Proximate Composition and Glycemic Index Profiling of Differently Composed Nutri-Cereal Biscuits

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An increasing body of evidence suggests that a low-glycemic-index (GI) diet has a therapeutic as well as a preventive potential in relation to the insulin resistance syndrome. Interest in development of low GI foods is growing worldwide; hence there is a need for more diversified food with low GI. At the same time the demand for nutri-cereals is also growing due to its nutrient density, hence in the present study, six types of nutri-cereal (millets) based biscuits made from sorghum, pearl millet and foxtail millet were estimated for their proximate composition and glycemic index (GI). There is significant difference in the nutritional composition of all the biscuits, except ash content of SPB and PB, moisture content of SSB and FB, available carbohydrates of SWB and SCB. The protein, fat, carbohydrate, ash and dietary fibre content ranged from 5.88 g to 9.01 g, 19.98 g to 23.78 g, 59.67 to 64.20 g, 0.61 g to 1.04 g and 8.80 g to 12.20 g /100 g respectively. All the biscuits were found to have low GI (less than 55) and order of GI and GL is PB>SWB>SSB>FB>SPB>SCB.

Keywords: Biscuits; millet; glycemic index; coconut; peanut.

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1. INTRODUCTION

Several studies have documented the health benefits that can be gained by selecting foods of low glycemic index. These benefits are of crucial importance in the dietary treatment of diabetes mellitus: glycemic control is improved as well as several metabolic parameters, such as blood lipids. Glycemic control is also important for the non-diabetic population for minimizing the future risk of diabetes. The number of low-GI foods is very limited, and so a much wider range of low-GI products will be required to make a well-balanced low-GI diet practicable [1].

Biscuits are ready to eat, cheap and convenient food product that is consumed among all age groups in many countries. However, most of the biscuits available in market are made from refined wheat flour which is low in dietary fibre and other major nutrients. These biscuits might provide a quick energy for majority of the population. However, consumption of these biscuits is not suitable for the population who are suffering from obesity, diabetics, cardiac problems, cancer, hyperlipidemia and hypertension. These biscuits might belong to the high glycemic index food (GI > 70), which limits the choice of obese and diabetic and other consumer groups. Recently, emerging studies focus on adding different ingredients into baking products to reduce GI value and improve the quality.

Several papers reported that nutri-cereals are not only nutritionally comparable but also superior to major cereals with respect to protein, energy, vitamins, and minerals. They have a higher proportion of non-starchy polysaccharides and dietary fiber. Sorghum is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols. These types of phytochemicals have been purported to reduce the risk of certain types of cancer, cardiovascular disease, obesity and diabetes [2]. The starches and sugars in sorghum are released more slowly than in other cereals [3] and thus have a low glycemic index (GI) [4] and hence can be used in therapeutic diet. Lower incidences of diabetes have been reported in millet-consuming population [5]. Millet-based preparations are believed to elicit lower glycemic responses and are therefore recommended for individuals with diabetes. Despite all these health benefits consumptions of these grain is low when compared with wheat and rice due to the unavailability convenience foods in the market.

Few researchers have developed biscuits and other bakery ingredients using sorghum [6,7,8,9,10,11] but most of the studies are done on a laboratory scale using traditional processes, limiting their availability to consumers due to lack of industrial scalability and also there are very few studies focusing on the effect of these biscuits on glycemic response. [12] reported that biscuits from foxtail millet flour had the low GI of 50.8 when compared to 68 for biscuits from barnyard millet flour and refined wheat flour. There were no studies on the different types of biscuits produced on commercial scale using different formulations. Hence, in the present study the biscuits were developed using different formulations and manufactured at commercial scale.

2. MATERIALS AND METHODS

2.1 Procurement and Preparation of Raw Material

Sorghum, Pearl millet and Foxtail millet were procured directly from farmers. Other ingredients such as wheat flour, fat, skim milk powder, coconut powder, peanuts and sugar were procured from the local market, Hyderabad. Sorghum and other millets were initially passed through a destoner/grader to remove any foreign material and the grains were dehulled in an abrasive dehuller (Mathesis engineering Pvt. Ltd, Hyderabad) up to 17 percent removal of bran. The dehulled grain was then milled into flour in a Pulverizer (Able manufacturers, Hyderabad) and sieved to get uniform particle size using mesh BSS No 60.

