Assiut Vet. Med. J. Vol. 47 No. 94, July 2002

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Fac. Vet. Med., Assiut University.

EFFECT OF DIFFERENT PHOSPHORUS SOURCES ON THE PERFORMANCE, DIGESTIBILITY AND METABOLIC BALANCE OF SOME MINERALS IN GROWING GOATS

(With 11 Tables and 3 Figures)

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(Received at 26/6/2002)

تأثير مصادر الفوسفور المختلفة علي كفاءة الأداء, معاملات الهضم والتمثيل الغذائي لبعض العناصر المعدنية في الماعز النامية

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أجريت هذه التجربة علي عدد ١٥ من ذكور الماعز النامية (٢٥ كجم , ١٠ شهور) لدراسة تأثير مدي الاستفادة من الفوسفور من مصادر مختلفة علي كفاءة الأداء, معاملات الهضم والتمثيل الغذائي لبعض العناصر المعدنية (الفوسفور , الكالسيوم , الماغنسيوم). قسمت الحيوانات الي خمس مجموعات بكل منها ثلاث حيوانات. تم تغذية الحيوانات علي علائق تحتوي علي مصادر مختلفة من الفوسفور: نخالة القمح في المجموعة الاولي والتي اعتبرت مجموعة ضابطة, مسحوق العظم في المجموعة الثانية , أحادي فوسفات الصوديوم في المجموعة الثالثة, ثنائي فوسفات الصوديوم في المجموعة الرابعة وثنائي فوسفات الكالسيوم في المجموعة الخامسة حيث روعي أن تعطي الخمس علائق احتياجات هذا النوع من الحيوانات من الفوسفور. وقد استمرت هذه التجربة مدة ٣٥ يوما منها ٢٨ يوم فترة تمهيدية و ٧ أيام كفترة تجميعية. وقد أظهرت النتائج مايلي : وجود فروق معنوية في معدل استهلاك العليقة اليومي بالاضافة الي زيادة وزن الجسم بين المجموعة الضابطة والمجموعات التي غذيت علي مصادر مختلفة من الفوسفور. مجموعات الحيوانات التي غذيت علي علائق تحتوي علي مسحوق العظم وثنائي فوسفات الصوديوم أعطت أفضل نتائج في كل من وزن الجسم ومعدل التحويل الغذائي. النسب الظاهرية لامتصاص وأختزان كل من الفوسفور والكالسيوم كانت أعلي مايمكن في المجموعة التي غذيت علي العليقة المحتوية علي مسحوق العظم بينما كانت أقل في المجموعة المغذاة علي ثنائي فوسفات الكالسيوم. نسب امتصاص وأختزان الماغنسيوم الظاهرية كانت أعلي في المجموعة المغذاه علي ثنائي فوسفات الكالسيوم بينما كانت أقل في المجموعة التي غذيت علي احادي فوسفات الصوديوم. تغذية الحيوانات علي مصادر مختلفة من الفوسفور لم يكن له أي تأثير علي مستوي العناصر المعدنية في الدم. نستخلص من هذه الدراسة أن ذكور الماعز النامية تستفيد من الفوسفور الموجود في مسحوق العظم وثنائي فوسفات الصوديوم بصورة أفضل من مصادر الفوسفور الأخرى.

