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Sodium metabisulphite enhances energy utilisation in broiler chickens offered sorghum-based diets with five different grain varieties

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ABSTRACT

The reducing agent, sodium metabisulphite, was included in sorghum-based broiler diets at 0.00, 1.75 and 3.50 g/kg from 7 to 28 days post-hatch. In Experiment 1 two sorghum varieties (MP, JM) were evaluated and three sorghums (HP, Tiger, HFQ) in Experiment 2; the two experiments were separate but very similar. The five sorghums were extensively characterised and all five diets contained 620 g/kg sorghum and were formulated to be nutritionally equivalent. In both studies, each dietary treatment was offered to six replicate cages (6 birds per cage) for a combined total of 540 male Ross 308 chicks. The effects of sodium metabisulphite on growth performance, nutrient utilisation, apparent digestibility coefficients of starch and protein (N) and starch and protein digestive dynamics were determined. Sodium metabisulphite significantly enhanced energy utilisation. Across both experiments, 3.50 g/kg sodium metabisulphite increased AME on a dry matter basis by 0.34 MJ from an average of 11.97–12.31 MJ/kg and similarly increased N-corrected AME by 0.42 MJ from 11.43 to 11.85 MJ/kg. Sorghum variety by sodium metabisulphite interactions were not observed for energy utilisation (AME, ME:GE ratios, AMEn) parameters but this was not always the case for other parameters, which indicates that diverse sorghums respond differently to sodium metabisulphite. Consideration is given to the basis for these variable responses to sodium metabisulphite because of its dual modes of action (reducing disulphide cross-linkages, depolymerising starch polysaccharides) and the possible relevance of RVA starch pasting profiles of grain sorghum to feed grain quality.

Abbreviations: AIA, acid insoluble ash; AME, apparent metabolisable energy; AMEn, nitrogen-corrected apparent metabolisable energy; cP, centipoise; DJ, distal jejunum; DI, distal ileum; FCR, feed conversion ratio; ME:GE, metabolisable: gross energy ratios; N, nitrogen; PJ, proximal jejunum; PI, proximal ileum; RVA, rapid visco analysis.

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1. Introduction

Sorghum is a problematic feed grain for chicken-meat production which has been considered in two reviews (Selle et al., 2010; Liu et al., 2015). A distinctive feature of sorghum is kafirin, the dominant protein fraction. Kafirin classically makes up 55% of sorghum protein and is present as discrete protein bodies located in the sorghum endosperm with a central core of a-kafirin enveloped by peripheral layers of β- and γ-kafirin. Kafirin protein bodies and starch granules are embedded in the glutelin protein matrix of sorghum endosperm. Both β- and γ-kafirin are relatively rich in cystine and disulphide cross-linkages. As a consequence of disulphide cross-linkages and protein polymerisation, kafirin can form resilient sheet-like structures within sorghum endosperm with the potential to impede starch gelatinisation and to deny amylase access to its substrate (De Mesa-Stonestreet et al., 2010).

A range of sulphite reducing agents, including sodium metabisulphite ($Na_2S_2O_5$), have the capacity to cleave disulphide cross-linkages according to the following Cecil and Wake (1962) equation: $RS^*SR + SO_3^{2-} \Leftrightarrow RS^{1-} + RS^*SO_3^{1-}$. On the basis of *in vitro* data, reducing agents have the capacity to enhance both protein (Hamaker et al., 1987; Rom et al., 1992; Oria et al., 1995) and starch (Zhang and Hamaker, 1998) digestibility of grain sorghum. Given this potential, eight sodium metabisulphite inclusion levels, ranging from 0.0 to 15.0 g/kg, were previously assessed in 'all-sorghum' diets (Selle et al., 2013). Inclusions of 1.25, 5.0, 10.0 and 12.5 g/kg sodium metabisulphite significantly increased AME by 0.39, 0.53, 0.56 and 0.32 MJ, respectively, in a quadratic manner and 5.0 g/kg sodium metabisulphite (the only level assessed) significantly increased proximal jejunal and distal ileal starch digestibility coefficients. Finally, sodium metabisulphite linearly increased free sulphydryl groups and linearly decreased disulphide bonds in the 'all-sorghum' diets.

