REVIEW

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

Sheila F. Abacan*[1], Wilma A. Hurtada[1], Erlinda I. Dizon[2], and Aimee Sheree A. Barrion[1]

[1]Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, College, Laguna, Philippines
[2]Food 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 panelist. 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 [*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 phytochemical lags behind other commodities like fruits and vegetables. As a result, utilization of sorghum in improving nutrition and health among Filipinos is limited.

*Corresponding Author
Email Address: sfabacan@up.edu.ph
Submitted: June 15, 2014
Revised: January 3, 2015
Accepted: March 1, 2015
Published: November 1, 2015

Phytochemicals are bioactive non-nutrient plant compounds in fruits, vegetables, grains, and other plant foods that have been linked to reducing the risk of major chronic diseases (Liu 2003). A diet rich in sorghum has a beneficial effect against diseases with uncontrolled free radical production (Kamath *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 (Ragaee *et al*. 2006; Bravo 1998).

Hot beverages, like coffee, are very popular among Filipinos. However, caffeine-sensitive individuals and other persons that refrain from taking caffeinated beverages resort to consuming 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 (Belitz *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^{-1} water and 24 g powder in 250 mL^{-1} 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 brew 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 jigger at minimum temperature of 70°C. Distilled water was provided for each panelist for mouth rinsing between samples. Sensory attributes of the sweet sorghum coffee substitute such as color, aroma, taste, and its general acceptability was rated using a 7-point Hedonic scale (7-like extremely, 1-dislike extremely) adopted from the study of Naggers *et al*. (2011).

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 (FNRI-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 catechin equivalents per 100 gram of dry sample weight (mg of CE/100 g) using the calibration curve of (±)-catechin.

Total flavonoid content

The total flavonoid concentration was measured using a calorimetric assay developed by Zhishen *et al*. (1990). One (1) mL^{-1} of appropriately diluted sample was added to a 10 mL^{-1} volumetric flask containing 4 mL^{-1} of diluted water. At time zero, 0.3 mL^{-1} of 5% $NaNO_2$ was added to each volumetric flask; then at 5 min, 0.3 mL^{-1} of 10% $AlCl_3$ was added; and at 6 min, 2.0 mL^{-1} of 1 M NaOH was added. Each reaction flask was immediately diluted with 2.4 mL^{-1} of distilled water and was mixed. Upon the development of pink color, absorbance of the mixtures was determined at 510 nm relative to the prepared blank. The total flavonoid content was expressed as milligrams of quercetin equivalents per 100 gram of dry sample weight (mg of QE/100 g) using the calibration curve of (±)-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^{-1} of absolute methanol. An aliquot, 1.0 mL^{-1} of the sample extract was mixed with 5.0 mL^{-1} 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 (±)-vanillin.

2, 2-diphenyl-1-pierylhydrazyl (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 adjusted to 5 mL volume with the addition of distilled water. Freshly prepared, 1 mL^{-1} DPPH solution (0.1 mM 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 1. Evaluation ratings for the characteristics of brewed sweet sorghum samples.[1,2]

Roasting (min)	Powder:Water (g/250 mL^{-1})	Brewing (min)	Sensory Characteristics				
			Color	Aroma	Flavor	Bitterness	General Acceptability
50	16	3	3.44^{c}	4.20^{c}	3.95^{b}	3.65^{b}	3.84^{c}
		6	3.40^{c}	3.91^{c}	3.78^{b}	3.71^{b}	3.84^{c}
	24	3	3.89^{c}	4.67^{c}	4.27^{b}	4.27^{b}	4.53^{c}
		6	4.00^{c}	4.67^{c}	4.44^{b}	4.49^{b}	4.65^{c}
60	16	3	4.56^{b}	4.56^{b}	4.75^{a}	4.55^{a}	4.65^{b}
		6	4.95^{b}	4.85^{b}	4.80^{a}	4.73^{a}	4.84^{b}
	24	3	5.04^{b}	5.20^{b}	4.62^{a}	4.64^{a}	4.91^{b}
		6	5.35^{b}	5.18^{b}	5.09^{a}	5.02^{a}	5.13^{b}
70	16	3	5.90^{a}	5.47^{a}	5.24^{a}	5.15^{a}	5.35^{a}
		6	5.89^{a}	5.47^{a}	5.27^{a}	5.11^{a}	5.38^{a}
	24	3	5.29^{a}	5.05^{a}	4.84^{a}	4.62^{a}	4.82^{a}
		6	5.27^{a}	5.04^{a}	4.56^{a}	4.53^{a}	4.75^{a}

[1]Taste panel scores (n=55) based on a 7-point hedonic scale, where 1-dislike extremely 2-dislike very much 3-dislike slightly 4-neither liked nor dislike 5-like slightly 6-like very much 7-like extremely

[2]Means with different superscripts within a column is significantly different ($p<0.05$).