SUMMARY

Fifteen male growing goats of about 10 months of age and 25 kg body weight were used in this experiment to study the effect of different dietary phosphorus sources on their performance, digestibility of nutrients and the metabolic balances of some minerals (P, Ca & Mg). The animals were allotted into five equal groups and were fed on diets supplemented with different phosphorus sources; wheat bran as control (group I), bone meal (group II), monobasic sodium phosphate (group III), dibasic sodium phosphate (group IV) and dibasic calcium phosphate (group V). The phosphorus level in the five experimental diets was 0.33% which cover the needs of goats according to the NRC (1983). The experiment extended for 28 days preliminary period followed by 7 days for urine and feces collection. The results showed a significant difference ($P<0.05$) between animal groups fed on the supplemented diets and the control one in which the wheat bran was the phosphorus source. A significant difference in weight gain and feed intake was also recorded between the supplemented groups. The groups receiving either bone meal or dibasic sodium phosphate supplements did well in gain and feed conversion throughout the experiment. The apparent absorption and net retention percentages of both phosphorus and calcium were significantly ($P<0.05$) high in groups fed on the bone meal-supplemented diet, while the lowest value was recorded for the dibasic calcium phosphate-supplemented group. Magnesium absorption and retention % was significantly ($P<0.05$) high with dicalcium phosphate diet, while the lowest value was recorded with monobasic sodium phosphate diet. The different supplemented sources of phosphorus had no significant ($P<0.05$) effect on the serum mineral levels of the different animal groups. From this study, it could be concluded that, the phosphorus in the bone meal is more available to growing male goats, followed by dibasic sodium phosphate, while the dibasic calcium phosphate and monobasic sodium phosphate were of fair phosphorus availability.

Key Words: *Phosphorus sources, digestibility, metabolic balance, goats*

INTRODUCTION

There is a marked difference in the availability of mineral elements provided from different sources. The variation in the availability of minerals must be taken into consideration when evaluating or formulating a mineral supplement (McDowell, 1992). The availability of feed minerals depends on the age and species of the animal; the intake of the mineral and its needs; the chemical form in which the mineral is ingested, and the amounts and proportions of other dietary components with which it interacts during assimilation (McDowell, 1992). A problem is that, certain chelating agents may improve the bioavailability of one essential mineral, while they make another equally essential mineral less available (Fritz, 1973). The major minerals required in animal nutrition are mostly those of phosphorus and calcium in addition to potassium, sodium and chlorine. Some levels of these elements are supplied naturally in most feedstuffs. In addition, they are also added as supplements to meet the dietary requirements. The supplements are chiefly chemical compounds of varying purity and composition as well as by-products from various industrial processes (Peeler, 1972). The variation in phosphorus availability from plant products and commercially used phosphorus supplements can be quite large. Since phosphorus is an expensive ingredient in the diet, and the feedstuff phosphorus-availability can be quite variable, knowledge of phosphorus bioavailability is critical for efficient animal production (Soares, 1995). A number of supplemental sources of phosphorus are available on the market, including calcium phosphates (dicalcium phosphate, monocalcium phosphate, and bone meal), sodium phosphate (monosodium and disodium phosphate). The sources of phosphorus are readily available, but there is a considerable variation in the biological availability of phosphorus within these types, especially within the calcium phosphates (Cheek, 1991).

Most practical phosphorus problems are due to insufficient levels of available phosphorus. The lack of available phosphorus is normally due to the use of a phosphate source which has a lower than expected available phosphorus content. Plant phosphorus sources are present as phytate-bound phosphorus, which is unavailable to poultry and other monogastric animals (Cuhna, 1977), but ruminants utilize phytin phosphorus quite satisfactorily (McDowell, 1992). The inorganic sources can be quite variable both in total phosphorus content and in phosphorus availability. Dicalcium and monocalcium phosphates are usually considered to have availabilities between 95 & 99%, while defluorinated phosphate has 90% (Schwartz, 1996).

One of the most critical aspects of practical nutrition is to ensure that all feeds contain the proper levels and ratios of calcium and available phosphorus (Schwartz, 1996). Knowledge of net requirements and availability are necessary for factorially deriving mineral requirements (Petri *et al.*, 1989).

A large volume of research has been reported on the need of phosphorus in goats, but very little work has been reported on the comparative utilization of phosphorus from the various sources. Thus, the work presented herein was designed to obtain information on the effect of phosphorus from various supplemental sources on performance, digestibility of different nutrients and metabolism of some minerals in goats.

