Australian sorghum for broilers: value and opportunity

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Introduction

Sorghum ranks fifth in global cereal production after corn, wheat, rice and barley. Most of the world's sorghum grain is fed to animals, including poultry, but it is also used for food (Africa) and alcohol (ethanol, beer in Africa and baijiu in China).

World sorghum production for the last 5 years averaged about 63 million metric tonne (Mmt), the USA being the largest producer (about 12 Mmt or 18% of world production). Australian production averaged about 1.5 Mmt (2.4% of world production). World exports of about 9.1 Mmt were dominated by the USA, about 7.05 Mmt (78% of world trade), followed by Argentina and Australia, each about 0.7 Mmt (8% of world trade). Most of Australia's 0.8 Mmt domestic consumption is for poultry and pig feeds in the states of Queensland and NSW.

The two most important nutritional attributes of grains for accurate feed formulation and value assessment for broilers are metabolisable energy (ME) and protein, or more specifically, digestible essential amino acids from the protein. Fibre and some minerals also have high importance for feed formulation.

The chemical composition and energy content of Australian grains, including sorghum were surveyed extensively under the 'Premium Grains for Livestock Program' (PGLP). NIR calibrations were developed from PGLP data, now commercialised internationally as 'AusScan'.

Anti-nutritional factors

The reputation of sorghum is harmed, mostly unnecessarily by concerns about tannins. Some tannin 'bird resistant' sorghum may be produced in other countries but 'condensed tannins' or proanthocyanidins are not present in any Australian commercial sorghum. However, some phenolic compounds ('phenols') are present in all sorghum, including Australian commercial hybrids. Phenols include the yellow, brown and red pigments that colour the sorghum seed coat. Some sorghum phenols appear to be moderately anti-nutritive with potential to depress both starch digestion and glucose absorption. Recent Australian reviews describe phenols, kafirin protein and phytate as the 'Bermuda triangle' of sorghum nutritional quality for poultry. Paradoxically, products containing a selection of tannins are now marketed for improving poultry health and performance, and as AGP alternatives (Asian Feed Magazine, April/May 2018 page 25).

Starch

Starch is the main component of, and contributor to ME in all grain types. Sorghum starch content is typically slightly lower than corn and higher than wheat and barley. The starch content of Australian sorghum typically averages about 70% DM (62% as-fed). There is considerable evidence that variation in starch (and fibre) content of Australian sorghum is small compared to other grains. Some low starch values have been reported, possibly due to analytical methods used. The amylose content of sorghum starch is similar to that of 'normal' (not waxy or high amylose) cultivars of other grains, typically 25-28% amylose and 72-75% amylopectin.

Starch digestibility is lower for sorghum than corn. Recent research reported average ileal starch digestibility coefficients of about 0.88 for sorghum and 0.94 for corn. Phenols, kafirin and phytate (the 'Bermuda triangle') may all contribute to this lower digestibility, of which kafirin seems to have the greatest impact.

Fibre

Non-starch polysaccharides (NSP) are the most significant fibre components of grains. Sorghum, like corn is a non-viscous grain without high levels of soluble NSP found in barley, wheat and rye. Sorghum has a lower total fibre content (NSP plus lignin) than corn. Soluble fibre is very low in both grains, but insoluble fibre is considerably lower in sorghum than corn (Table 1).

Table 1: Typical fibre content (% of grain, DM) of sorghum, corn, barley and wheat[1]

		Arabino-xylan	ß-Glucan	Cellulose	Other NSP[2]	Lignin	Total fibre
Sorghum	Soluble	0.10	0.10				0.20
	Insoluble	2.00	0.10	2.20	0.25	1.10	5.65
	Total	2.10	0.20	2.20	0.25	1.10	5.85
Corn	Soluble	0.10					0.10
	Insoluble	5.10		2.00	0.80	1.10	9.00
	Total	5.20		2.00	0.80	1.10	9.10
Barley	Soluble	0.80	3.60		0.10		4.50
	Insoluble	7.10	0.70	3.90	0.50	3.20	15.40
	Total	7.90	4.30	3.90	0.60	3.20	19.90
Wheat	Soluble	1.80	0.40		0.20		2.40
	Insoluble	6.30	0.40	2.00	0.30	1.80	10.80
	Total	8.10	0.80	2.00	0.50	1.80	13.20

[1]from Choct (2006) and Bach Knudsen (2014)

[2]Mannans + Galactans + Uronic Acid

Metabolisable energy (ME)

