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Preliminary assessment of including a reducing agent (sodium metabisulphite) in 'all-sorghum' diets for broiler chickens

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ABSTRACT

The preliminary assessment was designed to determine appropriate inclusion levels of the reducing agent, sodium metabisulphite (SMBS), in 'all-sorghum' broiler diets. Dietary SMBS inclusion levels of 0, 1.25, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 g kg^{-1} were investigated with corresponding reductions (923–908 g kg^{-1}) in dietary sorghum concentrations. *In vitro* evaluations included the determination of concentrations of free sulphydryl groups and disulphide bonds in all-sorghum diets. *In vivo* parameters included growth performance (14–21 days post-hatch), nutrient utilisation and apparent nitrogen (N) digestibility coefficients in four small intestinal sites in broilers at 21 days post-hatch. In addition, the effect of 5.0 g kg^{-1} SMBS on starch digestibility coefficients and sites of starch disappearance along the small intestine were determined. The reducing agent significantly increased free sulphydryl group and decreased disulphide bond concentrations. SMBS significantly depressed feed intakes at 5.0 g kg^{-1} and at higher inclusion levels and there was a linear reduction in feed intakes ($r = -0.783$; $P<0.001$). SMBS had cubic effects on weight gain ($r = 0.588$; $P<0.001$) and feed conversion ratios ($r = 0.500$; $P<0.01$). It may be deduced from the relevant regression equations that the optimum SMBS inclusions are 2.47 g kg^{-1} for weight gains and 2.14 g kg^{-1} for feed conversion ratios. SMBS significantly increased apparent metabolisable energy (AME) at inclusions of 1.25, 5.0, 10.0 and 12.5 g kg^{-1}. At the lowest inclusion of 1.25 g kg^{-1} SMBS increased AME by 0.39 MJ (14.80 versus 14.41 MJ kg^{-1}; $P<0.001$) and the most profound response of 0.56 MJ (14.97 versus 14.41 MJ kg^{-1}; $P<0.001$) was observed at 10.0 g kg^{-1}. SMBS linearly increased N retention ($r = 0.592$; $P<0.001$). In the distal jejunum, SMBS significantly depressed N digestibility coefficients at inclusions of 1.25, 2.5, 10.0, and 15.0 g kg^{-1} and in the distal ileum with SMBS inclusions of 1.25, 10.0 and 15.0 g kg^{-1}. SMBS did not influence N digestibility in the proximal jejunum ($P>0.60$) and proximal ileum ($P>0.55$). At 5.0 g kg^{-1}, SMBS increased starch digestibility coefficients by 3.76% in the proximal ileum (0.966 versus 0.931; $P<0.01$) and 3.27% in the distal ileum (0.980 versus 0.949; $P<0.001$). Also, SMBS significantly decreased the quantity of starch disappearance in the proximal jejunum, or abruptly digestible starch, by 16.3% (245.6 versus 293.4 g bird^{-1}; $P<0.01$). It is concluded that birds are able to tolerate dietary inclusions of SMBS approaching 5.0 g kg^{-1} and that SMBS has the capacity to enhance energy utilisation of sorghum-based diets by broiler chickens. Consideration is given to the mechanisms whereby SMBS might enhance energy utilisation.

Abbreviations: AIA, acid insoluble ash; AME, apparent metabolisable energy; AMEn, nitrogen-corrected apparent metabolisable energy; DI, distal ileum; GE, gross energy; MJ, mega-joule; N, nitrogen; Na, sodium; NBD-Cl, 7-chloro-4-nitrobenzo-2-oxa-1,3-diazole; NIRS, near infra red spectroscopy; DM, dry matter; PJ, proximal jejunum; S, sulphur; —SH, free sulphydryl group; —S—S—, disulphide bond; SMBS, sodium metabisulphite.

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1. Introduction

The protein quality of grain sorghum may be inferior to alternative cereals and kafirin is the dominant protein in sorghum (Duodu et al., 2003; Selle et al., 2010; Selle, 2011). Kafirin is located in protein bodies that are embedded, in close proximity with starch granules, in the glutelin protein matrix of sorghum endosperm. The central core of protein bodies is composed of α-kafirin while the peripheral layers are comprised of β-kafirin and γ-kafirin (De Mesa-Stonestreet et al., 2010). The presence of disulphide cross-linkages in kafirin, especially the relatively cystine rich β- and γ-kafirin fractions, is thought to limit the nutritional value of sorghum as a feedstuff for broiler chickens. Pivotally, Taylor (2005) considered disulphide cross-linkages (or disulphide bonds) in the periphery of kafirin protein bodies are an important limiting factor on the digestibility of both protein and starch in sorghum.

The presence of disulphide cross-linkages in β- and γ-kafirin is believed to impede the digestion of the central α-kafirin core of protein bodies (Duodu et al., 2003; Belton, 2004). The formation of disulphide cross-linkages is amplified by hydrothermal processes such as 'wet-cooking'. Steam-pelleting is a hydrothermal process and steam-pelleting three sorghum-based broiler diets at a 90 °C conditioning temperature reduced protein solubility from 56.3% to 38.3% (Selle et al., 2012). Moreover, this reduction in protein solubility was negatively correlated ($r = -0.518$; $P<0.001$) with disulphide bond concentrations indicating that disulphide cross-linkages induced by the steam-pelleting were partially responsible for the reduction in protein solubility.