MATERIALS and METHODS

Animals, housing and diets:

Fifteen castrated male growing goats, of about 10 months of age and 25kg body weight were used in this experiment. They were housed individually in metabolism cages designed for the separate collection of feces and urine and quantitative recording of any feed refusal and all animals had free access to clean water. The animals were allotted into five groups, each group comprising 3 growing goats. The animals in group I were fed on the control unsupplemented diet which contain wheat bran as a natural source of phosphorus. Animals in the other four groups were fed on diets supplemented with four different phosphate sources; bone meal (group II), monobasic sodium phosphate (group III), dibasic sodium phosphate (group IV) and dibasic calcium phosphate (group V). The phosphorus level in the five experimental diets was 0.33% which cover the needs of goats according to the NRC (1983) as shown in table (3). The chemical composition and mineral contents of the feed ingredients, experimental diets and phosphorus supplements are given in tables (1-3).

The diets were given twice daily and any residues were collected throughout the experimental period. Each of the 7-days collection period was preceded by a preliminary feeding period of 28-days. The goats were weighed at the beginning and at the end of the experiment.

Samples:

1-Blood samples were taken before the mornings meal from the jugular vein. Blood was centrifugated at 1500 rpm for 20 minutes and the sera was then stored at –18°C until further analysis.

2- The daily fecal matter excreted from each animal was collected and weighed for 7 days. The daily samples were mixed thoroughly and representative sample (one-fourth) was taken, dried at 60°C, pooled together, mixed for analysis. Urine samples were collected in 100ml samples, acidified with 2 ml of conc. HCl as preservative, and then stored at 4°C for analysis.

Chemical analyses:

1-The feed ingredients 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 fibre in addition to ash contents and the averages were calculated.

2-The phosphorus was determined in serum, feed materials, fecal matter and urine according to the method of Yee (1968) at 650 nm, while serum calcium was determined after the method described by Lehman and Henry (1984) at 550 nm by using spectrophotometer (HP 8452 A) and test kits supplied by Sentinel Chem. Co. (Milano, Italia). Magnesium kit supplied by CARO Co. (Hohenstein, Germany) was used to determine the magnesium in serum as well as ashed faecal, urinary and feed samples, according to the method described by Khayan *et al.* (1977) using the spectrophotometer at 520 nm.

Calculation of digestion coefficient:

Digestion coefficients of the nutrients for the different experimental diets were calculated by using the direct method.

Mineral balance:

A balance study was conducted to compare the phosphorus, calcium, and magnesium absorption and retention in goats which received the control unsupplemented diet or the other groups supplemented with the different sources of inorganic phosphorus.

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

Feed consumption:

The average daily consumption during the experiment was 718.3g for the control group which fed on the unsupplemented diet, while for the supplemented groups the values were 703.3, 706.7, 738.3 and 733.3g in groups II, III, IV & V, respectively as shown in Table (4). There was no significant ($P<0.05$) differences in feed intake between animal groups fed on the supplemented diets and that fed on the control diet. This observation agreed with the results of El-Tayeb *et al.* (1984) and Doyle and Pandy (1990) who reported that, the dry matter intake was not affected by calcium and phosphorus supplementation in sheep.

Weight gain:

The mean daily weight gains for animal groups calculated from the total weight gains over 35-days of the experiment were 48.57g for the control group and 57.14, 42.86, 48.57 & 37.14g for the supplemented groups (II, III, IV & V respectively) as shown in Table (4) and Fig. (1). There were significant differences ($P<0.05$) in daily gain and feed efficiency between the control group and those of the supplemented ones and the highest value was recorded with group fed on diet supplemented with bone meal (57.14g), while the lowest value was recorded for the group fed on diet supplemented with dibasic calcium phosphate (37.14g). Also, when the various phosphorus supplements were compared at the same total phosphorus level (0.33%), significant differences ($P<0.05$) were noted between the treated groups in both average daily gain and feed efficiency. From daily gain data, it was obvious that, the growing goats fed diets supplemented with dibasic calcium phosphate and monobasic sodium phosphate supplements gained at slower rate than those fed diets with the other supplements. The groups fed on diets supplemented with bone meal, or dibasic sodium phosphate did well in gain and feed conversion throughout the experiment. Daily gain for group fed dibasic sodium phosphate supplement was equal to animals in group fed wheat bran supplement (48.57g). Feed conversion was improved from 19.74 in group fed on diet supplemented with dibasic calcium phosphate to 12.31 for group fed on diet supplemented with bone meal.

