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Effects of phytase supplementation on growth performance, nutrient utilization and digestive dynamics of starch and protein in broiler chickens offered maize-, sorghum- and wheat-based diets

S.Y. Liu[a,*], D.J. Cadogan[b], A. Péron[c], H.H. Truong[a], P.H. Selle[a]

[a] Poultry Research Foundation within The University of Sydney, 425 Werombi Road, Camden, NSW 2570, Australia
[b] Feedworks, PO Box 369, Romsey, VIC 3434, Australia
[c] Danisco Animal Nutrition, DuPont Industrial Biosciences, 61 Science Park Road, 117525 Singapore, Singapore

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ABSTRACT

To investigate the effects of phytase supplementation on growth performance, nutrient utilization and digestive dynamics of starch and protein, a study was conducted using 288 male Ross 308 chicks (6 treatments with 8 replicate cages of 6 birds). Birds were offered steam-pelleted diets based on maize, sorghum or wheat, without or with phytase supplementation, from 7 to 27 days post-hatch. Experimental diets were formulated to be equivalent for energy, protein/amino acids and were P-adequate. Digesta samples from proximal jejunum, distal jejunum, proximal ileum and distal ileum were collected in their entirety at day 27. Digestion rates of starch and protein were determined by fitting exponential mathematical model to apparent digestibility coefficients with mean retention times in each small intestinal segment. The growth performance of birds offered maize and sorghum were comparable but those offered wheat-based diets were inferior. Phytase improved weight gain ($P<0.001$), feed intake ($P<0.001$) and feed conversion ($P<0.05$) in maize-, sorghum- and wheat- based diets, although the most pronounced improvements tended to be for maize. There were grain type-phytase interactions ($P<0.01$) for nutrient utilization (AME, N retention, AMEn) where substantial phytase responses were observed for maize but not for sorghum- and wheat-based diets. Phytase did not influence digestion rates of starch and protein ($P>0.05$), but it significantly increased disappearance rates of starch in maize-based diets ($P<0.05$). In conclusion, phytase improved weight gain and feed conversion efficiency in maize-, sorghum- and wheat-based diets with more pronounced response in maize-based diets. Moreover, phytase also significantly enhanced nutrient utilization in maize-based diets.

Abbreviations: AME, apparent metabolizable energy; AMEn, nitrogen-corrected apparent metabolizable energy; AIA, acid insoluble ash; FCR, feed conversion ratio; FI, feed intake; MRT, mean retention time; N, nitrogen; PDN, potential digestible nitrogen; PDS, potential digestible starch.

* Corresponding author. Tel.: +61 2 93511638; fax: +61 2 93511693.
E-mail address: sonia.liu@sydney.edu.au (S.Y. Liu).

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Table 1
Characteristics of maize, wheat, sorghum (as-is).

Item (g/kg)	Maize	Sorghum	Wheat
Dry matter	119	128	116
Protein	82.9	82.4	113
Calcium	0.034	0.069	0.309
Total phosphorus	2.33	2.9	2.37
Phytate phosphorus	1.74	2.4	1.77
Starch	636	614	593
Fat	33.1	34.0	16.3

1. Introduction

Phytate (*myo*-inositol hexaphosphate; IP_6) is a ubiquitous component of human foods and animal feedstuffs of plant origin. Dependent on context, phytate is considered to possess both positive and negative properties in human nutrition (Harland and Morris, 1995); whereas, the anti-nutritive properties of phytate are well recognized in pig and poultry nutrition (Selle and Ravindran, 2007, 2008). As a consequence, the inclusion of phytate-degrading enzymes in broiler diets is an increasingly routine practice to facilitate sustainable chicken-meat production.

Efficient feed conversion, which may be quantified by feed conversion ratios (FCR), is probably the most important parameter. The relationship between feed conversion efficiency and digestive dynamics was demonstrated by Batterham (1974) and Batterham and O'Neill (1978). Improvements in FCR in grower pigs following free lysine supplementation were more pronounced when diets were offered continuously (six times – daily) than on a restricted (once – daily) basis. Lysine HCl is rapidly absorbed in comparison to protein-bound amino acids, including lysine, because the latter requires prior digestion in the gut lumen. Continuous feeding may accommodate the potential imbalance between free and protein-bound lysine at sites of protein synthesis. Hence, increasing attention is being paid to the influence of digestive dynamics of starch and protein on growth performance (Weurding et al., 2003a; van den Borne et al., 2007; Drew et al., 2012; Kim et al., 2013; Liu et al., 2013a) in pigs and poultry because efficient muscle protein deposition requires synchronous availability of both glucose and the full complement of amino acids (Pelley and Goljan, 2011). Kim et al. (2013) showed that digestion rates of starch and protein from different dietary sources significantly influenced N retention in growing pigs. Usually, starch is digested more rapidly and completely than protein (Liu et al., 2013b). It is a challenge to synchronize the availability of glucose and amino acids at the sites of protein synthesis. Very few studies have explored the importance of small intestinal digestive dynamics of starch and protein in relation to feed conversion efficiency in broiler chickens.

Presently, exogenous phytase is routinely included in poultry diets as they effectively represent economical sources of phosphorus. The enzymatic dephosphorylation of phytate liberates phosphorus moieties, thereby increasing phosphorus digestibility. Phytate may form binary or ternary complexes with protein depending on the isoelectric point of protein and gut pH (Selle and Ravindran, 2007). Phytate may also influence starch digestion by directly binding starch or indirectly by complexing with starch granule-associated protein and/or inhibiting amylase activity (Oatway et al., 2001). Hence, the extra-phosphoric effects of phytase may influence starch and protein digestion in broiler chickens.

Maize, wheat and sorghum are the three commonly used grains in broiler diets. There may be variations in phytate concentrations in maize, sorghum and wheat (Selle et al., 2003). Moreover, phytate is located in the germ of maize but in the aleurone layers of sorghum and wheat (O'Dell et al., 1972; Doherty et al., 1982). Therefore, the response to phytase may differ in maize-, sorghum- and wheat-based broiler diets. The intention of this study was to determine the effects of phytase on efficiency of growth performance, nutrient utilization and digestive dynamics of starch and protein in maize-, sorghum- and wheat-based diets offered to broiler chickens with the hypothesis that phytase would improve these parameters irrespective of the type of grain on which the diets were based.

2. Materials and methods

2.1. Diet preparations

The feeding study comprised six dietary treatments with three grain varieties (wheat, sorghum and maize) without and with a *Buttiauxella* phytase produced in *Trichoderma reesei* (Axtra® PHY; Danisco Animal Nutrition) at 1000 FTU/kg. The nutritional characteristics of the three grains are documented in Table 1. The experimental diets were based 560 g/kg maize, sorghum or wheat and were formulated to be equivalent for energy density (12.54 MJ/kg) protein (205 g/kg) and amino acids. The formulated, calculated and analyzed nutrient compositions of the three diets are shown in Table 2. Acid insoluble ash (Celite™ World Minerals, Lompoc, CA, USA) was included in the diets at 20 g/kg as an inert marker to determine nutrient digestibility coefficients at four small intestinal sites. The three grains were hammer-milled through a 3.2 mm screen prior to dietary incorporation. The particle size distribution of milled grains was determined by sieving 100 g sample through 250 μm, 500 μm, 1000 μm, 1500 μm and 2000 μm screen for 5 min. The sieved material obtained, for each sieve fraction size and weighed. The patterns of particle size distribution are shown in Fig. 1. The diets were steam-pelleted through a Palmer PP330 pellet press (Palmer Milling Engineering, Griffith, NSW, Australia) at a conditioning temperature of 80 °C