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Comparative analysis on some quality attributes of sorghum stem sheath-moringa instant and infused drinks

Abstract

As per the records of World Health Organization (WHO), it is assumed that more than 60% of the global population is using the traditional medicine system in order to overcome several health related issues. Recent findings revealed that over 80% of the African population relies on medicinal plant species for their primary healthcare. Due to the unaffordability of conventional dugs, medicinal plants like sorghum stem sheath and moringa represent the key products for both urban and rural populations for their healthcare needs. These plants have found to have great therapeutic relevance for fighting major health problems. The research study investigated the proximate, vitamin C, mineral composition and organoleptic properties of sorghum stem sheath-moringa instant and infused drinks at ambient temperature. The result showed that minimal increases were observed in ash and vitamin C compositions of the enriched drinks with increased inclusion of moringa leaf extract. There was also a marginal increase in mineral contents not significantly improved in the enriched drink. The proximate compositions of the instant drinks were in the range of 0.079-0.232% (protein), 10.88-11.51% (carbohydrate), 0.005-0.008% (fat) and 0.25-0.28% (ash). The vitamin C contents of the infused drink ranged between 0.22 and 0.88 mg/100ml. Moreover, based on sensory evaluation, the sample with 15% moringa flour was most preferred in terms of all the sensory attributes evaluated by the panelists. This improved the nutritional value of the enriched drinks which can replace the laden fizzy carbonated commercial drinks in the market.

Keywords: Instant, infused, drink, moringa, sorghum, stem, sheath

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Introduction

Many human degenerative diseases been as a result of free radical damage has necessitated many researches to be undertaken on how to prevent the onset of these diseases.[1] The most likely and practical way is to improve body antioxidant status, by consuming foods rich in antioxidant substances. Diets high in vegetables and fruits can decrease burden of chronic/degenerative disease, like cancers being particularly strong.[2,3] In Nigeria, many people are living with higher levels of chronic diseases and disabilities, and governments have to cope with spiraling social and health care costs.[4–6] There is a growing demand for clean label and natural plant foods, especially those rich in antioxidant substances. These substances have been reported to improve physical and mental well-being of man, as well as reduce the risk of certain debilitating diseases (Dada et al., 2007). Food sources from plant origin such as cereals, oilseeds, fruit and vegetables have been recognized worldwide as good sources of phytochemicals.[7]

Sorghum bicolor stem extract rich in natural antioxidants that can scavenge free radicals has been reported to fight against degenerative diseases (cyclophosphamide- induced oxidative stress) thereby improving the body's antioxidant status.[1] Sorghum stem sheath drink has been shown to have phytochemical and bioactive compounds which can ameliorate free radicals and associated lipid peroxidation and cell damage (Ogiehor et al., 2004). Increased utilization of these vegetables like moringa leaf as foods and industrial raw material has necessitated the search for viable alternatives. Furthermore, industrial exploitation of local plants such as sorghum (Sorghum bicolor) stem sheath, a hitherto agricultural waste reported to be high in antioxidant substances, in developing a non –alcoholic beverage will indeed be of benefit to the people in terms of food, well- being and economy.[8] However, Adetuyi et al.[9] reported that Sorghum bicolor stem sheath lacks vitamin C which is abundant in Moringa.

Moringa young leaves are edible, commonly cooked and consumed like spinach or used to make soups and salads. They are an exceptionally good source of provitamin A, vitamins B, and C, minerals, and the sulphur-containing amino acids methionine and cystine. The composition of the amino acids in the leaf protein is well balanced. The young green pods are very tasty and can be boiled and eaten like green beans.[10] The pods are best for human consumption at the stage when they can be broken easily without leaving any visible strings of fibre. These are rich in free leucine. The leaves, rich in vitamin A and C, are considered useful in scurvy and respiratory ailments; they are also used as an emetic. The juice extracted from the leaves has strong antibacterial and antimalarial properties. A paste of the leaves is used as an external application to promote healing of wounds.[11] This study therefore deemed it fit to fortify sorghum stem sheath with Moringa oleifera to produce nutritious health drinks which can replace laden fizzy carbonated drinks in the market. This will bring a number of benefits to both children and adults in Nigeria and the whole nation at large.

