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Influence of feed form and particle size on performance, nutrient utilisation, and gastrointestinal tract development and morphometry in broiler starters fed maize-based diets

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ABSTRACT

The influence of feed form and particle size on the performance, coefficient of apparent ileal digestibility (CAID) of nutrients, apparent metabolisable energy (AME) and intestinal morphology in broiler starters fed maize-based diets was examined in this study. Two feed forms (mash and pellet) and three particle sizes (fine, medium and coarse) were evaluated in a 2 × 3 factorial arrangement of treatments. Birds fed pelleted diets had higher ($P < 0.05$) weight gain and feed intake than those fed mash diets. In mash diets, fine grinding resulted in lower ($P < 0.05$) feed per unit gain compared to medium and coarse grinding, whereas, in pelleted diets, there was no effect ($P > 0.05$) of particle size. Gizzard pH was not influenced ($P > 0.05$) by particle size in mash diets, but fine grinding increased ($P < 0.05$) gizzard pH compared to medium and coarse grinding in pelleted diets. Pelleting reduced ($P < 0.05$) the CAID of nitrogen but increased ($P < 0.05$) the ileal fat digestibility. Particle size had no effect ($P > 0.05$) on CAID of starch and AME in mash diets, but in pelleted diets, pellets made from medium and coarsely ground maize showed higher ($P < 0.05$) starch digestibility. Coarse grinding resulted in higher ($P < 0.05$) AME in pelleted diets. Feeding pelleted diets reduced ($P < 0.05$) the CAID of calcium and phosphorus, but increased ($P < 0.05$) that of sodium. Medium and coarse grindings resulted in higher ($P < 0.05$) calcium digestibility than fine grinding. Feeding pelleted diets reduced ($P < 0.05$ to 0.001) the relative length of all small intestinal segments and the relative weight of pancreas, proventriculus, and gizzard. Medium and coarse grinding increased ($P < 0.05$) the gizzard weight compared to fine grinding. In both the duodenum and jejunum, birds fed pelleted diets had greater ($P < 0.05$) villus height than those fed mash diets. Goblet cell number in duodenum was higher ($P < 0.05$) in birds fed diets containing fine particles compared to those fed medium and coarse particle sizes. The crypt depth in jejunum was greater ($P < 0.05$) in birds fed pelleted diets. Overall, the present data showed that coarse grinding of maize, through enhanced gizzard development and functionality, is beneficial to nutrient and energy utilisation and growth performance in broilers fed pelleted diets.

Abbreviations: AME, apparent metabolisable energy; CAID, coefficient of apparent ileal digestibility; Ca, calcium; Cu, cupper; DM, dry matter; FI, feed intake; GIT, gastrointestinal tract; GMD, geometric mean diameter; GSD, geometric standard deviation; GE, gross energy; Mg, magnesium; Mn, manganese; N, nitrogen; NSP, non-starch polysaccharides; P, phosphorus; PP, phytate phosphorus; K, potassium; Na, sodium; Ti, titanium; Zn, zinc.

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1. Introduction

The relatively consistent and high energy value of maize has made it the widely used cereal in the poultry industry worldwide, contributing up to 65% of the metabolisable energy and 20% of the protein in typical poultry diets. It is common practice to grind cereal grains prior to incorporation into the diets. It is generally believed that a smaller particle grain size has larger surface area and might be better digested due to greater access to digestive enzymes in the gastrointestinal tract (GIT; Goodband et al., 2002). However, published data regarding the effect of particle size on broiler performance fed maize-based diets are inconsistent. Reece et al. (1985) found that the maize particle size with geometric mean diameter (GMD) of 680 vs. 1290 μm had no effect on the performance of broilers fed crumbled or pelleted diets. Lott et al. (1992) reported that increasing maize particle size from 716 to 1196 μm in a crumbled diet impaired weight gain and feed efficiency, possibly as a result of producing large particles which are not efficiently utilised by birds. Parsons et al. (2006) and Chewning et al. (2012), using maize-based mash diets, reported that increasing particle size increased broiler feed intake (FI) but decreased feed efficiency. Amerah et al. (2008) showed that coarsely-ground maize (7-mm hammer mill screen size) had positive effects on broiler performance compared with fine grinding (1-mm screen size) in pelleted diets.

