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# Effects of Sodium Polyacrylate and Phytase-Supplemented Diet on Performance and Phosphorus Retention in Chicks

**M. Yamazaki*, H. Murakami, H. Ohtsu, H. Abe and M. Takemasa**

National Institute of Livestock and Grassland Science, Tsukuba, Ibaraki, 305-0901, Japan

**ABSTRACT :** Two experiments were conducted to evaluate the effects of addition of sodium polyacrylate (SPA) to a phytase-supplemented diet on the performance and phosphorus (P) retention of chicks. In experiment 1, chicks were randomly allocated to four dietary treatments which were fed from 7 to 21 days of age: i) basal diet (low nonphytate phosphorus (0.23% NPP)); ii) basal with 250 U/kg diet of phytase; iii) as (ii) with 2.5 g/kg diet of SPA; and iv) as (ii) with 5.0 g/kg diet of SPA. In experiment 2, three replicates, each with three chicks, were fed from 7 to 28 days of age the basal diet (0.23% NPP) with supplementation of phytase (0, 300, 600, 900 U/kg diet) and SPA (0, 2.5 g/kg diet) in a 4×2 factorial arrangement. In Experiment 1, feed efficiency was improved and excreted P was 10% less with phytase supplementation. However, the addition of SPA did not affect performance or P excretion. Dietary SPA supplementation to the diets showed significantly higher amounts of P retention, and highest values were observed in chicks fed 2.5 g/kg of the SPA-supplemented diet. In Experiment 2, feed efficiency was improved with phytase supplementation, and the addition of SPA showed significant improvement in feed efficiency. Excreted P was significantly lower in chicks fed SPA-supplemented diets, and the retained P coefficient improved with SPA supplementation. In conclusion, the increased transit time of digesta with suitable supplementation levels of SPA may allow phytase activity to be more effective in the degradation of phytate, and improve P retention. (**Key Words : S**odium Polyacrylate, Phytase, Phosphorus, Chick)

## INTRODUCTION

Environmental pollution from poultry manure is becoming a serious issue, as feed phosphorus (P) not retained by the bird can ultimately contaminate ground water. More than 60% of the total P contained in feed ingredients of plant origin occurs as phytates (myo-inositol hexakis (dihydrogen phosphate):IP6, (Nelson, 1967). Phytate P is unavailable or poorly utilized by monogastric animals (except cecotrophs like the rabbit) due to insufficient quantities of endogenous phytase (Nelson, 1967), hydrolysis of IP6 in corn and soybean meal is only around 30%, but increased to 70% with the supplementation of a 600 U phytase/kg diet in broiler chicks (Leske and Coon, 1999). However, over 30% of phytate P still remains in digesta, indicating the need for improvement of phytate P degradation.

Sodium polyacrylate (SPA) is a polyanionic high molecular compound and highly viscous in water. It has been reported that supplementation of SPA to swine diet delayed passage of digesta, and the digestibility of crude protein and ash significantly increased (Furuya et al., 1978). Therefore, delaying food passage, and allowing more time for phytase to act on phytate, may enhance the hydrolysis of P from phytin and improve P retention.

Thus, the objective of the present experiments was to study the influence of the addition of SPA to a phytase-supplemented diet on the performance and P balance of chicks.

## MATERIALS AND METHODS

### Animals and diets

Day-old male White Leghorn chicks purchased from a local hatchery were used in the two experiments. Both experiments employed in this study followed the recommendations of the Guide for the Care and Use of Agricultural Animals in Agricultural Research of the National Institute of Livestock and Grassland Science (Tsukuba, Japan). Chicks were housed in electrically-heated battery cages and had free access to water and a commercial starter diet for 7 days. In both experiments, the basal diet