Digestion coefficient of the nutrients:

The chemical composition of fecal matter and urine of the different groups of animals are presented in Tables (5&6). Digestibility of different nutrients for goats fed on the control diet and supplemented diets are presented in Table (7). There were significant ($P<0.05$) differences in dry matter and organic matter digestibilities between the supplemented groups and the control one. Also goat groups fed on the bone meal, monobasic and dibasic sodium phosphate recorded significantly ($P<0.05$) highest dry matter and organic matter digestibility values in comparison with other treated groups. For crude protein digestibility, there were significant ($P<0.05$) differences between treated groups and the highest value was recorded with the animal group fed on the bone meal supplemented diet (59.56%). Ether extract digestibility values were significantly ($P<0.05$) high in groups fed on the diets supplemented with dibasic calcium phosphate (77.60%) and bone meal (77.52%) in comparison with other treated groups. Crude fiber digestibility values were significantly ($P<0.05$) high in group fed on bone meal supplemented diet (39.77%) and the lowest value was recorded with group fed on the control diet (24.83%). These results are not in agreement with that reported by *Flachowsky et al. (1998)* who found that various sources of phosphorus did not significantly influence apparent digestibility of organic matter and crude nutrients in fattening bulls.

Mineral balance:

1-Phosphorus:

The recorded average daily intake of phosphorus ranged from 2.10 to 2.22g. There were no significant ($P<0.05$) differences in phosphorus intake between the supplemented groups and the control one and the highest values were recorded with goats fed on the diets supplemented with bone meal (2.22g) followed by those supplemented with dibasic sodium phosphate (2.20g) as shown in Table (8 and Fig. 1). The goat groups supplemented with dibasic sodium phosphate or dibasic calcium phosphate excreted nearly the same amount of phosphorus through feces, while groups fed on bone meal, monobasic or dibasic sodium phosphate supplementation excreted the same amounts of phosphorus through urine (0.11g). The apparent absorption % of phosphorus calculated from the intake were significantly ($P<0.05$) high in the goat group fed on the diet supplemented with bone meal (40.09%), while the lowest value was recorded with those supplemented with dibasic calcium phosphate and the control one (23.22 & 23.83%). The absorbed phosphorus % was not significantly ($P<0.05$) different either in those fed diet containing wheat bran (control group) or diet supplemented with dicalcium phosphate and these findings were supported by that reported by Koddebusch and Pfeffer (1988) who found no differences in the absorbability of phosphorus of dicalcium phosphate and wheat bran in lactating goats. On the contrary, Lofgreen (1960) recorded higher absorption from the dicalcium phosphate than bone meal and soft phosphate in Wethers. In most studies with beef cattle, dicalcium phosphate has been found significantly more available than soft phosphate (Arrington *et al.*, 1963 and Ammerman *et al.*, 1965). On the other hand, the apparent retained % of phosphorus calculated from the absorbed amount showed significant (P<0.05) differences between treated groups and the highest value was found in the group fed on diet supplemented with bone meal (86.52%), while the lowest value with group fed on dibasic calcium phosphate supplement (80%). These results are coincided with that reported by McDowell (1985) who recorded high phosphorus availability from bone meal in comparison with other phosphorus sources. In contrast, Gutierrez *et al.* (1983) found that bone meal had phosphorus availability equal to dicalcium phosphate, while Plumlee *et al.* (1958) recorded equal phosphorus availability from dicalcium phosphate, monocalcium phosphate and phosphoric acid followed by that of steamed bone meal in swine.