Hamaker et al. (1987) reported that *in vitro* pepsin digestibility of sorghum was reduced by 30.3% following wet-cooking (boiling water-bath for 20 min); whereas, pepsin digestibility of barley, maize, rice and wheat was reduced by an average of only 8.8%. However, the reducing agent 2-mercaptoethanol increased pepsin digestibility of raw and wet-cooked sorghum by an average of 25.9% (0.881 versus 0.700) and also increased trypsin and chymotrypsin digestibility. In this study, sodium bisulphite was more effective than 2-mercaptoethanol in enhancing the pepsin digestibility of sorghum. Similarly, both Rom et al. (1992) and Oria et al. (1995) found that sodium bisulphite improved pepsin digestibility of cooked and uncooked sorghum flour. These increases in protein digestibility were attributed to the reduction of disulphide bonds mainly in the cystine-rich β- and γ-kafirin fractions of sorghum. Zhang and Hamaker (1998) reported that sodium metabisulphite increased *in vitro* starch digestibility by an average of 12.9% in four sorghums, which suggests that kafirin may impede starch digestion. Choi et al. (2008) found that sodium bisulphite diminished the scale of the protein matrix surrounding starch granules in sorghum endosperm by laser scanning microscopy, which could facilitate starch digestion. It seems generally accepted that proteins in sorghum endosperm (kafirin especially and glutelin) can interfere with starch digestion by biophysical and biochemical interactions (Wong et al., 2009) but support for this concept is not unanimous (Gidley et al., 2011).

Sulphite reducing agents include sodium sulphite (Na_2SO_3), sodium bisulphite ($NaHSO_3$) and sodium metabisulphite ($Na_2S_2O_5$). In practice, sodium sulphite has been used in the production of dry-extruded, whole soybeans because it enhances protein solubility and facilitates destruction of trypsin inhibitors (Friedman and Gumbmann, 1986). Several feeding studies with diets containing dry-extruded whole soybeans ('full-fat soy'), without or with sodium sulphite, have shown advantages for the reducing agent in growth performance and nutrient utilisation in weaner pigs (Kim and Kim, 1997; Kim et al., 2000; Piao et al., 2000; Burnham et al., 2000). Also, Herkelman et al. (1991) investigated the addition of 10 g kg^{-1} sodium metabisulphite to whole soybeans heated at 121 °C for 0, 10, 20 and 40 min that were incorporated into maize-based broiler diets. The diets contained 3.9 g kg^{-1} sodium metabisulphite and the reducing agent improved weight gain in broiler chickens by an average of 4.4% and feed efficiency by 3.2%.

A project was funded to investigate the possibility that inclusions sodium metabisulphite (SMBS) in sorghum-based broiler diets is beneficial pursuant to the reduction of disulphide cross-linkages. In this preliminary evaluation sodium metabisulphite was included in 'all-sorghum' mash diets at graded levels ranging from 0 to 15 g kg^{-1}. The primary objective was to identify appropriate SMBS inclusion levels in diets for broiler chickens in terms of bioefficacy and economic feasibility.

2. Materials and methods

The red sorghum used in this feeding study contained 766.4 starch, 78.6 protein, and 43.4 g kg^{-1} fat on a dry matter basis. A pigmented testa was not detected in this sorghum by the Clorox bleach test (Waniska et al., 1992), which indicates that it did not contain condensed tannin. From an NIR aminogram, the concentration of cystine was 1.8 g kg^{-1} and concentrations of leucine, arginine, histidine and lysine were 10.9, 4.0, 2.2 and 2.4 g kg^{-1}, respectively. The grain component was incorporated into eight dietary treatments with concentrations ranging from 908 to 923 g kg^{-1} in the 'all-sorghum' broiler diets to accommodate SMBS inclusions of 0, 1.25, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 g kg^{-1} as shown in Table 1. On average, the diets contained 702.3 starch, 72.0 protein and 59.8 g kg^{-1} fat, which approximately correspond to an energy density of 14.9 MJ kg^{-1} of which 11.7 MJ is from starch, 2.1 MJ from fat and 1.1 MJ is derived from protein.

A proprietary starter ration was initially fed to a total of 288 male Ross 308 chicks, with unlimited access to feed and water, under a '23 hours-on' lighting regime in an environmentally controlled facility. At 14-days birds were individually identified (wing-bands) and weighed and allocated into 48 cages on the basis of body-weights. Each of the eight dietary treatments was offered to six replicate cages (6 birds per cage) from 14 to 21 days post-hatch. Feed intakes were recorded and the birds were re-weighed at 21-days to determine growth rates, feed intakes and feed conversion ratios. The incidence of dead or culled birds was recorded daily and their body weights used to adjust feed conversion ratio calculations.