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THE INFLUENCE OF DIFFERENT CONCENTRATE-ROUGHAGE PROPORTION ON THE METABOLISM OF SOME MINERALS IN CAMELS

(With 6 Tables and 2 Figures)

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تأثير مستويات مختلفة من مواد العلف المركزة والمواد الخشنة علي التمثيل الغذائي لبعض العناصر المعدنية في الجمال

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أجريت ثلاث تجارب متتالية علي الجمال النامية التي تراوحت أعمارها من ٢٠ إلى ٢٢ شهرا وأوزانها من ٣٥٠ إلى ٣٥٨ كجم لدراسة تأثير مستويات مختلفة من المواد علف مركزة والمواد الخشنة في علائق الجمال علي التمثيل الغذائي لبعض العناصر المعدنية (الكالسيوم , الفوسفور, الماغنسيوم, البوتاسيوم, الصوديوم, الزنك) وقد استمرت كل تجربة شهرا غذيت فيها الحيوانات علي ثلاث أنواع من العلائق احتوت علي نسب مختلفة من مواد العلف المركزة والمواد الخشنة. غذيت مجموعة الجمال في التجربة الأولى علي عليقة محتوية علي نسبة ٥٠ مواد علف خشنة :٥٠ مواد علف مركزة روعي في تكوينها تغطية احتياجات هذه الحيوانات من المواد الغذائية في هذه المرحلة من العمر وأعتبرت كعليقة ضابطة بينما غذيت الجمال في التجربتين الثانية والثالثة علي علائق بها نسبة مواد علف مركزة :مواد علف خشنة ٢٥:٧٥ و ٧٥:٢٥ علي التوالي. وقد أوضحت النتائج أن مجموعة الجمال المغذاة علي عليقة أحتوت علي ٧٥% مواد علف مركزة سجلت أعلي معدل استهلاك ومعامل هضم للمادة الجافة بينما سجلت المغذاة علي ٢٥% مواد علف مركزة أقل قيمة. كان معدل امتصاص وتخزين الكالسيوم والفوسفور والصوديوم والبوتاسيوم والماغنسيوم والزنك في الجسم أعلي معنويا في مجموعة الجمال المغذاة علي العليقة التي احتوت علي ٧٥% مواد علف مركزة مقارنة بالمجموعات الأخرى. من هذه الدراسة نستخلص أن معدل استهلاك وهضم المادة الجافة ومعدلات امتصاص وتخزين الكالسيوم والفوسفور والماغنسيوم والبوتاسيوم والصوديوم والزنك في جسم الجمال زادت مع زيادة نسبة مواد العلف المركزة في العلائق من ٥٠% إلى ٧٥%.

SUMMARY

Three experiments were conducted on growing camels to study the effect of feeding different proportions of concentrate and roughage on Ca, P, Mg, K, Na and Zn metabolism, each durated 30 days. Four growing camels, of about 20-22 months in age and 350-358 kg in weight were used in these experiments. The camels as one group, were fed on 3 kinds of rations differing in roughage and concentrate ratios. In the first experiment, the concentrate: roughage was designed to be 50:50 providing the nutrient recommendations for growing camels and designated as mixture I. In the second and third experiments, the rations were 75:25 and 25:75 and designated as mixtures II and III. Significant differences ($P<0.05$) in DMI were found among the three mixtures and that containing 75% concentrates (II) recorded the highest value, while that containing 25% concentrates (III) recorded the lowest one. The highest value of dry matter excreted was recorded for group fed on the 75% concentrates, while the lowest value with group fed on 25% concentrates. For volume of urine, the highest value was recorded with the animals fed on the 25% and 50% concentrates, while the lowest was recorded with group fed on the 75% concentrates. The digestibility of dry matter increased significantly ($P<0.05$) with the increase in the proportion of concentrates in the diets. The apparent absorption and retention percentages of calcium, phosphorus, sodium, potassium, magnesium and zinc were significantly ($P<0.05$) higher in the camels fed on 75% concentrates compared to other treated groups. These results suggested that dry matter intake, DM digestibility, absorption and retention of Ca, P, Na, K, Mg and Zn were increased by increasing concentrates proportion in the diets of camels from 50% to 75%.

