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SOLUBILITY OF SOME MINERALS IN FEEDSTUFFS INCUBATED IN RUMEN OF BARKI SHEEP FED DIFFERENT TYPES OF DIET.

Hassan, N. I.[1]; M. A. Hanafy[2]; G. M. Abdul Aziz[2] and M. M. A. Ghandour[1]

1- Desert Research Center, Cairo, Egypt.

2- Faculty of Agriculture, Cairo Univ., Giza, Egypt.

ABSTRACT

The present experiment comprised two parts to study solubility of some macro-elements(Na, K, Ca and P) and some micro-elements (Zn and Cu) from some common Egyptian feedstuffs, berseem hay rice straw concentrate feed mixture and barley grains. In part one the feedstuffs were soaked in water for 15 minutes to determine mineral solubility. In Part two, feedstuffs were incubated for 72 hours in rumen of fistulated Barki sheep fed different roughage to concentrate ratios (70:30, 50:50, and 30:70). \

Results showed the following:

1. Soaking feedstuffs in water had a significant effect on the DM disappearance and minerals solubility . Sodium and potassium were the highest soluble among the macro-elements, while copper was more soluble than zinc.
2. Although there was no significant difference in solubility of most minerals among feedstuffs incubated in the rumen of sheep fed diets of different R/C ratios, zinc solubility tended to increase in high roughage diet.
3. There was significant difference in rumen fluid pH among experimental treatments. The VFA's were higher in high concentrate diets (and the difference was significant at 6 hours). Moreover NH_3-N concentration was not significantly different among diets, and tended to increase in high concentrate diet.

It could be concluded that, solubility of minerals may be affected by kind of element, fiber constituents of feedstuffs and rumen fluid pH.

Keywords : Minerals, solubility, rumen metabolites, in situ and R/C ratios.

INTRODUCTION

Solubility of minerals is the primary factor for their absorption. It is a complex process affected by many factors including solubility in water, kind of minerals, concentration of the mineral in the rumen, minerals binding to plant cell walls, type and quality of roughage, incubation period, and rumen fluid pH.As far as cell wall constituents is concerned, Kincaid and Cronrath (1983) reported that neutral detergent fiber (NDF) in alfalfa hay was responsible for the binding of 24, 31, 77, 29, 31 percent of calcium, phosphorus , iron , copper and zinc, respectively. Moreover, 23, 19, 43 percent of zinc, iron, and copper respectively were bound to acid detergent diber (ADF). On the other hand , in grass silage both NDF and ADF caught 52, 62 and 100 percent of zinc, ferrous, copper respectively.

There is a general agreement among different studies that sodium and potassium are highly soluble, exceeding 90 percent (Kincaid and Coronrath, 1983; Ibrahim *et al* , 1990; Emanuele and Staples, 1990 and Emanuele and Staples, 1994). On the contrary calcium was the least soluble in poor quality roughages reaching 4 and 11 percent in rice straw and wheat straw respectively compared to 79 percent in maize silage, (Ibrahim *et al* , 1990).

Rumen was considered the main site of absorption of sodium ,potassium, chlorides and magnesium in ruminants. Meanwhile, it is a secondary site for the absorption of calcium and phosphorus (Dua 2002).

Therefore, rumen fluid pH had the first role for minerals solubility. Rumen pH was highly related to the type of diet especially roughage to concentrate ratio. In concentrate based diets, phosphorus was more soluble than roughage diets (Flachowsky and Grün, 1992). Macro-elements were better released than trace-elements in sheep fed concentrate diets. Moreover, copper and zinc release were much lower in high concentrate diet when rumen pH was low (El-Gllad and Mehrez , 1982).

The present study aimed to clarify the effect of type of diet on minerals solubility in rumen of Barki sheep, relationship between rumen metabolites and solubility of minerals.

MATERIALS AND METHODS

Location and Duration :

The present study was carried out at Maryout Desert Research Station, south of Alexandria , Egypt. The experiment lasted four months during 2005-2006.

Animals :

Nine rumen fistulated adult Barki rams with an average body weight of 52.4 **±** 1.77 kg were individually distributed at random into three feeding treatment.

Animals were fed the maintenance requirements of energy and protein (NRC, 1985).