Materials and methods

Materials

Sorghum stem sheath was purchased from Igbona market in Osogbo, Osun State, Nigeria while moringa leaf was collected from Obafemi Awolowo Teaching 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) (Tables 1 & 2) (Figure 1).

Table 1 Sorghum stem sheath -moringa instant drink and designation

Sample codes	Drink designation
SS	Sorghum stem sheath Instant Drink- Control
ML	Moringa Leaf Instant Drink-Control
ST5	Sorghum stem sheath Instant Drink + 5% Moringa leaf
ST10	Sorghum stem sheath Instant Drink + 10% Moringa leaf
ST15	Sorghum stem sheath Instant Drink + 15% Moringa leaf

Table 2 Sorghum stem sheath -moringa infused drink and tea designation

Sample codes	Tea designation
STP	Sorghum stem sheath Infused drink – Control
MLP	Moringa Leaf Infused Drink-Control
STP5	Sorghum stem sheath Infused Drink + 5% Moringa leaf
STP10	Sorghum stem sheath Infused Drink + 10% Moringa leaf
STP15	Sorghum stem sheath Infused Drink + 15% Moringa leaf

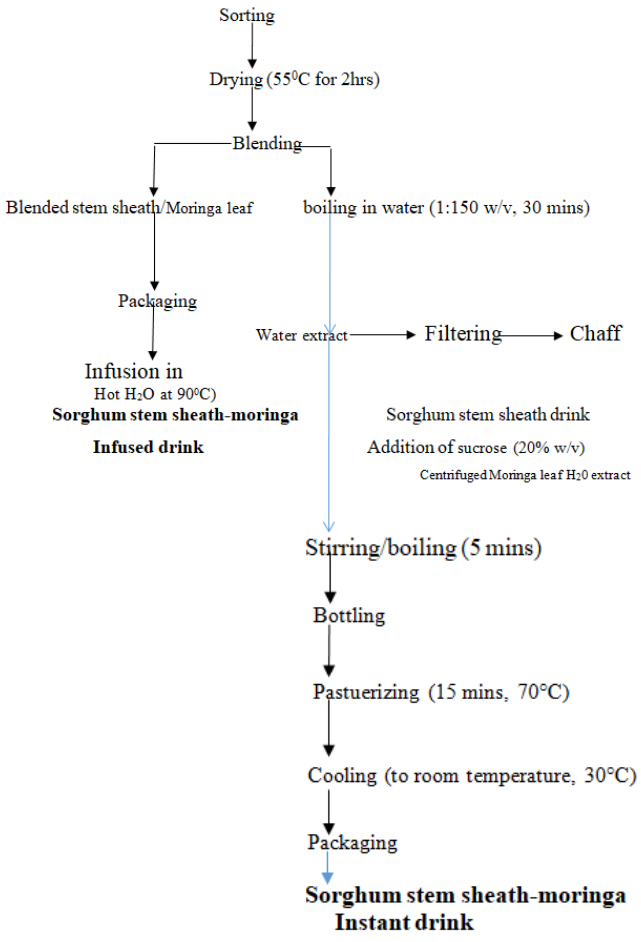

Figure 1 Flow chart for the production of Sorghum stems sheath-moringa instant and infused drink.

Source: Modified methods of Anjorin et al.[12]; Adetuyi et al.[9]

Methods

Sensory evaluation: The sample of each sorghum stem sheath-moringa instant and infusion drinks were presented as coded sample to 20 semi–trained panelists comprising of undergraduate and postgraduate students in the Department of Food Science and Technology, Obafemi Awolowo University of Technology, Nigeria. They were required to assess the enriched sorghum stem sheath drinks in terms of the following quality parameters: taste, flavour, colour and overall acceptability. The scale was rated from one, corresponding to like extremely, to nine corresponding to dislike extremely. Stem sheath extract without moringa leaves extract served as the control sample. The panelists were provided with a mouth-rinse after each testing. The scores from each rating was subjected to analysis of variance (ANOVA) and means were separated.[13] Copies of the questionnaire used for sensory evaluation are in the Appendix I and II.