Key Words: Concentrate, roughage, mineral metabolism, camels

INTRODUCTION

Concentrates are fed along with roughages especially to meet the requirements of animal for higher production when the quality of roughage is poor. Although adaptation of ruminants to high concentrate diets and associated digestive disturbances have been shown to centre around changes in rumen microbial fermentation, metabolic changes also occurs in the animal during adaptation (Allison *et al.*, 1964; Dunlop, 1972 and Slyter, 1976). A minimum level of fiber in the diet is needed to avoid digestive disorders such as acidosis (Giger-Reverdin and Sauvant, 1991). It has been known that ruminants mainly fed the concentrates are apt to get the result in nutritional disorders generally. One of them, urinary calculi have been often observed in fattening cattle and these are caused by the disorders in mineral metabolism in many cases (Terashima and Itoh, 1975). It is well established that, excessive grain consumption by ruminants cause acute indigestion and lactic acid acidosis (Dirksen, 1970). Mackenzie (1980) stated that the production of lactic acid in rumen is stimulated by the concentrate feeding and lactic acid will be one of the factors influencing the mineral metabolism. It has been observed that, the mineral metabolism in ruminants changes in response to lactic acid acidosis (Nokata *et al.*, 1977 and Telle and Preston, 1971). Intakes of high protein and energy may bring the special effects on the mineral metabolism in ruminants (Yano and Kawashima, 1976). Terashima *et al.* (1975) and Yano *et al.* (1976) reported that mineral metabolism in ruminants fed concentrates considerably differs from that in animals fed roughages. Urinary excretion of calcium and phosphorus was increased in sheep with the acidosis symptoms by the concentrate feeding as reported by Nokata *et al.* (1977). Terashima and Itoh (1975) found that a lower urine volume and a higher urinary excretion of phosphorus were observed in sheep fed the concentrate compared to that fed roughage. Funaba (1990_a) found that urinary calcium increased with the elevation of dietary grain contents in the diet of sheep. Urinary calcium and phosphorus concentrations had been elevated by giving a high concentrate ration in sheep (Funaba *et al.*, 1991). Yano *et al.* (1972) observed that urine concentrations of magnesium had occurred during the latter fattening period in steers given high concentrate rations.

The present study was conducted to clarify the effect of different ratios of concentrates in the rations of camels on the metabolism of some minerals (Ca, P, Mg, Na, K and Zn).

MATERIALS and METHODS

Animal and experimental design:

Four growing camels (ranged from 20 to 22 months of age and from 350 to 358 kg body weights) were used in three successive metabolism experiments at the Dept. of Animal and Clinical Nutrition, Faculty of Veterinary Medicine, Assiut Univ. The animals were clinically healthy and free from parasite infestation. The four camels, as a group, were fed on 3 kinds of mixtures having different concentrate proportions, each was respective to one of the three balance experiments. Each experiment durated 30 days of which the last 6 were assigned for feces and urine collection. The balance of five macromineral elements (Ca, P, Na, K and Mg) and one micro (Zn) was determined, under the feeding condition of three concentrate proportions.

The ingredients in the three tested diets, roughage and concentrates, were totally mixed and the daily amounts were offered each in separate two meals. The animals were housed in separate pens, managed individually, and fed the total mixed rations on ad-libitum basis.

Diets:

In the first experiment, the four animals were fed on a diet having 50% concentrates mixture and 50% wheat straw and providing the nutrient requirements recommended for growing camels by Gihad and El-Bedawy (1995). In the second experiment, the camels were fed a diet containing high concentrate (75%) and low roughage (25%) proportions, while in the third one a low concentrates (25%), high roughage (75%) diet were tested. The rations and its respective experiments were designed as I, II and III, respectively.

The three diets were formulated to differ in concentrate/ roughage ratios and supplemented with the limestone, bone meal, salt, minerals and vitamins. The varying proportions of the concentrate mixture in the diets resulted in differences in crude protein and crude fiber percentages and metabolizable energy density. The proportions of the different ingredients in the concentrate mixtures of the three diets differed slightly in order to maintain the protein in diet I around 12% and in diet III not less than 8%. The crude protein in diet I was 12.48, while in diet II was 16.69% (34% higher than the control). In diet III, the CP decreased only 33.7% that of the control (8.27%). As to the crude fiber, the ratio was 1: 0.63 : 1.37 and the metabolizable energy 1: 1.17 : 0.84 for the diets I, II and III, respectively. Clean water was available at all times. The physical and chemical composition of the ingredients and tested diets are shown in Tables (1 and 2).

Sampling:

Ingredients and experimental diets were sampled, dried, ground and thoroughly mixed, and then stored for further chemical analysis and mineral estimation.

The fecal matter was collected from each animal during the 6-days collection period in a collection bag which designed to adapt each experimental camel. The collection bag was made impervious by having a polyethylene inner side and an outer water-proof one. The daily fresh fecal matter was weighed where one-tenth was taken, dried at 60°C for 16 hours, ground and stored at room temperature for further analysis and ashing.

Urinary output was collected, during the 6 days-collection period, from each animal using plastic bags, measured and sampled at the rate of 100 ml/day. Few drops of concentrated hydrochloric acid were added to the samples to be stored at -20°C till analysis.

