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Standard phytase inclusion in maize-based broiler diets enhances digestibility coefficients of starch, amino acids and sodium in four small intestinal segments and digestive dynamics of starch and protein

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ABSTRACT

The effects of the 500 FTU/kg inclusion of *Buttiauxella* phytase in maize-based broiler diets were investigated where each treatment consisted of eight replicates of six male Ross 308 chicks per cage. Apparent digestibility coefficients of starch, sixteen amino acids and nine minerals in four small intestinal segments were determined in broilers offered P-adequate, maize-based diets at 40 days post-hatch. The disappearance rates of starch and protein (the sum of amino acids) from the four small intestinal segments were calculated and starch:protein disappearance rate ratios deduced in order to assess the effects of phytase on digestive dynamics. Phytase increased starch digestibility coefficients in the proximal jejunum (0.681 versus 0.538; $P = 0.001$) and distal ileum (0.959 versus 0.936; $P = 0.009$) and starch disappearance rates in the proximal jejunum (58.0 versus 43.4 g/bird/day; $P = 0.004$) and proximal ileum (80.8 versus 71.4 g/bird/day; $P = 0.036$). Phytase significantly increased ($P = 0.003 – <0.001$) amino acid digestibilities in four small intestinal segments with the most pronounced responses being observed in the proximal jejunum. Average amino acid data indicated that protein digestibility coefficients and disappearance rates were significantly ($P = 0.002 – <0.001$) increased in the four small intestinal segments. The magnitude of the responses to phytase in the proximal jejunum for both protein digestibility (0.791 versus 0.481; $P < 0.001$) and protein disappearance (23.77 versus 15.06 g/bird/day; $P < 0.001$) were substantial. Digestibility coefficients of both Na and P were significantly ($P = 0.027 – <0.001$) improved in four small intestinal segments by phytase but this did not apply to Ca. Na digestibility coefficients were significantly correlated to those of starch in three small intestinal segments including the proximal jejunum ($r = 0.900$; $P < 0.001$) and Na digestibilities were significantly correlated to protein in four small intestinal segments including the proximal ileum ($r = 0.862$; $P < 0.001$). Phytase condensed starch:protein disappearance rate ratios ($P = 0.015 – <0.001$) in the three caudal segments of the small intestine. A multiple linear regression equation ($r = 0.936$; $P < 0.001$) indicated that increasing protein disappearance rates from the proximal ileum would be advantageous, whereas, increasing starch

Abbreviations: AIA, acid insoluble ash; AME, apparent metabolisable energy; AMEn, nitrogen-corrected apparent metabolisable energy; Ca, calcium; Cu, copper; DI, distal ileum; DJ, distal jejunum; HCl, hydrochloric acid; iP, isoelectric point; K, potassium; Mg, magnesium; Mn, manganese; Na, sodium; P, phosphorus; PI, proximal ileum; PJ, proximal jejunum.

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disappearance rates would be disadvantageous in terms of 40-day weight gains. Consideration is given to the likelihood that the impact of phytase on Na absorption along the small intestine holds relevance to the intestinal uptakes of glucose and amino acids.

1. Introduction

Liu et al. (2015) investigated the effects of standard and elevated phytase inclusions in maize-based broiler diets with two tiers of reduced nutrient specifications. In this study, a *Buttiauxella* phytase (Axtra® PHY; Danisco Animal Nutrition, DuPont) was included at 500 and 1000 FTU/kg and has been described by Yu et al. (2014). In Liu et al. (2015) study, the finisher diet (28–40 days post-hatch) was formulated to contain 4.75 g/kg total phosphorus (P) and 2.5 g/kg non-phytate P and was considered P-adequate as phytase did not significantly increase tibial P contents. To 40 days post-hatch, 500 FTU/kg phytase improved weight gain by 11.8% (2937 versus 2627 g/bird), feed intake by 9.97% (4556 versus 4143 g/bird) and feed conversion ratios by 1.52% (1.553 versus 1.577). Interestingly, 500 FTU/kg phytase significantly improved apparent nitrogen digestibility coefficients in four small intestinal segments including an increase of 11.3% (0.883 versus 0.793) in the distal ileum, which was the most conservative response recorded. However, in the proximal jejunum the response was more pronounced with an increase of 79.9% (0.682 versus 0.379).

