Accepted for publication: November 1, 2015

Acceptability, nutritional, and potential health values of sweet sorghum \([\text{Sorghum bicolor (L.) Moench}]\) coffee substitute

Sheila F. Abacan*1, Wilma A. Hurtada1, Erlinda I. Dizon2, and Aimee Sheree A. Barrion1

1Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, College, Laguna, Philippines
2Food Science Cluster, College of Agriculture, University of the Philippines Los Baños, College, Laguna, Philippines

Abstract—Utilization of sorghum to improve nutrition and health among Filipinos is limited due to insufficient information from research on the crop as a source of valuable nutrients and health promoting phytochemicals. The objective of this study was to develop an acceptable, nutritious, and healthful coffee substitute from sweet sorghum grains. The sweet sorghum coffee substitute (SSCS) was made by combining different roasting time of the grains (50, 60, and 70 min) at 226±5°C, powder to water ratio (16 g/250 mL⁻¹, 24 g/250 mL⁻¹), and brewing time (3 and 6 min). The 12 SSCS brewed samples were subjected to sensory evaluation composed of 55 untrained coffee drinker panelists. The most acceptable SSCS and the raw sorghum grain were analyzed for proximate composition, starch, amylose, dietary fiber, fatty acid profile, phytochemicals (total phenols, flavonoids, tannins) and antioxidant activity. The results showed that roasting time of the grains had a significant effect on the sensory characteristics and acceptability of the SSCS brew while powder to water ratio and brewing time have no effect. Roasting sweet sorghum grains for 70 min at 226±5°C and brewing using the powder to water ratio of 16 g/250 mL⁻¹ for 3 min produced the most acceptable sample with characteristic dark brown color, aroma and flavor resembling “rice coffee”, and coffee-like bitterness. This study also revealed that SSCS could be a potential health and nutritious beverage as its powder provides energy from carbohydrates and protein, is low in fat particularly saturated fat, contains essential fatty acids, and has dietary fiber. Moreover, SSCS powder contains phytochemicals, such as phenols particularly flavonoids, which contribute to its high antioxidant activity. These findings suggest that, in general, SSCS could be a beneficial in preventing diseases involving oxidative stress and chronic diseases.

Keywords—antioxidants, coffee substitute, nutrition, phytochemicals, sweet sorghum

INTRODUCTION

Sweet sorghum \([\text{Sorghum bicolor (L.) Moench}]\), a multipurpose crop, is used as food, feed, forage and source of fuel. Its grains can be a staple food to people while its leaves can be forage for animals (ICRISAT 2012). Over the past decade, world sorghum production has risen from 60 to 65 million metric tons (US Grains Council 2013) with the United States, Argentina and Australia as top exporters, accounting to 93 to 97 percent of total world exports. In the Philippines, the high demand of ethanol for blending with petrol (gasoline) with sweet sorghum as bio-fuel source has necessitated large-scale production of this crop (Layaoen et al. 2011). The North Luzon Super Region (Cordillera Administrative Region, Ilocos, Cagayan Valley and Central Luzon) has been identified as a suitable area for this purpose. The stem of sweet sorghum is known to produce high yields of syrup which is used as the primary feedstock in bio-fuel production. Although the grains can be processed and utilized as food, sweet sorghum, however, is not popular consumed as such in the country. Consequently, its multifaceted potential, to a large degree, remains untapped.

Sorghum offers not only nutritional benefits but also health advantage to human as it contains a wide range of phytochemicals. Research aimed on unlocking information regarding valuable health-promoting phytochemicals lags behind other commodities like fruits and vegetables. As a result, utilization of sorghum in improving nutrition and health among Filipinos is limited.
Phytochemicals are bioactive non-nutrient plant compounds in fruits, vegetables, grains, and other plant foods that have been linked to reducing the risk of many chronic diseases (Linn 2003). A diet rich in sorghum has a beneficial effect against diseases with uncontrolled free radical production (Karnath et al. 2004). According to Awika and Rooney (2004), sorghum is a good source of many phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and policosanols. Sorghums also contains higher amount of polyphenols compared to wheat, barley, millet or rye, and maize (Raguen et al. 2006; Bravo 1998).

