Industry Summary

Survey and review of grain sorghum in chicken meat production

PRJ-010489
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Summary

Feed grains, such as wheat and sorghum, are included in poultry and livestock diets to provide energy from the digestion of starch. Although wheat is the dominant feed grain for poultry in Australia, it is expected that approximately 400,000 tonnes of sorghum will be required, annually, as feed grain for meat chickens. The purpose of this review was to provide a comprehensive analysis of sorghum as a feed grain for meat chicken production in Australia.

Meat chickens are unable to derive energy from the digestion of starch in sorghum-based diets to the fullest extent. This is due to the presence of kafirin, phenolic compounds and phytate in grain sorghum where kafirin is the dominant protein. Definitive, negative associations have been identified between the percentage of kafirin present in a sorghum variety and the lack of energy utilisation by meat chickens. White sorghum varieties contain less phenolic compounds than red sorghums, which is almost certainly advantageous. Fortunately, the addition of phytase to chicken feed can aid the digestion of sorghum starch, and the efficiency of phytase should be improved when there are lower concentrations of kafirin and phenolic compounds in sorghum-based diets.

In Australia, the proportions of kafirin protein in sorghum may be increasing as a result of agricultural practices, which has created a fundamental challenge to chicken meat production that relies on sorghum-based diets. If the trend towards higher kafirin proportions could be reversed, then the value of sorghum as a feed grain for chicken meat production can be improved through the increase of starch digestion and energy utilisation.

Background

Approximately 56% of Australian sorghum crops are used as a feed grain for poultry, pigs and feedlot cattle, however, chicken meat production generates the greatest demand (Selle et al., 2017). Hughes and Brook (2005) suggested that meat chickens fed sorghum-based diets have a decrease in feed-conversion efficiency and productivity,

which generated a series of investigations supported by AgriFutures Australia (formerly, RIRDC) to identify the causal factors. The Bryden et al. (2009) review of the nutritive value of sorghum for meat chickens was one of the first initiatives taken to address the issue, which was followed by a second review in 2010 by Selle et al. (2010a).

A series of three research projects investigated the limiting factors of sorghum as a feed grain for chickens (publications listed in Appendix 1; Selle et al., 2013; Liu et al., 2013, 2015), which culminated in a "Sorghum Summit" in March 2017. This current project supports that series of research by providing an update of the literature and incorporating the perspectives of relevant stakeholders (Selle et al., 2017).


A Luke Witt, @alukewitt instagram

"Sorghum is one of the really indispensable crops required for the survival of humankind." Jack R. Harlan, 1971. American botanist, agronomist and campaigner for the conservation of crop plant biodiversity.

Sorghum and starch digestion

Energy in feed grains is primarily derived from their starch component, and the core problem with sorghum as a feed grain for chicken meat production is the inability for chickens to completely digest the starch, which compromises energy utilisation. Further problems include, modest responses to exogenous feed enzymes, sub-standard pellet quality and a poor amino acid profile. However, it is believed that if the starch digestibility issue was rectified, the associated problems would also be resolved.

The predicted glycaemic index (the rate of starch digestion and glucose absorption) of sorghum is substantially less than that of other feed grains, as shown in Figure 1. The efficiency of energy utilisation is expressed as ME:GE ratios, or the apparent metabolisable energy (AME) determined in chickens divided by the gross energy (GE) of the diet. The average ME:GE ratio of meat chickens' sorghum- based diets (0.723) is less than those of maize (0.788) and wheat (0.762) based diets by 8.99% and 3.41%, respectively (Figure 2).