Proximate Analysis of Sorghum Stem Sheath-Moringa Drink: The samples were analyzed for moisture content, crude fat, crude protein, ash content, crude fibre, carbohydrate content based on the method of analysis of the association of official analytical chemists.[14]

Mineral Element Analysis: The analyses for essential mineral elements were carried out by atomic absorption spectrophotometric using the method of Fashakin et al.[15].

Determination of Ascorbic Acid: Ascorbic acid concentration in the flour samples was determined using the method of.[16]

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 compositions (%) of sorghum stem sheath-moringa instant and infused drink

The proximate composition of the sorghum stem sheath and moringa instant and infused drinks are presented in Table 3. This showed an increase in crude fat, ash, protein and moisture content with increase in the levels of moringa leaf. The moisture content of the enriched sorghum stem sheath increased significantly ($P > 0.05$) from (88.00 to 90.00) % with the unfortified sorghum stem sheath (control) having the lowest moisture content (88.00) % and the moringa drink with the highest value (90.00) %. The values increased insignificantly ($p > 0.05$) as addition of moringa leaves to sorghum stem sheath extract increased. The moisture content of sample SS (88.00%) was in the same range with that reported by Adetuyi et al.,[9] to be 87.70%, (88.88, 88.85 and 88.50) % reported for roselle (zobo) drinks by Egbere et al.,[17], Ezearigo et al.,[18] and Fasoyiro et al.,[19] respectively. This is also confirmed by Adedeji, 2020 during enrichment of sorghum stem sheath with Spondia mombin fruits. The moisture contents of sorghum stem sheath-moringa infused drinks ranged from (98.00 to 98.20) %. The values increased significantly ($p < 0.05$) with the increased inclusion of moringa leaf to stem sheath drink. Sample SSP had the highest value 98.20% while STP15 had the highest value (98.16%) among the enriched samples. The moisture content of sample SSP 98.20% was higher than (87.70) % reported by Adetuyi et al.,[9]. Other researchers like Egbere et al.[17], Ezearigo et al.,[18] and Fasoyiro et al.,[19] also reported (88.88, 88.85 and 88.50%) for zobo respectively which were lower than SSP value of (98.20%) reported in this study. The addition of moringa leaf caused a reduction in the moisture content of the infused drink but as the quantity of moringa leaf extract added increased, the moisture content also increased.

Table 3 proximate composition (%) of the enriched drinks

	Sample	Moisture	Fat	Protein	Ash	CHO
Instant	SS	88.00±0.09d	0.009±0.0007a	0.050±0.005e	0.30±0.03a	11.64±0.01a
	ML	90.00±0.10a	0.003±0.0003d	0.884±0.001a	0.20±0.07a	8.90±0.05e
	ST5	88.10±0.11c	0.005±0.0010c	0.079±0.005d	0.25±0.04a	11.51±0.04b
	ST10	88.21±0.01c	0.006±0.0001c	0.146±0.002c	0.26±0.03a	11.39±0.01c
	ST15	88.60±0.05b	0.008±0.0002b	0.232±0.003b	0.28±0.02a	10.88±0.02d
Infused	SSP	98.20±0.10a	0.007±0.0005a	0.040±0.004e	0.20±0.01a	1.55±0.05a
	MLP	98.00±0.05d	0.001±0.0002d	0.725±0.001a	0.10±0.07a	1.17±0.05e
	STP5	98.10±0.02c	0.003±0.0010c	0.060±0.005d	0.15±0.02a	1.68±0.02b
	STP10	98.12±0.01c	0.004±0.0001c	0.101±0.005c	0.16±0.01a	1.60±0.08c
	STP15	98.16±0.03b	0.006±0.0003b	0.182±0.002b	0.18±0.01a	1.44±0.02d

Note: SS = sorghum stem sheath instant drink, ML = moringa leaf instant drink, ST5 = 95% sorghum stem sheath + 5% moringa leaf instant drink, ST10 = 90% sorghum stem sheath + 10% moringa leaf instant drink, ST15 = 85% sorghum stem sheath +15% moringa leaf instant drink, SSP = sorghum stem sheath infused drink, MLP = moringa leaf infused drink, STP5 = 95% sorghum stem sheath + 5% moringa leaf infused drink, STP10 = 90% sorghum stem sheath + 10% moringa leaf infused drink, STP15 = 85% sorghum stem sheath +15% moringa leaf infused drink, Values are means ± standard deviation of triplicate determinations.

