



Physicochemical and Organoleptic Properties of Sorghum Stem Sheath- Moringa Leaf Flour and its Tea Infusion

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Abstract: The blends were produced from sorghum stem sheath and moringa leaf flour in the proportion of 100:0, 95:5, 90:10, 85:15 and 0:100 respectively. The proximate composition, vitamin C, pH, total soluble solids, bulk density, reconstitution index, particle size, titratable acidity, reducing sugars, antioxidant and antinutrient content were determined using standard methods. The proximate compositions of the samples were in the range of 3.20-20.45% (protein), 2.85-44.60% (carbohydrate), 8.35-13.21% (fat), 32.01-39.67% (fibre), 5.34-14.70% (ash) and 5.72-6.50% (moisture). The vitamin C contents ranged between 0.00 and 26.04 mg/100 g. The pH, total soluble solids and reducing sugar increased significantly ($p < 0.05$) with the degree of enhancement being dependent on the increased concentration of moringa leaf inclusion. The titratable acidity, bulk density, reconstitution index and mass mean diameter decreased significantly ($p < 0.05$) with increase in inclusion of moringa leaf to sorghum stem sheath flour. Moreover, based on sensory evaluation, the sample (STP) 15% moringa flour was most preferred in terms of all the sensory attributes evaluated by the panelists. In conclusion, the inclusion of 15% moringa leaf into sorghum stem sheath flour enhances utilization and also brings about a nutritious health promoting alternative new food product that can compete with the commercial lipton tea bags.

Keywords: Physicochemical; infusion drink; moringa; sorghum stem sheath

Introduction

Sorghum (*Sorghum bicolor*) is one of the most important staple crops in Nigeria. Its production was estimated to surpass all other cultivated crops in Nigeria. For instance, in the Nigeria savannah zone, sorghum is grown on an estimated area of 4.5 million hectares with annual production output of about 6 million tonnes. The leaves and grains are also

incorporated into livestock feeds and the stalks for thatching houses and making fences. Sorghum (*Sorghum bicolor*) stem is sweet and contains some sugars and minerals which make it useful for syrup manufacture. The dried stem is used as fuel in the tropics. Sorghum is a very valuable industrial crop for brewing alcoholic and non-alcoholic drinks as well as in the baking and confectionery industry in

Nigeria(Odetokun,1997).Sorghum has greater unutilized potentials than any other crop.The mature black purple sheath of the stem (locally known as poporo) generally sold in small bundles is used as color additives in cooking meals and also taken as beverages when steeped or boiled in water in many homes in Nigeria (Adetuyi, 2004). The resultant solution is bright red. It is also used as a food preservative. Information available in the literature reveals that the sorghum stem sheath is still confined to traditional use only. Hence, its industrial exploitation in beverage making would be of great advantage to the people of Nigeria and beyond in terms of nutrition, food and livelihood security.

Moringaoleifera is a tropical plant edible by man and animal. Every part of *Moringaoleifera* tree - the fruits, pods, flower, leaves, roots and seed is considered useful. The parts have been reported to be rich in protein, vitamins and minerals, essential amino acids, antioxidants and antimicrobial properties (Jabeenet al., 2008; Anwar and Rahid 2007). Seeds of *Moringaoleifera* are also known for their coagulation properties for treating water and waste water (Katayonet al.,2005). The seed extract has been found to have microbial properties (Kebreabet al., 2005 and Jamil et al., 2007). *Moringaoleifera* has been used as supplements in different food products ranging from bakery products (Dachanaet al., 2010; Ogunsinaet al., 2011) to cereal based snacks and has been found suitable and acceptable by the consumer. *Moringa oleifera* tree contains many nutrients such as essential vitamins, minerals, amino acids, beta-carotene, anti-oxidants, anti-inflammatory nutrients, phytochemicals and it also contains omega-3 fatty acids (Kasolo, 2010 and Khalafalla et al., 2010). The tender pods, which have a taste very similar to asparagus are eaten as a

nutritious vegetable, either cooked or pickled (Fuglie, 2001 and Foidl et al., 2001). The leaves are highly nutritious, being a significant source of beta-carotene, vitamin C, protein, iron, and potassium. The tender leaves taste like watercress and, along with the flowers, are eaten cooked or raw like spinach. In addition to being used fresh as a substitute for greens, its leaves are commonly dried and crushed into a powder, and used in soups and sauces. Leaves can be stored as dried powder for many months without refrigeration, and reportedly without loss of nutritional value (Moyoet al., 2011).

Sorghum stem sheath is being used locally in folklore medicine to boost blood immune system of children, sickle cell anaemic and as anti-malaria (Ben-Nwadibia and Ndukwu, 2005; Adetuyiet al., 2007). Adetuyiet al., 2007 fortified the stem sheath drink with pineapple juices and lemon grass and found out that the unfortified drink sample lacked vitamin C but rich in minerals like Mg, Ca, K and Na. The minerals however increased when fortified with pineapple juices and lemon grass. Oluwalana and Adedeji(2013)examined the nutrient profile of sorghum stem sheath drink spiced with *Aframomummelegueta* which increased significantly and the degree of enhancement was dependent on the concentration of the spice. Looking at the insignificant utilization of sorghum stem sheath, finding practical and economic uses for the underutilized plant part will create an opportunity to build an agro-allied economy delivering sustainable economic growth with job creation and social cohesion as key outcomes.As a consequence of increasing the use of the hitherto underutilized stem sheath with moringa leaf in Nigerian beverage production sector, the agro-allied economy will bring benefits in a number of areas.This study therefore

aims to investigate the physicochemical and sensory properties of sorghum stem sheath-moringa