* Corresponding Author: M. Yamazaki. Tel: +81-29-838-8657, Fax: +81-29-838-8657, E-mail: yamazaki@affrc.go.jp
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consisted mainly of corn and soybean meal (Table 1). Lighting was provided 24 h per day, and temperature was maintained between 25 and 28°C. In Experiment 1, forty 7-d-old chicks were randomly allocated to four treatments. Five replicates per treatment were used with 2 chicks per replicate. The four dietary treatments consisted of: i) basal diet (low NPP); ii) as 1 with 250 U/kg diet of phytase; iii) as 2 with 2.5 g/kg diet of SPA; iv) as 2 with 5.0 g/kg diet of SPA, and were fed from 7 to 21 days of age. From 7 to 14 days of age, chicks were fed Cr free diets to estimate the rate of passage parameters. In Experiment 2, three replicates with three chicks each were fed the basal diet with the supplementation of phytase (0, 300, 600, 900 U/kg diet) and SPA (0, 2.5 g/kg diet) in a 4×2 factorial arrangement from 7 to 28 days of age. The SPA used in experiments was reagent grade (Wako Pure Chemical Industries, Co. Ltd., Tokyo, Japan), and degree of polymerization was from 22,000 to 70,000. In both experiments, addition of phytase and/or SPA to diet was made at the expense of lactose. The microbial phytase originated from non-recombinant *Aspergillus niger* (Kyowa Hakko Kogyo Co. Ltd., Tokyo, Japan). From 17 to 21 days of age (Experiment 1), and from 24 to 28 days of age (Experiment 2), P balance trials were conducted on the difference in concentrations of chromic oxide in the diets and that in the digesta and excreta. The parameters measured during the experiments were body weight gain, feed consumption, P intake, and P excretion. For each replicate group, body weight gain and feed consumption were recorded weekly.

**Table 1.** Composition of experimental diet (g/kg)

| Ingredient | |
|---|---|
| Maize | 658.2 |
| Soybean meal | 230.0 |
| White fish meal | 30.0 |
| Defatted rice bran | 56.5 |
| $CaCO_3$ | 14.0 |
| NaCl | 3.0 |
| DL-methionine | 0.3 |
| Lactose | 5.5 |
| Vitamin mixture[1] | 1.0 |
| Mineral mixture[2] | 0.5 |
| $Cr_2O_3$ | 1.0 |
| Calculated value | |
| MEn (MJ/kg) | 12.3 |
| CP (g/kg) | 190 |
| Total P (g/kg) | 5.7 |
| Nonphytate P (g/kg) | 2.3 |
| Calcium (g/kg) | 8.0 |

[1] Vitamin mixture provided the following (per kilogram of diet): vitamin A (from retinyl acetate) 4,000 IU; Cholecalciferol, 600 IU; vitamin E (from dl-α-tocopheryl acetate), 15 IU; vitamin K (menadione sodium bisulfate), 1.5 mg; riboflavin, 10 mg; D-calcium pantothenate, 20 mg; nicotinic acid, 50 mg; choline chloride, 500 mg; pyridoxine hydrochloride, 3 mg; folic acid, 2 mg; thiamine mononitrate, 3 mg. d-biotin, 0.3 mg; vitamin $B_{12}$, (cyanocobalamin), 20 μg.

[2] Mineral mixture provided the following (per kilogram of diet): iron ($FeSO_4 \cdot 7H_2O$), 80 mg; manganese ($MnCO_3 \cdot nH_2O$), 60 mg; zinc (ZnO), 40 mg; copper ($CuSO_4 \cdot 5H_2O$), 8 mg; iodine (calcium iodate), 0.5 mg.

## Chemical analyses

Phytase activity was determined prior to inclusion in experimental diets in following method. Phytase samples were diluted in 0.2 mol/L acetate buffer, pH 5.5, and filtered to separate the solids from the soluble enzyme. Aliquots of samples were incubated with 2.44 mmol/L Na-phytate (diluted in 0.2 mol/L acetate buffer, pH 5.5) in a water bath at 37°C for 10 min, the reaction was stopped by adding 10% trichloroacetic acid. Blanks were run by adding the trichloroacetic acid to enzyme samples and incubating in the water bath for 10 min before adding the Na-phytate. Samples were then centrifuged (3,000×*g*, 10 min) and supernatant was determined by the method of Allen (1940). The enzyme activity was 481 U/g and 1 U of phytase activity was defined as the quantity of enzyme required to produce 1 micromole of inorganic P/min from 2.44 mmol/L of Na-phytate at a pH 5.5 and 37°C. The chromic oxide content of diets and excreta were analyzed using the modified method described by Hill and Anderson (1958). Following dry ashing, addition of 2.36 mol/L $K_3PO_4$ and 4.46 mol/L KOH, and heated at 800°C to oxidize Cr. After transfer to the volumetric flask, optical density was determined at 370 nm in a spectrophotometer. Total P concentrations of ingredients was determined colorimetrically (Allen, 1940) after sulfuric acid digestion.