Although the influence of maize particle size on growth performance in broilers has been investigated in a number of studies, information on the utilisation of nutrients and energy is limited. Moreover, the effect of particle size on nutrient utilisation is confounded by the physical form of feed (mash or pellet). Kasim and Edwards (2000) showed that coarser maize particles in mash diets improved the phytate phosphorus (PP) retention. Kilburn and Edwards (2001) reported that feed form interacted with maize particle size to affect calcium (Ca) retention, with coarse particles improving Ca retention in mash diets, but offering no advantage in pelleted diets. These researchers also reported lower PP retention, regardless of particle size, in pelleted diets than mash diets. Abdollahi et al. (2013) reported that, in maize-based diets, pelleting had no effect on the ileal digestibility of starch and nitrogen (N) but improved that of fat, Ca and phosphorus (P) compared to mash diets.

Only minimal attempts have been made to elucidate the interaction between feed form and particle size on the utilisation of minerals, other than Ca and P, in broilers fed maize-based diets. Moreover, the effects of feed form and particle size on intestinal morphology have not been evaluated and merit further investigation. The present experiment was designed to investigate the interaction between feed form (mash and pellet) and particle size (fine, medium and coarse) on the performance, coefficient of apparent ileal digestibility (CAID) of N, starch and fat, minerals, apparent metabolisable energy (AME) and small intestine morphology in broiler starters.

2. Materials and methods

2.1. Diets

The experiment utilised a completely randomised design with 2×3 factorial arrangement of treatments evaluating two feed forms (mash and pellet) and three particle sizes (fine, medium and coarse). Whole maize was obtained from a commercial supplier, and ground in a hammer mill (Bisley's Farm Machinery, Auckland, New Zealand) to pass through screen sizes of 2.0, 5.0 and 8.0 mm for fine, medium and coarse grade, respectively. A maize-soy-based diet was formulated to meet the Ross 308 strain recommendations for major nutrients for broiler starters (Ross, 2007; Table 1). The diets contained 3.0 g/kg of titanium dioxide (TiO_2, Merck KGaA, Darmstadt, Germany) as an indigestible marker for the determination of ileal nutrient digestibility. Diets were mixed in a single-screw paddle mixer (Bonser Engineering Co. Pty. Ltd., Merrylands, Australia). Following mixing, each diet was split into two equal batches. The first batch was retained as unprocessed mash. The second batch was steam-conditioned to 70 °C for 30 s and pelleted using a pellet mill (Model Orbit 15; Richard Sizer Ltd., Kingston-upon-Hull, UK) capable of manufacturing 180 kg of feed/h and equipped with a die ring with 3-mm holes and 35-mm thickness.

2.2. Birds and housing

Experimental procedures were conducted in accordance with the Massey University Animal Ethics Committee guidelines. A total of 288 day-old male broilers (Ross 308), obtained from a commercial hatchery, were individually weighed and allocated to 36 cages in electrically heated battery brooders so that the average bird weight per cage was similar. Each of the six dietary treatments was then randomly assigned to six cages, each housing eight birds. The birds were transferred to grower cages on d 12. The battery brooders and grower cages, with wire floor, were housed in an environmentally controlled room with 20 h of fluorescent illumination per day. The temperature was maintained at 31 °C on day 1, and was gradually reduced to 22 °C by 21 day of age. The experimental diets were offered *ad libitum* from 1 to 21 day and water was freely available.

Body weights and FI were recorded on a cage basis at weekly intervals throughout the 21-day trial. Mortality was recorded daily. Feed per unit gain values were corrected for the body weight of any bird that died during the course of the experiment.