GENETICS OF PHYTATE PHOSPHORUS BIO-AVAILABILITY IN POULTRY

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INTRODUCTION

Phosphorus is an essential mineral required in poultry diets for normal growth and development. It plays an important role in the metabolism of carbohydrates, amino acids and lipids. To meet metabolic demands, poultry of each species and age require specific amounts of phosphorus readily available for absorption and utilization. In broiler chickens, the amount of phosphorus required varies from 0.45 % per 100 g of diet to 0.3 %, depending on the age of the broiler (NRC, 1994). About 70 % of all phosphorus in plant products is present as phytate (phytic acid) or its salts, and is essentially unavailable to poultry because chickens lack adequate levels of the enzyme phytase, which is needed to hydrolyze phytate and release phosphorus for absorption and utilization. The inability to utilize phytate phosphorus results in a substantial loss of nutrient efficiency and creates a significant pollution threat when manure containing residual phosphorus is applied to land. Punna and Roland (1996) demonstrated that variation in phytate phosphorus utilization in the same strain of chicken is related to growth, livability and skeletal strength. Carlos and Edwards (1997) further observed large individual differences in phytate phosphorus utilization with a strain when fed phosphorus deficient diets with or without phytase. Thus, it appears that there is genetic variation between birds of different breeds and within the same strain as well. The large variability within a strain (Edwards, 1983 ; Punna and Roland, 1996 ; Carlos and Edwards, 1997) suggests that chickens can be selected for phytate phosphorus utilization with success**.** Genetic modification of birds for phytate phosphorus utilization provides us with a permanent, long-term solution to environmental pollution problems. In this paper we report the inheritance of phytate phosphorus utilization and the relationship between phytate phosphorus utilization and progeny body weight.

MATERIALS AND METHODS

A population was established with 40 males and 200 females from the Athens-Canadian random bred population. The birds were reproduced in 6 hatches with an interval of 7 days between hatches. At 4 weeks of age, the birds were transferred into individual metabolism cages. After an acclimatization of 3 days, feed intake and excreta produced in 3 days were collected. Excreta collected were weighed and dried. Phytate Phosphorus in feed and excreta were determined using a standard laboratory method as described by Latta and Eskim (1980). Weekly body weight and feed intake were also measured. Between 3-4 weeks of age, the levels of metabolizable energy, crude protein, calcium, total phosphorus and available phosphorus were 3.20 Kcal/g, 20 %, .90 %, .675 % and .45 % respectively. In the acclimatization and excreta-collecting periods, the mineral source phosphorus was largely removed and the total phosphorus level was adjusted down to .35 %. Other nutrient levels were the same as for the 4 wk old birds and the phytate phosphorus in the diet was measured as .35 %. From the phytate phosphorus content in the feed and excreta and the amount of feed consumed, the phytate phosphorus utilized by each bird was determined. A data set of 1004 chickens of the population was used to estimate the heritability of phytate phosphorus utilization. In another experiment five roosters categorized as high sire excreta phytate Phosphorus (1.17 ± 0.002) and low PP (1.09 ± 0.002) were selected to sire progeny. The PP values were significantly different ($P < 0.0001$) among the two sire groups. 350 progeny were hatched, 170 chicks from Low PP and 180 chicks from the High PP. All the chicks were fed a P deficient diet (.53 % P). When the chicks were 16 days of age, they were sacrificed using carbon dioxide asphyxiation and body weight was recorded. The left tibia was collected for ash determination on a dry fat-free basis (Method 22.10, Association of Official Analytical Chemists, 1995). Statistical analysis were performed using PROC CORR and PROC GLM (SAS Inst. Inc., 1993).