Materials and methods

Materials

Sorghum stem sheath was purchased from Igbona market in Osogbo, Osun State, Nigeria while moringa leaf was collected from ObafemiAwolowo Teaching

Methods

Production of moringa leaf

Moringa leaf was produced following a modification of the method of Ilyaset al. (2015). Green and mature moringa leaf was desalted, sorted, rinsed with water, dried in a laboratory hot air oven (Gallenkamp hot air oven, OVB 305, UK) at 55°C for 2 h. After

Production of sorghum stem sheath flour

Sorghum stem sheath flour was produced following a modification of the method of Adetuyiet al. (2007). Dry sorghum stem sheath was freed from dirt and extraneous materials by sorting and winnowing manually to remove adhering dirt before drying in a

Production of sorghum stem sheath-moringa infused tea bags and its drink

Moringa leaf flour was added to sorghum stem sheath flour at different proportions (100:0, 95: 5, 90:10 and 85:15) % w/w, mixed thoroughly and then packaged in tea bags. The preparation of the drink is such that 2g of sorghum stem sheath-moringa infusion flour taken from each bulk sample already packaged in tea bags was infused each into 100ml of

flour and its tea infusion.

and Reseach Farm, Ile Ife, Osun state. All chemicals used for analyses were of analytical grade. These chemicals were procured from Fisher Scientific (Oakville, ON, Canada) and Sigma Chemicals (St. Louis, MO).

drying, it was milled using an electric blender (Marlex KitchenBlender D-564, China) at maximum speed for 1 min, sieved, cooled at room temperature (27± 3°C) and then packaged in an air-tight Ziploc bag for further use.

laboratory oven at 55°C for 2h. The stem sheath was then milled using Marlex blender D-564 at max speed for 1 min. Then, sorghum stem sheath flour was cooled at room temperature (27± 3°C) and then packaged in an air- tight Ziploc bag for further use.

boiled water 2:100 (w/v) with the addition of 20% sucrose. The infused tea bags was soaked in boiled water for five minutes and stirred once. It was then allowed to cool before it was served to the panelists for sensory evaluation. The sorghum stem sheath-moringa infusion flour and their tea designation are shown in Table 2.1. The flow chart for the production of sorghum stem sheath-moringa infused tea bags and its drink is shown in Fig 2.1.

Table 2.1: Sorghum stem sheath -Moringa Infusion Flour and Tea Designation

Sample Code	Tea Designation
STP	Sorghum stem sheath Flour – Control
STP5	Sorghum stem sheath + 5% Moringa Leaf Flour
STP10	Sorghum stem sheath + 10% Moringa Leaf Flour
STP15	Sorghum stem sheath + 15% Moringa Leaf Flour
ML5	5% Moringa Leaf Flour