## Rate of passage study and statistical analyses

In Experiment 1, the rate of passage parameters was estimated by fitting one compartment model with the time delay of Pond et al. (1986) to the Cr excretion data. At 12 days of age, all chicks were fasted for 1 h, and fed each diet mixed with 0.3% of Cr for 5 hrs, and then returned to the Cr free diets. Fecal collections were conducted at 1, 2, 3, 4, 6, 9, 12, 24, and 48 h after the time when the feeding of 0.3% Cr diets was started (Table 2). Excreta were pooled with each treatment, and chromium oxide contents were analyzed as previously described. The accumulated amount of pulse dosed marker excreted over consecutive collection intervals was fitted to one-compartment model with time delay as described by Ellis et al. (1984). The model was:

$$M_{(t)} = C_o \times (1-(\exp^{-B(t-C)} \times (1+B \times (t-C))))$$

Where

$M_{(t)}$ = accumulative amount of pulse dosed marker excreted through time t

**Table 2.** Feeding and excreta collection schedule

| Day | Time | Feeding | Excreta collection |
|---|---|---|---|
| -5 | 0900 | Regular meal | |
| 0 | 0900-1000 | Fasted | |
| | 1000 | Marked meal | |
| | 1100 | | 1 h |
| | 1200 | | 2 h |
| | 1300 | | 3 h |
| | 1400 | | 4 h |
| | 1500 | Regular meal | |
| | 1600 | | 6 h |
| | 1900 | | 9 h |
| | 2200 | | 12 h |
| 1 | 1000 | | 24 h |
| 2 | 1000 | | 48 h |

$C_o$ = amount of marker dosed or total marker excreted during the interval from 0 to ∞ h

B = age-dependent rate parameter for compartment turnover

t = time lapse between pulse dosing and midpoint of the respective fecal collection interval (h)

C = residence time due to displacement flow (time delay between pulse dosing and first appearance of marker in excreta)

The parameters for B and C were estimated using the nonlinear (NLIN) procedure of SAS (SAS Institute, 1988) using the DUD method. Mean retention time (MRT) of the marker was calculated as:

$$MRT = (2/B)+C$$

The results of Experiment 1 were analyzed as a completely randomized design. Experiment 2 as analyzed as a 2 (SPA)×4 (phytase) factorial arrangement of treatments were used to determine treatment effects. In all experiment, pen of chicks was the experimental unit for all data. Data were analyzed using the GLM procedures of SAS (SAS Institute, 1988) by the following model, and treatment means were compared with Tukey's multiple range method.

The model for analysis of Experiment 1 was:

$$Yij = \mu+Ai+eij$$

Where μ is overall mean, A is the effect of dietary treatment and e is the residue error.

The model for analysis of Experiment 2 was:

$$Yijk = \mu+Ai+Bj+ABij+eijk$$

Where μ is overall mean, A is the effect of SPA, B is the effect of phytase, AB is the interaction effect of SPA and phytase and e is the residue error.

## RESULTS

Supplementation with SPA tends to delay the first appearance time and mean retention time of digesta (Table 3). In Experiment 1, no differences in body weight gain and feed intake value were observed when chicks were fed phytase or SPA-supplemented diets (Table 4). Feed efficiency was improved with phytase supplementation, but was not improved or hindered with SPA supplementation. The excreted P was over 10% lower in chicks fed phytase-supplementation diets than chicks fed the unsupplemented diet (Table 5). Supplementation of SPA to the diets showed higher amounts of P retention, and highest values were observed in chicks fed 2.5 g/kg of the SPA-supplemented diet.

In Experiment 2, there was no interaction between SPA and phytase supplementation on these variables (Table 6). Body weight gain and feed efficiency were improved with phytase supplementation, and the addition of SPA showed

**Table 3.** Flow parameters estimated by associated marker for the diets (Experiment 1)

| Phytase (U/kg diet) | - | 250 | 250 | 250 |
|---|---|---|---|---|
| SPA (g/kg diet) | - | - | 2.5 | 5.0 |
| B ($h^{-1}$) | 0.409 | 0.414 | 0.395 | 0.377 |
| First appearance time (h) | 1.68 | 1.60 | 1.60 | 1.79 |
| Mean retention time (h) | 6.57 | 6.43 | 6.66 | 7.10 |

**Table 4.** Effects of phytase and SPA supplementation on performance of chicks from 7 to 21 days of age (Experiment 1)

| Phytase (U/kg diet) | - | 250 | 250 | 250 | Pooled SEM |
|---|---|---|---|---|---|
| SPA (g/kg diet) | - | - | 2.5 | 5.0 | |
| Body weight gain (g/14 days) | 131 | 136 | 146 | 143 | 4.9 |
| Feed intake (g/14 days/bird) | 309 | 289 | 308 | 307 | 9.1 |
| Feed efficiency (BW gain/feed intake) | 0.427[b] | 0.469[a] | 0.473[a] | 0.467[a] | 0.0096 |

[a,b] Means within rows with no common superscript differ significantly ($p<0.05$).