Grain ME measurement by bioassay typically uses test diets without enzymes, fed to growing broilers. Reported ME values for sorghum are variable as for any grain but seem no more variable than corn and less variable than wheat. Some variation can be attributed to different methodologies, including test diet composition and bird age for bioassay, prediction from chemical composition, AME, AMEn and TME. Although sorghum ME has been reported by many researchers, relatively few compared sorghum and corn under the same test methods and conditions. Sorghum ME values reported are mostly similar to corn, sometimes a little lower or higher. Studies indicate an appropriate average ME value for Australian sorghum for broilers is 3,300 kcal/kg as-fed (12% moisture basis).

Protein / amino acids

The protein content of Australian sorghum is typically higher than corn, 2% or more, similar to barley but less than wheat. Australian feed sorghum protein averages about 10% as-fed (11.4% DM), range typically 8 to 12% as-fed (9 to 13.5% DM). The prolamin protein kafirin is the main storage protein in sorghum and is similar to zein in corn. Kafirin is hydrophobic and poorly soluble, with disulphide cross-linkages that have an important role in folding and stability of the protein. Kafirin is classically about 55% of total sorghum protein but as protein rises the proportion of kafirin increases and glutelin, the second protein fraction, decreases.

Sorghum, corn, barley and wheat protein differ in amino acid composition (amino acid as % of crude protein). The amino acid composition of a grain type is not a constant ratio to protein and in general, the essential amino acid content decreases as the protein content increases (AMINODat 5.0).

Protein digestibility of all cereal grains is high, but digestibility coefficients reported for sorghum are lower than for corn and wheat. Evidence indicates that disulphide cross-linkages in kafirin fractions in the periphery of protein bodies reduce digestibility of sorghum protein and starch. Moreover, hydrothermal processes, including ‘wet cooking’ and perhaps steam pelleting, induce disulphide bond formation in kafirin. Corn zein is less susceptible to disulphide bond formation than sorghum kafirin.

Sorghum with 9% crude protein is lower than or similar to 9% corn in all standardised ileal digestible essential amino acids (SID EAA) except for tryptophan, according to AMINODat 5.0 (Table 2). However, sorghum with its typically 2% higher crude protein than corn contributes more of all SID EAA except for lysine, cystine and M+C, all just slightly lower (Table 3). Sorghum and corn protein have similar SID leucine: isoleucine ratios (about 3.2:1), both higher than the ‘ideal’ ratio (about 2:1).

Table 2: SID EAA[1] composition of sorghum, corn and wheat at the same 9% crude protein (CP) expressed as % of grain and % of CP[2]

		as % of grain			as % of CP		
		Sorghum	Corn	Wheat	Sorghum	Corn	Wheat
CP	%	9.0	9.0	9.0	100	100	100
SID eaa							
Lys	%	0.19	0.25	0.24	2.11	2.8	2.7
Met	%	0.14	0.18	0.14	1.56	2.0	1.6
Cys	%	0.13	0.17	0.20	1.44	1.9	2.2
M+C	%	0.27	0.34	0.33	3.00	3.8	3.7
Thr	%	0.25	0.28	0.23	2.78	3.1	2.6
Try	%	0.10	0.06	0.11	1.11	0.7	1.2
Arg	%	0.31	0.36	0.39	3.44	4.0	4.3
Ile	%	0.31	0.30	0.28	3.44	3.3	3.1
Leu	%	1.00	1.03	0.55	11.11	11.4	6.1
Val	%	0.39	0.39	0.36	4.33	4.3	4.0

[1]Standardised ileal digestible essential amino acid

[2]from Evonik AMINODat 5.0

Table 3: SID AAA[1] composition of sorghum, corn, barley and wheat for typical crude protein content (CP)[2]

		Sorghum	Corn	Barley	Wheat
CP	%	10	8	10	11
SID eaa					
Lys	%	0.20	0.22	0.31	0.27
Met	%	0.16	0.16	0.15	0.16
Cys	%	0.14	0.16	0.19	0.23
M+C	%	0.30	0.32	0.35	0.39
Thr	%	0.28	0.25	0.25	0.27
Try	%	0.12	0.05	0.09	0.12
Arg	%	0.34	0.33	0.40	0.46
Ile	%	0.35	0.27	0.29	0.35
Leu	%	1.10	0.89	0.57	0.66
Val	%	0.44	0.35	0.40	0.43

[1]Standardised ileal digestible essential amino acid

[2]from Evonik AMINODat 5.0

Oil / linoleic acid

The oil and linoleic acid contents of sorghum are a higher than barley and wheat but lower than corn. In high sorghum broiler feeds, linoleic acid levels would be above 1%, sufficient to meet requirement.

