The challenge for sorghum breeders: Improving the feed grain quality of sorghum for chicken-meat production

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Fundamentally the need is for sorghums that generate better energy utilisation in broiler chickens (AME, ME:GE ratios, AMEn etc) the bulk of which is provided by starch.
$64 MILLION DOLLAR QUESTION?

Is Kafirin a Negative Factor?

This paper claimed that kafirin, *as a proportion of sorghum protein*, was negatively correlated with AME and TMEn in poultry to significant extents. *In real terms kafirin (g/kg) was not correlated with AME* ($r^2 = 0.0003$) *or TMEn* ($r^2 = 0.051$).
Across 5 feeding studies and 13 observations involving 9 sorghums [LVP 3, LVP 5, FW, Tiger, Block I, HP, Liberty #2, MP, JM] dietary kafirin levels were negatively correlated \( (r = -0.655; P = 0.015) \) with ME:GE ratios.

\[
y_{(\text{ME:GE})} = 0.834 - 0.0016^{*}\text{kafirin}(\text{g/kg})
\]
Across 5 feeding studies and 13 observations involving 9 sorghums [LVP 3, LVP 5, FW, Tiger, Block I, HP, Liberty #2, MP, JM] Dietary levels of total phenolic compounds were negatively correlated \((r = -0.569; P = 0.042)\) with ME:GE ratios

\[
y_{(\text{ME:GE})} = 0.847 - 0.051 \times \text{phenolics}_{(\text{mg GAE/g})} 
\]
Dietary levels of kafirin AND total phenolics compounds were negatively correlated

\( (r = -0.782; P = 0.009) \) with ME:GE ratios

\[
y_{(ME:GE)} = 0.901 - 0.0023*kafirin_{(g/kg)} - 0.0390*phenolics_{(mg \text{ GAE}/g)}
\]

\[ R^2 = 0.612 \]
A meta-analysis of the relationship between dietary concentrations of kafirin and energy utilisation (ME:GE ratios and AMEn) in broiler chickens offered sorghum-based diets

<table>
<thead>
<tr>
<th>Item</th>
<th>n</th>
<th>Expt. leverage</th>
<th>Kafirin</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME:GE</td>
<td>10</td>
<td>P = 0.109</td>
<td>P = 0.034</td>
<td>R² = 0.71</td>
</tr>
<tr>
<td>AMEn</td>
<td>13</td>
<td>P = 0.485</td>
<td>P = 0.013</td>
<td>R² = 0.71</td>
</tr>
</tbody>
</table>

Thus our conclusion is that kafirin does indeed compromise starch/energy utilisation in sorghum-based diets and the real possibility that the chicken-meat industry is being confronted with ‘high-kafirin’ sorghums is a predicament that needs to be addressed fundamentally by the revision of sorghum breeding programs.

Put simply, the availability of relatively low protein sorghums with lesser kafirin proportions should be substantially beneficial.
Australian sorghums contain kafirin but there are indications that the kafirin proportion of total sorghum protein is increasing........
It was proposed that kafirin, as a proportion of total protein, is increasing in Australian sorghum crops in recent decades (Selle, 2011). In a quest to enhance grain weathering resistance, Henzell (1992) stated that sorghums with a relatively dense or corneous endosperm, a red pericarp and a thin mesocarp and are most commonly selected for in Australia. However, it is almost axiomatic that selecting for sorghums with hard, corneous endosperms will lead to higher kafirin contents as a consequence.

Instructively, the texture of Australian sorghums are relatively high by international standards

De Alencar Figeiredo et al. (2006) n = 117
44% had textures >12

<table>
<thead>
<tr>
<th>Category</th>
<th>PSI %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra Hard</td>
<td>Up to 7</td>
</tr>
<tr>
<td>Very Hard</td>
<td>8-12</td>
</tr>
<tr>
<td>Hard</td>
<td>13-16</td>
</tr>
<tr>
<td>Medium Hard</td>
<td>17-20</td>
</tr>
<tr>
<td>Medium Soft</td>
<td>21-25</td>
</tr>
<tr>
<td>Soft</td>
<td>26-30</td>
</tr>
<tr>
<td>Very Soft</td>
<td>31-35</td>
</tr>
<tr>
<td>Extra Soft</td>
<td>Over 35</td>
</tr>
</tbody>
</table>

**Frequency of Symes PSI textures in 38 sorghum varieties**
92.2% fall into the “very hard” category of 8-12
82.1% ⇒ 8-11

5.3% had textures >12
The mean crude protein content of the six “1998 sorghums” (98.7 g/kg) and the eleven “2009 sorghums” (103.6 g/kg) were similar.
41 sorghum samples with an average protein content of 111 g/kg
As sorghum protein levels increase kafirin as a proportion of protein increases at the expense of glutelin

Kafirin
\[ r = 0.469; \ P < 0.005 \]

Glutelin
\[ r = -0.401; \ P < 0.01 \]

Taylor et al. (1984)
Kafirin: in the order of 70% of sorghum protein
80% α-kafirin
5% β-kafirin
15% γ-kafirin

β-kafirin 5% cysteine on a molar basis
γ-kafirin 7% cysteine on a molar basis
Effect of wet-cooking without and with a reducing agent (2-mercaptoethanol) on the pepsin digestibility of major cereals (adapted from Hamaker et al. 1987)

Sorghum: 80.8% ⇒ 56.5% ⇒ 81.8%
Effect of cooking with sodium metabisulphite (100 mM) on *in vitro* starch digestibility of maize (NS) and sorghum (P < 0.05) flours (Zhang and Hamaker, 1998)
Disulphide-mediated polymerization of kafirin protein into sheets or webs which impede starch gelatinisation and digestion

Confocal micrographs of cooked sorghum, protein stained with CBCQA, showing the sheet-like and web-like protein structures
Chicken-meat producers need sorghums with

(i) **less kafirin**

(ii) **less phenolic compounds**

\[ y_{\text{ME:GE}} = 0.834 - 0.0016 \cdot \text{kafirin}_{(g/kg)} \]

\[ y_{\text{ME:GE}} = 0.847 - 0.051 \cdot \text{phenolics}_{(mg \text{ GAE/g})} \]
We need a pink ‘Jane McGrath’ sorghum
Low on protein with a low kafirin proportion
Low on polyphenols and phenolic acids

Without the agronomic disadvantages of a white sorghum

Phytase should ‘work’ in broiler diets based on ‘Jane McGrath’ sorghums
Acknowledgments...