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BIOAVAILABILITY OF PHOSPHORUS AND ITS EFFECT ON THE NUTRIENT UTILIZATION IN CATTLE

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Abstract

Eighteen indigenous growing cattle of two years old having initial live weight of 100 ± 4.5 kg were used to investigate the bioavailability of phosphorus from different sources (Di-calcium phosphate, Bone meal, Sesame oil cake, Mustard oil cake and Poultry liter) and its effect on the nutrient utilization and phosphorus balance of cattle. The animals were divided into 6 groups having 3 animals in each to one of group and randomly allocated into six diets in a Completely Randomized Design (CRD). Six dietary treatments are : T_0 (control diet), T_1 (Control + DCP), T_2 (Control + Bone meal), T_3 (Control+ mustard oil cake), T_4 (Control+ sesame oil cake) and T_5 (Control + poultry litter). The controlled diet contained 0.20% P and DCP, Bone meal, mustard oil cake, sesame oil cake and poultry litter were added to diets T_1, T_2, T_3, T_4 and T_5, respectively to elevate the dietary P level of 0.45% for meet up the deficiency. The lowest daily DM intake (g/d) was observed in animals fed on diet T_0 and the highest value was recorded for diet T_5 and significantly ($P<0.05$) differences were observed among the dietary treatments. The P supplementation either from DCP (T_1), bone meal (T_2), mustard oil cake (T_3), sesame oil cake (T_4) or poultry litter ((T_5) had no significant effect on organic matter (OM) and CP intake. The apparent digestibility of DM and OM were significantly ($P<0.05$ and $P<0.01$) affected by the supplementation of P either from DCP, bone meal, mustard oil cake, sesame oil cake or from poultry litter. But the digestibility of CP, CF, NFE and EE was not significantly ($P>0.05$) affected by the supplementation of P from these sources. There was no significant ($P>0.05$) difference in DCP and DCF contents among the dietary treatments. The apparent absorption of P (g/100g) was significantly ($P>0.05$) higher for dietary groups T_2, T_3 and T_5 (74.50) than T_0 (62.16), T_1 (73.15) and T_4 (70.16%). The true absorption of P for supplemented diets (T_1, T_2, T_3 and T_5) was numerically higher than the diet T_0, and T_4. P balance was significantly ($P<0.01$) higher for diets T_1 (9.11 g/d), T_2 (10.87 g/d), T_3 (9.65g/d), T_4 (8.62g/d) and T_5 (11.16g/d) compared to diet T_0 (2.75 g/d). The bioavailability of P from control diet, DCP, bone meal, mustard oil cake, sesame oil cake and poultry litter were 62.16, 80.46, 81.97, 81.84.75.22 and 81.47%, respectively among the test materials. It may be concluded that bone meal, mustard oil cake and poultry litter may be used as phosphorus supplement in cattle ration.

Key words: Bioavailability, Phosphorus, Nutrient utilization, Cattle

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Introduction

Phosphorus is an important mineral for bone and other hard tissue formation, maintenance of normal cell fluid and is a major component of high energy transfer (ATP and creatine phosphate) for muscle contraction, DNA and RNA formation, several enzymes and co-factors needed in the TCA cycle which is ultimately involved with energy synthesis of ATP (Berne and Levey, 1993). It is also required for proper functioning of rumen microorganisms, those that digest plant cellulose (McDowell, 1985). Phosphorus is involved in almost every aspect of feed metabolism and utilization of fat, carbohydrate, protein and other nutrients in the body. Phosphorus deficiency can be prevented or overcome by direct treatment of the animal through supplementation of phosphorus in the diet or with drinking water or indirectly by appropriate fertilizer treatment of soils. Normally, P supplements are incorporated into concentrate diets which generally ensure that the animals receive required quantities. Phosphorus is one of the costly mineral elements required for all mammalian biological systems. Chandler (1996) indicated that phosphorus accounts for more than 50 percent of the cost of typical vitamin-mineral mix used in dairy farms. The chronic deficiency of phosphorus in animal results in reduction of food intake and organic matter digestibility, depraved appetite, low growth rates and reduced reproductive rates. There are considerable differences in the availability of P being provided from different sources. All P sources are not equal in their relative availability for cattle (Oliveira *et al.,* 2008). Bioavailability of plant phosphorus is lower than animal phosphorus. Di-calcium phosphate (DCP), bone meal, mustard oil cake, sesame oil cake and poultry litter are the common sources of phosphorus supplement in our country but no information regarding the bioavailability of phosphorus in animal body is available. The research on Phosphorus bioavailability in indigenous cattle has not yet systematically done in Bangladesh. Therefore, this research work has been undertaken to study the bioavailability of phosphorus from different sources and its effect on feed intake, digestibility of nutrients and phosphorus balance of growing cattle.