2-Calcium:

The recorded average daily intake of calcium was non significantly (P<0.05) different between supplemented and control groups and the highest value was recorded with goats fed on diet supplemented with dibasic sodium phosphate (2.92g), while the lowest with bone meal supplemented group (2.78g) as shown in Table (9) & Fig. (2). The average daily faecal excretion of calcium was high in group fed on diet supplemented with dicalcium phosphate (2.18g) and low in bone meal supplemented one (1.89g). Also, the amount of calcium excreted in feces was high compared to that excreted in urine. These values can be explained by the fact that in all species, the faeces is the primary path for calcium excretion (McDowell, 1992). Braithwaite (1975) reported that, the urinary excretion of calcium by ruminants is usually very low and accounts for a small proportion of the total endogenous loss of calcium under conditions of adequate calcium and phosphorus nutrition. The apparent absorption percentages of calcium were significantly (P<0.05) high in goats of the group fed on bone meal supplemented diet (32.01%) and the lowest value was recorded with animals of the group fed on diet supplemented with dicalcium phosphate (23.24%). These results are in agreement with findings of HanSard *et al.* (1957) who found that calcium absorption from bone meal was higher than from dicalcium phosphate in young and mature steers. There was significant (P<0.05) differences in the apparent retention % of calcium and the bone meal-supplemented-group had the highest value (84.27%), while the lowest values were recorded with animals fed on diet supplemented with dicalcium phosphate (75.76%). On the contrary, Dutton and Fontenot (1967) recorded that, the form of dietary P had no significant (P<0.05) effect on absorption and retention of calcium and magnesium in sheep.

3-Magnesium:

The average daily intake of magnesium was significantly (P<0.05) high in group fed on the control diet (1.36g) compared with the groups fed the supplemented diets as it ranged from 1.01 to 1.13g as shown in Table (10) & Fig. (3). The average daily faecal excretion of magnesium was high in animal group fed on the basal diet (1.01g), while there were no differences between animal groups in the amount of magnesium excreted in the urine. The apparent absorption % of magnesium was significantly (P<0.05) high in group fed on diet supplemented with dicalcium phosphate (33.93%) followed by that supplemented with dibasic sodium phosphate (30.09%) in comparison with other groups and the lowest values were recorded with goats in group fed diet supplemented with bone meal and control one (25.74%). The apparent retention % of magnesium was significantly (P<0.05) high in animals of the group fed on the diet supplemented with dicalcium phosphate (78.95%), while the group fed monobasic sodium phosphate supplementation recorded the lowest value (68.97%).

Dicalcium phosphate affect the apparent absorption and retention % of magnesium and recorded the highest values in comparison with other supplemented phosphorus sources.

Serum mineral levels:

From Table (11), it was obvious that, there were no significant (P<0.05) differences in the serum levels of either phosphorus, calcium or magnesium between the supplemented groups and the control one and the highest values for serum phosphorus were recorded with groups fed on the bone meal (5.98 mg/100ml) and dibasic sodium phosphate supplemented diet (5.98 mg/100ml), while goats in group fed on diet supplemented with monobasic sodium phosphate recorded the highest values for serum calcium and magnesium (9.72 & 3.89 mg/100ml respectively). The different phosphorus sources had no effect on the serum levels of phosphorus, calcium and magnesium.

It could be concluded that, bone meal as a phosphorus supplement followed by dibasic sodium phosphate recorded the best results in weight gain and feed efficiency. The apparent absorption and retention % of phosphorus and calcium were high with bone meal. Moreover, the different sources of phosphorus had no effect on the serum levels of either calcium, phosphorous or magnesium.

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Table 1: Chemical composition of the used feed ingredients in the basal diet (% on DMB)

	Ingredients			
	Corn, white	Soybean meal	Wheat bran	Wheat straw
Dry matter	89.70	91.30	90.65	90.00
Organic matter	97.88	93.09	93.00	86.70
Crude protein	9.20	47.00	16.80	3.50
Ether extract	3.76	5.47	3.50	1.66
Crude fibre	2.77	7.44	9.67	38.00
NFE	82.15	33.18	63.03	43.54
Ash	2.12	6.91	7.00	13.30
P	0.27	0.70	1.38	0.05
Ca	0.03	0.34	0.13	0.18
Mg	0.14	0.30	0.60	0.12
ME (Mcal/kg diet)*	3.15	3.18	2.53	1.59

*NRC (1983).