Treatments :

Three different diets were formulated to achieve 70:30, 50:50, 30:70 of roughage to concentrate ratios on TDN basis according to NRC (1985).sheep were fed individually and feeds were offered at two times daily at 08:00 a.m. and 03:00 p.m.

Feeds and feeding :

Roughages used in the experiment included sun dried second-third cut berseem hay(***Trifolium alexandrenum***), and chopped rice straw. Meanwhile, two concentrate feeds (a concentrate feed mixture and barley grains) were also used to study the availability of their minerals. Chemical composition of feed ingredients is listed in table (1).

Table (1) : Chemical composition (% on DM Basis) of experimental ingredients and calculated composition of the experimental diets.

Chemical composition	Ingredients				Diets[1]		
	Rice straw	Berseem hay	Barely grains	Rice straw	D1	D2	D3
DM	92.1	58.1	87.8	91.6	88.7	89.4	90.3
OM	79.4	83.9	95.2	90.7	84.2	85.7	87.4
CP	4.9	16.0	12.8	15.6	11.9	12.3	12.5
CF	29.8	26.5	9.3	6.9	23.2	19.8	16.0
EE	1.4	2.2	1.5	2.8	2.0	2.1	2.2
NFE	43.3	39.3	71.6	65.4	46.9	51.7	56.8
Ash	20.6	16.1	4.8	9.3	15.8	10.6	9.7
NDF	76.9	53.1	33.4	31.7	56.4	51.8	46.8
ADF	48.5	41.9	12.96	8.2	36.6	30.7	24.1
ADL	10.9	12.1	1.3	1.7	9.2	7.5	5.5
Macro-elements (%)							
Na	0.61	1.69	0.03	0.45	1.0	0.82	0.61
K	0.69	1.9	0.51	0.72	1.3	1.1	0.92
Ca	0.12	0.44	0.06	0.82	0.38	0.43	0.48
P	0.05	0.63	0.54	0.89	0.47	0.53	0.59
Micro-elements (ppm)							
Zn	59.9	45.9	96.4	121.6	67.1	78.7	91.6
Cu	27.3	23.8	40.9	12.9	24.0	22.9	21.9

1- calculated
2-Concentrate Feed Mixture
D1 : 70: 30 R/C Roughage to Concentrate ratio
D2: 50: 50 R/C Roughage to Concentrate ratio
D3: 30: 70 R/C Roughage to Concentrate ratio

Incubation and minerals availability :

Nylon bags (9x17 cm) in two replicates and with two runs each were incubated in sheep rumen according to the procedure of Mehrez and Ørskov (1977) to study mineral release from feeds which were ground to pass through to a 2-mm screen (Flachowsky and Grün, 1992). The minerals solubility was measured at zero and 72 hours of incubation period (Emanuele and Staples, 1994). To study minerals solubility in water (zero time), feed samples in nylon bags were soaked in water for 15 minutes (Ørskov, *et.al*., 1980), and washed by running tap water until the washing out water became clear then washed with re-distilled water and dried, weighed and kept for determining minerals to obtain dry matter disappearance and minerals release (washing loss).

Another set of samples (all the four feedstuffs) were incubated for 72 hours in the rumen (in two runs), then withdrawn and soaked in cold water for 15 minutes to remove adhered rumen microorganisms from incubated feed particles (Emanuele and Staples, 1994) then washed similar to the procedure of zero time samples

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Determination of minerals:

Wet ashing procedure (Kabaija and Little 1989) using sulphuric acid and hydrogen peroxide were used in preparing samples of feeds, feed refusals and nylon bags content for mineral analysis. Sodium, Potassium and Calcium were determined by flame photometer as suggested by Jackson (1958). Phosphorus was determined by spectrophotometer **(** Murphy and Riley 1962)**,** while zinc and copper were determined by atomic absorption spectrophotometer, (Pye Unicam model 220) according to Chapman and Partt (1961).

Analysis of feeds :

Proximate analysis was conducted for feeds , feed refusal and nylon bags content before and after incubation in the rumen using official methods as described in A.O.A.C (1990). Fiber fractions of these samples were conducted according to Van Soest and Robertson (1985).