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

Sample	Moisture (%)	Crude Fat (%)	Crude Protein (%)	Crude Fiber (%)	Total Ash (%)	NFE[2] (%)
RSSG	11.74±0.16[a]	3.65±0.35[a]	9.65±0.25[a]	2.70±0.00[a]	1.33±0.03[a]	70.93±0.19[b]
SSCS	10.52±0.05[b]	0.78±0.03[b]	8.33±0.30[b]	2.52±0.31[a]	2.00±0.01[a]	75.85±0.12[a]

[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).
[2]NFE (Nitrogen Free Extract)

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 Kayiteshi *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 Seena *et al*. (2008) and on maize of Oboh *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 is calculated 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 3. Starch, amylose, and dietary fiber content of sweet sorghum grain (RSSG) and sweet sorghum coffee substitute (SSCS) powder (per 100g, dry basis).[1]

Sample	Starch (%)	Amylose (%)	Dietary Fiber (%)
RSSG	73.27±0.18[b]	24.03±0.86[a]	2.68±0.03[a]
SSCS	75.69±0.28[a]	16.44±0.65[b]	2.50±0.02[b]

[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).

The raw sweet sorghum grain used in this study has amylose content of 24.03±0.86 % which fell under intermediate amylose content (20-25%) based on IRRI amylose content classification for rice (IRRI 2006). The SSCS yielded 16.44±0.65 % of amylose classified under low amylose (<20%) (IRRI 2006). The decrease in amylose in SSCS could be due to the high temperature (226±5°C) used in roasting the grains. The amylose may have undergone degradation resulting to shorter amylose molecules with reduced iodine binding capacity thereby lowering the overall apparent amylose content of starches (Htoon *et al*. 2009).

The established dietary fiber content of raw sweet sorghum grain was 2.68±0.03 %, which is higher than that of raw corn and rice (FNRI 2002). Dietary fiber is important as it appears to reduce the risk of developing heart disease (Rimm *et al*. 1996), diabetes (Fung *et al*. 2002) and diverticular disease (Aldoori *et al*. 2002). Fiber also helps in preventing constipation parallel with increased water intake. It also aids in weight control as it adds bulk to the diet, provides satiety and delays hunger (Whitney *et al*. 2002). The calculated dietary fiber content of SSCS was lower than the raw sweet sorghum grain. Kutos *et al*. (2003) have reported that thermal processing decreased the insoluble fiber content, and consequently the total dietary fiber content of beans (*Phaseolus vulgaris* L.). Increased temperature leads to a breakage of weak bonds between the polysaccharide chains of the dietary fiber. Likewise, the glycosidic linkages in the dietary fiber polysaccharides may be broken (FAO 1998).

TABLE 4. Fatty acid composition of raw sweet sorghum grains (RSSG) and sweet sorghum coffee substitute (SSCS) powder (g/100g).[1]

Fatty Acids	RSSG	SSCS
Saturated fat	0.72±0.05	0.64±0.08
Palmitic (C_{16})	0.65±0.04	0.58±0.08
Steric (C_{18})	0.07±0.00	0.06±0.01
Oleic ($C_{18:1}$)	1.12±0.08	1.14±0.18
Linoleic ($C_{18:2}$)	0.99±0.08	1.47±0.24
Linolenic ($C_{18:3}$)	0.03±0.00	0.07±0.01

[1]Data are expressed as mean ± standard deviation (n=2) on a dry weight basis. Data presented were not significantly different at 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 acid 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 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-Infante *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*. 1983). 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 decarboxylated and degraded to several types of simple phenolics (Galvez-Ranilla *et al*. 2009). These findings could further explain the increase in total phenolic content of sweet sorghum when roasted to produce SSCS.

TABLE 5. Phytochemical content and total antioxidant of raw sweet sorghum grains (RSSG) and sweet sorghum coffee substitute (SSCS) powder.[1]

Sample	Tannins mgVE/ 100g)	Phenols (mgCE/ 100g)	Flavonoid (mg QE/ 100g)	Total Antioxidant (% DPPH[2] Scavenging Activity)
RSSG	8.29±0.11[b]	15.79±0.36[b]	10.46±0.34[b]	13.01±0.31[b]
SSCS	21.18±0.35[a]	30.63±0.60[a]	28.49±0.1.30[a]	91.25±0.15[a]

[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).
[2]DPPH-2, 2 diphenyl-1-picrylhydrazyl

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 5). 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.