**Table 5.** Effects of phytase and SPA supplementation on phosphorus balance of chicks from 17 to 21 days of age (Experiment 1)

| Phytase (U/kg diet) | 0 | 250 | 250 | 250 | Pooled SEM |
|---|---|---|---|---|---|
| SPA (g/kg diet) | 0 | 0 | 2.5 | 5.0 | |
| P intake (mg/bird/4 days) | 763 | 669 | 741 | 737 | 35.0 |
| P excreted (mg/bird/4 days) | 496 | 402 | 410 | 431 | 28.6 |
| P retained (mg/bird/4 days) | 266[b] | 267[ab] | 331[a] | 306[ab] | 15.9 |
| Retained P coefficient | 0.353[b] | 0.396[ab] | 0.448[a] | 0.417[ab] | 0.0173 |

[a,b] Means within rows with no common superscript differ significantly ($p<0.05$).

significant improvement in feed efficiency. No consistent differences in feed intake were observed among the treatments. Excreted P was significantly lower in chicks fed SPA supplemented diets, and the retained P coefficient improved with SPA supplementation (Table 7). There was no significant effect of phytase supplementation on the amount of retained P, however, the retained P coefficient was affected with phytase supplementation level, and interaction was significant.

## DISCUSSION

The above results show that the feed efficiency of chicks can be improved with phytase supplementation in the low NPP diet. Dietary phytase did not affect feed consumption, however, body weight gain was tend to increase with phytase supplementation in Experiment 2. Similar improvements in feed conversion ratio with supplemental phytase have been reported (Simons et al., 1990; Farrell et al., 1993). Results from the balance trial in Experiment 2, showed that retention of P was not increased by phytase supplementation. However, Um and Paik (1999) reported that dietary phytase supplementation improved the retention of P and other minerals in layers. Yi et al. (1996) also reported that dietary phytase supplementation enhanced not only the P retention but also nitrogen and amino acid digestibility in turkey poults. Our results agree with the earlier studies that phytase enhances performance in corn-soybean meal diets, however, no significant improvement of P retention. This phenomenon and the interaction observed

**Table 6.** Effects of SPA and phytase supplementation on performance of chicks from 7 to 28 days of age (Experiment 2)

| SPA (g/kg diet) | Phytase (U/kg diet) | n[2] | BWG[1] (g/21 days) | Feed intake (g/21 days/bird) | Feed efficiency (BWG/feed intake) |
|---|---|---|---|---|---|
| 0 | 0 | 3 | 199 | 544 | 0.367[b] |
| 0 | 300 | 3 | 210 | 548 | 0.384[ab] |
| 0 | 600 | 3 | 226 | 557 | 0.405[a] |
| 0 | 900 | 3 | 221 | 558 | 0.396[ab] |
| 2.5 | 0 | 3 | 218 | 550 | 0.395[ab] |
| 2.5 | 300 | 3 | 204 | 518 | 0.394[ab] |
| 2.5 | 600 | 3 | 218 | 535 | 0.407[a] |
| 2.5 | 900 | 3 | 220 | 531 | 0.414[a] |
| SEM | | | 5.9 | 15.7 | 0.0070 |
| Main effect means | | | | | |
| 0 | | 12 | 214 | 552 | 0.388[b] |
| 2.5 | | 12 | 215 | 534 | 0.402[a] |
| SEM | | | 2.9 | 7.8 | 0.0035 |
| | 0 | 6 | 208 | 547 | 0.381[b] |
| | 300 | 6 | 207 | 533 | 0.389[ab] |
| | 600 | 6 | 222 | 546 | 0.406[a] |
| | 900 | 6 | 220 | 545 | 0.405[a] |
| SEM | | | 4.1 | 11.1 | 0.0049 |
| Source of variation | | | ---------- Probability ---------- | | |
| SPA | | | 0.859 | 0.126 | 0.010 |
| Phytase | | | 0.042 | 0.791 | 0.005 |
| Interaction | | | 0.128 | 0.655 | 0.300 |

[a,b] Means within lines with no common superscript differ significantly ($p<0.05$).
[1] BWG = Body weight gain. [2] n = Number of replicates per mean value.