2.2 Biscuit Production

The clean, dried nutri-cereals were dehulled and blended with refined wheat flour at a definite proportion (The exact formulation was not revealed here) based on preliminary studies. Briefly, Sorghum, Ragi, pearl millet and foxtail grain were used for the biscuits preparation. In sorghum four variations were used; refined wheat flour was replaced with 70 percent millet flours, and again the blended flour was replaced with either with peanut / coconut depending upon the type of biscuit, in case of sugar and salt biscuits 20 and 10 percent of blended flour was replaced respectively. Sugar and fat was initially creamed in a planetary mixer (Kar Engineering
works, Hyderabad) for 5 minutes and flour, baking powder, ammonia, flavoring agents, water and flour was added and mixes for another 10 minutes till it became a pliable dough. The dough was passed through the biscuit dropping machine (Kar Engineering works, Hyderabad) using a desired shape onto a biscuit tray and then baked in a rotary drier (Kar Engineering works, Hyderabad) for 20 Minutes. The biscuits were then cooled and packed in a commercial packing and stored until further use. All the biscuits were subjected for sensory evaluation using a 9-point hedonic scale with the help of semi trained panel and found acceptable, the detailed results are reported elsewhere.

2.3 Nutritional Profiling

The biscuits were estimated for their moisture [13], protein [14], carbohydrate, fat [15], ash [14] content using standard methods. Total dietary fiber (TDF) was estimated by enzymatic gravimetric method [16]. Carbohydrate content was calculated the difference (dry extract – (ash + lipids + proteins) method. Energy value was determined by adding lipid, carbohydrate and protein contents with the formula:

\[(9 \times \text{Lipids}) + (4 \times \text{Carbohydrates}) + (4 \times \text{Proteins})\]. Energy value is expressed in kcal/100 g [17].

2.4 Glycemic Index (GI) Profiling

Ten healthy subjects were recruited in the age group of 18-22 after screening through Glucose Tolerance Test (GTT) and BMI. The subjects are working in the offices as lab assistants and residing near the research center where the tests were carried out.

Subjects excluded if they reported a history of gastrointestinal disorders, diabetes, were taking medication for any chronic disease conditions, or intolerant or allergic to any of the foods and high BMI. The method used for measuring and calculating the GI of the foods was in accordance with WHO/FAO recommendations (FAO/WHO, 1998)[18].

Using crossover design, the control and test foods were fed in random order on separate occasions after an overnight fast. Subjects were instructed not to consume unusually large meals, drink alcohol or exercise vigorously on the previous day, and to avoid cycling or walking to the laboratory. Finger-prick capillary blood samples (Accu-check active blood glucose meter) were obtained from all the participants. The reference / test foods were consumed immediately after this. Glucose of 50.0 g was added to 250 mL water and given to subjects as reference food to drink. Portion sizes of test foods were calculated to provide 50 g available carbohydrate. The time of first bite in the mouth was set as time 0 and blood samples were taken exactly 30, 60, 90 and 120 min later. The test foods were consumed in random order between the reference food sessions, with at least 3 days gap between measurements (FAO/WHO.13).

The glycemic index was calculated by following formula

\[
\text{Glycemic Index} = \frac{\text{Area under the Glucose curve of biscuits}}{\text{Area under the glucose curve of the glucose}} \times 100.
\]

Glycemic load (GL) was estimated by multiplying the amount of carbohydrate contained in one serving (20 g) of biscuits with GI value of the product, divided by 100 [19].

2.5 Statistical Analysis

Results are expressed as mean values and standard deviation of their mean. Data were analyzed using one-way analysis of variance (ANOVA) to determine the significance of mean differences between groups by using statgraphics 18.0 version. Varginia. The criterion for statistical significance was \( p < 0.05 \). The results related to the characterization of the sample are presented as mean ± standard deviation. Dietary intake and glycemic responses results are presented as mean ± standard deviation.

3. RESULTS AND DISCUSSION

3.1 Nutritional Profile

The nutrient composition of the biscuits is presented in Table 1. All the nutrients in the biscuits are significantly different from each other \((p < 0.05)\) except the available carbohydrate content of SWB and SCB, Ash content of SPB and PB and moisture content of SSB and FB. The estimation of nutrient composition revealed that all biscuits contained nutrients in varied amounts. The differences can be attributed to the different composition of ingredients used in the production of sweet, salt, coconut, and peanut biscuits. The dietary fibre content
Table 1. Nutrient composition (100 g) of biscuits used for glycemic response