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

	DPPH Radical-Scavenging Activity	
	Correlation coefficient (r)[1]	p-value
Total phenols	0.8407	0.0361
Flavonoids	0.8407	0.0361
Tannins	0.7058	0.1170

[1]Significant at $p < 0.05$ (two-tailed, Spearman rho).

In general, the role of antioxidants is to terminate the chain reactions by removing free radical intermediates and to inhibit other oxidation reactions (Sies 1997). Thus, 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).

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 potential health and nutritious beverage as its powder contains carbohydrates, protein, essential fatty acids, dietary fiber, and is low in fat, particularly saturated fat. Moreover, the SSCS powder contains phytochemicals contributing to its high antioxidant activity. These findings suggest that consumption SSCS may help in preventing diseases in which free radical production plays a key role.

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 substitute 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 Sheree A. Barrion 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

Aldoori WH, Giovannucci EL, Rockett HR, Sampson L, Rimm EB, Willett WC. A prospective study of dietary fiber types and symptomatic diverticular disease in men. J Nutr 1998; 128:714-9.

AOAC [Association of Official Agricultural Chemists]. Method 991.39, Fatty Acids in Encapsulated Fish and Fish Oil Methyl and Ethyl Esters. Gas Chromatographic Method. 18th Ed. Gaithersburg, MD:AOAC Int., 2005:21-24.

Awika JM, Rooney LW. Sorghum phytochemicals and their potential impact on human health. Phytochemistry 2004; 65(9): 1199–221.

Belitz HD, Grosch W, Schieberle P. Food Chemistry. 4th ed. Berlin Heidelberg: Springer-Verlig, 2009: 949.

Bravo L. Polyphenols: Chemistry, dietary sources, metabolism, and nutritional significance. Nutr. Rev 1998; 56: 317–333.

Clifford MN. Cholorogenic acids and other cinnamates – Nature, occurrence, dietary burden, absorption and metabolism. J Sci Food Agric 2000; 80(7): 1033–1043.

Dewanto V, Wu X, Liu RH. Processed sweet corn has higher antioxidant activity. J. Agric. Food Chem 2002; 50: 4959 – 4964.

FAO [FOOD AND AGRICULTURE OFFICE. Carbohydrates in Human Nutrition. Retrieved September 10, 2013, from World Wide Web: http://www.fao.org/docrep/W8079E/W8079E00.htm

FNRI [Food and Nutrition Research Institute]. The Philippine Food Composition Table. Manila, Philippines:FNRI-DOST Foundation, 1997:1-13.

Fung TT, Hu FB, Pereira MA, Liu S, Stampfer MJ, Colditz GA, Willett WC. Whole-grain intake and the risk of type 2 diabetes: a prospective study in men. Am J Clin Nutr 2002; 76:535-40.

Gallegos-Infante JA, Rocha-Guzman NE, Gonzalez-Laredo R F, Pulido-Alonso J. Effect of processing on the antioxidant properties of extracts from Mexican barley *(Hordeum vulgare)* cultivar. Food Chem 2010; 119(3), 903–906.

Galvez-Ranilla L, Genovese MI, Lajolo F. Effect of different cooking conditions on phenolic compounds and antioxidant capacity of some selected Brazilian bean *(Phaseolus vulgaris L.)* cultivars. J Agric Food Chem 2009; 57(13): 5734–5742.

Hahn DH, Rooney LW, Faubion JM. Sorghum phenolic acids, their HPLC separation and their relation to fungal resistance. Cereal Chem 1983; 60:255–259.

Htoon A, Shrestha AK, Flanagan BM, Lopez-Rubio A, Bird AR, Gilbert EP, Gidley MJ. Effects of processing high amylose maize starches under controlled conditions on structural organisation and amylase digestibility. Carbohydr Polym 2009; 75 (2):236-245.

ICRISAT [International Crops Research Institute for the Semi-Arid Tropics]. Sorghum (*Sorghum bicolor* (L.) Moench). Retrieved August 7, 2012, from the World Wide Web: http://www.icrisat.org/crop-sorghum.htm

IRRI [International Rice Research Institute].2006. Breeding program management. Retrieved September 12, 2013 from the World Wide Web: http://www.knowledgebank.irri.org/ricebreedingcourse/Grain_quality.htm

Kayitesi E, De Kock HL, Minnaar A, Duodu KG. Nutritional quality and antioxidant activity of marama–sorghum composite flours and porridges. Food Chem 2012; 131(3):837–842.

Kutoš T, Golob T, Kač M, Plestenjak A. Dietary fibre content of dry and processed beans. Food Chem 2003; 80(2):231–235.

Layaoen H, Reddy BVS, Dar WD, Srinivasa Rao P and Eusebio JE. 2011. Sweet Sorghum in the Philippines: Status and Future.Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 116 pp.