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

The ash contents of the sorghum stem sheath-moringa instant drinks ranged between 0.20 to 0.30%. The ash content of the enriched sorghum stem sheath drink was not significantly ($p > 0.05$) affected by the level of addition of moringa leaf although the ash content increased with increase in the level of addition of the moringa leaf from 0.20 to 0.30 %. Sorghum stem sheath with 15% moringa leaf had the highest ash content while the moringa leaf extract 0% had the lowest. Sample ML had the lowest value 0.20% while ST15 had the highest value 0.30%. The value obtained for sample ST15 0.30% was lower than the values reported by Egbere et al.[17] and Ezearigo et al.,[18] for zobo extract which were 0.54% and 0.50% respectively.

The ash contents of sorghum stem sheath- moringa infused drink ranged between 0.10 to 0.20%. The ash content of the enriched sorghum stem sheath drink was not significantly ($P>0.05$) affected by the level of addition of moringa leaf. Sample MLP had the lowest value (0.10%) while SSP had the highest value (0.20%). The ash content of sample STP15 0.18% was lower than the values reported by Egbere et al.,[17] and Ezearigo et al.,[18] for zobo extract which were 0.54% and 0.50%, respectively. The protein content of the enriched instant drink varied significantly ($P<0.05$) with increase in addition of moringa leaf from 0.050 to 0.232 %. The control (SS) had the lowest (0.050%) protein value showing clearly that sorghum stem sheath is low in protein, while (15) % Moringa oleifera leaf enriched drink had the highest 0.232% protein content. The protein content of sample SS 0.050% was higher than 0.005 % reported by Oluwalana et al.,[20] for sorghum stem sheath beverage but lower than the values reported by Fasoyiro et al.,[19] and Egbere et al.,[17] for zobo extract which were 0.26% and 0.31 % respectively. Dried Moringa oleifera leaf has been reported by several researchers to contain moderate amounts of protein.[21] A similar trend of increase in protein content was observed when Moringa oleifera leaf was added to full fat and low fat yoghurt.[22] Adedeji,[23] reported increased protein content with increased inclusion of *Spondias mombin* extract. The incorporation of moringa leaf had (36.71, 65.75, 78.45) % significant increases on the protein content of ST5, ST10 and ST15 respectively.

The protein contents of the sorghum stem sheath- moringa infused drink ranged between (0.040 to 0.182) %. The values increased significantly ($p < 0.05$) as the concentration of moringa leaf to stem sheath drink increased. The values of samples SSP, MLP, STP5, STP10 and STP15 were all significantly different ($p > 0.05$) from one another. The incorporation of Moringa leaf had 20% increase in protein content of the samples. The protein content of sorghum stem sheath infused drink (STP15) (0.182) % was lower than that reported by Oluwalana et al.,[20] for sorghum stem sheath beverage (0.005) % but lower than the values reported by Fasoyiro et al.,[19] and Egbere et al.,[17] for zobo extract which were 0.26% and 0.31 % respectively. The incorporation of moringa leaf had (33.33, 60.40, 78.02) % significant increases on the protein content of ST5, ST10, ST15, respectively.