Sodium metabisulphite (six inclusions from 1.50 to 5.25 g/kg) was subsequently evaluated in conventional, steam-pelleted (84 °C) sorghum-based broiler diets. As reported by Selle et al. (2014), sodium metabisulphite again linearly increased free sulphydryl groups and decreased disulphide bonds to significant extents and, notably, linearly increased protein solubility of the diets from 34.8% to >60.0%. Sodium metabisulphite improved FCR in a linear manner and every positive inclusion level significantly increased energy utilisation (AME and AMEn).

Clearly, the status of sodium metabisulphite as a reducing agent was confirmed by these stiudies. However, sulphite reducing agents also have the capacity to depolymerise starch polysaccharides via oxidative-reductive reactions (Paterson et al., 1996, 1997). Therefore, the impact of sodium metabisulphite on starch pasting properties of sorghum-based diets was determined by rapid visco-analysis (RVA). Liu et al. (2014) reported that sodium metabisulphite linearly reduced peak, holding, final and setback RVA viscosities to significant extents, which was attributed to starch depolymerisation. Interestingly, in the Liu et al. (2014) study, sodium metabisulphite reduced rapidly digestible starch but increased slowly digestible starch and it was thought that this shift in starch digestive dynamics in favour of slowly digestible starch may have contributed to the FCR improvements.

A further evaluation of sodium metabisulphite in conventional sorghum–based broiler diets was completed without and with exogenous phytase and it was anticipated that this study would confirm the previous findings. However, Truong et al. (2015a) reported that 1.75 g/kg sodium metabisulphite numerically reduced AME by 0.42 MJ and AMEn by 0.37 MJ and tended to increase rapidly digestible starch. Predictably, these contradictory outcomes prompted additional evaluations of sodium metabisulphite in sorghum–based broiler diets in an attempt to appreciate the potential reducing agents may have in this and other contexts. Thus this paper investigates the impacts of 1.75 and 3.50 g/kg sodium metabisulphite inclusions in broiler diets based on five sorghum grain varieties on bird performance in two separate, but similar, feeding studies.

2. Materials and methods

Five grain sorghum varieties were used in the two experiments to evaluate the impacts of sodium metabisulphite on broiler growth performance and nutrient utilisation. As outlined in Table 1, MP and JM sorghums were used in Experiment 1 and HP, Tiger and HFQ sorghums were used in Experiment 2. White HFQ sorghum was imported from Kansas, USA which meant that HFQ had to be ground (4.0 mm hammer-mill screen) prior to being shipped to Australia to meet quarantine requirements. The five sorghums were extensively characterised and concentrations of protein, kafirin, total P, phytate-P, grain texture, AusScan data and RVA starch pasting profiles are shown in Table 2. Kafirin was quantified by analytical procedures adapted from Wallace et al. (1990) and Hamaker et al. (1995) and the amino acid profiles of MP and HP sorghums appear in Table 3. Concentrations of total phenolic compounds, polyphenols, free, conjugated and bound phenolic acids in

Table 1
Background information for the five grain sorghum varieties used in Experiment 1 (MP, JM) and Experiment 2 (HP, Tiger, HFQ).

Sorghum	Harvest	Growing location	Colour	Pigmented testa[a]
MP	2013	Liverpool Plains, NSW	Red	Negative
JM	2013	Not known	Red	Negative
HP	2013	Liverpool Plains, NSW	Red	Negative
Tiger	2013	Murrumbidgee Irrigation Area, NSW	Red	Negative
HFQ	2013	Kansas, USA	White	Negative

[a] Pigmented testas were not detected by the Clorox bleach test, which indicates that the sorghums are Type I and do not contain condensed tannin.