Analysis:

1-The ingredients, diets and fecal samples were analyzed according to the official methods of AOAC (1984). Duplicate samples were analyzed for dry matter, crude protein, ether extract, crude fiber and ash and the average was calculated.

2-Mineral determination in diets, ingredients and fecal matter: Duplicate samples, 1g each, were ashed by using concentrated hydrochloric acid and diluted to 100 ml with bidistilled water in a volumetric flask. The macrominerals (Ca, P, Mg, K and Na) were determined in g/kg, while the micromineral (Zn) was measured in ppm by using Flame Atomic Absorption Spectrophotometer.

3-Minerals determination in the urine were estimated by using Flame Atomic Absorption Spectrophotometer.

Dry matter digestibility:

The digestion coefficient of DM in the three diets was calculated according to Maynard (1979) as the following:

$$\text{Digestibility of DM} = \frac{\text{DM digested}}{\text{DM eaten}} \times 100$$

Metabolic balance:

The mineral balances were calculated to compare the rates of absorption and retention in the same animals when fed different proportions of concentrates and roughages.

Statistical analysis:

The experimental data were analyzed statistically by analysis of variance and treatment means were subjected to the multiple range test of Duncan (1955).

RESULTS and DISCUSSION

Dry matter intake:

The daily dry matter intakes (DMI) in the three experiments are presented in Table (3). Dry matter intake was significantly ($P<0.05$) higher with camels fed on diet II (6.61 kg) and lower with camels fed on diet III (5.24 kg) compared with the control group fed on diet I (5.74 kg). The increasing in dry matter intake with animal fed on diet II was 15.16% higher than the animals fed the control diet, while the DMI decreased by 8.71% with animals fed diet III lower than that fed the control diet. The decrease in feed intake may be due to the bulky nature of the large amount of roughage in diets (I and III). Similar result was found by Harmon and Britton (1983) who reported that dry matter intake increased with each increase in dietary concentrates in lambs. In addition, Kawas *et al.* (1991) and Haenlein (2002) reported that DMI increased with a decrease in forage:concentrate ratio or increasing energy density in the diets of goats. Feed intake progressively increased as the proportion of grain in the diet increased and this may be due to grains generate a lower heat increment than roughage and tend to improve feed intake by lowering the overall heat increment of the diet (Battachharya and Uwayjan, 1975 and Mahgoub *et al.*, 2000). On the other hand, Huntington *et al.* (1981) and Karim and Rawat (1997) reported that increased concentrates intake caused decreased daily dry matter intake.

Dry matter digestibility:

The difference in the digestibility of dry matter between the three different treatments was statistically significant ($P<0.05$) as shown in Table (3). The digestibility of dry matter increased with increasing the proportion of concentrates. This is in agreement with the reports of Hyder *et al.* (1979), Huntington *et al.* (1981), Forster *et al.* (1991) and Karim and Rawat (1997). The DM digestibility was increased as the level of protein increased in the ration and this may be attributed to that low protein ration may reduce rumen microbial function and subsequently lower the efficiency of feed utilization (Griffith, 1978 and Mohan *et al.*, 1987). Singh *et al.* (1991) found that higher levels of energy and protein improved nutrient utilization in terms of DM intake and digestibilities of proximate principles.

Urinary and fecal matter excreted:

There was no significant difference in the dry matter of the excreted feces between different treated groups as shown in Table (3). The amount of urine excreted was significantly ($P<0.05$) higher with camels fed diet III (5.08 liters), while decreased with animals fed diet II (3.98 liters) compared with control group fed on diet I (4.58 liters). Similar results were found with sheep and cattle by Terashima and Itoh (1975); Terashima *et al.* (1975); Yano and Kawashima (1976) and Huntington *et al.* (1981) who reported that increased concentrates in the diets of animals led to decreased urine volume, reflecting effects of dietary concentrates level and alteration of acid-base status on renal hemodynamics and reabsorption functions.

Calcium metabolic balance:

The metabolic balance of calcium in the three experiments is presented in Table (4). Limestone and bone meal, and limestone only represents the main source for calcium in diet I and II, while bone meal was the main source for the mineral in diet III. The three sources supplies the three experimental diets with 53.7, 57.1 and 48.4%, while the wheat straw shared by 16.4, 8.33 and 25%, respectively. The daily intake of calcium significantly differed ($P<0.05$) in the three treatments. The average daily fecal excretion of calcium (sum of endogenous and unabsorbed) was significantly ($P<0.05$) higher with camels fed the diet III (29.39g) and control diet (27.72g) diets compared with that fed the diet II (23.65g) one. Similar result was found by Funaba *et al.* (1990_b) who reported that fecal Ca excretion was decreased in sheep fed high protein ration. These findings also are in accordance with that found by many authors (Terashima and Itoh, 1975; Terashima *et al.*, 1975 and Yano *et al.*, 1976) who reported that fecal Ca excretion was higher in sheep fed roughage than those fed high concentrate ration.