The crude fat content in Table 4 of the enriched sorghum stem sheath instant drink increased and differed significantly ($p < 0.05$) with increase in the addition of moringa leaf. The crude fat contents of the sorghum stem sheath- moringa instant drink ranged between (0.003 to 0.009) %. Sample ML had the lowest value (0.003) % while SS had the highest value (0.009) %. The values increased significantly ($p < 0.05$) as the concentration of moringa leaf to sorghum stem sheath extract increased and this might be as a result of higher fat content in moringa leaf (0.003) % compared to sorghum stem sheath extract (0.009) %. The fat content of sample ST15 was significantly ($p < 0.05$) higher than the other samples. The fat content of sample SS was significantly ($p< 0.05$) lower than other samples. The fat contents of the sorghum stem sheath drink (0.009) % compared favourably with that reported by Oluwalana et al.,[20] which were (0.009) % but lower than the value reported for roselle calyces extract by Egbere et al.[17] and Ezearigo et al.,[18] which were 0.24 and 0.38 % respectively. A similar trend of increase in protein content was observed when *Spondia mombin* was added to Sorghum stem sheath extracts.[23] The ash content increased insignificantly ($p> 0.05$) from (0.34 to 0.42) % with increased inclusion of *Spondias mombin* extract. However, the lower amount of fat (0.003 to 0.009) % in the drinks can be used as diet drink and preventive measures for other chronic diseases.[24]

The crude fat contents of sorghum stem sheath- moringa infused drink ranged between 0.001 to 0.007%. The values increased significantly ($p < 0.05$) as the proportion of moringa to sorghum stem sheath drink increased. Control sample (MLP) had the lowest value (0.001 %) while SSP had the highest value (0.007%) of fat content. The crude fat content of sample SSP (0.007%) compared favourably with

that reported by Oluwalana et al.[20] which were (0.009) % but lower than the value reported for roselle calyces extract by Egbere et al.,[17] and Ezearigo et al.,[18] which were 0.24 and 0.38 % respectively. The carbohydrate contents of sorghum stem sheath- moringa instant drinks ranged from (8.90 to 11.64) %. Similarly, as observed for moisture content (Table 4), the carbohydrate content decreased significantly ($p < 0.05$) with increase in the addition of Moringa oleifera leaf with the control (SS) having the highest (11.64%) and the ML having the lowest (8.90%) carbohydrate content. The value of sample SS (11.64) % was significantly ($p < 0.05$) higher than the values reported by Egbere et al.,[17], Fasoyiro et al.,[19] and Ezearigo et al.,[18] for roselle calyces extract which were 10.60%, 6.31 % and 10.99% respectively. This might be due to the high amount of carbohydrate contained in the moringa leaf which is important in foods as a major source of energy.[25]

Table 4 Vitamin C Composition (mg/100ml) of the enriched drinks

Instant sample	Vitamin C	Infused sample	Vitamin C
SS	0.00±0.00e	SSP	0.00±0.00e
ML	4.43±0.01a	MLP	4.20±0.02a
ST5	0.23±0.02d	STP5	0.22±0.04d
ST10	0.46±0.04c	STP10	0.44±0.03c
ST15	0.92±0.03b	STP15	0.88±0.01b

Note: SS = sorghum stem sheath instant drink, ML = moringa leaf instant drink, ST5 = 95% sorghum stem sheath + 5% moringa leaf instant drink, ST10 = 90% sorghum stem sheath + 10% moringa leaf instant drink, ST15 = 85% sorghum stem sheath +15% moringa leaf instant drink, SSP = sorghum stem sheath infused drink, MLP = moringa leaf infused drink, STP5 = 95% sorghum stem sheath + 5% moringa leaf infused drink, STP10 = 90% sorghum stem sheath + 10% moringa leaf infused drink, STP15 = 85% sorghum stem sheath +15% moringa leaf infused drink, Values are means ± standard deviation of triplicate determinations.

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

The carbohydrate contents of sorghum stem sheath- moringa infused drinks ranged between 1.17 to 1.68%. The values decreased significantly ($p < 0.05$) as addition of moringa leaf to sorghum stem sheath extract increased. The value of sample ST (11.38) % was however higher than the values reported by Egbere et al.,[17], Fasoyiro et al.,[19] and Ezearigo et al.,[18] for roselle calyces extract which were 10.60%, 6.31 % and 10.99% respectively. The high values of carbohydrate in all samples indicate that sorghum stem sheath enriched drink may have a better keeping quality. Carbohydrate content of the enriched drink was obtained by difference. The least value was obtained in Moringa oleifera leaf (8.90%) which was lower than the 10.59% reported by Abiodun et al.,[26] for moringa leaf drink, 16.51% reported by Singh et al., (2011) for moringa leaf drink, 9.17% reported by Compaore et al.,[27] for moringa leaf drink. The variations observed in the values obtained in this study and other studies for protein, ash, crude fibre, fat and carbohydrate contents of Moringa oleifera leaf and sorghum stem sheath drink may be due to differences in specie variety (genetic), climatic, storage, environmental and processing conditions (time, temperature, humidity), geographical location, soil composition and stage of maturity of the plant before harvest, harvesting time.[27]

