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Effect of Dietary Phosphorus on Nutrient and Phosphorus Digestibility in Thai-Indigenous x Brahman Crossbred Cattle

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Abstract: The effect of dietary Phosphorus (P) on nutrient and P digestibility in Thai-indigenous×Brahman crossbred cattle was studied. The experimental design was a 4×4 Latin square design with 21 days period. Four male crossbred cattle of about 1.5±0.5 years-old and weighing 220±30 kg were randomly received 1 of 4 dietary treatments containing 1.9, 2.4, 3.1 and 4.2 g P kg^{-1}, respectively. The findings revealed that digestibilities of DM, OM, CP, NDF and ADF were not affected ($p>0.05$) by dietary P. However, P digestibility (818.71, 706.02, 625.25 and 537.90 g P kg^{-1} diet) decreased ($p<0.05$), but plasma P (35.36, 40.66, 46.97 and 55.42 mg L^{-1}) increased ($p<0.05$) with increasing dietary P. The results indicated that dietary P affected ($p<0.05$) P digestibility and plasma P content in Thai-indigenous×Brahman crossbred cattle. The optimal dietary P for Thai-indigenous× Brahman crossbred cattle ranged from 1.7-3.1 g kg^{-1} diet.

Key words: Dietary phosphorus, phosphorus digestibility, phosphorus requirement, crossbred cattle

INTRODUCTION

Tropical areas often have short rainy seasons (3-4 months) and long dry seasons (8-9 months), which significantly affect the quality and quantity of available forage (Abdelrahman *et al*., 1998). Phosphorus (P) deficient soils (Underwood and Suttle, 1999) and forages (Ndebele *et al*., 2005) occur widely in this area. Therefore, P deficiency can be regarded as the most prevalent and serious mineral limitation to livestock production (McDowell, 1985). However, to meet the dietary requirements of cattle, P supplementation should be seriously considered. It is an expensive element in cattle diets and overfeeding of P can result in environmental contamination (Knowlton *et al*., 2004; Ekelund *et al*., 2006).

Kearl (1982) recommended P requirements for tropical beef cattle ranging from 1.7-3.5 g P kg^{-1} diet. Similarly, NRC (2000) suggested that growing beef cattle required 2.7 g P kg^{-1} diet. These requirements were higher than that reported by Erickson *et al.* (1999), who observed P requirement for finishing yearling crossbred steers was 1.4 g P kg^{-1} diet or less. Additionally, the P requirement for finishing feedlot steers was <1.6 g P kg^{-1} diet (Erickson *et al*., 2002). The dietary P concentration needed to meet dietary requirements varies widely with feed intake, breed, body weight, growth rate and physiological state (Knowlton *et al*., 2004). Thus, the above recommended P requirements probably are not suitable for Thai-indigenous x Brahman crossbred beef cattle. The population of crossbred cattle is approximately 2.4 million head of a total of 8 million head of cattle in Thailand (DLD, 2006). It has been predicted that in the near future the number of crossbred cattle may rapidly increase. The increase can be attributed to the new found popularity of crossbred cattle among Thai farmers who prefer raising them to raising indigenous cattle. Furthermore, beef farmers mostly prepare mix feeds on farms. This is normal in situations where knowledge of feed requirements and feed formulations are critical (Khemsawat and Phonbumrung, 2008). Currently, P requirement of Thai-indigenous × Brahman crossbred cattle has not been scientifically reported. Thus, the objectives of this study were to investigate the effect of dietary P on nutrient and P digestibility and to determine the optimal dietary P level of Thai-indigenous x Brahman crossbred cattle.

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MATERIALS AND METHODS

This study was conducted in Maha Sarakham province located in Northeastern Thailand. Four-male Thai-indigenous × Brahman crossbred cattle of about 1.5±0.5 years-old with an initial body weight of 220±30 kg were used. The experimental animals were dewormed by Ivomectin (1 mL/30 kg BW) and injected with AD_3E vitamin-complex (1 mL/50 kg BW) before the beginning of the study. They were placed in individual stalls and daily fed *ad libitum* at 0800 and 1600 h. Drinking water was freely available at all times. Animals were randomly allocated to one of four dietary treatments in a 4×4 Latin Square Design with 21days periods. Each period consisted of 16 days of adaptation and 5 days test. Dietary treatments contained 1.9, 2.4, 3.1 and 4.2 g P kg^{-1}, respectively (Table 1). Dicalcium phosphate was used as P source in the experimental diets. The diets were prepared in total mixed ration with rice straw as a roughage source and formulated to be isocaloric and isonitrogenous diets according to NRC (1996). During the 5 days test period, cattle were placed in metabolism crates and fed 90% of previous intake in adaptation period. Feed and feces were collected daily and composite at the end of each period. Feed and feces samples were dried and ground for analyses of DM, OM, CP (AOAC, 1990), ADF and NDF (Van Soest *et al*., 1991). Spot samples of urine were taken in the morning and afternoon of the last day of each period. The urine samples were pooled by animal and immediately stored at -20°C. Samples of feed, feces and urine were incinerated at 550°C for 4 h in a muffle furnace. Subsequently, ashed samples were dissolved in 5 mL HCl and made up volume to 25 mL prior to P determination using spectrophotometer (Nicolet Evolution 100, Thermo Electron Corporation, UK). Blood was obtained from the jugular vein after 3 h post feeding at the last day of each period and collected into tubes containing EDTA as an anticoagulant. Plasma was harvested by centrifugation of the whole blood for 15 min at 3000 g and kept at -20°C. Finally, the samples of plasma were analyzed for P following deproteinization with 10% trichloroacetic acid. Nutrient and P digestibility were estimated using the procedure of Schneider and Flaltt (1975).