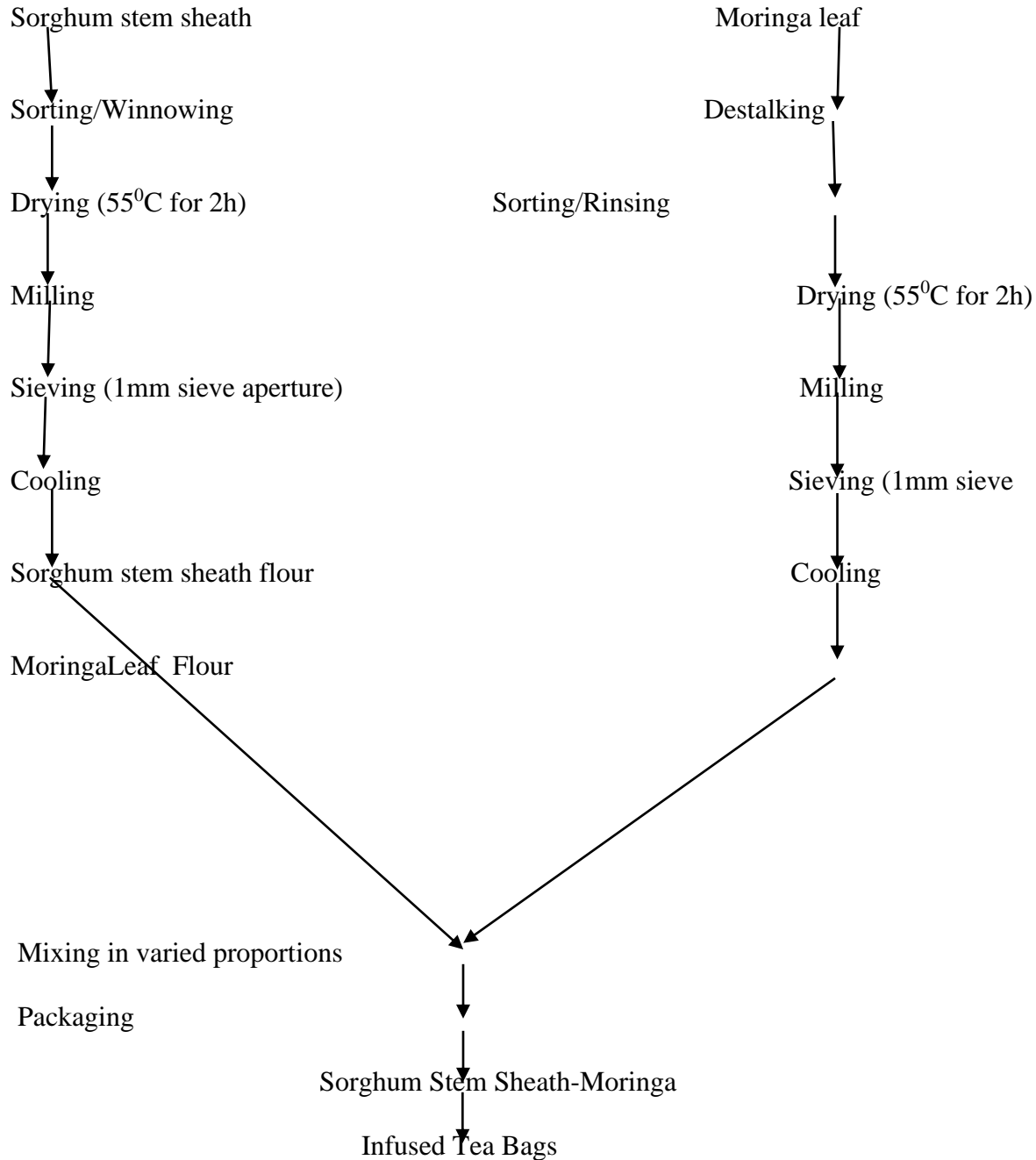


Fig 2.1: Flow chart for the production of Sorghum stem sheath-moringa infused Tea Bags

Source: Ilyaset *al.*, (2015); Adetuyiet *al.*, (2007) modified

Proximate analysis

The proximate compositions were determined using AOAC (2010) methods for protein, fat, ash, moisture and crude fibre contents respectively. The carbohydrate content was determined by difference.

Determination of vitamin C

The quantity of the vitamin C contained in each sample was determined by titrimetric method (using 2, 6-dichlorophenol indophenol dye) described by Hassan and Hassan (2008).

Mineral analysis

The analysis for essential mineral element was investigated using the method by Fashakin *et al.*, (1991). Nitric and HCl acid (10 ml each) were individually added to a sample of 0.5 g in a digestion flask. The mixture was digested for 10 min and then filtered. The filtrate was made up to 50 ml with distilled water. Calcium, sodium, iron, potassium and magnesium were measured by Flame Atomic Absorption Spectrophotometer (Perkin Elmer Analyst 400, USA).

Physicochemical properties

pH

The pH was measured by making a 10% w/v suspension of the sample in distilled water. The suspension was mixed thoroughly and the pH (after standardizing the pH meter with buffer solutions of pH 4 and pH 7) was measured with a pH meter (Hanna checker Model HI1270, USA).

Titrateable acidity

This was assessed according to AOAC (2000) method. One gram of sample was weighed and placed in a 100 ml glass beaker. Distilled water (40 ml) was added, heated to reach 70°C, and allowed to stand for 1 h. The supernatant was filtered. The sorghum stem sheath-moringa residues were rinsed with two portions of 20 ml of hot distilled water. The filtrate was transferred to a 100 ml flask, cooled down to room temperature, brought to volume and thoroughly mixed. An aliquot of 25 ml of the extract was titrated with 0.1 N NaOH until reaching pH 8.3. Results were reported as % malic acid.

Total soluble solids

An extract was obtained by mixing 1 g of sorghum stem sheath-moringa flour with 10 ml of distilled water. This blend was allowed to stand for 1 h at room

temperature and stirring manually sporadically. Determination of total soluble solids was carried out using a hand refractometer. The refractometer prism surface was cleaned with distilled water and tissue paper, followed by placing a drop of the sample on the prism of the refractometer. The reading was taken by looking through the eyepiece of the refractometer and the soluble sugar was expressed in °brix (AOAC, 2000).

Reducing sugars

A solution of the sugar containing sample was prepared by weighing 5 g of the sample into a beaker and adding about 100 ml of warm water. It was stirred until all the soluble matter dissolved and then filtered into a 250 ml volumetric flask. The beaker was rinsed into the volumetric flask and the solution was made up to volume. This solution was used for titration. The burette was filled with the sugar solution. Mixed Fehling's solution (10 ml) was pipetted into a conical flask and 4 drops of 1% methylene blue was added. The solution was brought to boil and whilst boiling, sugar solution was added from the burette until the blue colour disappeared. Reducing sugar was calculated using Equation (1) (James, 1996) where T = titre of non-hydrolysed sugar solution,

W = weight of sample used.

$$\text{Reducing sugars} = \frac{49.5 \times 250}{T \times W \times 10}$$

(% glucose).....(1)

Bulk density

A 10 ml graduated cylinder was gently filled with the samples. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume

of sample (g/ml) as shown in Equation (2) (Siddique *et al.*, 2010)

$$\text{Bulk Density} = \frac{\text{wt of sample}}{\text{vol of sample after tapping}} \text{ (g/ml)} \dots \dots \dots (2)$$