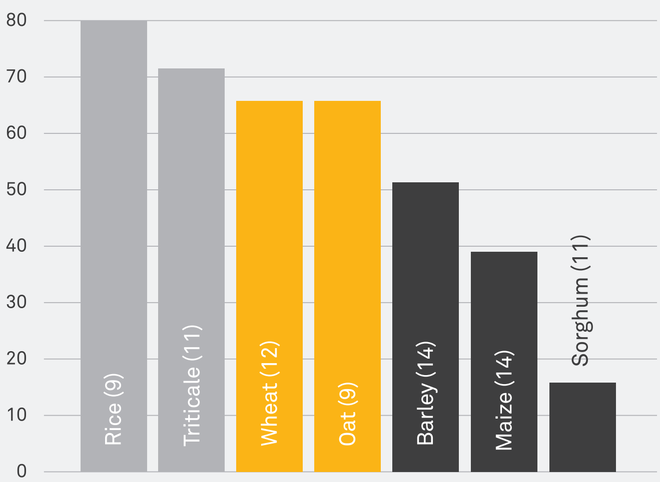

Figure 1
Predicted glycaemic indices of unprocessed food/feed grains with the number of samples tested in parentheses (adapted from Giuberti et al. 2012).

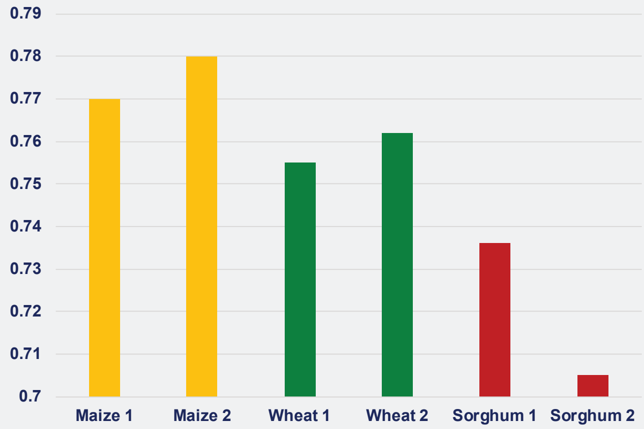

Figure 2
A comparison of ME:GE ratios in broiler chicks (25 to 27 days post-hatch) offered nutritionally equivalent diets based on three different feed grains.

Limiting factors of sorghum as a feed grain for chickens

Kafirin

Selle et al. (2010a) determined that kafirin is the dominant protein fraction in sorghum, and both kafirin and starch are embedded in the protein matrix of the sorghum endosperm. Selle et al. (2017) presented evidence that the total kafirin concentration of sorghum-based diets have negative impacts on energy utilisation in chickens. This association was clearly demonstrated in research conducted by Truong et al. (2015), which found that the inferiority of sorghum-based diets was attributed to the higher dietary concentration of kafirin, especially in relation to energy utilisation.

The precise mechanism of how kafirin compromises energy utilisation in feed has yet to be identified, although it is thought that kafirin partially prevents swelling of starch granules and starch gelatinisation, which subsequently impedes the breakdown of starch.

Phenolic compounds

Condensed tannin is an anti-nutritive polyphenolic compound and has been considered a contributing factor of poor starch digestibility in sorghum. However, this is not the case for Australian sorghum crops (Khoddami et al., 2015) and other phenolic compounds should be considered (Taylor, 2005; Barros et al., 2012; Lemlioglu-Austin et al,. 2012).

Liu et al. (2016) found that there was a significant, negative correlation between total phenolic compounds and ME:GE ratios, AME and starch disappearance. In addition, total phenolic compounds tended to be negatively correlated with weight gain and positively correlated with feed conversion ratio (FCR) in meat chickens. The negative correlation with starch disappearance rates are noteworthy, as they imply that phenolic compounds are impeding starch digestion, glucose absorption and, consequently, energy utilisation in poultry.

Axiomatically, white sorghums will contain less polyphenols than red sorghums, and analysis of a limited number of samples determined that white sorghums also contain less phenolic acids. While speculative, the superiority of white sorghums as a poultry feed grain may simply be attributed to lesser concentrations of phenolic compounds.

