases was low (Walker *et al.*, 1998; Charbonnean *et al.,* 2009).

Regarding with the lactating cows, it was found a liner incrases in DMI as + DCAD increased. The optimum + DCAD for DMI and milk production was suggested between + 25 and +50 mEq/100 g (West *et al.,* 1992; Sanchez and Beede, 1994).

It is notable to report that the similarity of milk production and composition among different ratios of Na^+ and K^+ with the same DCAD ($Na^+ + K^+ - Cl^- + S^=$) (33m Eq/100g DM) can emphasize that DCAD is the most important not the dietary cations (Annick *et al.,*, 1995; Hu and Kmg, 2009).

But, what about milk electrolytes? It is well known that Ca^{++}, PO_4^-, Na^+, K^+, Mg^{++} and Cl^- comprise the milk electrolytes. They are absorbed directly, from the blood via the mammary gland.

Concerning milk Na^+, K^+ and Cl^-, they are present almost entirely as ions dissolved in milk whey. Beyond their value to sucking calf and human consumers, they affect the physical characteristics of milk such as freezing point, boiling point and osmotic pressure. Moreover, there is a positive correlation between electrical conductivity and chloride content.

Concentration of Na^+, K^+ and Cl^- in milk could be affected by the lactation stage and animal breed. (Ross Cockrill, 1974; Bath *et al.,* 1985.)

The present work aims at determination of DCAD and milk electrolytes for lactating cattle fed winter and summer diets and their effect on milk yield and composition.

MATERIALS AND METHODS

This study was carried out at the native farm of Atfih village, Helwan governorate and the Dairy Science Department, National Research Center, Dokki, Giza, from June 2009 to February 2010.

Animals and diets:

Forty heteroparity lactating cattle, (twenty cows and twenty buffaloes in summer and winter seasons) at different stages of lactation were used in this trail. Live body weight were 450 ±25 kg and 550 ±25 kg for cows and buffaloes, respectively.

The trial was conducted in summer (June and July, with a temperature range of 35-40 C°) and winter (January and February, with a temperature range of 18-22 °C). All animals were fed twice daily and all of them received the diet consisting of concentrate feed mixture (CFM), fodder and rice straw as 2 : 1 : 1 (on dry matter basis). In summer, fodder was Rayana corn-forage (*Zea mays mexicana*), while, in winter it was fresh berseem clover (*Trifolium alexandrinum*). Clean water was available at all time. The chemical composition of feed ingredients and diets are shown in Tables (1 & 2, respectively). The analytical methods were performed according to A.O.A.C. (1995). Samples of feeds were taken for dietary electrolytes determination.

Sampling and analysis of milk:

Cows and buffaloes were handily milked individually twice daily (6.00 a.m. and 6.00 p.m.). Biweekly, milk yield was recorded at each milking. Fat corrected milk (4% FCM) was calculating according to Gaines and Davidson (1923) using the formula :

$$FCM = Milk\ (kg) \times (0.3925 + 0.1510 \times fat\%)$$

Representative samples of milk were taken for analysis from morning and evening milkings once every two weeks. Milk fat was determined using infrared spectrophotometry (Foss 120 Milko-Scan, Foss Electric, Hillerød, Denmark) according to A.O.A.C. (1995) procedures.

Sodium (Na^+), potassium (K^+), chlorine (Cl^-) and sulfur. (S^{2-}) were determined using Atomic Absorption in the feed and milk samples according to the methods of Chapman and Pratt (1978). The instruments of these methods are available at the Central Services Lab (Project of microelements and plant nutrition problems), National Research Center. Dokki, Egypt.

Table (1): The chemical composition of feed stuffs on DM basis %.

Item	DM	OM	CF	CP	EE	NFE	Ash
CFM	93.49	86.55	15.23	14.10	4.08	53.14	13.45
Fresh berseem	18.00	85.84	27.40	13.80	2.60	42.04	14.16
Rayana corn forage	23.26	85.86	25.47	4.15	3.42	52.82	14.14
Rice straw	91.80	91.57	34.20	3.50	1.40	52.47	8.43

CFM: Concentrate feed mixture consisted of 35% yellow corn, 25 % wheat bran, 23% decorticated cotton seed meal, 15% rice bran, 1.5% ground limestone and 0.5% mineral and vitamin mix contained 42 ppm Co, 3500 ppm Cu, 20,000 ppm Fe, 12,000 ppm Mn, 12,000 ppm Zn, 1200 ppm I, 3800 IU/g of vitamin A, 1200 IU/g of vitamin D, and 30 IU/g of vitamin E.

