**BACKGROUND:** Whole grain intake is associated with reduced risk of chronic diseases. Sorghum is an example of a so-called ancient whole grain cereal food that is gaining attention from food manufacturers, consumers and researchers as a beneficial ingredient in novel product development. Sorghum whole grain has been shown to have slow starch digestibility in vitro, and some cultivars are high in fiber and rich in polyphenolic compounds. Based on their purported mechanisms, these attributes may contribute to positive effects on metabolic markers and body weight outcomes when sorghum is consumed regularly. Animal studies have shown positive results in relation to key biomarkers of disease but few human clinical trials exist.

**STUDY RATIONALE:** Research examining sorghum intake and chronic disease (such as diabetes, obesity and heart disease) requires clinical studies to elucidate the potential protective roles of the sorghum grain as a constituent of foods within a whole diet. Examining effects on satiety and body-weight regulation is a logical starting point, particularly as healthy weight is a key preventative measure in these diseases.

**AIM:** To compare the effects of three different sorghum-derived flaked breakfast biscuits (white, red, brown sorghums) and a wheat-based control on acute biochemical and subjective measures of satiety and energy intake at a subsequent meal.

**METHODS & STUDY DESIGN**

- Randomised, double-blinded feeding trial with 40 healthy subjects (20 males; 20 females; BMI range 20–31 kg/m²; aged 20-50 years) using a within-subjects repeated measures design.

- Subjects attended our laboratory at The University of Wollongong, Australia, on four occasions after a 12-hour overnight fast. At baseline on each visit, they consumed 50 grams of one of four treatment meals, in the form of flaked breakfast biscuits, with water.

- The biscuits were produced from three different cultivars of sorghum (a white, red and brown variety — differing in polyphenolic content) or a wheat-based control.

- Satiety was measured as subjective hunger and satiety ratings using visual analogue scales (VAS) and was assessed at 8 time-points: 0, 15, 30, 60, 90, 120, 180 and 240 minutes.

- A subset of 20 subjects were cannulated and blood samples were drawn at the same time-points. Plasma glucose, insulin, and appetite-related hormones (GIP, GLP-1, PIY, ghrelin) were assessed.

- Prospective food intake was measured at 1) an ad-libitum lunch and 2) during the remainder of the test day via weighed food records.

**RESULTS**

**A. Formulation of flaked breakfast biscuits**

<table>
<thead>
<tr>
<th>Flaked Breakfast Cereal</th>
<th>Total PP (mg GAE/g as is)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1.37 ± 0.21</td>
</tr>
<tr>
<td>White sorghum</td>
<td>1.46 ± 0.07</td>
</tr>
<tr>
<td>Red sorghum</td>
<td>2.27 ± 0.12</td>
</tr>
<tr>
<td>Brown sorghum</td>
<td>2.99 ± 0.01</td>
</tr>
</tbody>
</table>

*Means (n=2) ± standard deviation. Values with the same superscript letter denote no significant difference (p>0.05).*

The breakfast biscuits were made by steaming whole grains, then passing them through a flaking mill after air-drying, followed by baking at 130°C.

The final test biscuits differed in PP content reflective of cultivar, with tannin-containing brown sorghum biscuits having the highest levels of PP, followed by flavonoid-rich red sorghum (Table 1).

**B. Subjective Satiety**

Subjects reported significantly greater subjective satiety sensations after eating sorghum breakfast biscuits compared to wheat biscuits (p < 0.01 for all 4 questions).

**C. GLP-1 as a measure of satiety**

GLP-1 is associated with increased satiety in humans and was used as a biochemical marker of satiety in this study.

GLP-1 results (incremental AUC, corrected for baseline) differed significantly between-treatment responses over the 4 h testing period (p=0.018), being significantly higher after all sorghum biscuits compared to wheat (Figure 2).

**CONCLUSIONS & FUTURE DIRECTIONS**

Subjective satiety sensations and post-prandial GLP-1 responses were significantly increased after intake of sorghum biscuits compared to wheat. Further analysis of subsequent food intake data, together with a review of glucose, insulin, CYP, PP and ghrelin responses will enable a more complete interpretation of results. Polyphenol interactions effected starch digestibility and glycemic index of foods may be an underlying mechanism of action, yet to be confirmed.

The use of sorghum whole grain as an ingredient in the formulation of foods targeted for weight control through appetite regulation is promising and relevant in developed countries where obesity-related chronic diseases are prevalent and consumer demand for novel food products is high. However, further evidence is needed from future randomized controlled trials that aim to directly examine specific effects on chronic disease biomarkers or health outcomes between a control and sorghum-intervention diet.