Particle size analysis

The particle size distribution of each sample was determined by placing 50 g of the samples on a tier of Endecotts test sieves arranged on an Endecotts test sieve shaker with sieves of decreasing aperture diameter as follows: 1180, 630, 425, 315, 212, 150 and 63 µm pore diameter sieve. The sieveshaker was operated for duration of 10 min in each test. Percentage particle retention on each sieve was determined. The percentage retention on each sieve and pore diameter of the sieves were used to determine the mass mean diameter of each sample using Equation (2) (Fellows, (2002)

Sensory evaluation

The enriched sorghum stem sheath drinks were prepared by adding 2g of the mixed powdered samples to 100ml of boiled water. About 10% sucrose added to each sample drink was presented to ten semi-trained sensory panelists who are used to sorghum stem sheath drink. The panelists evaluated the samples based on colour, flavour, taste and overall acceptability on a 9-point hedonic scale where 9 represents like extremely and 1 denotes dislike extremely.

Reconstitution index

Reconstitution index was determined as described by Oluwatooyin, *et al.* (2002). Ten grams of the sample was mixed with 100 ml of boiling water for 90 s. The volume of the sediment was measured after pouring into a 250 ml graduated glass cylinder. The volume of the sediment recorded after 10 min was taken as the reconstitution index

Statistical analysis

All data were subjected to one-way Analysis of Variance and means were separated using Duncan’s multiple range tests using SPSS for Windows version 16.

Results and discussion

Proximate composition

The results of proximate compositions of sorghum stem sheath-moringa infusion flour samples are presented in Table 3.1.

The moisture contents of the infusion flour ranged between (6.50 to 8.07) %. The values increased significantly (p < 0.05) with the increased inclusion of moringa leaves to stem sheath flour. Sample STP had the lowest value (6.50%) while STP15 had the highest value (9.12%). The moisture content of sample STP (6.50%) was lower than the value (6.54%) reported by Adetuyi *et al.*, 2007 for sorghum stem sheath flour. The differences in moisture content may be due to the differences in geographical locations, stages of maturity of the plants and drying methods. Wahid *et al.* (2012), Bahaeldeen *et al.* (2012) and Gbadegesin *et al.*, (2016) also reported 7.6%, 11.0% and 6.57% for roselle flour (produced from oven-dried and sun-dried roselle calyces) respectively. The moisture content of sample STP (6.50%) was higher than (5.10%) reported by Ameh *et*

al. (2009) for oven-dried roselle calyces. The low moisture contents of the flour indicated that the samples have good keeping qualities (Saldanha, 1995). The results of proximate analysis demonstrated that an acceptable level of moisture content was present in the enriched flour samples.

The ash contents of sorghum stem sheath- moringa infusion flour ranged between 2.82 to 14.70%. The values increased significantly ($p < 0.05$) as the concentration of moringa leaves to stem sheath flour increased. Sample STP had the lowest value (5.34%)

while STP15 had the highest value (14.70%). The ash content of sample STP (5.84%) was higher than that reported for sorghum stem sheath flour (5.34%) by Adetuyiet *al.*, 2007 but lower than 9.50, 12.2 and 9.93% reported by Bahaeldeen *et al.* (2012); Wahid *et al.* (2012) and Gbadegesin *et al.*, (2016) for dried roselle calyces respectively. Variability observed in the ash content of sample STP (5.84%) and that reported for sorghum stem sheath flour (5.34%) by Adetuyiet *al.*, 2007 may be due to the differences in the composition might be attributed to the differences in the stages of maturity of the plants as well as the soil fortified with different chemical fertilizer.

Table 3.1: Proximate Compositions (%) of Sorghum Stem Sheath- Moringa Infusion Flour

Sample	Moisture	Protein	Crude fat	Total Ash	Crude fibre	CHO
STP	6.50 ± 0.01a	3.20 ± 0.06a	8.35 ± 0.07b	5.34 ± 0.06a	32.01 ± 1.13b	44.60 ± 1.25e
STP5	7.74 ± 0.02b	5.41 ± 0.08b	8.43 ± 0.09c	7.06 ± 0.10b	33.12 ± 1.15c	38.24 ± 1.19d
STP10	8.60 ± 0.05d	10.82 ± 0.10c	9.05 ± 0.12d	10.50 ± 0.13c	35.40 ± 1.18d	25.63 ± 1.09b
STP15	9.12 ± 0.08e	20.45 ± 0.12d	9.21 ± 0.20e	14.70 ± 0.17e	39.67 ± 1.20e	6.85 ± 1.01a
ML5	8.07 ± 0.03c	28.11 ± 0.19e	2.82 ± 0.01a	10.51 ± 0.15d	19.60 ± 0.10a	30.89 ± 0.17c

Values are means ± standard deviation of triplicate determinations,

The mean values along the same column with different superscripts are significantly different ($p < 0.05$)

STP: 100% Sorghum Stem Sheath Flour, STP5: 95% Sorghum Stem Sheath and 5% Moringa Leaves Flour

STP10: 90% Sorghum Stem Sheath and 10% Moringa Leaves Flour, STP15: 85% Sorghum Stem Sheath and 15% Moringa Leaves Flour, ML rep 5% moringa leaf flour

Incorporation of moringa leaf had significant effects of 24%, 33% and 52% on ash content of samples STP, STP5, STP10 and STP15 respectively.