Rumen parameters:

Rumen samples were withdrawn from the fistulated rams just before feeding (zero time) and then at 3, 6, 9, 12 hours after feeding to determine rumen metabolites. Rumen pH was determined immediately using electrical pH meter. Rumen samples were then filtered through three layers of cheese cloth to remove feed particles. The filtrate was kept in freezer blew zero °C for determining rumen ammonia nitrogen using Kjeldahl method and VFA͵s by steam distillation as described by A.O.A.C (1990) and Warner (1964), respectively.

Statistical analysis :

Differences among dietary treatments and rumen metabolites were checked using one way analysis of variance and Duncan's new multiple range test (Duncan, 1955). The General Linear Model (GLM) procedure of SAS (1996) was employed. The relationship between rumen metabolites and solubility of minerals were checked for linearity

RESULTS AND DISCUSSION

As outlined, differences among treatments lied only in the roughage-concentrate ratio. Concentration of NDF and ADF were 56.4 and 46.8%;36.6 and 24.1%in roughage and concentrate diets, respectively (table 1). Moreover, table (1) showed that sodium and potassium concentration were higher in diet (1) than diet (3). Therefore, the intake of both were higher in roughage diet (table 2). Meanwhile zinc intake was higher in concentrate diet(table 2).

Table (2): Dietary intake by sheep fed the experimental diets (means± SE).

Item	Treatments		
	D1	D2	D3
DM intake			
Roughage intake, g/d			
Rice straw	279.97±32.7	225.37±24.6	248.31±11.6
Berseem hay	456.7±20.5^a	307.78±10.2^b	140.42±6.5^c
Total	754.7±53.0^a	533.5±22.8^b	388.7±18.1^c
Concentrate intake, g/d			
CFM	195.43±4.0^c	334.33±11.5^b	465.68±31.0^a
Barley grains	58.55±1.5^c	95.15±2.9^b	131.75±9.1^a
Total	253.99±5.23^c	429.53±14.44^b	597.43±40.91^a
Total DM intake	1008.66±57.91	963.04±25.54	986.15±58.10
Macro-elements intake, g/d			
Na	10.47^a± 0.55	8.09^b± 0.16	6.20^c± 0.30
K	13.30^a± 0.75	10.95^b± 0.28	9.15^b± 0.51
Ca	3.85± 0.32	4.14± 0.17	4.80± 0.41
P	4.73± 0.29	5.35± 0.12	5.83± 0.33
Micro-elements intake, mg/d			
Zn	65.1± 4^b	73.25± 2.2^b	91. 5± 5.2^a
Cu	25.4± 1.3	22.83±0.57	22.12± 1.3

a, b, c, values with different superscripts in the same row differ significantly (P<0.05).

1-Dry matter disappearance and mineral solubility in water :

Table (3) showed that DM disappearance in water was twice as much in concentrate feed mixture as in the rice straw, and this may be due to higher values of NDF% and ADF % in rice straw than concentrate feed mixture (table 1).

Table (3): Dry matter disappearance, and minerals solubility of some Egyptian feeds in water. (means ± SE).

Item	Rice straw	Berseem hay	Barley grains	CFM
% of initial[1]				
DM	21.96± 0.31^d	30.95.± 0.1^b	27.29± 1.83^c	46.76±0.99^a
Na	97.45±0.01^a	97.37± 0.01^a	66.4± 0.01^c	96.01± 0.48^b
K	98.66±0.01^b	99.32±0.01^a	79.78± 0.01d	94.04±0.29^c
Ca	35.2± 0.25^b	59.42±0.05^a	31.94± 0.25^c	23.53± 0.99^d
P	60.54± 0.16^c	78.73±0.03a	55.78± 0.16^d	66.04± 0.64^b
Zn	49.57± 0.1^c	22.14±0.2^d	65.92±0.2^c	96.95±0.45^a
Cu	58.39± 0.16^d	71.55± 0.03^b	67.53± 0.2^c	88.83± 0.5^a

1- % from the sample without any incubation
- a, b, c, values with different superscripts in the same row differ significantly (P<0.05).

Potassium and sodium were the most soluble, 79.8-99.3% and 66.4-97.4% respectively. This trend confirmed the previous results of Whitehead *et al*., (1985); Emanuele and Staples, (1990) ; Ibrahim *et al* , (1990); Flachowsky and Grün (1992); that the water solubility of potassium and sodium ranged from 89.5to100 % and 86 to 97%, respectively.