Phytate

There are significant, negative correlations between sorghum phytate concentrations, ME:GE ratios and starch disappearance rates in chickens offered sorghum-based diets (Liu et al., 2016). This suggests that phytate can have a negative influence on starch absorption and energy utilisation, however, polyphenols and phytate have the capacity to reduce in vitro starch digestion rates (Thompson and Yoon, 1984). This raises the possibility that phenolic compounds and phytate in tandem are compromising starch digestion and glucose absorption in meat chickens offered sorghum-based diets.

Several research studies have evaluated the effects of feed enzyme additions to sorghum-based meat chicken diets (Selle et al., 1999, 2010b, 2012; Liu et al., 2014). Overall, it was concluded that phytase responses in sorghum-based diets are muted in comparison to maize- or wheat-based diets, which was very evident in the Liu et al. (2014) study. While speculative, it seems likely that the reason for the subdued response is that phytase simply cannot address the anti-nutritive properties of kafirin and phenolic compounds in sorghum. If so, it would be expected that phytase responses would be more robust in sorghum-based meat chicken diets that have lower concentrations of both kafirin and phenolic compounds.

Enhancing the value of sorghum

Leucine is the dominant essential amino acid in kafirin, and it is concerning that Australian sorghums surveyed in 1998, 2009 and 2016 had a linear increase ($r = 0.721$; $p < 0.001$) in leucine concentrations (Selle et al., 2017). This suggests that kafirin, as a proportion of sorghum protein, has been increasing in Australian sorghums over the past two decades. If so, this may be an inadvertent outcome of sorghum selection programs that have targeted red sorghums with relatively dense or corneous endosperm, in a quest to enhance grain weathering resistance (Henzell, 1992). It would be expected that selecting sorghums with hard, corneous endosperms would result in higher kafirin concentrations, as positive relationships between kafirin content and grain hardness have been demonstrated in sorghum (Mazhar and Chandrashekar 1995).

The value of sorghum as a feed grain for chicken meat production would be enhanced through the improvement of starch digestion and energy utilisation, which could be achieved by a reduction in kafirin proportions of feed. It is also expected that responses to the inclusion of phytase feed enzymes in sorghum-based diets would become more robust. Further, sorghums with less kafirin and phenolics should have lower starch gelatinisation temperatures, which will result in better pellet quality.

Conclusion

It is highly likely that 'low kafirin sorghums' will improve the FCR and performance of meat chickens in Australia and it is likely that sorghums selected for softer textures would contain less kafirin.

The value of sorghum as a feed grain for chicken meat production can be improved. This could be achieved through the development of sorghum varieties with low, or altered, kafirin concentrations and low phenolic concentrations. The pivotal issue may then be whether the poultry integrators and feed-mills are prepared to pay premiums for enhanced quality sorghums to encourage use by farmers.

Related research

- PRJ-010216: Formulating broiler diets based on protein and starch digestive dynamics
- PRJ-003810: Steam pelleting temperature of sorghum-based broiler diets
- PRJ-007639: Evaluation of sodium bisulphite in sorghum-based broiler diets
- PRJ-008695: The factors influencing sorghum starch digestibility in broiler chickens

Further reading

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Appendix 1

Sorghum orientated research papers published by the Poultry Research Foundation

PRJ-003810: Steam-pelleting temperature of sorghum-based broiler diets

Khoddami A, Truong HH, Liu SY, Roberts TH, Selle PH (2015) Concentrations of specific phenolic compounds in six red sorghums influence nutrient utilisation in broilers. Animal Feed Science and Technology 210, 190-199.

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PRJ-007639: Evaluation of sodium bisulphite in sorghum-based broiler diets

Liu SY, Selle PH, Khoddami A, Roberts TH, Cowiesona AJ (2014) Graded inclusions of sodium metabisulphite in sorghum-based diets: II. Modification of starch pasting properties in vitro and beneficial impacts on starch digestion dynamics in broiler chickens. Animal Feed Science and Technology 190, 68-78.

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PRJ-008695: The factors influencing sorghum starch digestibility in broiler chickens

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