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Influence of conditioning temperatures on amino acid digestibility coefficients at four small intestinal sites and their dynamics with starch and nitrogen digestion in sorghum-based broiler diets

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ABSTRACT

The influence of conditioning temperatures on apparent digestibility coefficients of amino acids at proximal jejunum, distal jejunum, proximal ileum and distal ileum were investigated in this study. Broilers were fed sorghum-based diets steam-pelleted at three conditioning temperatures (65, 80, 95 °C) from 7 to 28 days post-hatch. Digesta samples were collected at day 28 and freeze-dried and weighed for determination of amino acid digestibilities and mean retention time in each small intestinal segment. The digestion kinetics of amino acids were determined using an exponential mathematical model to relate digestion coefficients with mean retention times in each small intestinal segment. Increasing conditioning temperatures from 65 to 95 °C significantly increased apparent digestibility coefficients of phenylalanine at proximal jejunum, apparent digestibility coefficients of aspartic acid and proline at proximal ileum and apparent digestibility coefficients of arginine, lysine, aspartic acid and glycine at distal ileum. Conditioning temperatures linearly increased retention times in the distal ileum ($P < 0.05$). There were no significant differences in digestion rates of amino acids, starch and nitrogen between treatments. Nitrogen retention was positively correlated ($P < 0.05$) with amino acid digestibility coefficients at the proximal jejunum, but not at the other three small intestinal sites. Interestingly, relative gizzard weights were positively correlated with amino acid digestibility coefficients at the proximal ileum ($P < 0.05$) and distal ileum ($P < 0.05$). Starch digestion rate was positively correlated with digestion rates of 8 amino acids ($P < 0.05$). Percentage responses of amino acid digestibilities to increased conditioning temperatures were negatively correlated with their initial digestibility at 65 °C ($P < 0.001$). Increasing conditioning temperatures from 65 to 95 °C improved the average digestibility coefficients of amino acid by 29.8% at the proximal jejunum, 4.8% at the proximal ileum and 4.0% at the distal ileum. These results indicate that increasing conditioning temperatures generally enhanced amino acid digestibilities. These increases may have been generated by reversible protein denaturation that facilitated proteolysis, by heavier and more functional gizzards promoting protein digestion and, to a lesser extent, by inactivation of protease inhibitors inherent in the diet

Abbreviations: AIA, acid insoluble ash; AUC, area under the curve; CCK, cholecystokinin; DI, distal ileum; DJ, distal jejunum; MRT, mean retention time; N, nitrogen; PI, proximal ileum; PJ, proximal jejunum.

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1. Introduction

Raastad and Skrede (2003) may have been the first researchers to suggest that conditioning temperatures at which broiler diets are steam-pelleted influence growth performance and Creswell and Bedford (2006) subsequently advanced the argument that high conditioning temperatures compromise broiler performance. Diets for broiler chickens may be based on 'viscous' grains (wheat and barley) and high conditioning temperatures have been shown to solubilise non-starch polysaccharides and increase gut viscosity thereby depressing performance (Silversides and Bedford, 1999; Cowieson et al., 2005). This does not apply to 'non-viscous' grains (maize and sorghum); however, the pepsin digestibility of sorghum is highly susceptible to hydrothermal processes, in this instance 'wet-cooking', relative to other grains (Hamaker et al., 1987). The reduction in pepsin digestibility is attributed to the formation of disulphide cross-linkages, especially in β- and γ-kafirin protein fractions residing in the periphery of protein bodies, which are located in sorghum endosperm. Steam-pelleting is a hydrothermal process and at 90 °C it has been shown to reduce protein solubility (Selle et al., 2012). Thus, sorghum is a good candidate grain for assessments of the impact of steam-pelleting conditioning temperatures on broiler performance because of its vulnerability to 'moist-heat' (Selle et al., 2010).

