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Review

Implications of sorghum in broiler chicken nutrition

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ABSTRACT

Sorghum-based diets have been associated with inconsistent, and even sub-optimal, growth performance of broiler chickens. Sorghum is unique in that it contains kafirin, phytate and may contain condensed tannin; these factors can negatively influence the nutritive properties of sorghum. Both phytate and tannin have the capacity to complex proteins in the gut and depress protein digestibility and intestinal uptakes of dietary and endogenous amino acids (AA). A substantial proportion of sorghum protein is composed of kafirin, which is relatively poorly digested and contains a paucity of lysine (lys). Therefore, as kafirin proportions of sorghum protein increase, digestibility of AA and lys concentrations decline. Because of variable AA concentrations in sorghum protein, the accuracy with which intended dietary levels of AA are met in formulating sorghum-based diets may not be precise. Kafirin is also associated with harder grain textures and higher starch gelatinisation temperatures and the digestibility of starch in sorghum is generally inferior to other grains. The particle size and method of grinding sorghum influences broiler performance but the optimal particle size appears to be dependent on grain texture. Sorghum is vulnerable to 'moist-heat' because it induces disulphide cross-linkages in β- and γ-kafirin located in the periphery of protein bodies that represents a barrier to the more digestible, centrally located α-kafirin component. Starch granules are intimately associated with protein bodies and the protein matrix in sorghum endosperm and starch digestibility is also compromised by the formation of disulphide cross-linkages, which impede starch gelatinisation and enzymic degradation. This raises the possibility that steam-pelleting sorghum-based diets at high temperatures may constitute sufficient 'moist-heat' to compromise nutrient utilisation. The identification of the most appropriate processing methods of sorghum-based diets should prove advantageous and inclusion of exogenous proteases with the capacity to degrade kafirin may hold promise. In low-tannin, phytase-supplemented, sorghum-based diets the more important causes of inconsistent broiler performance may be the kafirin content, variable concentrations and digestibilities of AA and grain texture coupled with inappropriate processing methods.

Abbreviations: AA, amino acid; AID, apparent ileal digestibility; AME, apparent metabolisable energy; Arg, arginine; Cys, cystine; DM, dry matter; FTU, phytase units; His, histidine; HCl, hydrochloric acid; Kg, kilogram; MJ, Lys, lysine, megajoule; N, Met, Methionine, nitrogen; Na, sodium; NaH_2CO_3, sodium bicarbonate; NSP, non-starch polysaccharides; P, phosphorus; Phytate-P, phytate bound-phosphorus; SKCS, single kernel characterisation system; TID, true ileal digestibility; TME, true metabolisable energy; WHC, water holding capacity; μm, micron.

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Contents

1. Introduction

The genesis of this review was concerns relating to the growth performance and nutrient utilisation of broiler chickens offered sorghum-based diets in Australia. Broiler diets are usually based on wheat, sorghum or wheat-sorghum blends with sorghum constituting perhaps one-third of the cereal grain base. However, during the last decade, empirical evidence has suggested that performance of broilers offered sorghum-based diets has declined relative to wheat. Indeed, sorghum has been associated with depressed feed conversion efficiency and variable breast-meat yields in comparison to wheat-based broiler diets (Robertson and Perez-Maldonado, 2006) and both parameters impact on the profitability of chicken-meat production.

Sorghum can be produced economically in relatively hot and dry climates; with global warming and the declining global grain inventory, it is imperative that sorghum is fully utilised as a food and feed resource for humans and animals. Given the perceived association between sorghum and sub-optimal broiler performance, the purpose of this paper is to consider the anti-nutritive properties of kafirin, phytate and tannin and the conditions under which sorghum-based diets are processed in order to identify strategies that may enhance the value of sorghum in chicken-meat production.

Grain sorghum (*Sorghum bicolor* L. Moench) is the world's fifth cereal crop with an annual production in the order of 56 million tonnes (Taylor and Shewry, 2006). Sorghum is used for both human consumption, particularly in Africa and India, and animal production. However, one limitation of sorghum is the poor nutritional quality of its protein, which has been attributed to low solubility, deficiencies in essential AA including lys and interactions with tannin (Sastry et al., 1986). A second limiting factor is that sorghum generally has the lowest starch digestibility amongst cereal grains, which has been attributed to the resistant, peripheral endosperm layer encasing starch granules (Rooney and Pflugfelder, 1986).

Harms et al. (1958) evaluated sorghum as an alternative feedstuff to maize in poultry diets; nevertheless, 50 years later, sorghum is still not commonly included into diets for broiler chickens on a global basis. In comparisons of sorghum with wheat, it is relevant that wheat-based diets invariably contain xylanase-based enzyme preparations. These enzymes degrade non-starch polysaccharides (NSP) and enhance growth performance by increasing cell wall permeability and reducing gut viscosity. Sorghum, being a 'non-viscous' grain, is not similarly advantaged, which was recently demonstrated by Shakouri et al. (2009). This may contribute to the perception that sorghum is inferior to wheat in practice.

As summarised by Black et al. (2005, 2006), the energy density of sorghum (15.2–16.5 MJ kg^{-1} DM) in broilers both exceeds and is more consistent than wheat (12.4–15.6 MJ kg^{-1} DM). However, in Australian feeding studies, broilers offered wheat-based diets outperformed their sorghum counterparts in weight gain and feed efficiency. The grains were 'coarsely-milled' but there is evidence to suggest that the performance differences may have been less pronounced had both wheat and sorghum been ground more finely (Mikkelsen et al., 2008). Black et al. (2005, 2006) proposed that the difference between wheat and sorghum were due to AA deficiencies because of the lower concentration and digestibility of protein in sorghum. These researchers also suggested that the release rates of energy and protein from sorghum may not be synchronous, which could result in catabolism of AA following absorption rather than efficient incorporation into protein, including breast-meat.

One of the more remarkable outcomes of the Perez-Maldonado and Rodrigues (2007) project was the difference in apparent ileal digestibility (AID) of AA between sorghums harvests. As shown in Table 1, the 2005 crop had an 18% higher average AID coefficient (0.768 *versus* 0.652) for 12 AA. The results from the 2005 harvest are very similar to those recorded