Vitamin C Contents (mg/100ml) of Sorghum Stem Sheath-Moringa Instant and Infused Drinks

The vitamin C contents of sorghum stem sheath-moringa instant and infused drinks are shown in Table 4. The vitamin C content of the beverages ranged from 0.00 to 4.43 mg/100 ml which is lower than the value (9.33 mg/100 g) reported by Fasoyiro et al.,[19] for zobo drink. This is in agreement with the report of USDA Nutrient data base (2009) that sorghum stem sheath does not contain vitamin C. Therefore, the vitamin C content measured from the non-alcoholic beverage was a result of the inclusion of moringa leaf which is rich in vitamin C content (4.43) mg/100ml as reported by Illyas et al.,[28]. Gbadegesin et al.,[29] reported that the vitamin C status of beverages (such as zobo) can be improved by blending with plant materials and fruits (Table 4).

Vitamin C content increased slightly with increased concentration of moringa leaf extract to sorghum stem sheath extract. The sample ST15 had the highest (0.92%) vitamin C content among the enriched samples while sample SS had no discernable (0.00) % vitamin C content. This could be attributed to the differential vitamin C content of the two base materials which are sorghum stem sheath and moringa leaf extracts. As Moringa inclusion increased, samples had percentage increases of 23%, 46%, 92% and 22%, 44%, 88% of vitamin C for both instant and infused drinks, respectively. Adetuyi et al.,[9] obtained a similar result for vitamin C content of sorghum stem sheath extract (0.00) %. Adedeji,[23] also reported observable increases in Vitamin C composition during enrichment of Sorghum bicolor Stem Sheath with *Spondias mombin.* Extract the vitamin C contents of sorghum stem sheath-moringa infused drinks ranged from (0.00 to 4.20) mg/100 ml. Sample STP had the lowest value (0.00 mg/100 g) while STP15 had the highest value (0.88mg/100ml). The vitamin C of the sample (SS) 0.00 mg/100ml was in agreement with the value (0.00) mg/100ml reported by Adetuyi et al.[9] for sorghum stem sheath. This is therefore the need for enrichment of sorghum stem sheath drink. The vitamin C content of sample SS (0.00 mg/100ml) was lower than the values (31.33 and 35.62) mg/100ml reported by Fasoyiro et al.,[19] and Gbadegesin et al.,[29] for roselle calyces extract, respectively. Vitamin C content in food is related to the state of freshness or dryness (Williams, 1998). Extraction of vitamin C at high temperature reduced its content. This observation agrees with the report of Ashaye et al. (2006) that vitamin C is unstable at elevated temperatures. Also, vitamin C in solution degrade at high temperatures.[14,30,31]

Mineral Compositions (mg/100ml) of Sorghum Stem Sheath-Moringa Instant and Infused Drink

The mineral compositions of sorghum stem sheath-moringa instant and infused drinks are shown in Table 5. The calcium contents of sorghum stem sheath-moringa. The mean values along the same column with different superscripts are significantly different ($p< 0.05$). Table 5 shows the effect of addition of Moringa oleifera leaf on the mineral composition of sorghum stem sheath- moringa infused drinks. Generally, the calcium content of the enriched sorghum stem sheath–moringa infused drink increased significantly ($p < 0.05$) with increase in addition of Moringa oleifera leaf from 103.60 to 145.97 mg/100ml. The (MLP) and (SSP) had the lowest (103.60) mg/100ml and highest (145.97) mg/100ml Ca values respectively. This observation agrees with previous reports that Moringa oleifera leaf contain relatively low amounts of minerals particularly Ca.[28] Furthermore, the addition of Moringa oleifera leaves to sorghum stem sheath indicates that sorghum stem sheath- moringa infused drinks will increase the utilization of the leaf and thus promote better health for consumers of this drink. The percentage increases of calcium content in samples STP5 and STP10 were 2.3 and 1.2% respectively. Samples STP5 and STP10 were not significantly different at ($p > 0.05$) in their Calcium contents. The calcium content of the sorghum stem sheath flour (SSP) which was 145.97 mg/100ml was higher than the values 14.6 mg/100ml and