<table>
<thead>
<tr>
<th>Type of biscuit</th>
<th>Moisture (g)</th>
<th>Ash (g)</th>
<th>Fat (g)</th>
<th>Protein (g)</th>
<th>Dietary fiber (g)</th>
<th>CHO (g)</th>
<th>Available carbohydrate (g)</th>
<th>Energy (kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWB</td>
<td>3.56 ±0.31</td>
<td>0.90 ±0.1</td>
<td>19.98 ±1.4</td>
<td>5.88 ±1.18</td>
<td>12.20 ±1.45</td>
<td>64.20 ±2.23</td>
<td>52.0 ±1.21</td>
<td>460.14 ±18.53</td>
</tr>
<tr>
<td>SSB</td>
<td>3.12 ±0.31</td>
<td>0.61 ±0.3</td>
<td>20.45 ±1.5</td>
<td>6.87 ±1.17</td>
<td>8.80 ±1.44</td>
<td>59.76 ±2.21</td>
<td>50.96 ±1.22</td>
<td>450.52 ±18.54</td>
</tr>
<tr>
<td>SCB</td>
<td>3.90 ±0.32</td>
<td>0.73 ±0.2</td>
<td>23.78 ±1.6</td>
<td>7.90 ±1.16</td>
<td>12.10 ±1.43</td>
<td>64.01 ±2.20</td>
<td>51.91 ±1.23</td>
<td>501.64 ±18.57</td>
</tr>
<tr>
<td>SPB</td>
<td>3.80 ±0.34</td>
<td>1.02 ±0.4</td>
<td>22.13 ±1.3</td>
<td>9.01 ±1.17</td>
<td>9.10 ±1.41</td>
<td>59.67 ±2.24</td>
<td>50.57 ±1.24</td>
<td>473.89 ±18.56</td>
</tr>
<tr>
<td>PB</td>
<td>3.52 ±0.35</td>
<td>1.04 ±0.3</td>
<td>21.03 ±1.2</td>
<td>6.12 ±1.18</td>
<td>10.30 ±1.42</td>
<td>63.50 ±2.22</td>
<td>53.2 ±1.20</td>
<td>467.75 ±18.55</td>
</tr>
<tr>
<td>FB</td>
<td>3.15 ±0.35</td>
<td>0.57 ±0.2</td>
<td>20.69 ±1.2</td>
<td>6.78 ±1.16</td>
<td>10.50 ±1.44</td>
<td>60.24 ±2.22</td>
<td>49.74 ±1.21</td>
<td>454.29 ±18.58</td>
</tr>
<tr>
<td>Mean</td>
<td>3.49 ±0.32</td>
<td>0.87 ±0.2</td>
<td>21.28 ±1.4</td>
<td>7.30 ±1.17</td>
<td>9.96 ±1.44</td>
<td>61.136 ±2.22</td>
<td>51.17 ±1.22</td>
<td>465.31 ±18.56</td>
</tr>
</tbody>
</table>

Note: Values with similar superscripts are significantly different with each other.

SWB- Sorghum sweet biscuits, SSB- Sorghum salt biscuits, SCB- Sorghum coconut biscuits, SPB- Sorghum peanut biscuits, PB- Pearl millet biscuits, FB- Foxtail millet biscuits

ranged from 8.80 (SSB) to 12.20 (SWB) g/100 g. The total carbohydrate and available carbohydrates ranged from 59.67 (SPB) to 64.20 (SWB) and 49.74 (FB) to 53.2 (PB) respectively. The protein, fat content ranged from 5.88 g to 9.01 g and 19.98 g to 23.78 g, respectively. The moisture and ash content of the biscuits ranged from 3.12 g to 3.9 g and 0.61 g to 1.04 g respectively. The high ash content indicates, high amounts of minerals, though they were not estimated in the present study. Millets were reported to contain as much as 60-70% dietary carbohydrates, 6-19% protein, 1.5-5% fat, 12-20% dietary fiber, 2-4% minerals, and several phytochemicals [20].

Dietary fibers intake was found to inversely associate to food intake, body weight and abdominal obesity [21,22]. It has been projected that dietary fibers decrease energy density of foods, need more time to be chewed, and slow down gastric emptying. In addition, foods containing dietary fibers have lower glycemic index that leads to a more balanced insulimemic response. Dietary fibers also control food intake by affecting gut hormones secretion.

3.2 Glycemic Index Profile

3.2.1 Glucose response at different intervals during 2 hours

There was a significant difference (p < 0.05) in the mean glucose concentrations of the subjects after the consumption of biscuits at every interval. The peak response was observed at 30 minutes (Fig. 1). At 30 and 60 minutes the reference food has highest glucose concentration. At 90 and 120 minutes PB has highest concentration than reference food.

Post-prandial glycemic response can be affected by several factors, including the type of method used to process starch: the amount of fiber, fat and protein present in a product and the digestibility of the carbohydrate present in that product [23,24]. The technology and cooking methods applied to cereal products also result in various degrees of starch digestion from rapidly (e.g., extruded cereals) to slowly digested carbohydrates (e.g., in some types of biscuits or pasta) [25].

3.2.2 iAUC

Despite higher glucose concentration of glucose at 90 and 120 minutes due to ingestion of PB, the iAUC values are lower than the reference food (glucose), the order from highest to lowest; PB>SSB>SWB>FB>SPB>SCB (Fig. 2). Among the six types of biscuits smallest change in glucose level was exhibited by SWB consumption, followed by SCB and SPB after 2 hours. It was also observed that SCB ingestion attained fasting glucose levels after 60 minutes itself and later on further reduced by 0.62 units, but again gained by 3 units. Similar trend was observed in SSB also. This phenomenon has
reflected in the relatively lower GI and GL of these biscuits, suggesting that inclusion of coconut and peanut in the biscuit formulation is beneficial in lowering GI of foods. However, at any point of time the increase from basal glucose level was lower than the reference food (glucose) (Table 2).