Table 2: Mineral contents of the different phosphorus supplements (%)*

	P	Ca	Mg
Bone meal	12.5	29.80	0.30
Monobasic sod.phosp.	25.80	-----	-----
Dibasic sod.phosp.	20.80	-----	-----
Dibasic calc.phosp.	18.7	21.30	0.60

*NRC (1983).

Table3: Composition of the control and the different supplemented diets used in the study.

Composition	Control diet I	Supplemented diets/animal groups			
		bone meal II	NaH_2PO_4 III	Na_2HPO_4 IV	$CaHPO_4$ V
Physical composition					
White corn, ground	45.00	49.50	49.50	49.50	49.50
Soybean meal	6.00	8.50	8.50	8.50	8.50
Wheat straw	37.50	40.30	40.10	40.30	40.00
Ground limestone	0.80	-----	0.80	0.50	0.80
Wheat bran	10.00	-----	-----	-----	-----
Bone meal	-----	1.00	-----	-----	-----
Monobasic sod.phosp.	-----	-----	0.40	-----	-----
Dibasic sod.phosp.	-----	-----	-----	0.50	-----
Dibasic calc. phosp.	-----	-----	-----	-----	0.50
Common salt	0.50	0.50	0.50	0.50	0.50
Mineral mixture**	0.10	0.10	0.10	0.10	0.10
Vitamin AD3E***	0.10	0.10	0.10	0.10	0.10
Chemical composition*					
Dry matter, %	90.13	90.09	90.10	90.09	90.09
Organic matter, %	91.46	91.47	91.03	91.29	91.21
Crude protein, %	9.95	10.01	9.95	9.96	9.96
Ether extract, %	2.99	3.00	2.98	2.99	2.99
Crude fibre, %	16.93	17.33	17.20	17.31	17.28
NFE, %	61.59	61.13	60.90	61.03	60.98
Ash, %	9.04	8.53	8.97	8.71	8.79
P, %	0.33	0.35	0.33	0.33	0.32
Ca, %	0.44	0.44	0.44	0.44	0.43
Ca : P ratio	1.33	1.26	1.33	1.34	1.33
Mg, %	0.21	0.16	0.17	0.17	0.17
ME (Mcal/kg DM)	2.46	2.48	2.47	2.48	2.47

*Chemical composition calculated on the dry matter basis.

**Mineral mixture contains (g/kg): 40 Fe, 6.3 Mn, 44.9 Zn, 0.5 Cu, 0.4 I, 0.03 Se, 0.5 Co, 153.9 NaCl and 122.8 Mg.

***Vitamin AD_3E: Each g of vitamin premix contains 20,000 IU vit.A; 2000 IU vit.D_3 and 400 IU vit.E.

Table 4: Performance of the goat groups fed on the control and the P-supplemented diets.

Item	Control group I	Supplemented groups			
		II	III	IV	V
Initial weight, kg	25.0±0.35	24.9±0.20	24.83±1.05	25.0±0.20	25.3±0.24
Final weight, kg	26.7±0.24	26.9±0.20	26.33±0.85	26.7±0.24	26.6±0.20
Weight gain, kg	1.7±0.12 ^{b}	2.0±0.21 ^{a}	1.5±0.20 ^{c}	1.7±0.24 ^{b}	1.3±0.31 ^{d}
Average daily gain (g/head/day)	48.57 ^{b}	57.14 ^{a}	42.86 ^{c}	48.57 ^{b}	37.14 ^{d}
Feed intake (g/head/day)	718.3±5.1 ^{a}	703.3±2.4 ^{a}	706.7±4.7 ^{a}	738.3±5.1 ^{a}	733.3±6.2 ^{a}
Feed conversion	14.79±1.55	12.31±0.81	16.49±3.6	15.2±1.46	19.74±1.35