For urinary calcium excretion, it ranged from 0.65 to 0.67g with no significant differences found among the experimental groups. Urinary calcium represents only 2.2 to 2.8% of fecal calcium. The results agreed with that reported by Terashima *et al.* (1975) who found that urinary excretion of calcium was very low and not affected by high concentrates ration. In addition, these data are supported by the findings of Braithwaite (1975) who found that the urinary excretion of calcium by ruminants is usually very low and this may be attributed to the efficient reabsorption of calcium by the kidneys (McDowell, 1992). On the contrary, Terashima and Itoh (1975), Yano and Kawashima (1976), Yano *et al.* (1976) and Huntington *et al.* (1981) found that calcium of urine increased, while fecal calcium decreased significantly by higher ratio of concentrate in the ration as reported in the studies with sheep.

Concerning the amount and percentage of Ca absorbed; there were significant differences ($P<0.05$) between the three different treatments. The highest values were recorded with camels fed diet II (17.99g/d and 43.20%) compared with that fed the control diet (9.02g/d and 24.55%) and diet III (3.62g/d and 10.97%, respectively). This indicated that increasing concentrates in the diet resulted in increased calcium absorption and vice versa. On this respect, Deluca (1974) stated that high energy ration increased Ca absorption by decreasing pH in the stomach and increase stomach Ca absorption which might decrease the mechanism involved in the active absorption of Ca from the intestine beside the decrease in fecal Ca excretion which is the main route of Ca excretion because urinary Ca loss was minute. Also, Teun *et al.* (1984) stated that low protein supply could adversely affect intestinal Ca absorption.

The apparent retention of calcium as amount and percentage of intake or absorbed were significantly ($P<0.05$) higher with camels fed diet II (17.32g/d, 41.59%, 96.28%, respectively) compared with other treated groups (Figure, 1). The increasing in retention of absorbed calcium with animals fed diet II was 3.88% higher than the animals fed the control diet, while decreased by 11.48% with animals fed diet III lower than that fed the control diet. The calcium retention as % of intake or absorbed was increased with increasing the concentrates in the diet. On the other hand, the effect of concentrates on the Ca retention as % of absorbed was low, indicating that the effect was higher on the absorption. Similar results were found by Terashima and Itoh (1975) and Terashima *et al.* (1975) who found that retention of calcium was increased in sheep fed high concentrate diets. The retention of Ca was decreased by feeding low-energy ration than high energy one as reported by Singh *et al.* (1979) and Huntington *et al* (1981) in sheep and Kishan *et al.* (1981) in kids. On contrary, Huntington *et al.* (1981) reported that calcium retention was decreased with the increasing concentrate intake.

Phosphorus metabolic balance:

The concentrates and bone meal were the source of the phosphorus in the experimental diets, while the wheat straw failed to supplement the animals by this element which reached 10.53, 4.76 and 16.22% in the diets I, II and III, respectively. The average daily intake of phosphorus was significantly ($P<0.05$) higher with camels fed diet III

(27.76g) compared with the groups fed the control diet (21.81g) and diet III (19.39g) as shown in Table (4).

The amount of phosphorus excreted in feces was significantly ($P<0.05$) lower with the animals fed diet II (8.54g) compared to other treated groups (10.08 and 10.71g). These results agreed with that found by Huntington *et al.* (1981) who reported decreased fecal phosphorus by higher ratio of concentrates in the ration.

The amount of phosphorus excreted in urine was very low and ranged from 0.08 to 0.10g with no significant differences found among the experimental groups. Our results were supported by the findings of Walker and Al-Ali (1987) who stated that urinary excretion of phosphorus was generally low in most domestic animals. In addition, Terashima *et al.* (1975) reported that urinary P excretion was not affected by the elevation of energy concentrate level. However, an extremely high interrelation between the urine phosphorus and lactic acid may suggest that, the increase of lactic acid production affects the alteration of phosphorus metabolism in cattle and sheep given high concentrate rations (Terashima *et al.*, 1975 and Yano *et al.*, 1976).

The amount and percentage of P absorbed were significantly ($P<0.05$) higher with camels fed diet II (19.22g/d and 69.24%) compared with other treated groups (11.73g/d, 53.78% and 8.68g/d, 44.77%, respectively).