Selle et al. (2013) investigated the effects of steam-pelleting red sorghum-based broiler diets at conditioning temperatures of 65, 80 and 95 °C on growth performance and apparent digestibility coefficients of starch and nitrogen in broiler chickens from 7 to 28 days post-hatch. Increasing conditioning temperatures reduced protein solubility of diets from 501 g/kg in the unprocessed diet to 399, 353 and 316 g/kg in the processed diets, respectively. Increasing conditioning temperatures also linearly reduced dietary concentrations of free sulphydryl groups from 0.88 μmoles/g to 0.84, 0.85 and 0.75 μmoles/g, respectively. Efficiency of feed conversion was linearly depressed by elevating conditioning temperatures ($r = 0.505$; $P < 0.05$) and there was a trend for weight gains to be compromised ($r = -0.396$; $P < 0.10$). Based on *in vitro* results of protein solubility and concentrations of free sulphydryl groups, it was most likely that increasing conditioning temperature would depress nitrogen digestibility. However, Selle et al. (2013) reported that elevating conditioning temperatures influenced nitrogen digestibility coefficients in a quadratic manner in the distal jejunum ($r = 0.675$; $P < 0.01$) and distal ileum ($r = 0.543$; $P < 0.05$) to significant extents. In the distal jejunum, elevating conditioning temperatures from 65 to 80 °C numerically depressed nitrogen digestibility coefficients from 0.565 to 0.538 but the further elevation to 95 °C significantly increased nitrogen digestibility from 0.538 to 0.638. A similar pattern was observed in the distal ileum where the respective nitrogen digestibility coefficients were 0.720, 0.719 and 0.761 and the linear effect of conditioning temperatures was also significant ($r = 0.464$; $P < 0.05$).

According to Abdollahi et al. (2013), very few experiments have been conducted to assess protein digestibility following feed processing. It is of interest that increasing conditioning temperatures, on one hand, decreased *in vitro* protein solubility and concentration of free sulphydryl groups; on the other hand, linearly enhanced nitrogen digestibility coefficients in the distal ileum. To clarify the situation, the intention of the present study was to examine the influence of conditioning temperatures on apparent amino acid digestibility coefficients at four small intestinal sites and their rates of digestion in broilers at 28 days post-hatch. The hypothesis of the present study was that increasing conditioning temperatures would depress apparent digestibility coefficients of amino acids in small intestine because of the reduction in protein solubility with increasing conditioning temperatures. This may be the first study to assess the influence of steam-pelleting conditioning temperatures on amino acid digestion along the small intestine in diets for broiler chickens.

2. Materials and methods

2.1. Diets and animal husbandry

This feeding study complied with the guidelines (N00/6-2010/3/5344) approved by the Animal Ethics Committee of the University of Sydney. The materials and methods adopted in the present study were generally similar to those outlined by Selle et al. (2013). A diet based on sorghum, soybean meal and canola meal was formulated to meet Ross 308 nutrient recommendations as shown in Table 1. The sorghum was hammer-milled (screen size 3.2 mm) and mixed with the balance of feed ingredients. Then, the mash diet was divided into three equal quantities and steam pelleted through a Palmer PP300 pellet press (Palmer Milling Engineering, Griffith, NSW, Australia), which has a capacity of 3 tonnes per hour. The diets were subjected to three conditioning temperatures (65, 80 and 95 °C) by adjusting the steam flow rate into the conditioner which had a residence time of 7 s. The conditioning temperatures were continuously measured by a thermal probe at the exit of the conditioner. The diets then entered the pellet press with die dimensions of 4 mm in diameter and 45 mm in length. Each of the three dietary treatments was offered to seven replicate cages (six birds per cage) or a total 126 male Ross 308 chicks from 7 to 28 days post-hatch.

Day-old male Ross 308 chicks were offered a proprietary starter diet for the first week. They were then identified (wing bands), weighed and allocated into bioassay cages on the basis of bodyweight in an environmentally controlled facility. Birds had unlimited access to feed and water under a 23 h/1 h light/dark regime from 7 to 28 days post-hatch. An initial room temperature of 32 ± 1 °C was maintained for the first week, gradually decreased to 22 ± 1 °C by the end of the third week and maintained at the same temperature until the end of the feeding study.