**Table 7.** Effects of SPA and phytase supplementation on phosphorus balance of chicks from 24 to 28 days of age (Experiment 2)

| SPA (g/kg diet) | Phytase (U/kg diet) | n[1] | P intake | P excreted | P retained | Retained P coefficient |
|---|---|---|---|---|---|---|
| | | | (mg/4 days/bird) | | | |
| 0 | 0 | 3 | 783 | 495 | 288 | 0.368[ab] |
| 0 | 300 | 3 | 818 | 500 | 318 | 0.388[a] |
| 0 | 600 | 3 | 859 | 564 | 295 | 0.343[b] |
| 0 | 900 | 3 | 841 | 522 | 319 | 0.380[ab] |
| 0.25 | 0 | 3 | 812 | 508 | 304 | 0.375[ab] |
| 0.25 | 300 | 3 | 758 | 473 | 285 | 0.375[ab] |
| 0.25 | 600 | 3 | 793 | 485 | 308 | 0.388[a] |
| 0.25 | 900 | 3 | 789 | 474 | 315 | 0.399[a] |
| SEM | | | 25.1 | 19.0 | 9.3 | 0.0077 |
| Main effect means | | | | | | |
| 0 | | 12 | 825 | 521[a] | 304 | 0.370[b] |
| 0.25 | | 12 | 788 | 485[b] | 303 | 0.384[a] |
| SEM | | | 12.6 | 9.5 | 4.6 | 0.0039 |
| | 0 | 6 | 798 | 502 | 296 | 0.372[ab] |
| | 300 | 6 | 788 | 487 | 301 | 0.382[ab] |
| | 600 | 6 | 826 | 525 | 301 | 0.366[b] |
| | 900 | 6 | 815 | 498 | 317 | 0.389[a] |
| SEM | | | 17.8 | 13.5 | 6.5 | 0.0055 |
| Source of variation | | | | ---------- Probability ---------- | | |
| SPA | | | 0.052 | 0.019 | 0.754 | 0.019 |
| Phytase | | | 0.455 | 0.283 | 0.174 | 0.035 |
| Interaction | | | 0.234 | 0.145 | 0.063 | 0.012 |

[a,b] Means within lines with no common superscript differ significantly ($p<0.05$).
[1] n = Number of replicates per mean value.

in retained P coefficient, might be attributed to the higher feed intake and excreted P in chicks fed the diet supplemented 600 U of phytase without SPA.

Beneficial effects of supplemental SPA in improving P retention of the chicks were observed, and chicks consuming SPA-added diet had significantly higher feed efficiency compared with chicks fed the unsupplemented diet. It has been reported that SPA supplementation delayed passage rate of digesta, and improved digestibility of crude protein and ash in swine (Furuya et al., 1978). They reported a 5-hour delay in mean retention time in stomach and duodenum when 0.5% SPA was added to a corn and soybean meal based diet. Although the length of the gastro-intestinal tract of domestic fowl is shorter than swine, similar effects that improve nutrient digestibility are expected in chicks. Percentage of retained P was significantly improved with SPA supplementation suggesting that delaying the passage of digesta increased contact time between phytase and phytate in the digesta in the crop and intestine, because both organs have a favorable environment for phytase activity from the standpoint of pH.

In general, non-starch polysaccharide has been thought as an anti-nutritive factor. Feeding over a 2% inclusion of guar gum to the chicks' diet depressed the performance of chicks (Furuse et al., 1997). Van Der Klis et al. (1993) also observed that a 5.0 g/kg CMC inclusion did not affect body weight gain nor feed intake, while a 10.0 g/kg inclusion reduced both parameters significantly. One of the reasons for this phenomenon might be the high viscosity of these materials, resulting in slower gastric and crop emptying, and the excess highly-viscous material in the digesta may prevent the work of digestive enzymes by wrapping or covering digestible contents. In common feedstuffs, for example, barley, oats, wheat, rye and triticale contains highly viscous substances, like arabinoxylans and β-glucans, application of carbohydrate degrading enzymes makes nutrient digestibility improve (Choct, 2006). From the result of present experiments, however, proper level supplementation of highly viscous materials, like pectin, carboxy methyl cellulose sodium (CMC), guar gum, and carrageenan, to non-viscous grains such as corn and sorghum based diet, could have the same beneficial effect on chick performance and P utilization.

In conclusion, increased digesta transit time with

suitable supplementation concentration of SPA may allow phytase activity to be more effective in the degradation of phytate.

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