Materials and Methods

The experiment was conducted at the Department of Animal Nutrition, Bangladesh Agricultural University (BAU), Mymensingh. Eighteen indigenous growing cattle (about two years old) having initial live weight of 100 ± 4.5 kg were used for 21 days experimental period (14 days preliminary period and 7 days collection period) in a Completely Randomized Design (CRD). Six experimental diets were formulated with basal ingredients, of rice straw, Dhal grass, broken maize, rice polish, soybean meal, urea and common salt. The DCP, bone meal, mustard oil cake, sesame oil cake and poultry litter were used as P sources. The controll diet contained 0.20% P against the requirement for growing cattle of 0.39% (Tilden Wayne Perry *et al*., 1999).Di-calcium phosphate (DCP), Bone meal, mustard oil cake, sesame oil cake and poultry litter were added to diets T_1, T_2, T_3, T_4, and T_5, respectively to elevate the dietary P level to 0.45% to meet the deficiency. The diets were almost iso-nitrogenous (CP 8.5%) and iso-energetic (ME 7.5 MJ/kg DM) but differed in the source and level of P. The nutrient requirements of animals were calculated based on the recommendations of NRC

(2001). Ingredients, chemical composition and nutritive values of the dietary treatments are shown in Table 1**.**

Table 1. Chemical composition and nutritive values of the experimental diets

Parameters	Dietary treatments[#]					
	T_0	T_1	T_2	T_3	T_4	T_5
Ingredients DM (kg/100 kg diet)						
Rice straw	70.81	70.70	70.09	67.16	67.16	60.61
Dhal grass	11.52	11.62	11.50	11.00	11.00	11.64
Broken maize	10.76	10.65	11.15	9.90	4.60	6.70
Soybean meal	2.94	2.63	2.23	3.00	4.30	5.50
Rice polish	3.00	1.87	1.68	-	1.09	1.39
DCP	-	1.48	-	-	-	-
Bone meal	-	-	2.23	-	-	-
Mustard oil cake 8.82	-	-	-	8.80	-	-
Sesame oil cake	-	-	-	-	11.02	-
Poultry litter	-	-	-	-	-	13.96
Urea	0.94	0.90	0.92	-	0.65	-
Common salt 0.16	0.20	0.17	0.20	0.16	0.20	0.20
Nutrient composition (g/100g DM)						
CP	8.69	8.72	8.93	8.88	8.95	8.50
CF	30.91	30.66	30.44	29.83	29.14	30.08
EE	1.88	1.79	1.80	2.42	2.54	1.70
NFE	47.99	47.24	47.11	47.13	44.36	40.55
Ash	12.25	12.06	12.08	12.02	12.89	12.80
P	0.20	0.45	0.46	0.44	0.45	0.45
Estimated enrgy value						
ME(MJ/Kg DM)	7.30	7.30	7.29	7.60	7.50	7.20

T_0 = Control (0.20% P), T_1 = Control + DCP (0.45^0/o P) and T_2 = Control + Bone meal (0.46% P), T_3 = Control + Mustard oil cake (0.44^0/o P), T_4 = Control + Sesame oil cake (0.45^0/o P) and T_5 = Control +Poultry litter (0.45% P)

The experimental feeds (roughages and concentrates) were offered at the rate of 3 kg DM/100 kg live weight to satisfy the DM requirement of the animals. Daily feed intake was recorded throughout the experimental period. Daily feces and urine were collected, measured and a representative sample was preserved for chemical analysis. Representative samples of feed, faeces and refused were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), ash and nitrogen free extract (NFE) following the method of AOAC (1990). Phosphorus content of the samples (feed, feces and urine) was determined according to the method of Page *et al*. (1982) and the data were analyzed statistically using the analysis of variance in a Completely Randomized Design (CRD). The least significance differences ($P<0.05$ and $P<0.01$) was used to compare treatment means (Steel and Torrie, 1980).

Results

Feed intake

The average feed and nutrient intakes of cattle fed different diets are shown in Table 2. The daily DM intake (DMI) of the animals were 2700, 3140, 3170, 3290, 3190 and 3580g for treatment groups T_0 (Control), T_1 (Control + DCP), T_2 (Control +Bone meal), T_3 (Control + Mustard oil cake), T_4 (Control + Sesame oil cake) and T_5 (Control +Poultry litter), respectively. The lowest DMI (g/d) was observed in animals fed on diet T_0 and the highest value was recorded for diet T_5. Significant ($P<0.05$) difference in DMI was observed among the dietary treatments. The P supplementation from DCP (T_1), bone meal (T_2), mustard oil cake (T_3), sesame oil cake (T_4) and poultry litter ((T_5) had no significant effect on OM and CP intake.