Table (2): The chemical composition of diets on dry matter basis.

Item	Summer diet[1]	Winter diet[2]
Dry matter	75.51	74.20
Organic matter	87.64	87.63
Crude fiber	22.53	23.02
Crude protein	08.96	11.38
Ether extract	03.25	03.04
Nitrogen free extract	52.90	50.20
Ash	12.39	12.38

[1] *Concentrate (CFM): fresh berseem: rice straw (2 : 1 : 1).*
[2] *Concentrate (CFM): rayana corn forage: rice straw (2 : 1 : 1).*

Statistical analysis:

Analysis of variance was conducted according to Snedecor and Cochran, (1982). Since, four replications of a 2x2 factorial arrangement of groups were used. The applied model was:

$$Y_{iJK} = \mu + A_i + D_J + W_k + (AD)_{iJ} + E_{iJK}$$

Whereas Y_{iJK} is an observation, μ is a population mean, A_i is an effect of animal type (cow or buffaloe), D_J is an effect of diet type (summer or winter diet), W_k is an effect of sampling time (biweekly), $(AD)_{iJ}$ is an interaction effect between diet and animal, and E_{iJK} is a residual error. The Duncan's multiple range tests was used to test the significance between means (Duncan, 1955).

RESULTS AND DISCUSSION

Cations and anions:

With regard to dietary cations, data presented in Table (3), clearly indicated that berseem is a rich source of Na^+ (32.65g/kg DM) comparing with that of the other feed ingredients.

Rayana corn forage had a K^+ content (26.88g / kg DM) close to that of berseem (32.64g / kg DM). But this cation of both fodders was two times approximately of that in rice straw (13.44 g / kg DM). Obviously concentrate is the poorest ingredient in K^+ (4.44 g / kg DM) (Table 3).

It is of interest to report that Na^+ content of winter diet was three times approximately of that in summer diet, while, both diets had approximately the same level of K^+ (Table 3).

Inspection of the data concerning dietary anions, Table (3) showed that chlorine content ranged from 0.21 to 0.25 (g / kg DM) for all ingredients. Data showed no remarkable difference between the winter and summer diets for chlorine anion. However, there were detectable variations among sulphur contents of berseem, concentrate (CFM) and Rayana corn forage. Data of this Table indicated that winter diet had more sulphur (0.157g / kg DM) comparing with summer diet (0.103g / kg DM).

Table (3): Cations and anions concentration of feed ingredients and diets (g/kg DM).

Item	Cations		Anions	
	Na^+	K^+	Cl^-	$S^=$
Feed ingredients :				
Concentrate (CFM)	04.80	04.44	0.215	0.089
Fresh berseem	32.65	32.64	0.250	0.375
Rayana corn forage	03.84	26.88	0.195	0.161
Rice straw	02.88	13.44	0.215	0.070
Diets :				
Winter diet[1]	11.28	13.74	0.219	0.157
Summer diet[2]	04.08	12.30	0.205	0.103

[1] *Concentrate (CFM): fresh berseem: rice straw (2 : 1 : 1).*
[2] *Concentrate (CFM): rayana corn forage: rice straw (2 : 1 : 1).*

The present results couldn't be compared with the others due to the extensive variations among mineral contents of different feedstuffs, in particular, the fodders. These extensive variations are mainly affected by soil type, amount and type of fertilizer, roughage (green or dry) and agriculture season (Ghoniem, 1967).

Dietary Cation–Anion Difference (DCAD):

It could be noticed that the DCAD calculated as $(Na^+ + K^+) - Cl^-$ was 83.61 and 48.64 m Eq / 100g dry matter for winter diet, while, its calculation as $(Na^+ + K^+) - (Cl^- + S^=)$ was 82.63 and 47.99 mEq/100g dry matter for summer diet. Obviously, DCAD for winter diet closed approximately to the two times of that for summer diet (Table 4).