Statistical analysis: The data were analyzed using the general linear models procedure of Statistical Analysis System Institute SAS (1988) according to the following statistical model:

$$Y_{ijk} = \mu + A_i + P_j + D_k + e_{ijk}$$

where, A, P and D are animal, period and dietary P effects, respectively. The differences among means were detected by least significant different. Significance was declared at $p<0.05$.

Table 1: Ingredients and chemical composition of dietary treatments

	Dietary P (g kg^{-1})			
Ingredients (g kg^{-1} DM)	1.9	2.4	3.1	4.2
Rice straw	300.0	300.0	300.0	300.0
Rice bran	100.0	114.8	100.0	150.0
Cassava chip	441.5	431.0	440.0	373.8
Soybean meal (44% CP)	80.00	75.00	80.00	100.0
Urea	17.50	17.50	17.00	12.00
Molasses	40.00	40.00	40.00	40.00
Sulfur	2.000	2.000	2.000	2.000
Dicalcium phosphate	1.500	4.000	8.000	12.00
Oyster shell meal	7.500	5.700	3.000	0.200
Salt	5.000	5.000	5.000	5.000
Premix[1]	5.000	5.000	5.000	5.000
Chemical composition				
Dry matter	936.7	923.7	937.8	952.8
Organic matter	899.6	901.4	894.2	902.0
Crude protein	116.7	116.7	117.7	118.3
Neutral detergent fiber	311.9	320.6	310.1	304.1
Acid detergent fiber	171.1	191.5	186.9	176.0
Ca	6.100	6.000	6.000	6.1.0
P	1.700	2.600	3.400	4.6.0
Total digestible nutrient[2]	658.6	657.1	657.4	659.6

[1]The premix provided per kg of diet: 10,000 IU vitamin A; 2,000 IU vitamin D_3; 20 IU vitamin E; 0.01 g Cu; 0.08 g Mn; 0.04 g Zn; 0.05 g Fe; 0.0008 g I; 0.0003 g Co; 0.0003 g Se; 0.005 g Ethoxiquin; and 0.05 g SiO_2; [2]Calculated value

RESULTS AND DISCUSSION

The analyzed phosphorus contents in the experimental diets were 1.7, 2.6, 3.4 and 4.6 g kg^{-1}. However, the remaining chemical compositions in all diets were similar (Table 1). Dietary P levels did not influence ($p>0.05$) the feed intake of Thai-indigenous x Brahman crossbred cattle (Table 2). The previous studies in yearling crossbred steers (Erickson *et al*., 1999), finishing feedlot calves (Erickson *et al*., 2002) and Thai-indigenous heifers (Suppaso *et al*., 2008) obtained the same findings. Furthermore, digestibility of DM, OM, CP, NDF and ADF were not modified ($p>0.05$) by increasing dietary P (Table 2). The other reports (Valk *et al*., 2002; Wu *et al*., 2003) similarly found no effect of dietary P on nutrient digestibility in cattle.

P intake of crossbred cattle fed diets containing 1.7-4.2 g P kg^{-1} ranged from 12.82-35.24 g day^{-1} (Table 3). The P requirement for maintenance of Thai-indigenous x Brahman crossbred cattle predicted from NRC (2000) suggestion was 5.18 g day^{-1}. The NRC (2000) anticipated a 68% absorption rate, which reflects that the dietary P required for maintenance of crossbred cattle (BW = 220±30 kg) was 7.62 g day^{-1}. This value was slightly higher than the recommendation of the NRC (2000) for 200-250 kg growing and finishing cattle (5-6 g P day^{-1}). Although we could not estimate the P requirement for growth of the crossbred cattle used in this metabolism trial, P intake of 12.82 g day^{-1} obviously showed that the crossbred cattle possibly gain body

Table 2: Means feed intake and nutrient digestibility of Thai-indigenous x Brahman crossbred cattle fed different dietary P levels

	Dietary P (g kg^{-1})				
Items	1.9	2.4	3.1	4.2	SEM
Total feed intake (kg day^{-1})	7.45	7.42	7.53	7.62	0.07
BW (%)	2.82	2.81	2.86	2.90	0.04
BW$^{0.75}$ (g kg^{-1})	113.70	113.25	115.04	116.49	1.27
Digestibility (g kg^{-1})					
Dry matter	717.58	707.20	704.30	712.55	3.35
Organic matter	737.97	729.55	727.54	731.94	3.25
Crude protein	765.61	754.43	749.07	757.87	3.70
NDF[1]	522.67	505.52	491.87	492.13	6.67
ADF[1]	472.63	463.92	466.90	469.73	5.85