In the present study, solubility of phosphorus of barley grains in water (55.8%) was lower than berseem hay (78.7%). Similar results were obtained by Bromfield and Jones (1972) where phosphors solubility in ground hay of *Trifolium subterraneum* and intact pasture of *Phalaris tuberose* ranged from 23.5-59.4%. Meanwhiale, Emanuele and Staples, (1990) and Ibrahim *et. al.*, (1990) showed that calcium solubility in water was as low as 4 up to 79%.

Regardless the concentrate feed mixture which contained fine particles of feedstuffs, copper seemed more soluble (58.4 -71.6%) than zinc (22.1-65.9), because zinc was highly associated with plant cell wall (Bremner and Knight. 1970).

In the present study, the solubility in water for calcium(23.5-59.4%) and copper (58.4-88.8%) was higher than that obtained by Ibrahim *et. al.*, 1990 using different types of feedstuffs. They indicated that water solubility of calcium and copper was (4-79%) and (8-77%), respectively. Moreover, copper and zinc solubility were (53-67%) and (52-18%) in two grass and two legumes (Whitehead *et al*., 1985).

2- Dry matter disappearance and mineral solubility in rumen fluids :

Results of DM disappearance and minerals solubility of the four feedstuffs after 72h incubation in the rumen are listed in Tables (4) and (5).

No statistical differences in DM disappearance_and mineral solubility were detected among diets when hay, barley or concentrate mixture were incubated for 72h in the rumen. On contrary, rice straw showed the least disappearance of DM, calcium, phosphorus and zinc
(table 4). This may be related to the high content of NDF and ADF in rice straw 76.9 and 48.5%, respectively (Whitehead *et al*., 1985).

Furthermore, phosphorus was significantly ($P<0.05$) less soluble in high roughage compared to low roughage diets(-9.21% and 8.11% respectively). Similar results were reported by Flachowsky and Grün, (1992) that solubility of phosphorus ranged between -42.1%and 22.9 % in ryegrass incubated in roughage and concentrate diets, respectively. They reported that negative value of phosphorus solubility may be explained as attachment of cellulolytic microbes to the incubated feeds of higher fiber content in rumen.

Table (4) : Dry matter disappearance from rice straw and berseem hay and mineral solubility in rumen (means ± SE).

Item	Rice straw			Berseem hay		
	D1	D2	D3	D1	D2	D3
% of initial						
DM	55.20± 10	٥٦,٠٤±0.1	٥٣,٢٢±1.7	77.73±0.6	77.26±0.1	77.53±0.3
Na	٩٨,٩٦±0.1	٩٨.81±0.3	٩٨,٧٣±0.2	99.61±0.1	99.70±0.01	99.71±0.02
K	١٠٠±٠,٠	١٠٠±0.0	١٠٠±0.0	100±0.0	100±0.0	100±0.0
Ca	86.16±0.8	٨٤,٢٦±2.0	٨٢,٨٣±1.0	92.84±0.2	91.86± 0.2	92.55± 1.1
P	-9.21^{b}±6.8	11.86^{a}±5.4	8.11^{a}±0.3	95.22±0.2	96.15± 0.4	94.99± 0.6
Zn	48.68±4.2	55.21± 5.4	38.13±4.1	51.59±2.1	49.34± 5.3	39.5± 3.8
Cu	80.54±6.8	78.17± 2.2	79.01±4.7	86.45±1.2	86.22± 1.3	82.6± 3.4

- a, b, c, values with different superscripts in the same row differ significantly (P<0.05)

Table (5) : Dry matter disappearance from barley grains and CFM and mineral solubility in rumen (means ± SE).