Table 2. Effect of phosphorus supplementation on feed and nutrient intake

Parameters	Dietary treatments[#]						SED	Level of sig.
	T_0	T_1	T_2	T_3	T_4	T_5		
DM intake (g/d)								
Straw	1410	1720	1720	1720	2100	2100	-	-
Grass	840	840	840	840	520	520	-	-
Concentrates	454	590	610	730	576	963	-	-
Total DM intake (DMI)								
g/d	2700[b]	3140[a]	3170[a]	3290[a]	3190[a]	3580[a]	293.1	*
g/kgW$^{0.75}$	83.89	91.55	89.98	93.73	86.94	92.13	6.46	NS
Total OM intake (OMI)								
g/d	2370	2730	2550	3860	2680	2860	302.5	NS
g/kgW$^{0.75}$	73.65	79.59	72.50	83.17	73.91	76.69	7.16	NS
Total CP intake(g/d)	**234**	**273**	**283**	**288**	**287**	**304**	**25.6**	**NS**

[#] T_0 = Control, T_1 = Control + DCP, T_2 = Control +Bone meal, T_3 = Control + Mustard oil cake, T_4 = Control + Sesame oil cake and T_5 = Control + Poultry litter.
SED: Standard error difference
NS P>0.05, *P<0.05
[ab] Mean values having different superscripts in a row differ significantly

Apparent digestibility and nutritive value

The apparent digestibility of proximate components of different diets is shown in Table 3. The digestibility of DM and OM were significantly ($P<0.05$ and $P<0.01$) affected by the supplementation of P either from DCP, bone meal, Mustard oil cake, sesame oil cake or from poultry litter. But the digestibility of CP, CF and EE were not significantly ($P>0.05$) affected by the supplementation of P from either sources (Table 3). The digestibility of NFE was significantly ($P<0.01$) higher for diets T_2 (58.48%), T_0 (55.05), T_1 (56.14) and T_3 (53.78) than that of diet T_4 (46.15) and T_5 (34.13). There was no significant ($P>0.05$) difference in DCP and digestible crude fibre (DCF) contents among the dietary treatments. Digestible EE (DEE), DNFE and TDN values of diets T_0,

T_1, T_2, T_3, T_4 and T_5 were 0.89, 0.82, 1.02, 1.28, 1.29 and 0.63; 26.39, 26.48, 27.54, 25.23, 20.47 and 13.83; 53.71, 56.22, 56.10, 55.13, 49.80 and 41.15, respectively (Table 3) which revealed a significant (P<0.01) increase of DNFE content due to bone meal supplementation (T_2) and increase of TDN due to DCP supplementation (T_1).

Table 3. Effect of phosphorus supplementation from different sources on digestibility and nutritive value

Parameters	Dietary treatments#						SED	Level of sig.
	T_0	T_1	T_2	T_3	T_4	T_5		
Apparent Digestibility (g/100 g)								
DM	56.88^{ab}	56.26^{ab}	59.82^{a}	54.63^{ab}	50.64^{bc}	47.62^{c}	3.82	*
OM	62.49^{a}	62.79^{a}	62.62^{a}	62.30^{a}	56.18^{b}	50.42^{c}	2.57	**
CP	49.82	53.49	62.21	55.33	52.20	48.69	6.01	NS
CF	68.99	78.06	68.22	75.29	74.45	73.02	9.93	NS
EE	47.89	46.14	57.31	54.28	50.96	37.56	10.4	NS
NFE	55.05^{a}	56.14^{a}	58.48^{a}	53.78^{a}	46.15^{b}	34.13^{c}	4.20	**
Nutritive value (g/100 g DM)								
DCP	4.32	4.66	5.55	4.93	4.66	4.13	0.53	NS
DCF	21.31	23.93	20.76	22.10	21.74	21.96	3.04	NS
DEE	0.89^{bc}	0.82^{bc}	1.02^{ab}	1.28^{a}	1.29^{a}	0.63^{c}	0.20	**
DNFE	26.39^{a}	26.48^{a}	27.54^{a}	25.23^{a}	20.47^{ab}	13.83^{b}	1.95	**
TDN	53.71^{ab}	56.22^{a}	56.10^{a}	55.13^{ab}	49.80^{abc}	41.15^{c}	3.36	**