Hot beverages, like coffee, are very popular among Filipinos. However, caffeine-sensitive individuals and other persons who refrain from taking caffeinated beverages resort to consumer coffee substitutes. Coffee substitutes are the parts of roasted plants that are made into a product, which when added with hot water, provides a coffee-like brew. They serve likewise as a coffee blend. Coffee substitutes, such as the coffee brew made of chicory or clear drinks prepared from roasted cereals (Beltita et al. 2009), have been in the market for a long time. Some common coffee substitutes are made from grains such as rye and barley. Nonetheless, the potential of sweet sorghum as coffee substitute has yet to be thoroughly explored. With its nutritional and health benefits, developing coffee substitute from sweet sorghum grains may increase the crop’s utilization in the country.

The aims of the present study were: to evaluate the acceptability of the brew made from the different treatment of sweet sorghum coffee substitute and to determine the nutritional and phytochemical contents, as well as antioxidant activity, of the sweet sorghum grains and the most acceptable coffee substitute powder.

MATERIALS AND METHODS

Whole sweet sorghum [S. bicolor (L.) Moench var SPV 422] grain purchased from a commercial farm in Batac, Ilocos Norte, was utilized in making the coffee substitute powder. The brewed sweet sorghum coffee substitute (SSCS) were subjected to sensory evaluation. The most acceptable SSCS sample and the raw sorghum grain were analyzed for proximate content, total phenolic, total flavonoid, and tannin contents, as well as total antioxidant activity and fatty acid profile.

Sample Preparation

Sweet sorghum grains were dried, ground, and roasted at 226±5°C. Afterwards, the powdered sorghum (+0.420 mm) was roasted using convection oven (La Germania Model M64C71X) at durations of 50, 60, and 70 minutes. The effects of proportion of powder to water and of brewing time were also tested. The roasted sorghum powder was brewed using two different powder-to-water proportions: 16 g powder in 250 mL water and 24 g powder in 250 mL water, then brewed for 3- and 6-minute durations.

A simple steeping method was used in the preparation of the brew. Hot distilled water at 92±2°C and 10 g of white granulated sugar were mixed with the powder on a glass pitcher. The mixture was stirred, covered, and left to steep for duration of 3 and 6 minutes. The resulting brewed samples were filtered using coffee filter (Brew Rite® #2). The samples were contained on a 1.6 L-single thermal pots and kept at the minimum serving temperature of 70°C.

Sensory Evaluation

Sensory acceptability test using Hedonic scale was conducted to determine the most acceptable SSCS from the combinations of different variables, namely roasting time, powder to water proportion, and length of brewing time. Fifty five (55) untrained panelists, all coffee drinkers, from faculty members and staff of the University of the Philippines Los Baños (UPLB) evaluated 12 brewed samples.

Two sessions were conducted, with the same environmental conditions, to evaluate the characteristics and acceptability of all samples. For each session, six (6) samples were evaluated by the panel. The samples were presented on a tray in order of increasing flavor strength. Each sample was coded with 3 randomized numbers. Thirty (30) ml of each sample was served on 1.5 ounce transparent glass. The samples were presented on a tray in a randomized order. Each session was repeated 3 times.

Determination of nutrient composition

Proximate analysis, starch, and amylose content were analyzed at the Institute of Human Nutrition and Food, UPLB. Fatty acid profile was analyzed by the Food and Nutrition Research Institute, Department of Science and Technology (ENRI-DOST).

Total phenolic content

Total phenolic content was measured by the Folin–Ciocalteu method (Oyaizu 1986), with some modifications. The absorbance was measured using a UV–vis spectrophotometer at 710 nm against a reagent blank. The total phenolic content was expressed as milligrams of quercetin equivalents per 100 g of dry sample weight (mg of QE/100 g) using the calibration curve of (α)-quercetin.