Item	Barley grains			Concentrate feed mixture		
	D1	D2	D3	D1	D2	D3
% of initial						
DM	87.80±0.60	87.26± 0.3	86.95± 0.3	90.59±0.30	90.44± 0.3	89.63± 0.32
Na	95.83± 0.29	94.30±2.02	96.30± 0.2	99.77±0.04	99.84±0.01	99.73± 0.02
K	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0	100±0.0
Ca	97.68± 0.21	96.89±0.23	96.77±1.41	93.69± 1.1	92.91±0.72	94.33± 0.82
P	97.46± 0.72	97.52±0.28	96.92±0.69	98.68± 0.1	99.29±0.22	98.88± 0.22
Zn	91.04± 0.2	89.98±2.24	88.89±1.55	99.44±0.04	99.56± 0.2	99.3± 0.1
Cu	93.34± 0.85	93.15±0.44	94.27±0.47	94.53±0.53	90.62±0.13	93.95± 1.7

In the present study, solubility of zinc was not significantly affected by the type of feeds. Meanwhile, there was a trend to high Zn solubility in concentrate feeds, 88.9-91% and 99.3-99.6% in barely grains and CFM, respectively. In roughage diets also there was a trend to increase Zn solubility in feeds (high NDF and ADF%) when incubated in the rumen, the solubility was 48.7% and 38.1% ; 51.6% and 39.5 % in rice straw and berseem hay when incubated in roughage and concentrates diets, respectively. Similar rustles were reported by Bremner and. Knight (1970) that most of zinc was completely released when cellulase enzyme was added to ryegrass. Moreover, in the present study rumen pH was 6.3-6.7 and 5.5-6.2 in roughage and concentrates diets respectively (table 6). Ørskov (1999) reported that to get optimal conditions for digestion of roughage, rumen pH must be more 6.2.

Table (6) : Rumen fluid pH in sheep fed the experimental diets (means ± SE).

Time, h	Treatments		
	D1	D2	D3
0	6.72^{a}± 0.10	6.64^{a}± 0.18	6.23^{b} ± 0.01
3	6.59^{a}± 0.05	6.23^{a}± 0.20	5.74^{b} ± 0.2
6	6.41^{a}± 0.05	6.03^{b}±0.07	5.50^{c}± 0.13
9	6.39^{a}± 0.02	6.14^{a}± 0.01	5.50^{b} ± 0.10
12	6.32^{a}±0.07	6.15^{a}± 0.01	5.75^{b}± 0.01

- a, b, c, values with different superscripts on the same row differ significantly (P<0.05).

3-Some rumen parameters :

3.1. Rumen fluid pH

Table (6) showed that rumen pH seemed to be the most effective factor in mineral solubility where it was significant among diets during all sampling periods. Rumen pH tended to decrease as the sampling time progressed (figure 1).

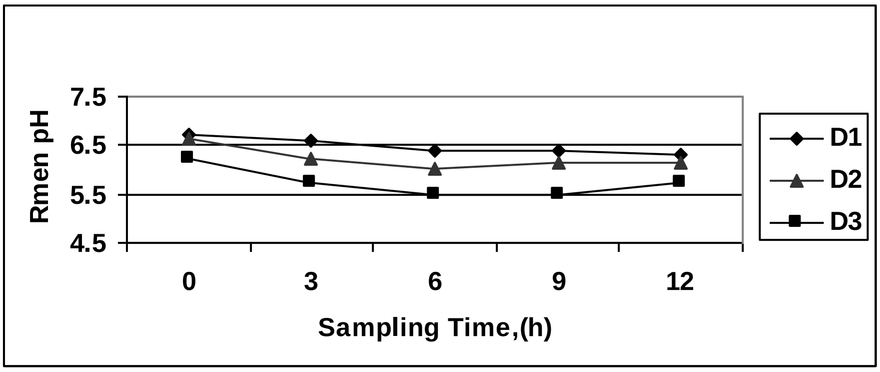

Fig. (1) : Rumen fluid pH during 12 hours of feeding.

Negative relationship was found between rumen pH and the level of dietary concentrate.

Low pH in silage seemed to enhance minerals release in rumen. Rooke *et. al*., (1983) showed that grass silage incubated for 48 h in the rumen had mineral solubility of 67.9, 73, 83.6, 63.2, 82.1, 67.6, 78.9 % for potassium, calcium, sodium, phosphorus, magnesium, zinc and copper, respectively.

3.2. Rumen ammonia nitrogen :

Table (7) indicated that, concentration of rumen fluid ammonia nitrogen was neither affected by dietary roughage–concentrate ratio nor the sampling time. It reached the peak at six hours after feeding as shown in figure(2). The concentration of rumen ammonia nitrogen at 12 hours after feeding was very close to that before feeding.

Table (7) : Rumen ammonia-N concentration, and VFA´s concentrations in sheep fed the experimental diets. (means ± SE).