T_0 = Control, T_1 = Control + DCP, T_2 = Control +Bone meal, T_3 = Control + Mustard oil cake, T_4 = Control + Sesame oil cake and T_5 = Control + Poultry litter.
SED: Standard error difference
NS P>0.05, *P<0.05
[ab] Mean values having different superscripts in a row differ significantly

Apparent and true absorption of phosphorus

The results of apparent and true absorption of P in growing bulls fed different diets are shown in Table 4. The apparent absorption of P (g/100g) was significantly (P<0.05) higher for dietary groups T_2, T_3 and T_5 than T_0 (62.16), T_1 (73.15) and T_4 (70.16%). It is seen from Table 4 that the true absorption of P (g/100g) were 79.40, 80.81, 82.13, 82.33, 76.84 and 81.50 % for growing bulls fed on diets T_0, T_1, T_2, T_3, T_4 and T_5, respectively. However, no significant (P>0.05) difference was observed among the dietary treatments.

Phosphorus balance

The results of the average P balance of the six dietary groups are presented in the Table 4. The average daily P intake was 5.38, 14.12, 14.59, 14.47, 14.38 and 16.12g for growing bulls fed on diets T_0, T_1, T_2, T_3, T_4 and T_5, respectively and differed significantly among the treatment (P<0.01) (Table 4). All the animals used in this experiment showed positive P balance. It can be observed from the Table 4 and P

balance was significantly (P<0.01) higher for supplemental diets (T_1 (9.11 g/d), T_2 (10.87 g/d), T_3 (9.65g/d), T_4 (8.62g/d) and T_5 (11.16g/d)) compared to unsupplemental diet (T0 (2.75 g/d)). Though P balance for the animals fed on diet T_2 and T_5 were numerically higher than that of animals fed on diets T_1, T_3, T_4 but no significant (P>0.05) difference was observed. The daily P retention (g/100g intake) was significantly (P>0.05) higher for the animals fed on diets T_1 (64.51), T_2 (74.50), T_3 (66.68), T_4 (59.94) and T_5 (69.23) when compared with the animals fed on diet T_0 (51.11). Although diet T_2 and T_5 showed numerically higher P retention value than that of diet T_1, T_3 and T_4 but the difference was not significant (P>0.01).

Table 4. Absorption and balance of phosphorus in growing bulls fed different experimental diets

Parameters	Dietary treatments[#]						SED	Level of sig.
	T_0	T_1	T_2	T_3	T_4	T_5		
Phosphorus intake (g/d)	5.38^{c}	14.12^{b}	14.59^{b}	14.47^{b}	14.38^{b}	16.12^{a}	0.73	**
Faecal excretion (g/d)	2.06^{b}	3.79^{a}	3.72^{a}	3.71^{a}	4.29^{a}	4.05^{a}	0.79	*
Urinary excretion (g/d)	0.57^{c}	1.22^{ab}	1.0^{abc}	1.11^{ab}	1.47^{a}	0.91^{bc}	0.26	*
Total P excretion (g/d)	2.63^{b}	5.01^{a}	4.72^{a}	4.82^{a}	5.76^{a}	4.96^{a}	1.03	*
Endogenous P (g/d)[@]	0.96	1.08	1.13	1.16	0.96	1.08	0.22	NS
Apparent absorption (g/100g)	62.16^{b}	73.15^{a}	74.50^{a}	74.36^{a}	70.16^{ab}	74.87^{a}	0.83	*
True absorption (g/100g)	79.40	80.81	82.13	82.33	76.84	81.50	5.41	NS
Phosphorus balance (g/d)	2.75^{c}	9.11^{b}	10.87^{ab}	9.65^{b}	8.62^{b}	11.16^{a}	0.75	**
Bioavailability (%)	62.16^{b}	80.46^{a}	81.97^{a}	81.84^{a}	75.22^{a}	81.47^{a}	7.64	*

[#] T_0 = Control, T_1 = Control + DCP, T_2 = Control + Bone meal, T_3 = Control + Mustard oil cake, T_4 = Control + Sesame oil cake and T_5 = Control + Poultry litter.
SED: Standard error difference,
NS P>0.05, *P<0.05, **P<0.01, [@]ARC, 1980
[abc] Mean values having different superscripts in a row differ significantly

Bioavailability of phosphorus

The results of bioavailability of P in growing bulls from different sources are presented in Table 4. The daily average P intake (g) and outgo (g/d) were 5.38, 8.74, 9.21, 9.09, 9.00 and 10.74 and 2.06, 1.73, 1.66, 1.65, 2.23 and 1.99, respectively for the diet T_0, T_1, T_2, T_3, T_4 and T5. The bioavailability of P from control diet, DCP, bone meal, mustard oil cake, sesame oil cake and poultry litter supplemented diets were 62.16, 80.46, 81.97, 81.84.75.22 and 81.47%, respectively. Bioavailability of P from DCP, bone meal, mustard oil cake, til oil cake and poultry litter did not differ significantly (P>0.05).