Consequently, retained samples of diets and digesta from four small intestinal segments were analysed for concentrations of sixteen amino acids, starch, and nine minerals to determine the impact of phytase on their apparent digestibility coefficients along the small intestine. Thus the primary purpose of this companion paper is to report on these outcomes. Also, the intention was to investigate relationships between Na digestibilities with those of starch and amino acids and the digestive dynamics of starch and protein.

Slight, but significant, increases in ileal starch digestibility to phytases in maize-based diets have been reported in broilers (Camden et al., 2001) but there are few reported investigations of the effects of phytase on starch digestibility. There is the possibility that starch digestibility determinations in more anterior segments of the small intestine, where the majority of starch digestion takes place and digestion is less complete, are more likely to detect responses to phytase and should prove more instructive. For example, Truong et al. (2015) reported that 500 FTU/kg phytase increased proximal jejunal starch digestibility by 17.6% (0.774 versus 0.658; $P < 0.005$) in maize- and wheat-based diets. Moreover, starch disappearance rates from the proximal jejunum were increased by 23.7% (65.3 versus 52.8 g/bird/day; $P < 0.001$).

Across the minerals, both phosphorus and calcium are obviously relevant in phytase digestibility assays but perhaps sodium should hold equal interest. Phytate has been shown to increase Na excretion in broilers, which was counteracted by phytase (Cowieson et al., 2004). Moreover, phytase has improved ileal Na digestibility coefficients to substantial extents in several studies (Ravindran et al., 2006, 2008; Selle et al., 2009a; Truong et al., 2014) but assessments of phytase on Na digestibility along the small intestine have only been investigated in one of these studies. Truong et al. (2014) reported that Na digestibility coefficients were substantially more negative in the proximal jejunum than in the distal ileum. This was almost certainly a consequence of endogenous sodium bicarbonate secretions into the duodenum buffering hydrochloric acid generated by the proventriculus (Allen and Flemstrom, 2005). The subsequent recovery of Na along the small intestine was enhanced by phytase supplementation in Truong et al. (2014) study.

Consideration has been given to the probability that phytate has anti-nutritive properties in respect of protein and energy utilisation in poultry and that phytase generates matching 'extra-phosphoric' responses (Ravindran and Selle, 2010). Selle and Ravindran (2007) raised the possibility that Na may be involved in extra-phosphoric phytase responses on the basis of the early Cowieson et al. (2004) and Ravindran et al. (2006) studies. Therefore, this companion paper will consider the role of Na in relation to exogenous phytase responses and to the formulation of phytase-supplemented diets for broiler chickens.

2. Materials and methods

Liu et al. (2015) have already documented the overall methodology followed in this experiment. However, the composition and specifications of the maize-based N1 diets offered to broilers from 28 to 40 days post-hatch is recorded in Table 1 together with the analysed concentrations of starch, sixteen amino acids and nine minerals. In essence, N1 maize–soy diets, without and with 500 FTU/kg phytase, were offered to 8 replicates (6 birds per cage) Ross 308 male chicks from 1 to 40 days post-hatch to each of the two dietary treatments. The analysed phytase activities in the two finisher diets (28–40 days post-hatch) were 113 FTU/kg in the NC1 diet and 769 FTU/kg in the NC1 plus phytase diet. On average, the birds had weight gains of 2782 g/bird, feed intakes of 4350 g/bird and feed conversion ratios of 1.564 at 40 days post-hatch when small intestinal digestibility coefficients were determined.

Concentrations of nutrients in diets and digesta were determined. Digesta samples included those from the proximal jejunum (PJ), distal jejunum (DJ), proximal ileum (PI) and distal ileum (DI) as defined by Liu et al. (2015). Starch concentrations were determined by a procedure based on dimethyl sulfoxide, α-amylase and amyloglucosidase, as described by Mahasukhonthachat et al. (2010). Amino acid concentrations of diets and digesta samples from four small intestinal segments were determined following 24 h liquid hydrolysis at 110 °C in 6 M HCl and then 16 amino acids are analysed using the