### 3.2.3 Glycemic Index (GI) and Glycemic Load (GL)

All the biscuits exhibited low GI (10.84 to 38.77) (Fig. 3). The glycemic load of all the biscuits (20 g serving) also exhibited low except Peal millet biscuit (PB) which showed medium GL (Fig. 3) The lower GI of all these biscuits can be attributed to the dietary fibre, a finding similar to previous work on dietary fibre and GI of foods [26,27,28]. Addition of fibers in refined flour based bread and biscuits resulted in a marked reduction of GI of 21% and 41% respectively [29]. The fat content (23.0 g) might not have contributed to the low GI, as a previous study reported that the addition of fat (about 23 g) to a carbohydrate-based meal caused an early (0–90 min) decrease in glucose response; however, the overall glucose response was the same between the carbohydrate meal and the added-fat meal, and opined that fat did not affected the overall glucose response to the food [28].

![Fig. 1. Mean glucose concentrations in healthy subjects after the intake of the different millet biscuits and glucose](image1.png)

![Fig. 2. iAUC of different nutri-cereal biscuits vs glucose (p < 0.05)](image2.png)
Table 2. Change in glucose concentration due to consumption of Glucose / Biscuits from basal to different intervals

<table>
<thead>
<tr>
<th>Time(min)</th>
<th>PB</th>
<th>SWB</th>
<th>SCB</th>
<th>SPB</th>
<th>SSB</th>
<th>FB</th>
<th>GL</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>26.37</td>
<td>18.75</td>
<td>1.88</td>
<td>4.12</td>
<td>16.88</td>
<td>28.20</td>
<td>64.80</td>
</tr>
<tr>
<td>60</td>
<td>15.62</td>
<td>10.25</td>
<td>0.00</td>
<td>-2.88</td>
<td>12.63</td>
<td>20.10</td>
<td>34.10</td>
</tr>
<tr>
<td>90</td>
<td>19.87</td>
<td>16.12</td>
<td>-0.62</td>
<td>-0.38</td>
<td>2.00</td>
<td>11.40</td>
<td>20.30</td>
</tr>
<tr>
<td>120</td>
<td>15.37</td>
<td>2.87</td>
<td>3.00</td>
<td>4.12</td>
<td>14.75</td>
<td>8.10</td>
<td>15.50</td>
</tr>
</tbody>
</table>

SWB- Sorghum sweet biscuits, SSB- Sorghum salt biscuits, SCB- Sorghum coconut biscuits, SPB- Sorghum peanut biscuits, PB- Pearl millet biscuits, FB- Foxtail millet biscuits, GL-Glucose

Fig. 3. Glycemic index and glycemic load of nutri-cereal biscuits

Among all the biscuits SCB exhibited the lowest GI and GL which can be attributed to its high dietary fibre content. The GI of coconut flour-supplemented foods decreased with increasing levels of coconut, dietary fibre contributed to delaying the glycemic responses of the coconut flour-supplemented food [30]. Similarly, the peanut biscuits (SPB) exhibited lower GI (19.73) after coconut (SCB) biscuits. Peanuts are rich in fiber, fat and protein, which may act synergistically to promote a reduction in the postprandial glycemic response [31]. It was also reported that ingestion of ground roasted peanuts resulted in lower glycemic response AUC than after raw peanuts occurred due to the grinding process to which the nuts were submitted. It was attributed to the release fat content of the nuts, resulting in the lower glycemic response observed [32]. Normal millet starches have amylose contents ranging from 20 to 32%. Amylose content of up to 34% was reported for foxtail, finger, proso and pearl millets. [20]. The amylose contents of some millet species may be linked to their hypoglycemic properties. Addition of high amylose starch to diets modulates glycemic response [33]. Refined wheat flour biscuits substituted with 45% foxtail millets and barnyard millets, had glycemic index values of 50.8 and 68 respectively [12].

4. CONCLUSION

The present study demonstrated that nutri-cereal based sweet, salt, coconut and peanut biscuits are nutri-dense with good amounts of protein and dietary fiber and low GI. Commercialization of these biscuits enables the availability of these biscuits and add to the existing low GI food basket.

DISCLAIMER

The products used for this research are commonly and predominantly used products in
our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the millet processing centre of the university.

CONSENT

Informed consent was obtained from all the participants.

ETHICAL APPROVAL

As per international standard or university standard ethical approval has been collected and preserved by the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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