12.7 mg/100ml reported by Okeniyi et al.,[32] and Bamishaiye et al.,[33] reported for roselle calyces extract respectively. The incorporation of moringa leaf had (1.45, 2.17, 4.36) % significant decreases on the calcium content of STP5, STP10, STP15. A similar trend of decrease in calcium content was observed when *Spondia mombin* was added to Sorghum stem sheath extracts.[23]

The potassium contents of sorghum stem sheath-moringa instant drinks are shown in Table 6. The potassium contents of sorghum stem sheath-moringa instant drink ranged between 123.04 and 178.2mg/100ml. The values increased significantly ($p < 0.05$) with increased inclusion of moringa extract to sorghum stem sheath drink. The sample ST15 had the highest 131.32mg/100ml potassium content while sample SS (control) had the lowest 123.04mg/100ml value. The incorporation of moringa leaf extract to sorghum stem sheath caused significant ($p < 0.5$) increases of 0.62, 0.91, 2.67% in the K content of sample ST5, ST10 and ST15, respectively. This could be attributed to the differential K content of the two base materials which are sorghum stem sheath and moringa leaf extracts. The potassium content of sample SS (123.04 mg/100ml) was higher than the values reported by Okeniyi et al.,[32] and Bamishaiye et al.,[33] for roselle extract which were 35.40mg/100ml and 32.40mg/l00ml respectively. However, the value obtained was substantially higher than 10.03mg/100 ml reported by Ezearigo et al.,[18] for roselle calyces extract. Therefore, sorghum stem sheath drink is a potassium rich product.

Table 5 Mineral composition (mg/100ml) of the enriched drinks

	Sample	Na	Ca	K	Fe
Instant	SS	780.00±0.10a	632.00±0.08a	123.04±0.06e	114.00±0.09a
	ML	40.10± 0.15e	84.73±0.09e	178.24±0.01a	41.15±0.12e
	ST5	743.06±0.13b	604.24±0.01b	123.80±0.05d	110.36±0.05b
	ST10	706.03±0.10c	580.75±0.02c	124.16±0.01c	107.54±0.06c
	ST15	609.02±0.15d	549.91±0.05d	126.32±0.02b	103.07±0.07d
Infused	SSP	730.98±0.10a	145.97±0.08a	122.70±0.08e	113.51±0.01a
	MLP	39.30± 0.18e	103.60±0.05e	171.80±0.05a	43.21±0.16e
	STP5	696.40±0.15b	143.85±0.03b	123.01±0.04d	109.99±0.11b
	STP10	669.11±0.12c	142.79±0.01c	124.00±0.01c	107.23±0.12c
	STP15	627.23±0.11d	139.61±0.02d	127.07±0.07b	102.96±0.04d

Note: SS= sorghum stem sheath instant drink, ML = moringa leaf instant drink, ST5 = 95% sorghum stem sheath + 5% moringa leaf instant drink, ST10 = 90% sorghum stem sheath + 10% moringa leaf instant drink, ST15 = 85% sorghum stem sheath +15% moringa leaf instant drink, SSP = sorghum stem sheath infused drink, MLP = moringa leaf infused drink, STP5 = 95% sorghum stem sheath + 5% moringa leaf infused drink, STP10 = 90% sorghum stem sheath + 10% moringa leaf infused drink, STP15 = 85% sorghum stem sheath +15% moringa leaf infused drink,Values are means ± standard deviation of triplicate determinations.