Vitamins and minerals

Differences in vitamin and mineral content between sorghum, corn, barley and wheat are minor and commercially irrelevant except perhaps for phosphorus (P).

Total and phytate P is reported to be slightly higher in sorghum than corn and considerably higher than barley and wheat. In sorghum and corn, a higher proportion of total P is in phytate form (above 80%) than in barley and wheat (about 70%).

Pigments

The carotenoid pigments present in yellow corn are absent in sorghum as in barley and wheat. If sorghum replaces corn, pigments sources may need to be included to meet market requirements for skin colour.

Mycotoxins

Australian grains, including sorghum are recognised as having low mycotoxin contamination. Sorghum is less susceptible to mould growth in the field than corn because of its open head. Generally dry conditions at harvest, rigorous moisture testing at receival and monitoring during storage in aerated facilities also contribute to the favourable mycotoxin status of Australian sorghum.

Enzymes and reducing agents

Phytase is a standard inclusion in sorghum-based feeds. Sorghum phytate is reported to be more resistance to phytase degradation than phytate in other grains. Reasons for this are not clear but kafirin and phenols may impede access of phytase to its substrate.

Xylanase has been reported to improve broiler performance with sorghum (and corn) based feeds. The low soluble NSP content of both grains indicates xylanase responses are not a result of digesta viscosity reduction.

Proteases have been reported to increase protein digestibility of grain protein, including sorghum. Because of the relatively low digestibility of sorghum protein, the potential for protease response is greater than with corn. However, kafirin with its disulphide cross-linking may be resistant to exogenous proteases.

Reducing agents solubilize proteins by cleaving disulphide bonds in cystine. Australia research has found inclusion of the reducing agent sodium metabisulphite (SMBS) increased ME of sorghum-based broiler feeds. Two modes of action are proposed: reduction in kafirin disulphide cross-linkages; and depolymerisation of starch. SMBS dose responses data indicates inclusion of 0.15% SMBS increases sorghum ME by about 90 kcal/kg and is commercially viable.

Processing

Good pellet quality (high PDI) is difficult to achieve with sorghum, as for corn and in contrast to wheat. Sorghum FPQF (Feed Pellet Quality Factor, Borregaard LignoTech) is lower for sorghum than corn, barley and wheat (FPQF 4, 5, 5 and 8, respectively). Cell wall and starch granule structure may contribute to FPQF differences between the grains. The gelatinisation temperature range of sorghum starch (68-78ºC) is higher than corn (62-72ºC), wheat (58-64ºC) and barley (52-60ºC). However, due to limited moisture content and moderate temperature during conventional pelleting, starch gelatinisation is not high for any grain and ranges from about 5 to 30%. Although gelatinisation may improve PDI, it has not been shown to increase starch digestibility for poultry. However, physical forces of pelleting may fracture cell walls allowing greater access to digestive enzymes.

Moist heat produced when sorghum is cooked for food is known to promote formation of intermolecular disulphide bridges between kafirin proteins. Conventional steam pelleting of sorghum may do the same. Further research is needed to find whether sufficient disulphide bonds are formed in kafirin during steam pelleting to materially depress protein and starch digestibility.

Breeders and other poultry

Australian sorghum is suitable for all classes of poultry, and with its low mycotoxin contamination may be less risky than locally produced corn for breeders.

Practical application - value and opportunity

Australian sorghum is a proven, reliable grain for commercial broiler feeds. It is nutritionally quite similar to corn without yellow pigment. In Australia sorghum is commonly included at above 50% in commercial broiler feeds, sometimes as the only grain. Australian sorghum is an opportunity worthy of consideration in the region. Feeds high in sorghum (and corn) are difficult to pellet, and some wheat is often included in Australia to increase PDI. Phytase inclusion is standard in sorghum-based broiler feeds, and there is some use of xylanases and proteases. Research is showing ways to improve sorghum ME and protein digestibility. Reducing agents may ‘unlock’ kafirin and increase efficacy of endogenous and exogenous enzymes, making sorghum an even better grain for broilers. Longer term, genetic selection for sorghum hybrids with lower kafirin, phenols and phytate may be economically feasible.

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