Liu RH.Health benefits of fruits and vegetables are from additive and synergistic combination of phytochemicals. Am. J. Clin. Nutr 2003; 78:517S–520S.

Nagares NDL, Hurtada WA, Rodriguez FM, Dizon EI. Nutritional value, physico-chemical properties and acceptability of rice (*Oryza sativa* L)-corn (*Zea mays* L.) composites. Asia Life Sci. 2011; 20 (1):199-214.

Oboh G, Ademiluyi AO, Akindahunsi AA. The effect of roasting on the nutritional and antioxidant properties of yellow and white maize varieties. Int J Food Sci 2010; 45(6):1236–1242.

Oyaizu M. Studies on products of browning reactions: Antioxidative activities of browning products of browning reaction prepared from glucosamine. Jpn J Nutr. 1986;44: 307–315.

Price ML, Butler LG. Rapid visual estimation and sphectrophotometric determination of tannin content of sorghum grain. J. Agric. Food Chem. 1977; 25:1268-1273.

Ragaee S, Abdel-Aal EM, Noaman M. Antioxidant activity and nutrient composition of selected cereals for food use. Food Chem 2006; 98:32–38.

Reddy BVS, Ramesh S, Reddy PS, Kumar AA, Sharma KK., Chetty Smk, Palaniswamy AR. 2006. Sweet Sorghum: Food, Feed, Fodder, and Fuel Crop. ICRISAT. Retrieved August 10, 2012 from the World Wide Web:www.icrisat.org

Rimm EB, Ascherio A, Giovannucci E, Spiegelman D, Stampfer MJ, Willett WC. Vegetable, fruit, and cereal fiber intake and risk of coronary heart disease among men. J Am Med Assoc 1996; 275:447-51.

Rooney, L.W. 1978. Sorghum and pearl millet lipids. Cereal Chem 55:584-590.

Sacchetti G, Di Mattia C, Pittia P, Mastrocola D. Effect of roasting degree, equivalent thermal effect and coffee type on the radical scavenging activity of coffee brews and their phenolic fraction. J Food Eng 2009; 90:74–80.

Sajid, M, Ilkay O, Zaheer A, Sinem A, Muhammad G. Fatty acid composition of seed oil of different Sorghum bicolor varieties. Food Chem 2008; 109(4): 855-859

Salter AM, White DA. Effect of dietary fat on cholesterol metabolism: Regulation of plasma LDL concentrations. Nutr Res Rev 1996; 9:241–257.

Seena S, Sridhar KR., Arun AB, Young C. Effect of roasting and pressure-cooking on nutritional and protein quality of seeds of mangrove legume *Canavalia cathartica* from southwest coast of India. J Food Com Anal 2006; 19:284–293.

Seis H. Oxidative stress: oxidants and antioxidants. Exp Physiol. 1997;82(2): 291-5.

Shimada, K, Fijikawa, K, Yahara, K, and Nakamura, T. Antioxidative properties of

xanthan on the autooxidation of soybean oil in cyclodextrin emulsion. J. Agric. Food Chem. 1992; 40:945-948.

Temple MJ. Antioxidants and disease: more questions than answers. Nutrition Research. 2000; 20:449–459.

Thomsen C, Rasmussen O, Lousen T, Holst Jj, Fenselau S, Schrezenmeir, J, Hermansen K. 1999. Differential effects of saturated and monounsaturated fatty acids on postprandial lipemia and incretin responses in healthy subjects. Am J Clin Nut 69(6):1135–43.

United States Grains Council. 2013. World Sorghum Production and Exports. Retrieved July 12, 2013 from the World Wide Web: http://www.grains.org/index.php/news-and-events/chart-of-the-week/3673-world-sorghum-production-and-exports

Von Schacky C. 2000. N-3 Fatty Acids and the Prevention of Coronary Atherosclerosis. Am J Clin Nut 71(1 Suppl):224S–7S.

Whitney EN, Cataldo CB, Rolfes SR.2002.Understanding Normal and Clinical Nutrition Textbook . 6th ed. Canada:Wadsworth Group. 97-99, 140145 pp.

Willet HS. 2007. Omega-3 fatty acids and cardiovascular disease: A case for omega-3 index as a new risk factor. Pharmacological Res. 55(3):217-223.

Wu L, Huang Z, Qin P, Ren G. Effects of processing on phytochemical profiles and biological activities for production of sorghum tea. Food Research International. 2012; 53 (2): 678-685.

Zhishen J, Mengcheng T, Jianming W. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem. 1999; 64: 555-559.

Zhao H, Fan W, Dong J, Lu J, Chen J, Shan L, Lin Y, Kong W. Evaluation of antioxidant activities and total phenolic contents of typical malting barley varieties. Food Chem. 2008; 107:296–304.