Total Tannin Content

Total tannin was determined using the modified Vanillin Assay (Price 1978). Fifty (50) mg of sample was mixed with 5.0 mL of absolute methanol. An aliquot, 1.0 mL of the sample extract was mixed with 5.0 mL of vanillin reagent in a test tube. The mixture was held for 20 minutes at room temperature. The absorbance was read at 500 nm. The tannin content was expressed as milligrams vanillin equivalents per 100 gram of dry sample weight (mg of VE/100 g) using the calibration curve of (α)-vanillin.

2.2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity

The total free radical scavenging capacity of soghum-methanolic extract was estimated by the DPPH using the modified method of Shimada et al. (1992). One (1) mL-1 of the extract was added to 5 mL volume with the addition of distilled water. Freshly prepared, 1 mL-1 DPPH solution (0.1 mL in absolute methanol) was mixed with the extract. The reaction mixture was shaken well and held for 30 min at room temperature, and the absorbance of the resulting solution measured at 517 nm against a reagent blank. The radical scavenging activity was measured as a decrease in the absorbance of DPPH, and expressed as percent radical quenching compared to that without the extracts.

Statistical Analysis

The sensory evaluation followed a factorial in completely randomized design (CRD) with three (3) factors namely roasting temperature for 50, 60, and 70 min duration; powder to water ratio (16 g/250 mL-1, 24 g/250 mL-1); and brewing time (3 and 6 min). Data from the sensory evaluation were analyzed using the Kruskal-Wallis test and the Wilcoxon Two-Sample Test through the Statistical Analysis System (SAS) program version 9.1 (SAS – Cary, NC, USA). Moreover, t-test was used to determine the difference in nutrient and phytochemical composition of the raw sweet sorghum grain and SSCS. Three replications were used. On the other hand, Spearman correlation analysis was used to determine the relationship between phytochemical contents and antioxidant activity of the raw sweet sorghum grains and SSCS. A probability value of p<0.05 was considered significant among the tests.

RESULTS AND DISCUSSION

Sensory evaluation of the SSCS brew

Prolonging roasting time from 50 to 70 min with 10-min intervals influenced the scores for color, aroma, flavor, bitterness, and general acceptability of the brewed SSCS (Table 1). However, powder to water ratio and brewing time showed no significant effect on the attributes of the SSCS brew. In terms of roasting time, the 70-min roasted samples gained the highest acceptability for all sensory attributes. The acceptability ratings varied from ‘like slightly’ to ‘like very much’ for color (5.29-5.90) and aroma (5.04-5.47). Bitterness (4.53-5.15), flavor (4.56-5.27), and general acceptability (4.75-5.38) had a varied rating from ‘neither like’ or ‘dislike’ to ‘like very much’. The brew has the characteristics of dark brown color, an aroma and flavor resembling “rice coffee”, and a coffee-like bitterness.

In order to make an acceptable sweet sorghum coffee substitute, the study suggests that the grains should be roasted for 70 min at 226±5°C and brew using the powder to water ratio of 16 g/ 250 mL-1 for 3 minutes.