Discussion

In the present study, there was no significance difference (P>0.05) of the total intake of DM, OM and CP due to supplementation of different levels of phosphorus. These results are in agreement with the findings of Witt and Owens (1983) who stated that animals fed diets containing 0.119 and 0.227% phosphorus of DM showed no effects of phosphorus

supplementation of feed intake. Similar results were also observed by Little (1980), who reported that the beef cattle receiving only *Stylosanthes humilis* (0.12%P) had similar DM intake compared to those animals supplemented at the rate of 5g of P per day, similarly, Jackson *et al*. (1988) observed that the average feed intake was almost same (3.24 vs. 3.29 kg/d) for the cattle receiving diet containing monoamonium phosphate and the dicalcium phosphate as a source of P supplement. In another study, Erickson *et al*. (2002) also reported that the average feed intake was almost same (19.7 vs. 18.11 lb/d) in finishing calves fed 0.16 and 0.28% phosphorus, respectively. In contrast, Jackson *et al*. (1988), observed increase in feed intake when dietary phosphorus was increased from 0.24 to 0.34%. Flatt *et al.* (2001) showed similar results who stated that P withdrawal from the diet did not increase feed intake in cattle. Witt and Owens (1983) reported that digestibility of DM (64.8 vs 67.0%) and OM (64.8 vs 66.9) was similar for 0.12% and 0.23% of dietary P, respectively. Almost similar results were also noted in the present experiment when control diet was supplemented either of the with DCP, bone meal, mustard oil cake, til oil cake and poultry litter. Ternouth *et al*. (1993**)** stated that there was a decrease in digestibility when low P source diets were fed. The digestibility of CP, EE and CF in different dietary groups did not differ significantly ($P>0.05$). The digestibility of CP, CF, EE and NFE did not differ significantly ($P>0.05$).The significantly ($P<0.01$) higher NFE digestibility of the diets supplemented with phosphorus (0.24 and 0.33%) in the present study is in agreement with the statement of Ternouth *et al.* (1993). It appears from the P balance trial (Table 4) that average phosphorus absorption was significantly increased with the supplemented P from DCP, bone meal, mustard oil cake, sesame oil cake and poultry litter compared to those unsupplemented control diets (T_0). Significantly ($P<0.05$) higher apparent absorption of phosphorus was found in highest (0.33% P) phosphorus supplemented groups of (T_2) and (T_3) compared to control group (T_0) which indicated that more phosphorus is available from bone meal and mustard oil cake to the animal for metabolism. There was no significant ($P>0.05$) difference among the dietary treatments for true absorption. However, there was a trend to increase true absorption with increasing levels of phosphorus supplementation from DCP, bone meal and mustard oil cake. The apparent absorption of phosphorus (AAP) was significantly ($P<0.05$) higher for the supplemental groups (T_1, T_2, T_3, T_4 and T_5) than the control group (T_0). Lofgreen (1960) reported that the apparent and true absorption of P by withers from bone meal were 45.6% and 46%, respectively of the animals fed on 3.86g P/d. These values are lower than that observed in the present experiment. It may be due to species differences.

The P balance study indicated that claves fed DCP, bone meal, mustard oil cake. Sesame oil cake and poultry litter retained an average of 64.51, 74.50, 66.68, 59.94 and 69.23 (g/100g), respectively of their dietary P, where as those fed only control diet retained and average of 51.11g/100g, and this value was significantly lower than those of the supplemented diets (T_1, T_2, T_3, $T_4$and T_5).

In the present study, significantly ($P<0.05$) higher bioavailability was observed in animals fed DCP (80.46%),bone meal (81.97%), mustard oil cake (81.84%), sesame oil cake (75.22%) and poultry litter (81.47%) when compared with control diet (62.16%).

From these results it is indicated that more P is available from DCP, bone meal, mustard oil cake, sesame oil cake and poultry litter to the animal for metabolism. Chase (2002) reported that biological availability of P from monocalcium phosphate, dicalcium phosphate, defluorinated phosphate, steam bone meal were 95-98, 93-95, 88-91 and 80-82%, respectively. Similarly, bone meal, ammonium phosphate and superphosphate were reported to have an equal P availability to dicalcium phosphate. From this study it may be concluded that bone meal, mustard oil cake and poultry litter may be used as phosphorus supplemental in cattle ration.

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