The protein contents of the sorghum stem sheath-moringa infusion flour ranged between 3.20% to 28.11%. The values increased significantly ($p < 0.05$) as the concentration of moringa leaf to stem sheath flour increased. The values of samples STP, STP5, STP10 and STP15 were significantly different ($p > 0.05$) from one another. The incorporation of Moringa leaf had 41%, 54%, 76% increase in protein content of the samples. The protein content of sorghum stem sheath flour (STP) which was (3.20)% compared favourably with 3.20% reported by Adetuyiet *al.*, (2007) but lower than 7.8% and 6.57% reported by Bahaeldeen *et al.* (2012) and Gbadegesinet *al.*, (2016) for dried roselle calyces respectively. However, the value of STP (3.20)% was higher than 2.64% reported by Wahid *et al.* (2012) for roselle flour.

The crude fat contents of sorghum stem sheath-moringa infusion flour ranged between 2.82% to 9.21%. The values increased significantly ($p < 0.05$) as proportion of moringa to sorghum stem sheath flour increased. Control sample (STP) had (8.35%) while STP15 had (9.21%) of fat content. The crude fat content of sample STP (8.35%) was comparable to the value (8.38)% reported by Adetuyiet *al.*, (2007) for sorghum stem sheath flour. The crude fat content of sample STP (8.35%) was higher than the value (2.0% and 2.31%) reported by Wahid *et al.* (2012) and Gbadegesinet *al.*, (2016) for roselle flour. Bahaeldeen *et al.* (2012) and Amehet *al.* (2009) reported 0.16% and 1.60% for dried roselle calyces respectively. The low fat content of the samples is advantageous because rancidity of the products will be prevented or inhibited. There are observable significant increases at ($p < 0.05$) in the fat content of samples STP, STP5, STP10 and STP15 with increase in moringa leaf inclusion at 0.1%, 0.3% and 0.6% respectively.

The crude fibre contents of sorghum stem sheath-moringa infusion flour ranged between 19.60 to 32.01%. The values increased slightly significantly ($p < 0.05$) with increasing additions of moringa to sorghum stem sheath flour at 3.35%, 6.44% and 10.76% for samples STP, STP5, STP10 and STP15 respectively. Sample STP15 had the highest value (39.67%) while STP had the lowest value (32.01%). The fibre content of sample STP (32.01) % was comparable to (32.02)% reported by Adetuyiet al., (2007) for sorghum stem sheath flour. Bahaeldeen et al. (2012) and Amehet al. (2009) reported 13.2% and

12.46% for dried roselle calyces while Wahid *et al.* (2012) reported 14.6% for roselle powder respectively which were lower than (32.01) % reported for STP. The significant increases in the crude fibre might be due to the fact that the dried moringa leaf flour (19.60)% blended with sorghum stem sheath contained high fibre content. Crude fiber in food is of utmost importance for many scientific, technical and economic reasons. High fiber contents aids in the digestion and prevention of many intestinal diseases (Saldanha, 1995).

Table 3. 2: Vitamin C Contents (mg/100g) of Sorghum Stem Sheath-Moringa Infusion Flour

Instant Samples	VitC (mg/100mg)
STP	0.00±0.00a
STP5	8.60±0.01b
STP10	15.19± 0.03d
STP15	26.04± 0.05e
ML5	10.00 ± 0.01c

Keywords: Values are means ± standard deviation of triplicate determinations. ML rep moringa leaf Flour
The mean values along the same column with different superscripts are significantly different ($p < 0.05$)
STP: 100% sorghum stem sheath Flour, STP5: 95% sorghum stem sheath and 5% moringa leave Flour
STP10: 90% sorghum stem sheath and 10% moringa leave Flour, STP15: 85% sorghum stem sheath and 15% moringa leave Flour.

Vitamin C contents

The vitamin C contents of sorghum stem sheath-moringa infusion flour are shown in Table 3.2. The values ranged between (0.00 to 26.04) mg/100 g. The values increased significantly ($p < 0.05$) with the degree of enhancement being dependent on the increased concentration of moringa inclusion. Sample STP had the lowest value (0.00 mg/100 g) while STP15 had the highest value (26.04 mg/100g). The vitamin C of the sorghum stem sheath flour (STP) which was (0.00) mg/100 g was in agreement with the value (0.00) mg/100g reported by Adetuyiet al.

(2007) for sorghum stem sheath. The value of sample STP (0.00 mg/100ml) was lower than the value (80 mg/100g, 32.36 mg/100g, 76.88mg/100g) reported by Bahaeldeen et al. (2012), Amehet al. (2012) for dried roselle calyces and Gbadegesinet al., (2016) for dried roselle flour. Vitamin C content in food is related to the state of freshness or dryness (Williams, 1998).

Mineral composition

The results of mineral compositions of sorghum stem sheath-moringa infusion flour are shown in Table 3.3. These values are relatively high which implied that sorghum stem sheath-moringa infusion flour can

be a useful source in enriching other food products that are not rich in essential minerals. Decrease in some minerals as the concentration of moringa leaves to sorghum stem sheath flour increased might be due to the leaching out of the extract containing water soluble minerals during washing and drying of moringa leaves.