[1]NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber

Table 3: Means P intake, P feces, P digestibility, P urine and plasma P of Thai-indigenous x Brahman crossbred cattle fed different dietary P levels

	Dietary P (g kg^{-1})				
Items	1.9	2.4	3.1	4.2	SEM
P intake (g day^{-1})	12.82^{d}	19.10^{c}	25.70^{b}	35.24^{a}	2.20
P feces (g day^{-1})	2.37^{d}	5.59^{c}	9.58^{b}	16.16^{a}	1.35
P digestibility (g kg^{-1})	818.71^{a}	706.02^{b}	625.25^{c}	537.90^{d}	27.88
P urine (g L^{-1})	0.02^{d}	0.05^{c}	0.10^{b}	0.14^{a}	0.01
Plasma P (mg L^{-1})	35.36^{d}	40.66^{c}	46.97^{b}	55.32^{a}	1.94

$^{a, b, c, d}$Row means with different superscripts differ ($p<0.05$)

weight with P of 5.20 g, the P that remained when using 7.62 g of P for maintenance. Similarly, 200-250 kg growing and finishing cattle required 5-6 g P for daily weight gain of 0.5 kg (NRC, 2000). Erickson *et al.* (2002) reported that P requirement for finishing steers was lower than 1.6 g kg^{-1} of diet or 14.2 g day^{-1}. Apparent P requirements vary for a variety of reasons; such as differences among breeds of cattle, P availability, interaction between nutrients and the effect of disease and parasitism (Ternouth, 1990; McDowell, 1996). The current obtained result clearly indicates that 1.7 g P kg^{-1} diet or 12.82 g P day^{-1} is adequate for maintenance and growth of Thai-indigenous x Brahman crossbred cattle.

P excretion of crossbred cattle increased ($p<0.05$) with increasing dietary P. However, P digestibility reduced ($p<0.05$) when dietary P was increased (Table 3). Previously, similar results were obtained in dairy cows (Wu *et al.*, 2001, 2003) and in Thai-indigenous heifers (Suppaso *et al.*, 2008). Cattle can actively absorb the amount of needed P when sufficient amounts or excessive P is fed (Morse *et al.*, 1992). Moreover, excessive dietary P resulted in decreasing P digestibility due to depressing 1.25 Dihydroxy vitamin D syntheses in the kidney (Reinhardt *et al.*, 1988). These are generally the highest levels of digestibility obtained when P is not supplied in excess (Ekelund *et al.*, 2006). The present P digestibility of crossbred cattle (537.90-818.71 g P kg^{-1}) seemed to be higher than that of dairy cows (240-525 g P kg^{-1}) (Ekelund *et al.*, 2003, 2006), but similar to that of Thai-indigenous heifers (569-753.3 g P kg^{-1}) (Suppaso *et al.*, 2008). The efficiency of P digestibility in lactating cows (0.69) was generally lower than that of growing cattle (0.76) (Bravo *et al.*, 2003). The results also revealed that Thai-indigenous x Brahman crossbred cattle and Thai-indigenous heifers had higher P digestibility than that of dairy cows. It was probably that the tropical cattle adapted to the low dietary P and insufficient P in tropical forages (McDowell, 1992; Ndebele *et al.*, 2005) by increasing the transport capacity in the small intestine (Huber *et al.*, 2002).

Plasma P concentrations normally reflect a cattle's P intake (Karn, 2001). Consequently, P content in the plasma of crossbred cattle increased ($p<0.05$) with increasing dietary P concentrations (Table 3). The result is in agreement with other studies (Valk *et al.*, 2002; Lopaz *et al.*, 2004). Cattle required a threshold concentration of plasma P for optimal growth between 31-46.5 mg L^{-1} (Underwood and Suttle, 1999). Plasma P of crossbred cattle fed diet containing 1.7-3.1 g P kg^{-1} was in the normal range. However, plasma of cattle fed the highest dietary P (4.2 g P kg^{-1}) contained 55.32 mg P L^{-1}, reflecting excessive P intake. It implied that dietary P at 4.2 g P kg^{-1} was in excess of the requirement of Thai-indigenous x Brahman crossbred cattle. Consistently, the previous report found that 4.0 g P kg^{-1} diet was an excessive requirement level for Thai-indigenous heifers (Suppaso *et al.*, 2008). Based on the present outcomes, P requirement for maintenance and growth of Thai-indigenous x Brahman crossbred cattle ranged from 1.7-3.1 g P kg^{-1} diet. It was close to the P requirement for beef cattle (1.4-3.5 g P kg^{-1} diet) recommended by Kearl (1982) and NRC (2000).

CONCLUSION

Dietary P influenced ($p<0.05$) P intake, P digestibility and plasma P concentration of Thai-indigenous x Brahman crossbred cattle. The optimal P requirement for maintenance and growth of crossbred cattle varied between 1.7-3.1 g P kg^{-1} diet.

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