The apparent retention of phosphorus as amount or percentage of intake was significantly ($P<0.05$) higher with camels fed diet II (19.12g/d and 68.88%) compared with that fed the control diet (11.65g/d and 53.41%) and diet III (8.59g/d and 44.30%, respectively) as shown in Figure (1), while the retained P as % of absorbed was nearly similar in the three experiments. Similar results were found with previous studies (Terashima and Itoh, 1975; Terashima *et al.*, 1975; Harmon and Britton, 1983; Giduck *et al.*, 1988 and Funaba *et al.*, 1990_b). They all found that retention of phosphorus was increased in sheep fed high concentrate diets. The apparent absorption and retention percentages of P were decreased in sheep and kids fed low energy rations (Yano *et al.*, 1976; Huntington *et al.*, 1981 and Kishan *et al.*, 1981).

Sodium metabolic balance:

Camels group fed on the diet containing 75% concentrates (diet II) recorded significantly ($P<0.05$) higher values for the average daily intake of sodium (33.05g) compared to that fed the control diet (29.27g) and diet III (26.72g) as shown in the Table (5).

The average daily fecal excretion of sodium was significantly ($P<0.05$) higher with the animals fed the diet III (15.96g) and control diet (12.39g) compared to that excreted by camels fed the diet II (7.45, 2.91g), while there was no significant differences in the urinary sodium excretion between the three treatments. In contrast, Yano and Kawashima (1976) found that, there was no difference in sodium excretion in urine with the increased concentrate in the rations.

The amount and percentage of sodium absorbed were significantly ($P<0.05$) higher with the camels fed diet II (25.6g/d and 77.46%) compared with that fed the control diet (16.88g/d and 57.67%) and diet III (10.76g/d and 40.27%, respectively). Common salt was the main source of sodium and the effect of concentrates on the sodium absorption was clear, as increasing the concentrates of the diets increase its absorption and vice versa but the effect not attain that of phosphorus.

The apparent retention of sodium as amount and percentage of intake or absorbed were significantly ($P<0.05$) higher with camels fed diet II (23.41g/d and 70.83, 91.45%, respectively) compared to the other treated groups (Figure, 2). The increasing in the retention of sodium absorbed with animals fed diet II was 15.20% higher than the animals fed the control diet, while decreased by 21.55% with animals fed diet III lower than that fed the control diet. The retention rate of the element affected similarly as the absorbed one.

Potassium metabolic balance:

Significant differences ($P<0.05$) in the average daily intake of potassium were recorded between the three treated groups as shown in Table (5). Camels fed the diet III excreted significantly ($P<0.05$) higher amount of potassium in the urine and decreased as the level of the concentrates increased in the diets. The highest value of potassium excreted in urine was recorded with animals fed the diet III (19.56g/d), while the lowest with group fed the diet II (13.53g/d) compared to the control group (17.18g/d). These results were in accordance with the report of Yano and Kawashima (1976) who found that potassium excretion in urine was decreased with the increased concentrates in the rations.

Concerning the amount and percentage of potassium absorbed, the camels fed the diet II recorded significantly ($P<0.05$) higher values (39.63g/d and 57.10%, respectively) in comparison with other two groups (30.70g/d, 49.52% and 27.78g/d, 47.33%, respectively).

The apparent retention of potassium as amount and percentage of intake (Figure, 2) or absorbed were significantly ($P<0.05$) higher in the camels fed the diet II (26.10g/d, 37.60%, 65.86%) compared with the other treated groups (14.11g/d, 22.76%, 45.96% and 8.22g/d, 14.01%, 29.59% for diets II and III, respectively). The increasing in the retention of potassium absorbed with animals fed diet II was 43.30% higher than the animals fed the control diet, while decreased by 35.62% with animals fed diet III lower than that fed the control diet.

Magnesium metabolic balance:

The average daily intake of magnesium was not significantly differed among the treatments and ranged from 10.48 to 13.22g/d as shown in Table (6).

The average daily fecal and urinary excretion of magnesium were nearly similar in the three balance experiments which ranged from 7.01 to 7.88g/d for feces and 0.47 to 0.51g/d for urine. These results disagreed with that found by Terashima *et al.* (1975) who reported that high concentrates of the ration increased urinary excretion of magnesium.

The amount and percentage of Mg absorbed were significantly ($P<0.05$) higher with the animals fed on diet II (6.21g/d and 46.97%) compared with that fed the control diet (4.49g/d and 37.26%) and diet III (2.6g/d and 24.81%, respectively)

The apparent retention of magnesium as amount or percentage of intake (Figure, 2) were significantly ($P<0.05$) higher in the camels fed on diet II (5.70g/d and 43.12%) compared to the other treated groups (4.02g/d, 33.36% and 2.13g/d and 20.32% for diet I and III, respectively). The increasing in the retention of potassium absorbed with animals fed diet II was 2.52% higher than the animals fed the control diet, while decreased by 8.50% with animals fed diet III lower than that fed the control diet. Similar result was found by Terashima and Itoh (1975) who reported that retention of magnesium was increased in sheep fed high concentrate diets.