The calcium contents of sorghum stem sheath-moringa infusion flour ranged between (150.60 to 596.09) mg/100g. The values increased significantly ($p < 0.05$) as the proportion of moringa leaves to sorghum stem sheath flour increased. Sample STP15 had the highest value (596.09 mg/100g) while STP had the lowest value (150.60 mg/100g). The percentage increase of calcium content in samples STP5 and STP10 were 40 and 20% respectively. All samples were significantly different at ($p > 0.05$). The calcium content of the sorghum stem sheath flour (STP) which was 150.60 mg/100g was higher than the value (14.8 mg/100g and 43.13mg/100g) reported by Wahid *et al.* (2012) and Gbadegesinet *al.*, (2016) for roselle flour but lower than the value (60 mg/100g) reported by Mohammed *et al.* (2012) for dried roselle calyces.

The potassium contents of sorghum stem sheath-moringa infusion flour ranged between (138.81 to 300.62) mg/100g. The values increased significantly ($p < 0.05$) as the addition of moringa laves to sorghum stem sheath flour increased. Sample STP had the lowest value (138.81 mg/100 g) while STP15 had the highest value (123.62 mg/100 g). The potassium content of the sorghum stem sheath flour (138.81) mg/100g was slightly higher than the value (101.5 mg/100g and 107.42 mg/100g) reported by Wahid *et al.* (2012) and Gbadegesinet *al.*, (2016) for roselle flour.

The sodium contents of sorghum stem sheath-moringa infusion flour ranged between (16.40 to 210.64) mg/100g. The values increased significantly ($p < 0.05$) with the degree of enhancement being dependent on the increased concentration of moringa inclusion. Sample STP had the lowest value (127.50 mg/100 g) while STP15 had the highest value (210.64mg/100 g). The sodium content of STP was higher than the value (72.1 mg/ 100g, 37.12mg/100g) reported by Wahid *et al.* (2012), Gbadegesinet *al.*, (2016) for roselle flour.

For iron, the values of sorghum stem sheath-moringa infusion flour ranged between 10.22 to 95.94 mg/100 g. The values increased significantly ($p < 0.05$) as the level of incorporation of moringa leaves to sorghum stem sheath flour increased. The value of the iron content (10.22mg/100g) of the sorghum stem sheath flour (STP) was higher than the value (7.46 mg/100 g, 7.14mg/100g) reported by Wahid *et al.* (2012), Gbadegesinet *al.*, (2016) for roselle flour but lower than the value (20 mg/100 g) reported by Mohammed *et al.* (2012) for dried roselle calyces. Iron is an essential micronutrient required for human growth and development. The results showed that the enriched stem-moringa leaf tea infusions can be a good source of iron. The values are in accordance to recommended daily allowance of iron–10 mg/100 g to 13 mg/100 g for children; 7 mg/100 g for men; and 12 mg/100 g to 16mg/100 g for women and feeding mothers (Fuglie, 2001).

The magnesium content of sorghum stem sheath-moringa infusion flour ranged between 50.00 to 335.21mg/100 g. The values increased significantly ($p < 0.05$) as the addition of moringa leaves to sorghum stem sheth flour increased. Sample STP had the. lowest value (185.05 mg/100 g) while STP15 had the highest value (335.21 mg/100 g). The

percentage increase in the magnesium content observed in samples STP5, STP10 and STP15 were 21, 46 and 69% respectively. The magnesium content of the sorghum stem sheath flour (STP) which was

185.05 mg/100g was higher than the value (100.7mg/100 g, 98.14mg/100g) reported by Wahid *et al.* (2012) and Gbadegesinet *al.*, (2016) for roselle flour.

Table3.3:Mineral Compositions (mg/100g) of Sorghum Stem Sheath-Moringa Infusion Flour

Sample	Na	K	Ca	Mg	Fe
STP	127.50 ± 1.15b	138.81±1.10b	150.60± 2.12a	185.05± 2.02b	10.22 ± 0.04a
STP5	140.61± 1.20c	170.02± 1.14c	255.15± 2.20b	200.01± 2.10c	25.13 ± 0.06b
STP10	163.96± 1.24d	235.11± 1.18d	400.02± 2.28d	259.14± 2.13d	51.02 ± 0.15d
STP15	210.64± 1.30e	300.62± 1.25e	596.09± 2.30e	335.21± 2.20e	95.94 ± 0.20e
ML5	16.40± 0.07a	150.00± 1.05a	365.00± 2.00c	50.00± 0.10a	28.20± 0.10c

Keywords: Values are means ± standard deviation of triplicate determinations. ML rep moringa leaf Flour extract

The mean values along the same column with different superscripts are significantly different (p < 0.05)

ST: 100% sorghum stem sheath Flour, ST5: 95% sorghum stem sheath and 5% moringa leave Flour

ST10: 90% sorghum stem sheath and 10% moringa leave Flour, ST15: 85% sorghum stem sheath and 15% moringa leave Flour

Physicochemical properties

pH

The pH of sorghum stem sheath-moringa infusion flour is presented in Table 3.4. The pH values ranged between 1.33 to 3.32. The pH values increased significantly ($p < 0.05$) as the level of incorporation of moringa to sorghum stem sheath flour increased and this could be attributed to the fact that moringa flour has a higher pH compared to sorghum stem sheath flour. Sample STP had the lowest pH value (acidity) (1.33) while STP15 had the highest pH value (acidity)(3.32). The pH value of the sorghum stem sheath flour obtained (1.33) was lower than the value (2.14) reported by Amehet *et al.* (2009) for dried roselle calyces. The pH values of the samples implied that the samples belong to a class of foods referred to as low acid foods (Frazier and Westhoff, 1988; Egbereet *et al.*, 2007).