It is of interest to report that there was no remarkable difference between the two equations for the diet one. This finding may reflect that the original equation $(Na^+ + K^+ - Cl^-)$ suggested by Mongin (1980) is sufficient.

Here, it could be pointed to the suggestion of Roche *et al.* (2003) who reported that sulphur should be included in the equation of DCAD, only where high potassium forage is the main feed.

Table (4): Dietary cation–anion difference (DCAD) for diets fed to Egyptian lactating cattle (mEq/100g)[1].

DCAD	Diets	
	Winter	Summer
$(Na^+ + K^+) - Cl^-$	83.61	48.64
$(Na^+ + K^+) - (Cl^- + S)$	82.63	47.99

[1] *milliequivalent per 100g DM.*

Milk Yield:

Data of Table (5), clearly showed the effect of feeding winter diet with a DCAD of 83.61 mEq/100g DM or summer diet with a DCAD of 48.64 mEq/100g DM to cows and buffaloes on milk yield and 4% fat corrected milk (4% FCM).

It could be reported that daily milk yield of the cows was around 5.2-5.6 kgh^{-1} in both winter and summer months, while, slight increase was recorded for milk yield and 4% FCM of cows fed the winter diet comparing with those fed the summer diet (Table 5).

Table (5): Milk yield and fat of lactating cattle fed winter and summer diets with DCAD[1] of 83.61 and 48.64 mEq/ 100 g DM, respectively.

Item	Experimental animals				±SE
	Cows		Buffaloes		
	Winter	Summer	Winter	Summer	
No of animals	20	20	20	20	
Milk yield :					
Kg/h/d	5.55^{bc}	5.21^{dc}	6.90^{a}	5.74^{b}	0.37
Mean	5.38^{b}		6.32^{a}		0.24
4% fat corrected milk:					
Kg/h/d	5.11^{c}	4.61^{cd}	8.37^{a}	6.28^{b}	0.84
Mean	4.85^{b}		7.79^{a}		0.62
Milk fat content %	3.50^{c}	3.26^{cd}	5.43^{a}	4.65^{b}	0.51
Mean	3.38^{b}		5.04^{a}		0.41
Milk fat yield :					
g/h/d	194.30^{c}	169.85^{cd}	365.7^{a}	266.91^{b}	43.97
Mean	182.00^{b}		316.31^{a}		33.9

[a,b,c,d] *means in the same row with different superscripts differed significantly at ($P<0.05$).*
[1] *DCAD = dietary cation–anion difference.*

However, for lactating buffaloes in summer months, the daily milk yield as absolute and 4% FCM were significantly ($P<0.05$) decreased by 20.9 and 33.8%, respectively comparing with buffaloes fed the winter diet.

Obviously, this finding can reflect that buffaloes are more sensitive to the heat in summer than cows and this sensitivity can be explained on the basis of color difference, skin thickness, number of sweat glands per unit area and the fact that the domestic buffalo is a semi aquatic animal (RossCockrill, 1974). In this respect, it could be reported that the primary cation in bovine sweat is potassium and sharp excretion occurs during hot climatic condition (Jenkinson and Mabon, 1973; Mallonee *et al.*, 1985). Potassium is an essential for the well function of muscles (including those of digestive tract), and for the proper appetite. (Frandson, 1986).

In the light of the previous, and with regard to the suggestion that feeding diets having a high + DCAD improved DMI and milk yield (Tucker *et al.*, 1988; West *et al.*, 1991), the present result suggests that the DCAD of summer diet (48.64 mEq / 100g DM) should be raised up to that of winter diet (83.61 mEq / 100g DM) for the lactating Egyptian buffaloes, regardless of whether Na^+ or K^+ should be used because DCAD equation is more significant than the individual element concentration (as recommended by West *et al.*, 1992; Annick *et al.*, 1995; Hu and Kmg, 2009).

In this respect, it could be reported that buffaloes exposed to heat–stress when an ambient temperature ranged from 28 to 44c° (Ross Cockrill, 1974). In the present work, the summer was with a temperature range of 35 – 40 c°.