Zinc metabolic balance:

The recorded average daily intake of zinc was significantly ($P<0.05$) higher in animals fed on the diet II (317.3 mg/d) compared with animals of the other treated groups (252.7 and 214.8 mg/d) as shown in Table (6).

The average daily fecal and urinary excretion of zinc were slightly higher in animals groups fed on the control diet and diet III compared with that fed the diet II, however, these differences were not statistically significant.

Concerning the amount and percentage of Zn absorbed, there were significant ($P<0.05$) differences between the three treatments. The highest values were recorded with camels fed the diet II (109.2mg/d and 34.42%) compared with that fed the control diet (38.5mg/d and 15.24%), while the camels fed the diet III recorded the lowest values (2.7mg/d and 1.26%).

The apparent retention of zinc as amount and percentage of intake or absorbed were significantly ($P<0.05$) higher in the camels fed the diet II (88.5mg/d, 27.89% and 81.04%%) compared to that fed the control diet (13.8mg/d, 5.46% and 35.84%), while camels fed the diet III recorded the negative balance in the amount of zinc retained (-23.2mg). Zinc absorption was vulnerable with the concentrates and in diet where the concentrates reached 75%, both the absorption and retention rates were about double that in case of diet I, and it seems that the 25% concentrate level failed to record any absorption or retention for the element. On this respect, the apparent absorption and retention of Zn were increased when dietary protein levels increased as reported by many investigators (Evans and Johnson, 1980; Greger and Sendeker, 1980; Gawthorne *et al.*, 1981 and Gibson *et al.*, 2001).

It could be concluded that increasing the ratio between concentrates and roughage from 50:50 to 75:25 in the rations of camel resulted in increasing the dry matter intake, DM digestibility, absorption and retention percentages of calcium, phosphorus, sodium, potassium, magnesium and zinc.

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Table (1): Chemical composition (on DM basis) of the diet ingredients

Items	Ingredients					
	Corn	SBM	Bran	Straw	Limestone	Bone meal
DM, %	89.4	91.9	89.4	91.2	98.0	96.0
CP, %	9.2	50.6	16.7	3.2	---	---
EE, %	4.3	2.2	4.4	0.4	---	---
CF, %	3.1	6.8	11.2	36.2	---	---
NFE, %	81.5	32.8	59.6	41.9	---	---
Ash, %	1.9	7.6	8.1	18.3	100	85.0
ME (Mcal/kg)	3.11	3.15	2.67	1.60	---	---
Ca, %	0.02	0.32	0.11	0.21	36.07	30.51
P, %	0.29	0.65	1.32	0.08	0.03	14.31
Mg, %	0.11	0.29	0.42	0.16	2.05	0.67
K, %	0.57	1.60	0.96	1.43	0.10	0.19
Na, %	0.01	0.31	0.07	0.14	---	0.48
Zn, ppm	47	45	87	36	---	400

Table (2): Physical and chemical composition (%) of the experimental diets

Items	Diets		
	I (50C:50R)	II (75C:25R)	III (25C:75R)
Physical composition			
White corn, ground	24.0	40.0	8.0
Soybean meal	14.0	20.0	8.0
Wheat bran	9.5	12.5	6.5
Wheat straw	**50.0**	**25.0**	**75.0**
Bone meal	0.3	---	1.0
Limestone, ground	0.7	1.0	---
Common salt	1.0	1.0	1.0
Mineral mixture*	0.35	0.35	0.35
AD3E**	0.15	0.15	0.15
Chemical composition			
DM, %	90.86	90.57	91.17
CP, %	12.48	16.69	8.27
EE, %	1.96	2.81	1.11
CF, %	20.86	13.05	28.67
NFE, %	50.34	57.23	44.59
Ash, %	14.36	10.22	17.36
ME (Mcal/kg DM)	2.24	2.61	1.88
Calcium, %	0.64	0.63	0.63
Phosphorus, %	0.38	0.42	0.37
Magnesium, %	0.21	0.20	0.18
Potassium, %	1.08	1.05	1.12
Sodium, %	0.51	0.50	0.51
Zinc, ppm	44.0	48.0	41.0

*Mineral mixture (Agrivet Co.) contains (g/kg):26.67 Zn, 6.67 Cu, 20 Fe, 33.33 Mn, 0.83 I, 0.16 Co, 0.066 Se, 912.274 calcium carbonate (39.39% Ca).