RESULTS AND DISCUSSION

The description of the data collected are provided in table 1. The variability in the population with respect to body weight, gain, feed intake and feed conversion ratio are consistent with a randomly mating unselected population. Figure 1 shows the distribution of phytate phosphorus utilization (PPU) in the population. Phytate phosphorus utilization follows a normal distribution suggesting that the trait is a quantitative trait with polygenic inheritance. Variability in the trait is about 28 % which is reasonable for selection to succeed. The retention of phytate phosphorus ranged from 1.98 to 67 %. The restricted maximum likelihood procedure (SAS Inst. Inc., 1993) was performed on the data. Estimated heritability of phytate phosphorus utilization was 0.33. The heritability estimate suggests that selection for PPU would demonstrate progress.

Table 1. Descriptive statistics of traits measured

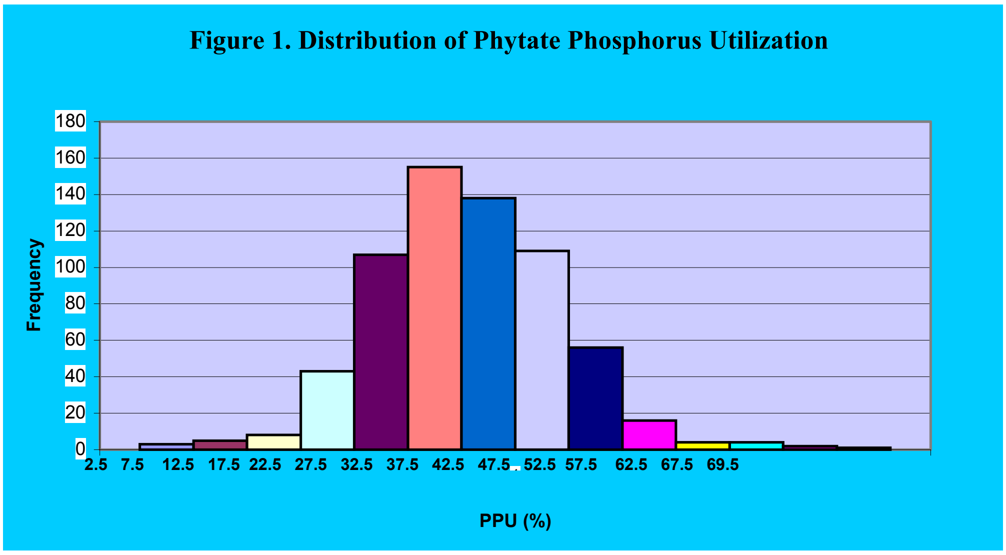
Trait	Mean±SD	C.V.
feed intake (g)	101.16 ± 18.26	18.06
feed conversion ratio	2.34 ± 0.40	17.28
Body wt (4 wk) g	290.68 ± 44.36	15.26
Body wt gain (3d) g	44.58 ± 11.83	26.55
Phytate P. Utilization (%)	30.63 ± 8.64	28.22

In experiment 2, there was a significant negative correlation ($r = -0.15$; $P = 0.0053$) between sire excreta phytate phosphorus and 16 day body weight. The correlation between PPU and tibia ash was also negative but not significant ($r = -0.01$; $P > 0.05$). The relation between phytate phosphorus utilization and body weight and tibia ash is shown in table 2.

GLM analysis indicated that progeny from High PPU sires (with low excreta) had significantly higher body weight than progeny from Low PPU. Similarly, progeny from High PPU sires had significantly higher tibia ash than progeny from Low PPU.

Table 2. Phytate Phosphorus Utilization, 16 d Body Weight (BWT), and Tibia ash

	High Phytate P. Utilizers	Low Phytate P. Utilizers	P > F
BWT (16 d), g	152.74 ± 1.47	146.81 ± 1.43	0.0042
Tibia Ash (16 d), %	36.57 ± 0.31	35.55 ± 0.30	0.0187



CONCLUSION

These results show that phytate phosphorus utilization in poultry is heritable, and selection program can be successful. Sires that excreted low phytate phosphorus, that is, those that are better able to utilize phytate phosphorus produced progeny that are significantly heavier chicks at day 16 and had better bone mineralization than progeny sired by poor phytate phosphorus utilizers. The potential for genetically modifying birds in increasing their usage of phytate phosphorus exists and can be exploited.

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