<table>
<thead>
<tr>
<th>Roasting (min)</th>
<th>Powder/Water (g/250 mL-1)</th>
<th>Brewing (min)</th>
<th>Sensory Characteristics</th>
<th>General Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>3</td>
<td>Color</td>
<td>3.44±0.03</td>
<td>3.69±0.04</td>
</tr>
<tr>
<td>24</td>
<td>6</td>
<td>3.40±0.02</td>
<td>3.91±0.03</td>
<td>3.78±0.03</td>
</tr>
<tr>
<td>6</td>
<td>3.88±0.02</td>
<td>4.67±0.05</td>
<td>4.27±0.03</td>
<td>3.65±0.03</td>
</tr>
<tr>
<td>6</td>
<td>4.00±0.02</td>
<td>4.67±0.05</td>
<td>4.44±0.05</td>
<td>4.65±0.05</td>
</tr>
<tr>
<td>16</td>
<td>3</td>
<td>4.56±0.04</td>
<td>4.56±0.04</td>
<td>4.79±0.04</td>
</tr>
<tr>
<td>6</td>
<td>4.95±0.06</td>
<td>4.85±0.04</td>
<td>4.80±0.04</td>
<td>4.73±0.04</td>
</tr>
<tr>
<td>24</td>
<td>6</td>
<td>5.04±0.07</td>
<td>5.20±0.06</td>
<td>4.62±0.04</td>
</tr>
<tr>
<td>6</td>
<td>5.35±0.07</td>
<td>5.18±0.05</td>
<td>5.09±0.05</td>
<td>5.02±0.05</td>
</tr>
<tr>
<td>6</td>
<td>5.90±0.12</td>
<td>5.47±0.05</td>
<td>5.24±0.05</td>
<td>5.15±0.05</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>5.89±0.07</td>
<td>5.47±0.05</td>
<td>5.27±0.05</td>
</tr>
<tr>
<td>70</td>
<td>6</td>
<td>5.89±0.07</td>
<td>5.47±0.05</td>
<td>5.27±0.05</td>
</tr>
<tr>
<td>24</td>
<td>6</td>
<td>5.29±0.07</td>
<td>5.05±0.04</td>
<td>4.84±0.04</td>
</tr>
</tbody>
</table>

Table 1. Evaluation ratings for the characteristics of brewed sweet sorghum samples.1,2

1Some panel score is 5.50: Based on a 7-point hedonic scale, where 1-dislike extremely, 7-like very much
2Dislike slightly 4-neither liked nor dislike 5-like slightly 6-like very much 7-like extremely
3Scores with different superscripts within a column is significantly different (p<0.05).


www.philscitech.org
Proximate composition

Raw grain has significantly higher amount of moisture, crude fat, and protein compared to the SSCS (Table 2). The raw sweet sorghum grains contain 11.74 % moisture, 3.65 % fat, 9.65 % protein, 2.70 % fiber, 1.33 % ash, and 70.93 % carbohydrates while the SSCS contains 10.52 % moisture, 30.78 % fat, 8.33 % protein, 2.52 % fiber, 2.00 % ash, and 75.85 % carbohydrates. This shows that roasting reduced moisture, fat, and protein of the sweet sorghum grain. Moisture within food is reduced with the application of dry heat method such as roasting. According to Kayneshi et al. (2012), heat application decreases fat as heating disrupts lipid bodies allowing the oil to be more readily expelled. The decrease in protein content of the roasted sweet sorghum could possibly be due to the partial or complete denaturation of protein due to heat during roasting. This result was also observed in roasted mangrove legume seed of Senna (2008) and on maize of Oboto et al. (2010). On the other hand, the increased NFE in the SSCS powder could be due to the evaporation of water during roasting thereby increasing the concentration of the carbohydrate in the sample. NFE is used to estimate the carbohydrate content of the sample which by calculating by subtracting the average of each of the other components (% crude protein, crude fat, crude fiber, moisture and ash) from 100 (AAFCO 2013). In contrast, data showed that roasting has no effect on ash and crude fiber content.

Starch, amylose, and dietary fiber

The values recorded for amylose and dietary fiber of SSCS were significantly lower (p<0.05) than that of the raw sorghum grain (Table 3). On the other hand, starch content significantly increased by 2% in SSCS. The increase in starch may be attributed to the evaporation of water during roasting, increasing the concentration of the starch in the sample.