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

Table 5: Chemical composition and mineral contents of fecal matter of the different groups

	Control group	Supplemented groups				
		1	2	3	4	5
DM intake	547.5 ± 3.6	647 ± 4.6	633.6 ± 2.1	636.7 ± 4.2	660.7 ± 5.6	665.2 ± 4.6
DM excreted	271 ± 2.8	296.4 ± 9.2	251.4 ± 1.3	272.3 ± 1.5	294.8 ± 1.1	284.3 ± 0.94
Chemical comp						
OM, %	91.00	88.0	86.0	87.0	85.0	83.0
CP, %	12.00	10.2	9.3	11.2	11.2	12.2
EE, %	2.00	1.9	1.7	1.9	1.5	1.8
CF, %	31.00	27.8	26.3	28.3	27.9	26.1
Ash, %	11.00	12.0	14.0	13.0	15.0	17.0
NFE, %	46.00	48.1	48.7	45.6	44.4	42.9
Minerals						
Ca, %	0.60	0.73	0.75	0.75	0.74	0.74
P, %	0.26	0.55	0.53	0.53	0.55	0.58
Mg, %	0.30	0.34	0.30	0.29	0.25	0.28

Table 6: Amount and chemical composition of the urine in the different groups.

Item	Control group	Supplemented groups			
	I	II	III	IV	V
Amount of urine (L/day)	1.65±0.14	1.5±0.16	1.52±0.14	1.55±0.17	1.5±0.10
P (g/L)	0.10±0.01	0.09±0.02	0.10±0.01	0.11±0.02	0.11±0.009
Ca (g/L)	0.05±0.002	0.07±0.003	0.07±0.002	0.07±0.001	0.06±0.001
Mg (g/L)	0.06±0.001	0.04±0.001	0.06±0.002	0.05±0.001	0.05±0.001

Table 7: Digestion coefficient (%) of nutrients for kid groups fed on the basal and P-supplemented diets.

Item	Control group	Supplemented groups			
	I	II	III	IV	V
Dry matter	54.20±1.4 [b]	60.30±0.25 [a]	57.10±0.15 [a]	57.30±0.42 [a]	55.40±0.30 [b]
Organic matter	55.99±1.35 [b]	62.73±0.25 [a]	59.18±0.16 [a]	61.1±0.39 [a]	58.49±0.28 [b]
Crude protein	53.07±1.44 [b]	59.56±0.27 [a]	51.87±0.20 [b]	47.63±0.53 [c]	49.81±0.34 [c]
Ether extract	70.88±0.89 [c]	77.52±0.15 [a]	72.73±0.11 [b]	74.26±0.27 [b]	77.60±0.15 [a]
Crude fibre	24.83±2.30 [c]	39.77±0.41 [a]	29.64±0.29 [b]	35.42±0.66 [a]	28.06±0.49 [b]
NFE	64.24±1.09 [b]	68.39±0.21 [a]	67.98±0.13 [a]	69.89±0.32 [a]	67.50±0.22 [a]
Ash	34.98±1.99 [c]	34.02±0.44 [c]	37.26±0.25 [b]	36.58±0.64 [b]	22.15±0.53 [d]

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

Table 8: Phosphorus balance (g/head/day) of the experimental groups

Item	Control group	Supplemented groups			
	I	II	III	IV	V
Intake	2.14±0.01	2.22±0.01	2.10±0.01	2.20±0.01	2.11±0.02
Faecal	1.63±0.05	1.33±0.01	1.44±0.01	1.65±0.01	1.62±0.01
Urinary	0.08±0.01	0.11±0.01	0.11±0.01	0.11±0.01	0.09±0.01
Absorbed	0.51±0.05	0.89±0.01	0.66±0.01	0.55±0.02	0.49±0.01
Retained	0.43±0.05	0.77±0.02	0.55±0.01	0.44±0.01	0.40±0.02
Absorbed, %**	23.83±2.30 [c*]	40.09±0.37 [a]	31.43±0.351 [b]	25.00±0.69 [c]	23.22±0.45 [c]
Retained, %***	84.31±10.35 [a]	86.52±11.18 [a]	83.33±11.10 [a]	80.00±9.15 [b]	81.63±10.10 [b]

Table 9: Calcium balance (g/head/day) of the experimental groups.