It is of interest to report that regardless of lactation season, Egyptian buffaloes yield significantly (P<0.05) more milk and 4% FCM by 17 and 50%; respectively by the comparison with the native cows (Table 5). This may be possibly related to the rumen size, udder size, and animal size or to other genetic factors.

Milk fat:

Data presented in Table (5), clearly illustrated that during winter months, cow milk fat either as content or yield were insignificantly higher than with those during summer months.

However, buffaloe's milk contained more fat content (5.43%) (P< 0.05) in winter than that (4.65%) in summer.

Actually, significant increases in milk yield and fat content and yield of buffalo during winter months comparing with summer months (Table 5).

The similarity of roughage to concentrate ratio (2 concentrate : 1 green fodder : 1 rice straw) and the non significance differences among milk cows as yield, 4% FCM, fat content and fat yield during winter or summer months may be possibly pointed to that DCAD can significantly affect these studied parameters only in heat–stressed buffaloes. The DCAD effect in this case can be via its effect on blood acid–base–status (West *et al.*, 1992).

Regardless of lactation season, milk buffaloes fat as content or yield was significantly (P<0.05) higher than that of cows (Table 5).

Milk electrolytes:

Data of Table (6) indicated that milk of lactating cows fed a winter diet with a DCAD of 83.61 mEq/100g DM contained significantly (P<0.05) more Na^+ (190.75 mg/100g milk) comparing with that (156.83 mg/100g milk) of those fed a summer diet with a DCAD of 48.64 mEq/100g DM.

Clearly, an opposite trend was observed for lactating buffaloes, whereas, milk Na^+ during summer (168.00 mg/100 g milk) was significantly (P< 0.05) higher than that (145.20 mg/100g milk) during winter. Milk Na^+ of cows was significantly higher than milk Na^+ of buffaloes (Table, 6).

Concerning with milk K^+, it could be reported that no remarkable difference was noticed for milk cow secreted either during winter or summer (both levels were around 60 mg/100g milk) (Table 6).

Table (6): Milk electrolytes of lactating cattle fed winter and summer diets with DCAD of 83.61 and 48.64 mEq/100g DM, respectively.

Item	Experimental animals				±SE
	Cows		Buffaloes		
	Winter	Summer	Winter	Summer	
No of animals	20	20	20	20	
Milk Na^+					
(mg / 100g)	190.75^a	156.83^c	145.20^{dc}	168.00^b	9.7
Mean	170.40^a		158.88^b		5.8
Milk K^+					
(mg / 100g)	61.93^{bc}	60.02^c	78.48^a	36.40^d	8.66
Mean	60.78^a		53.28^b		1.89
Milk $Na^+ : K^+$	3 : 1^b	2.6 : 1^{bc}	1.85 : 1^d	4.6: 1^a	0.58
Mean	2.8 : 1		2.98 : 1		0.05
Milk Cl^-					
(mg / 100g)	19.75^b	18.33^{cb}	17.00^{bd}	24.00^a	1.52
Mean	18.90^b		21.00^a		0.53

[a,b,c,d] *Means in the same row with different superscripts differed significantly at (P<0.05).*
[1] *DCAD = dietary cation – anion difference.*

However, significant remarkable (P<0.05) decreasing was recorded for milk K^+ of buffaloe secreted during summer (36.40 mg/ 100g milk) comparing with that during winter (78.48 mg K^+/100 g milk). Milk K^+ of cows was significantly higher than milk K^+ of buffaloes (Table, 6).

Inspection data of Table (6), clearly illustrated the ratios of Na^+ to K^+ among the two DCAD and the two cattle. These ratios were 3 : 1, 2.6 : 1; 1.85 : 1 and 4.6 : 1 for cows and buffaloes during winter (with DCAD of 83.61) and summer (with DCAD of 48.64 mEq/100g DM), respectively. Actually, this finding reflects that milk of lactating cattle had Na^+ approximately two to five folds of K^+. It is a reliable result because milk is considered as an extracellular fluid inside the udder. Na^+ and Cl^- are extracellular electrolytes, while K^+ functions principally as the cation of cells. Milk Na^+ to K^+ ratio of cows was insignificantly lower than milk Na^+ to K^+ ratio of buffaloes (Table, 6).