TABLE 2. Proximate composition of raw sweet sorghum grains (RSSG) and sweet sorghum coffee substitute (SSCS) powder (per 100g, dry basis). \(^1\)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture (%)</th>
<th>Crude Fat (%)</th>
<th>Crude Protein (%)</th>
<th>Crude Fiber (%)</th>
<th>Total Ash (%)</th>
<th>NFE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSG</td>
<td>11.74±0.16</td>
<td>3.65±0.35</td>
<td>9.65±0.25</td>
<td>2.70±0.02</td>
<td>1.33±0.02</td>
<td>70.93±0.19</td>
</tr>
<tr>
<td>SSCS</td>
<td>10.52±0.05</td>
<td>0.78±0.03</td>
<td>8.33±0.30</td>
<td>2.52±0.31</td>
<td>2.00±0.01</td>
<td>75.85±0.12</td>
</tr>
</tbody>
</table>

\(^1\) Data are expressed as mean±standard deviation (n=3) on a dry weight basis. Means in each column followed by different superscripts are significantly different (p<0.05).

TABLE 3. Starch, amylose, and dietary fiber content of sweet sorghum grain (RSSG) and sweet sorghum coffee substitute (SSCS) powder (per 100g, dry basis). \(^2\)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Starch (%)</th>
<th>Amylose (%)</th>
<th>Dietary Fiber (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSG</td>
<td>73.27±0.18</td>
<td>24.03±0.86</td>
<td>2.68±0.03</td>
</tr>
<tr>
<td>SSCS</td>
<td>75.69±0.28</td>
<td>16.44±0.65</td>
<td>2.50±0.02</td>
</tr>
</tbody>
</table>

\(^2\) Data are expressed as mean±standard deviation (n=3) on a dry weight basis. Means in each column followed by different superscripts are significantly different (p<0.05).

Fatty acid profile

Raw sweet sorghum and SSCS powder contain saturated fat, which is mainly composed of palmitic and stearic fatty acids (Table 4). Oleic, linoleic, and linolenic are the unsaturated fatty acids detected in both raw sweet sorghum and SSCS. Sajid et al. (2008) found out that the principal fatty acid components in the sorghum seed oils were palmitic, linoleic, and oleic acids and majority of the sorghum varieties contain linoleic acid as a major unsaturated fatty acid. Sorghum and corn have similar fatty acid composition but the former has more unsaturated fats (Rooney 1978). Oils being the source fatty acids are important in human body, particularly the linoleic and linolenic, as it cannot produce them. However, saturated fatty acids particularly lauric, myristic, and palmitic, are found to raise blood cholesterol levels (Salter and White 1996). On the contrary, monounsaturated fat, such as oleic acid, lowers blood levels of low density lipoprotein (LDL) cholesterol (Thomsen et al. 1999). In addition, omega-6 fatty acids or linoleic and omega-3 fatty acid or linolenic acid also help in lowering blood cholesterol and prevents heart disease (Von Schacky 2000, Willet 2007). Willet (2007) stated that adequate intakes of both omega-6 and omega-3 fatty acids are essential for good health and will lower the rates of cardiovascular disease and type 2 diabetes. Sajid et al. (2008) suggested that the S. bicolor seed oils may serve as potential dietary source of monounsaturated and polyunsaturated fatty acids.

There was no significant change found in fatty acid composition of the raw sorghum grain and SSCS powder upon roasting. Although fats are degraded when subjected to high temperature on roasting, the effect could possibly be counterbalanced by the evaporation of water in the sample. Thus, no apparent differences were observed in the amount of the fatty acids detected in the sorghum grain and SSCS powder.