Titrateable acidity (% malic acid)

The titrateable acidity of the sorghum stem sheath flour is presented in Table 3.4. The values ranged between 1.50 to 2.45% malic acid. The values decreased significantly ($p < 0.5$) as the concentration of moringa to sorghum stem sheath flour increased and this might be due to the incorporation of moringa flour which has a lower titrateable acidity (1.50) compared to sorghum stem sheath flour (4.50). Sample STP had the highest value (4.50%) while STP15 had the lowest value (2.45%). This observation agreed with the proposition that % TTA and pH are inversely related (Nwafor and Ikenebomeh, 2009; Egbereet *et al.*, 2007).

Total soluble solids (TSS)

The TSS of sorghum stem- moringa flour is shown in Table 3.4. The values ranged between 2.76 to 6.10 °brix. The values increased significantly ($p < 0.05$) as the concentration of moringa to sorghum stem sheath

flour increased. Sample STP had the lowest value (3.50°brix) while STP15 had the highest value (6.10 °brix). This might be because moringa contains more sugar than sorghum stem sheath flour. The total soluble solids of sample STP obtained (3.50) was higher than the value (3.20°brix) reported by Fasoyiroet *al.* (2005) for roselle extract without sugar. The essence of the determination of this parameter is to know the sugar content of the enriched flour samples.

Reducing sugar (% glucose)

The reducing sugar of sorghum stem sheath-moringa flour is shown in Table 3.4. The values ranged between 2.18 to 7.50%. The values increased significantly ($p < 0.05$) as the concentration of moringa to sorghum stem sheath flour increased. Sample STP had the lowest value (2.45%) while STP15 had the highest value (7.50%).

Bulk density

The bulk density of sorghum stem sheath-moringa flour is shown in Table 3.4. The values ranged between 0.35 to 0.70 g/ml. Sample STP had the highest value (0.73 g/ml) while sample STP15 had the lowest value (0.53 g/ml). There was significant difference ($p < 0.05$) between all the samples and the bulk density which decreased as the level of incorporation of moringa to sorghum stem sheath flour increased. There is decrease in bulk density of the flour samples as the inclusion of moringa to sorghum stem sheath flour increased. This could be attributed to the fact that moringa (0.35)% is less dense than sorghum stem sheath flour (0.70)%. Bulk density is a measure of heaviness of flour (Adejuyitan *et al.*, 2009) and an important parameter that determines the suitability of flours for ease of packaging and transportation of particulate foods (Shittu *et al.*, 2005). Bulk density is generally affected by particle

size. This means that more quantity of sample STP15 can be packed than other samples for the same specific volume .

Reconstitution index

The reconstitution index of the of sorghum stem sheath-moringa flour samples are presented in Table 3.4. The values ranged between 35.35 to 44.45%. Sample STP (control sample) had the highest value (44.45%) while sample STP15 (sample with highest amount of moringa flour) had the lowest value (37.00%). There were significant difference ($p < 0.05$) among all the samples and the reconstitution index decreased as the addition of moringa to sorghum stem sheath flour increased. All the samples reconstituted well in boiling water but the amount of sediment in the samples decreased as the concentration of moringa to sorghum stem sheath flour increased.

Particle size distribution

Particle size is important in packaging requirement and material handling (Karuna *et al.*, 1996). Particle size of flour sample is an essential part of their

characterization. This is closely linked to the behaviour of the material and/or its physicochemical properties (Guerrero-Beltran *et al.*, 2009). The percent mass retained on the different sieves used with the sieve apertures were used to calculate the mass mean diameter according to Fellows (2000).

The mass mean diameters of sorghum stem sheath-moringa infusion flour are shown in Table 3.5. The values ranged between (50.62 to 313.12) μm . Sample STP (sorghum stem sheath without moringa flour) had the highest value (313.12 μm) while sample STP15 (sample with highest amount of moringa flour) had the lowest value (267.43 μm). There was significant difference ($p < 0.05$) among all the samples and the mass mean diameter decreased as the concentration of moringa to sorghum stem sheath flour increased. The lower particle size of moringa flour therefore suggested its possible usefulness in infant food formulation, since low bulk density food materials are desirable in infant food preparation because of their relatively easy digestibility. Lower particle size of the samples will also increase the level of reconstitution.

Table 3.4: Physicochemical Properties of Sorghum Stem Sheath-Moringa Infusion Flour

Sample	TTA % malic acid	pH	TSS °brix	Reducing Sugar (% glucose)	Bulk Density (g/ml)	Reconstitn index (%)	Mass mean diameter µm
STP	4.50 ± 0.07d	1.33± 0.01d	3.50± 0.03d	2.45 ± 0.02d	0.70 ± 0.04a	45.45 ± 1.95a	313.12 ± 2.85a
STP5	3.83± 0.05c	2.15± 0.02c	4.70± 0.04c	4.90 ± 0.04c	0.62 0.03b±	43.70 ± 1.64b	291.28 ± 2.72b
STP10	3.06± 0.03b	2.74± 0.04b	5.40± 0.05b	6.75 ± 0.06b	0.56 ± 0.02c	40.75 ± 1.39c	275.44 ± 2.58c
STP15	2.45± 0.01a	3.32± 0.06a	6.10± 0.07a	7.50 ± 0.08a	0.52 ± 0.01d	37.00 ± 1.25d	267.43 ± 2.25d
ML5	1.50± 0.01	1.97± 0.04e	2.76± 0.02e	2.18± 0.03e	0.35± 0.02e	35.35± 1.45e	50.62± 1.68e

Values are means ± standard deviation of triplicate determinations.