Time, h	NH_3-N(mg/100 ml)			VFA´s (m. equiv./100 ml)		
	D1	D2	D3	D1	D2	D3
0	15.74± 1.3	16.92±2.5	19.13±1.1	7.16± 1.0	6.67±0.95	7.98± 0.4
3	28.47± 1.6	32.81±4.8	29.82±1.8	7.59± 0.6	9.27± 1.6	10.02±0.5
6	21.35± 1.2	25.39±2.3	30.07±4.1	6.50^b± 0.4	6.58^b±0.4	9.88^a± 0.6
9	19.75± 2.8	23.56±0.9	29.13±5.7	7.34± 1.4	6.08± 0.1	9.58±1.95
12	15.33± 3.0	18.4± 1.7	17.79±0.3	6.03± 1.0	5.52± 0.5	6.12± 0.4

- a, b, c, values with different superscripts on the same row differ significantly (P<0.05).

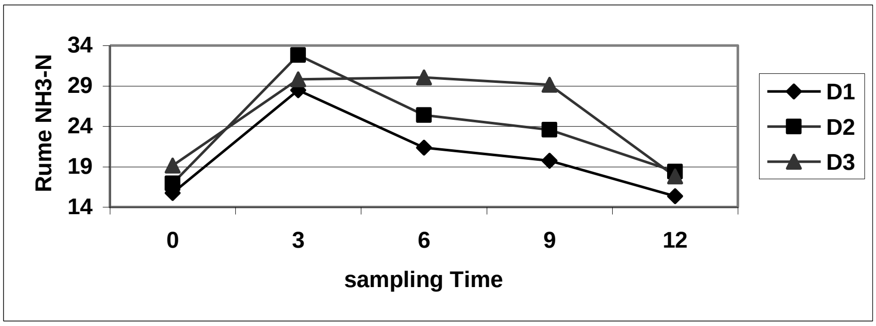

Fig. (2) : Rumen ammonia-nitrogen concentration(mg/100 ml) during 12 hours of feeding.

3.3 Rumen volatile fatty acids concentration :

Table (7) showed that concentration of VFA´s was only significant (P<0.05) at six hours after feeding. The relation between rumen VFA´s and the level of dietary concentrates seemed to be linear, as shown in figure(3) .

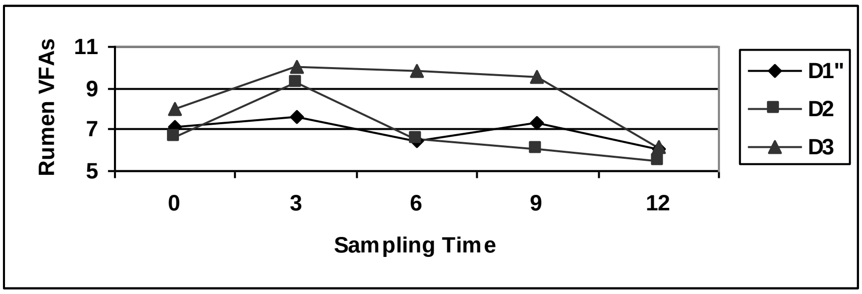

Fig. (3) : Rumen volatile fatty acids concentration(m. equiv./100 ml) during 12 hours of feeding.

Significant negative correlations were recorded between rumen pH and the concentration of VFA´s (r= -0.34) and the concentration of rumen ammonia nitrogen (r= -0.44). Meanwhile, positive correlation was found between concentrations of VFA´s and ammonia nitrogen (r= 0.62).

4- Relationship between Rumen parameters and minerals solubility:

As potassium solubility in all feed was 100%, no significant correlations were related to rumen parameter. Solubility of calcium phosphorus and cooper were the most affected in rumen, with occasional relations with sodium and zinc.

In all the experimental feeds, except concentrate feed mixture, calcium was negatively correlated with the concentration of rumen ammonia-nitrogen, with a significant correlation ranging from 0.68-0.9. The enhancing effect of low rumen fluid pH on calcium solubility is widely accepted (Ibrahim *et. al*., 1990; Emanuele *et. al*, 1991). It seemed to interfere with the concentration of ammonia –nitrogen. More alkalinity occurred because of increased ammonia concentration which in turn may decrease calcium solubility. Phosphorus solubility was affected by rumen fluid pH in rice straw (r= -0.73)and the concentration of rumen VFA´s in barley grains (r= -83). Copper solubility was positively correlated only in barley grains to the concentration of rumen VFA´s (r= 0.66) during the first nine hours after feeding. This correlation became negative at 12 hours after feeding (r= -0.7) with no reasonable explanation.