Phytochemicals and antioxidant activity

The SSCS contains higher amount of total phenols, flavonoids and tannins than the raw sweet sorghum grain (Table 5). The raw sweet sorghum grains contain 8.29 mg VE/100g tannins, 15.79 mg CE/100g phenols, and 10.46 mg QE/100g flavonoids while the SSCS contains 21.18 mg VE/100g tannins, 30.63 mg CE/100g phenols, and 28.49 mg QE/100g flavonoids. In the study of Gallegos-Inmite et al. (2010), roasting barley extracts increased its total phenolic content when compared to the unprocessed barley. This clearly showed that roasting aids in increasing the amount of the phytochemicals being studied. Dewanto et al. (2002) reported that thermal processing may release bound phenolics from cellular constituents. Major phenolic acids in sorghum can be derivatives of benzoic or cinnamic acid (Hahn et al. 2009). Wu et al. (2012) identified ferulic acid and p-coumaric acid to be the most abundant phenolic acids in sorghum grain. Clifford (2000) indicated that cinnamic acids, such as caffeic, ferulic and p-coumaric acids, are generally found in a conjugate form and are released after a hydrolysis process such as that produced during thermal treatment. Free cinnamic acids can be further deconjugated and degraded to several types of simple phenolics (Galvez-Ramilla et al. 2009). These findings could further explain the increase in total phenolic content of sweet sorghum when roasted to produce SSCS. Table 4, 5, and 6.
In this study, DPPH was used to evaluate antioxidant activity. When DPPH encounters a proton-donating substance such as an antioxidant, the radical is scavenged and the absorbance is reduced. Thus, the antioxidant capacity of the sweet sorghum grain and SSCS can be expressed as its ability in scavenging the DPPH free radical. The DPPH radical-scavenging activity of SSCS is higher than that of the raw sweet sorghum grain (Table 6). This suggests that the roasting process enhances the antioxidant activity in sweet sorghum. Although roasting enhances antioxidant activity in the SSCS, prolonging the roasting process might not be beneficial in increasing the antioxidant activity. Intense roasting could result in the degradation of polyphenols (Sachetti et al. 2009).

Total phenols and flavonoids were significantly correlated (r=0.8407) with the DPPH radical-scavenging activity with the same correlation coefficient, r, of 0.8407 (Table 6). This shows that high amounts of total phenols and flavonoids contributed to high antioxidant activity of the sweet sorghum grain and SSCS. A study on malting barley varieties by Zhao et al. (2008) reported that the total phenolic content of barley was significantly correlated with the antioxidant capacity, as measured by the DPPH and ABTS assays. Similarly, tannins showed a strong positive correlation with the antioxidant activity but which was significant at a lower probability value (r=0.7059, p = 0.1170). Tannins are one among the flavonoids that constitute the total flavonoid content of sweet sorghum.

**CONCLUSION**

A SSCS brew with dark brown color, “rice coffee”-like aroma and flavor, and coffee-like bitterness was found acceptable. The study also revealed that SSCS could be a beneficial product in preventing diseases that involves free radical production. These diseases include neurodegenerative disorders such as Alzheimer’s and Parkinson’s, and chronic diseases such as cancer, cardiovascular diseases, cataract and inflammation (Temple 2000).

**ACKNOWLEDGEMENTS**

The authors would like to acknowledge the Department of Science and Technology-Science Education Institute (DOST-SEI) and the Commission on Higher Education (CHED) for their financial support in this study.

**CONFLICT OF INTEREST**

The authors declare no conflict of interest.

**CONTRIBUTION OF INDIVIDUAL AUTHORS**

Sheila F. Abacan is the lead author of the study. She prepared the proposal, developed the coffee substrate from sweet sorghum grains, performed chemical analyses, interpreted the results, and wrote the paper for her MS thesis.

Dr. Wilma A. Hurtada is the chair of the advisory committee of the lead author. She provided guidance in the preparation of the proposal and accomplishments of the study.

Dr. Erlinda I. Dizon and Dr. Aimee Serosa A. Biron are members of the guidance committee of the lead author. They provided essential inputs in the development of the proposal and the final paper.

**REFERENCES**


**TABLE 6. Correlation coefficients of total phenols, flavonoids, tannings and 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity.**

<table>
<thead>
<tr>
<th></th>
<th>Correlation coefficient (r)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phenols</td>
<td>0.8407</td>
<td>0.0361</td>
</tr>
<tr>
<td>Flavonoids</td>
<td>0.8407</td>
<td>0.0361</td>
</tr>
<tr>
<td>Tannins</td>
<td>0.7058</td>
<td>0.0117</td>
</tr>
</tbody>
</table>

**Significant p < 0.05 (two-tailed, Spearman rho).**