With regard to the milk Cl^-, data presented in Table (6) clearly, indicated that no significant (P>0.05) increase was recorded for the concentration of Cl^- in milk cow during winter comparing with that during the summer.

However, significant remarkable (P<0.05) increasing was noticed for Cl^- milk buffaloe milked during summer (24.00mg/100g milk) comparing with that during the winter (17.00 mg/100g milk) (Table 6). Milk Cl^- of cows was significantly lower than milk Cl^- of buffaloes (Table, 6).

In the light of milk electrolytes results, it could be reported that hot summer stressed-buffaloes (with a DCAD of 48.64 mEq/100g DM) secreted milk high to somewhat in Na^+, low to the half in K^+, high to the five folds in the Na^+: K^+, and high to significant level

($P<0.05$) in Cl^- comparing with those received a winter diet with a DCAD of 83.61 mEq/100g DM. (Table 6).

Results reported here for milk cow during both winter and summer are in line with result of Abeni, *et al.* (2008) who found that milk Na^+, K^+, Na^+:K^+ ratio, and Cl^- didn't differ across the whole lactation of cows in Italy.

CONCLUSION

Of the foregoing, it could be concluded that milk production and milk electrolytes of the native Baladi cows were not significantly affected by receiving diets differed in DCAD during winter and summer. However, for lactating Egyptian buffaloes received a diet with a DCAD of 48.64 (mEq/100g DM) during summer months, milk production as 4% FCM decreased by 33.8% and milk Na / K ratio increased up to approximately five folds comparing with those received a diet with DCAD of 83.61 mEq/100g DM during winter months.

As a recommendation, the DCAD of hot summer stressed-Egyptian buffaloes should be increased. Additional research is needed to determine the optimum DCAD for these cattle, and to decide whether Na or K should be supplied to the summer diets.

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تقدير الأملاح الإلكتروليتية فى العلائق واللبن لكل من البقر والجاموس المصرى خلال موسمى الصيف والشتاء

أحلام عبد الحليم الشيوى ، صبحى محمود محمد خليف ، طارق عبد الفتاح مرسى و محمد محمود على عبده

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تم استخدام ٢٠ جاموسه حلابة و ٢٠ بقرة حلابة لدراسة محتوى العلائق واللبن من كل من الكاتيونات (الصوديوم و البوتاسيوم) والأنيونات (الكلور و الكبريت) خلال فصلى الصيف (٣٥-٤٠ درجة منوية) و الشتاء (١٨-٢٢ درجة منوية). حيث تم تغذية الحيوانات البقر والجاموس خلال فصل الصيف على علف مركز : أذرة ريانة : قش أرز بنسبة ١:١:٢ و خلال فصل الشتاء على علف مركز : برسيم أخضر : قش أرز بنسبة ١:١:٢ وأوضحت النتائج المتحصل عليها ما يلى:

١- محتوى العلائق من ميزان الكاتيونات و الأنيونات خلال فصل الصيف كان ٤٨,٦٤ وخلال فصل الشتاء كان ٨٣,٦١ (m Eq./100g DM) حسب المعادلة ($Na^+ + K^+ - Cl^-$).

٢- ارتفع اللبن المعدل نسبة الدهن (٤%) معنويا بنسبة ٣٣,٨% مع عليقة الشتاء للجاموس عن عليقة الصيف بينما لم يكن الارتفاع معنويا فى فى حالة البقر مع عليقة الشتاء عن عليقة الصيف.

٣- نسبة الصوديوم : البوتاسيوم فى لبن البقر كان ١:٣ و ١:٢,٦ وفى لبن الجاموس ١:١,٨٥ و ١:٤,٦ خلال فصلى الشتاء والصيف على التوالى .

٤- محتوى لبن البقر من الكلور كان ١٩,٧٥ و١٨,٣٣ وفى لبن الجاموس ١٧,٠ و ٢٤,٠ ملجم/١٠٠جم خلال فصلى الشتاء والصيف على التوالى.

ومن هذت النتائج يتضح ان لبن الجاموس كان أكثر تأثرا بالحرارة خلال فصلى الشتاء والصيف من لبن الأبقار المحلية. ولذلك يوصى بزيادة ميزان الكاتيونات الى الأنيونات فى علائق الجاموس خلال فصل الصيف.