**Vitamin AD3E: Each g of vitamin premix contains 20000 IU vit.A; 2000 IU vit.D3 and 400 IU vit.E.

Table (3): Average daily DM intake and amount of excreta in the three balance experiments

Items	Experiments		
	I (50C:50R)**	II (75C:25R)	III (25C:75R)
DM intake (kg)	5.74±0.32 [ab*]	6.61±0.41 [a]	5.24±0.38 [b]
DM excreted (kg)	2.10±0.25 [a]	2.19±0.18 [a]	2.02±0.12 [a]
Urine excretion (litre)	4.58±0.41 [a]	3.98±0.35 [b]	5.08±0.33 [a]
DM digested (kg)	3.64±0.15 [ab]	4.42±0.35 [a]	3.22±0.25 [b]
DM digestibility (%)	63.41±1.15 [b]	66.87±1.35 [a]	61.45±1.42 [b]

*Figures in the same row having the same superscripts are not significantly different ($P<0.05$).
** I : 50 concentrates : 50 roughages, II: 75 concentrates: 25 roughages, III: 25 concentrates:75 roughage

Table (4): Calcium and phosphorus metabolism in the three balance experiments expressed as g/head/day.

Items	Experiments		
	I (50C:50R)**	II (75C:25R)	III (25C:75R)
Calcium:			
Intake	36.74±0.23 [b*]	41.64±0.15 [a]	33.01±0.10 [b]
Fecal	27.72±1.21 [a]	23.65±1.10 [b]	29.39±1.35 [a]
Urinary	0.66±0.01 [a]	0.67±0.02 [a]	0.65±0.01 [a]
Absorbed	9.02±0.10 [b]	17.99±1.50 [a]	3.62±0.12 [c]
Absorption (%)	**24.55±1.63 [b]**	**43.20±2.40 [a]**	**10.97±1.10 [c]**
Retained	8.36±0.25 [b]	17.32±1.10 [a]	2.97±0.10 [c]
Retention (%) of intake	**22.75±1.75 [b]**	**41.59±2.10 [a]**	**9.00±1.01 [c]**
Retention (%) of absorbed	**92.68±3.15 [a]**	**96.28±5.10 [a]**	**82.04±4.03 [b]**
Phosphorus:			
Intake	21.81±0.40 [b]	27.76±0.15 [a]	19.39±0.10 [b]
Fecal	10.08±1.73 [a]	8.54±1.30 [b]	10.71±1.15 [a]
Urinary	0.08±0.01 [a]	0.10±0.02 [a]	0.09±0.01 [a]
Absorbed	11.73±1.15 [b]	19.22±1.50 [a]	8.68±0.01 [c]
Absorption (%)	**53.78±2.10 [b]**	**69.24±3.21 [a]**	**44.77±0.10 [c]**
Retained	11.65±1.10 [b]	19.12±1.34 [a]	8.59±0.01 [c]
Retention (%) of intake	**53.41±2.10 [b]**	**68.88±3.12 [a]**	**44.30±0.02 [c]**
Retention (%) of absorbed	**99.32±4.56 [a]**	**99.48±3.94 [a]**	**98.96±2.97 [a]**

*Figures in the same row having the same superscripts are not significantly different ($P< 0.05$).
** I : 50 concentrates : 50 roughages, II: 75 concentrates: 25 roughages, III: 25 concentrates:75 roughage

Table (5): Sodium and potassium metabolism in the three balance experiments expressed as g/head/day