The mean values along the same column with different superscripts are significantly different ($p < 0.05$)

STP: 100% Sorghum Stem Sheath Flour, STP5: 95% Sorghum Stem Sheath and 5% Moringa Leaves Flour

STP10: 90% Sorghum Stem Sheath and 10% Moringa Leaves Flour, STP15: 85% Sorghum Stem Sheath and 15% Moringa Leaves Flour, ML rep moringa leaf Flour

Sensory Evaluation of Sorghum Stem Sheath-Moringa Infusion Drinks

The result of sensory evaluation of the infusion drinks produced from sorghum stem sheath-moringa drink is shown in Table 3.7. In terms of appearance, there was no significant difference ($p > 0.5$) in the samples STP5 and STP10. This showed that the addition of moringa to the sorghum stem sheath flour at 5 and 10% did not affect the appearance of the drinks.

For flavour, sample STP15 was mostly preferred while sample STP was the least preferred. The mean score increased significantly ($p < 0.05$) with increase in the addition of moringa flour which has an attractive flavour. It was observed that the flavour was even retained after drying. The same trend observed in appearance was observed in flavor attributes: samples STP5 and STP10 were significantly different ($p < 0.05$). Sample STP was liked slightly, STP5

was liked moderately while STP10 and STP15 were liked very much. The order of the score for the flavour was STP15 > STP10 > STP5 > STP.

In terms of taste, sample STP15 was mostly preferred while sample STP was the least preferred. The score increased significantly as the concentration of moringa to sorghum stem sheath flour increased. Sample STP was liked slightly; STP5 was liked moderately while STP10 and STP15 were liked very much. The order of the score for the taste was STP15 > STP10 > STP5 > STP.

In terms of overall acceptability, all the samples were acceptable by the panelists. However, the preference also increased with increase in the level of incorporation of moringa to the sorghum stem sheath flour. Sample STP was liked slightly, STP5 was liked moderately, STP10 was liked very much while STP15 was liked extremely. The order of the score for the overall acceptability was STP15 > STP10 > STP5 > STP.

Table 3.7: Sensory Evaluation of Sorghum Stem Sheath- Moringa Infusion Drinks

Sample	Appearance	Flavour	Taste	Overall Acceptability
STP	6.90 ± 1.52b	6.00 ± 1.06b	5.70 ± 0.43d	4.80 ± 1.00d
STP5	6.75 ± 1.25ab	6.60 ± 1.07ab	6.90 ± 0.90c	6.30 ± 1.31c
STP10	6.74 ± 1.25ab	6.70 ± 1.07ab	7.50 ± 1.28b	7.30 ± 1.62b
STP15	7.00 ± 1.03a	7.50 ± 1.32a	8.60 ± 1.60a	8.10 ± 1.91a

Values are means ± standard deviation of triplicate determinations,

The mean values along the same column with different superscripts are significantly different ($p < 0.05$)

STP: 100% Sorghum Stem Sheath Flour, STP5: 95% Sorghum Stem Sheath and 5% Moringa Leaves Flour

STP10: 90% Sorghum Stem Sheath and 10% Moringa Leaves Flour, STP15: 85% Sorghum Stem Sheath and 15% Moringa Leaves Flour, ML rep moringa leaf Flour extract

Conclusions

The blends of sorghum stem sheath extract with moringa leaf are rich in Vitamin C and other essential minerals: fat, protein, ash, fibre, calcium, sodium, potassium and magnesium contents as the level of incorporation of moringa to sorghum stem sheath flour increased. Addition of moringa to sorghum stem sheath flour also impacted appearance and sample STP15 (sample with the highest proportion of

moringa flour) had the highest score in appearance, taste and overall acceptability when drinks produced from the samples were subjected to sensory evaluation.

It was evident that the stem-moringa leaf tea infusions might possess higher amount of minerals than other green/herbal tea infusions. It can, therefore, be concluded that the drinking of stem-moringa tea enhances the dietary intake of minerals. Minerals in water may be more readily

absorbed than those from food as they are in the free ionic state. These findings could have important nutritional implications in countries where tea is consumed in substantial amount.

Recommendation

There is a strong prospect that industrial production of sorghum stem sheath-moringa instant and infusion drink which could be rewarding to a growing economy like that of Nigeria since the acceptability of the drink cuts across religious and ethnic groups. If the production of these products is developed commercially, it can replace the existing commercially available non-alcoholic beverages in stores and supermarkets like red wine as a drink of choice, increase revenue generation and increase job opportunities. The result above may have direct implications on the commercialization of the product.

This study established that sorghum stem sheath- moringa infusion can be prepared more conveniently from moringa and sorghum stem sheath flour. This would help to reduce wastages of moringa leaf. This study established the ease of production of instant sorghum stem sheath-moringa infusion drink which can be packaged in tea bags and easily reconstituted in boiled water for human consumption.

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