Conclusion

Mineral solubility from feeds or range plants is the primary factor for their absorption by animal. Solubility of minerals may be affected by type of element (K and Na or Ca and Zn), fiber content of feedstuffs, anti-nutritional factors (phytic acid), particle size of the feeds and rumen fluid pH. Potassium and sodium were almost completely soluble. The solubility of other minerals from feeds seemed to be affected by the parameters of fermentation in the rumen . Calcium followed by phosphorus were the least soluble when soaked in water. Very low solubility was also realized for phosphorus and zinc when rice straw was incubated in the rumen, and this leads to low availability, therefore, must be supplemented for the high roughage diets based on rice straw. Rumen fluid pH, which was positively affected by R/C ratio in diet of sheep had unexplainatory effect regarding Ca and P solubility. In rice straw, significant positive correlation was found between rumen fluid pH at 3 hours and Ca solubility (r =86). Meanwhile, at the same time of incubation , negative simple significant correlation (r= -0.73) was obtained between pH at 3 hours and phosphorus solubility. No such correlation was found with other feeds. The present study verified the extent of solubility after 72 hours of incubation. Further studies are needed to specifying rate of solubility at several shorter incubation intervals.

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ذوبان بعض المعادن بمواد العلف المحضنة بكرش الأغنام البرقى المغذاة على أنواع مختلفة من العلائق.

نبيل إبراهيم حسن [١] ، محمد احمد حنفي [٢] ، جلال الدين محمد عبد العزيز [٢] و مصطفى محمد محمد غندور [١]

١- مركز بحوث الصحراء- المطرية – القاهرة - مصر

٢ - كلية الزراعة- جامعة القاهرة – الجيزة – مصر

أجريت هذه الدراسة على مرحلتين لدراسة ذوبان بعض المعادن (الصوديوم، البوتاسيوم، الكالسيوم، الفوسفور، الزنك، و النحاس) في بعض الأعلاف المصرية الشائعة (دريس البرسيم ، قش الأرز ، حبوب الشعير و مخلوط العلف المركز). في المرحلة الأولى تم نقع هذه الأعلاف في الماء العادي لمدة ١٥ دقيقة لتقدير مدى ذوبان هذه المعادن من هذه الأعلاف. في المرحلة الثانية تم تحضين هذه المواد لمدة٧٢ ساعة بكرش الأغنام البرقى المغذاة على نسب مختلفة من الأعلاف الخشنة للمركزة (30:70، 50:50، 70:30).

وأظهرت النتائج ما يلي :-

1. النقع في الماء اثر معنويا على ذوبان المادة الجافة و المعادن. و سجل الصوديوم و البوتاسيوم أعلى نسبة ذوبان عن العناصر الكبرى الأخرى بينما سجل النحاس نسبة ذوبان أعلى من الزنك.
2. لا يوجد اختلاف معنوي في ذوبان المعادن لمواد العلف عند تحضينها بكرش الأغنام المغذاة على نسب مختلفة من الأعلاف الخشنة للمركزة. و لكن هناك اتجاه لزيادة ذوبان الزنك في المجموعة المغذاة على نسبة عالية من الأعلاف الخشنة.
3. أظهرت درجات pH في سائل الكرش فروقا معنوية بين مجاميع، وبالنسبة للأحماض الدهنية الطيارة الكلية كانت أعلى تركيزا في المجموعة المغذاة على عالية نسبة من المركزات (وكانت الفروق معنوية عند ٦ ساعات)، وبالنسبة لتركيز الأمونيا لا يوجد اختلافات معنوية بين المجاميع و لكن يوجد اتجاه للزيادة في المجموعة المغذاة على عالية نسبة من المركزات.

وبناء على هذه الدراسة يمكن القول بأن ذوبان المعادن تأثر بنوع المعدن ومكونات الألياف بمادة العلف و pH سائل الكرش.