Item	Control group	Supplemented groups			
	I	II	III	IV	V
Intake	2.85±0.02	2.78±0.01	2.80±0.02	2.92±0.02	2.84±0.02
Faecal	2.16±0.07	1.89±0.01	2.04±0.01	2.10±0.01	2.18±0.01
Urinary	0.15±0.03	0.14±0.01	0.15±0.03	0.17±0.01	0.16±0.01
Absorbed	0.69±0.07	0.89±0.01	0.76±0.01	0.82±0.03	0.66±0.02
Retained	0.54±0.06	0.75±0.02	0.61±0.04	0.65±0.03	0.50±0.03
Absorbed, %**	24.21±2.37^{c*}	32.01±0.43^{a}	27.14±0.31^{b}	28.08±0.74^{b}	23.24±0.55^{c}
Retained, %***	78.26±12.10^{b}	84.27±11.65^{a}	80.26±10.40^{a}	79.27±12.05^{a}	75.76±9.75^{b}

* Figures in the same row having the same superscripts are not significantly different ($P < 0.05$).
**Absorbed % calculated from the intake.
***Retained % calculated from the absorbed amount.

Table 10: Magnesium balance (g/head/day) of the experimental groups.

Item	Control group	Supplemented groups			
	I	II	III	IV	V
Intake	1.36±0.01	1.01±0.01	1.08±0.01	1.13±0.01	1.12±0.01
Faecal	1.01±0.03	0.75±0.01	0.79±0.01	0.79±0.01	0.74±0.01
Urinary	0.09±0.01	0.06±0.01	0.09±0.01	0.08±0.01	0.08±0.01
Absorbed	0.35±0.03	0.26±0.01	0.29±0.01	0.34±0.01	0.38±0.01
Retained	0.26±0.03	0.20±0.01	0.20±0.01	0.26±0.01	0.30±0.01
Absorbed, %**	25.74±0.95^{c*}	25.74±0.35^{c}	26.85±0.37^{c}	30.09±0.70^{b}	33.93±0.44^{a}
Retained, %***	74.29±9.82^{a}	76.92±10.15^{a}	68.97±9.10^{b}	76.47±10.35^{a}	78.95±10.16^{a}

Table 11: Blood serum levels of minerals (mg/100 ml) of the experimental groups.

Item	Control group	Supplemented groups			
	I	II	III	IV	V
phosphorus	5.48±1.10^{a*}	5.98±1.20^{a}	5.70±1.18^{a}	5.98±1.15^{a}	5.76±1.12^{a}
Calcium	9.12±3.12^{a}	9.24±3.15^{a}	9.72±3.30^{a}	9.08±3.21^{a}	9.32±3.18^{a}
Magnesium	3.82±1.01^{a}	3.65±1.06^{a}	3.89±1.25^{a}	3.70±1.21^{a}	3.53±1.14^{a}

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

Fig.1. Phosphorus balance of the experimental groups

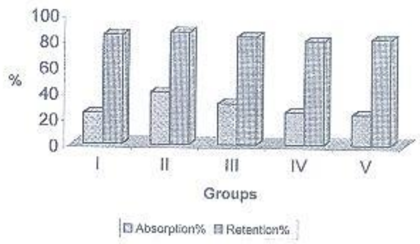

Fig .2. Calcium balance of the experimental groups

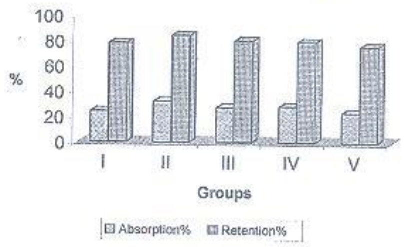

Fig.3. Magnesium balance of the experimental groups