Items	Experiments		
	I (50C:50R)	II (75C:25R)	III (25C:75R)
Sodium:			
Intake	$29.27\pm1.45^{ab*}$	33.05 ± 1.32^{a}	26.72 ± 1.20^{b}
Fecal	12.39 ± 1.02^{a}	7.45 ± 1.00^{b}	15.96 ± 1.05^{a}
Urinary	3.48 ± 0.25^{a}	2.91 ± 0.10^{a}	4.06 ± 0.32^{a}
Absorbed	16.88 ± 1.10^{b}	25.60 ± 1.30^{a}	10.76 ± 1.08^{c}
Absorption (%)	**57.67 ± 2.18^{b}**	**77.46 ± 3.05^{a}**	**40.27 ± 1.50^{c}**
Retained	13.40 ± 1.01^{b}	23.41 ± 1.80^{a}	6.70 ± 0.50^{c}
Retention (%) of intake	**45.78 ± 1.80^{b}**	**70.83 ± 2.95^{a}**	**25.07 ± 1.10^{c}**
Retention (%) of absorbed	**79.38 ± 3.01^{b}**	**91.45 ± 4.15^{a}**	**62.27 ± 2.10^{c}**
Potassium:			
Intake	61.99 ± 2.13^{b}	69.41 ± 2.50^{a}	58.69 ± 2.35^{b}
Fecal	31.29 ± 1.25^{a}	29.78 ± 1.34^{a}	30.91 ± 1.15^{a}
Urinary	17.18 ± 1.03^{a}	13.53 ± 1.01^{b}	19.56 ± 1.05^{a}
Absorbed	30.70 ± 1.55^{b}	39.63 ± 1.40^{a}	27.78 ± 1.30^{c}
Absorption (%)	**49.52 ± 1.85^{b}**	**57.10 ± 1.70^{a}**	**47.33 ± 1.53^{b}**
Retained	14.11 ± 1.15^{b}	26.10 ± 1.35^{a}	8.22 ± 1.50^{c}
Retention (%) of intake	**22.76 ± 1.28^{b}**	**37.60 ± 1.56^{a}**	**14.01 ± 1.10^{c}**
Retention (%) of absorbed	**45.96 ± 1.50^{b}**	**65.86 ± 2.10^{a}**	**29.59 ± 1.58^{c}**

*Figures in the same row having the same superscripts are not significantly different ($P< 0.05$).

Table (6): Magnesium (g/head/day) and zinc (mg/head/day) metabolism in the three balance experiments

Items	Experiments		
	I (50C:50R)	II (75C:25R)	III (25C:75R)
Magnesium:			
Intake	$12.05\pm1.02^{a*}$	13.22 ± 1.05^{a}	10.48 ± 1.00^{a}
Fecal	7.56 ± 0.20^{a}	7.01 ± 0.18^{a}	7.88 ± 0.15^{a}
Urinary	0.47 ± 0.01^{a}	0.51 ± 0.02^{a}	0.47 ± 0.01^{a}
Absorbed	4.49 ± 0.23^{a}	6.21 ± 0.30^{a}	2.6 ± 0.10^{b}
Absorption (%)	**37.26 ± 1.28^{b}**	**46.97 ± 1.63^{a}**	**24.81 ± 1.12^{c}**
Retained	4.02 ± 0.34^{ab}	5.70 ± 0.29^{a}	2.13 ± 0.15^{b}
Retention (%) of intake	**33.36 ± 1.18^{b}**	**43.12 ± 1.50^{a}**	**20.32 ± 1.10^{c}**
Retention (%) of absorbed	**89.53 ± 3.10^{a}**	**91.79 ± 4.02^{a}**	**81.92 ± 2.90^{b}**
Zinc:			
Intake	252.7 ± 21.15^{b}	317.3 ± 25.10^{a}	214.8 ± 20.13^{c}
Fecal	214.2 ± 2.30^{a}	208.1 ± 3.10^{a}	212.1 ± 2.73^{a}
Urinary	24.7 ± 1.13^{a}	20.7 ± 1.50^{a}	25.9 ± 1.18^{a}
Absorbed	38.5 ± 1.60^{b}	109.2 ± 4.23^{a}	2.7 ± 0.01^{c}
Absorption (%)	**15.24 ± 1.34^{b}**	**34.42 ± 1.20^{a}**	**1.26 ± 0.01^{c}**
Retained	13.8 ± 1.10^{b}	88.5 ± 3.15^{a}	-23.2
Retention (%) of intake	**5.46 ± 0.39^{b}**	**27.89 ± 1.10^{a}**	-
Retention (%) of absorbed	**35.84 ± 2.18^{b}**	**81.04 ± 3.83^{a}**	-

*Figures in the same row having the same superscripts are not significantly different ($P< 0.05$).

Fig.1. Apparent retention of calcium and phosphorus during experiments

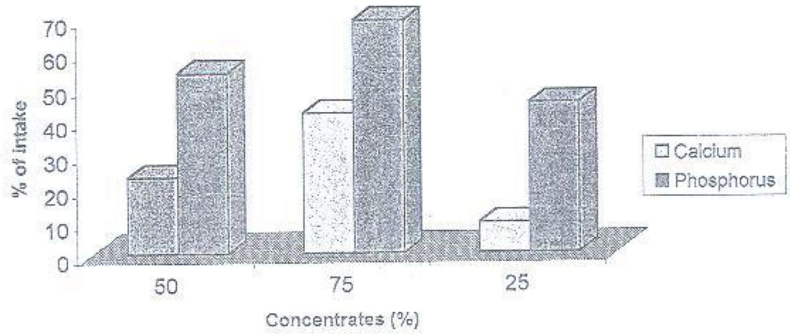

Fig.2. Apparent retention of sodium, magnesium and potassium during experiments