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

Table 6 Sensory evaluation of the enriched drinks

	Sample	Taste	Colour	Flavour	Ov. Accpt
Instant	SS	6.2±0.10d	7.5±0.04b	6.0±0.28d	6.2±0.12d
	ML	6.3±0.01d	7.3±0.06c	7.4±0.10c	7.0±0.08c
	ST5	6.9±0.07c	7.7±0.02a	7.5±0.01c	7.5±0.14b
	ST10	7.6±0.02b	7.7±0.02a	8.0±0.42b	7.6±0.05b
	ST15	7.9±0.15a	7.7±0.02a	8.7±0.34a	8.4±0.20a
Infused	SSP	6.0±0.07d	7.0±0.20d	7.0±0.12d	6.2±0.02d
	MLP	6.7±0.10c	8.4±0.15a	7.7±0.30c	7.1±0.01c
	STP5	6.8±0.02c	7.6±0.10c	7.8±0.20c	7.0±0.10c
	STP10	7.8±0.05b	7.7±0.01c	8.4±0.25b	7.9±0.01b
	STP15	8.4±0.12a	7.8±0.05b	8.6±0.15a	8.8±0.05a

Note: SS = sorghum stem sheath instant drink, ML = moringa leaf instant drink, ST5 = 95% sorghum stem sheath + 5% moringa leaf instant drink, ST10 = 90% sorghum stem sheath + 10% moringa leaf instant drink, ST15 = 85% sorghum stem sheath +15% moringa leaf instant drink, SSP = sorghum stem sheath infused drink, MLP = moringa leaf infused drink, STP5 = 95% sorghum stem sheath + 5% moringa leaf infused drink, STP10 = 90% sorghum stem sheath + 10% moringa leaf infused drink, STP15 = 85% sorghum stem sheath +15% moringa leaf infused drink,Values are means ± standard deviation of triplicate determinations.The mean values along the same column with different superscripts are significantly different ($p< 0.05$).

The potassium contents of sorghum stem sheath-moringa infused drink ranged between 122.70 and 171.80mg/100ml. The values increased significantly ($p < 0.05$) with the degree of enrichment being dependent on the increased concentration of moringa inclusion. Sample MLP had the highest K content 171.80mg/l00ml while SSP had the lowest K content 122.70 mg/l00ml. The incorporation of moringa leaf extract to sorghum stem sheath caused significant ($p < 0.5$) increases of 0.25, 1.05, 3.56% in the K content of sample STP5, STP10 and STP15, respectively. The potassium content of the sorghum stem sheath drink 122.70mg/100ml was higher than 35.40 mg/100ml and 32.40mg/l00ml and 10.03mg/100 ml reported by Okeniyi et al.,[32], Bamishaiye et al.,[33] and Ezearigo et al.[18] for roselle calyces extract, respectively. Adedeji,[23] also reported observable increases in potassium content during enrichment of *Sorghum bicolor* Stem Sheath with *Spondias mombin* Extract.

The potassium contents of the both instant and infused drinks were quite close. This may be due to the fact that they were both produced from the same starting materials irrespective of the method of preparation. The sodium contents of sorghum stem sheath-moringa instant drinks are shown in Table 6. The values of sorghum stem sheath-moringa instant drink ranged between (40.10 and 743) mg/100ml. The values decreased significantly ($p < 0.05$) as the concentration of moringa leave to sorghum stem sheath extract increased and this is because sorghum stem sheath is richer in sodium 780mg/100ml than moringa leaf 40.10mg/100ml. The sample SSP had the highest 780 mg/100ml while sample ML had the lowest value (39.30) %. The incorporation of moringa leaf extract to sorghum stem sheath in proportionate gradient caused a significant ($p < 0.5$) decrease in the Na content of the samples. This could be attributed to the differential sodium contents of the two base materials which are sorghum stem sheath and moringa leaf extracts. The value 780 mg/100ml reported in this study was higher than that reported by Bamishaiye et al.,[33], Ezearigo et al.,[18] and Okeniyi et al.,[32] for roselle calyces extract which were 9.98mg/l00ml, 10.98mg/100ml and 5.39mg/100ml respectively. Adedeji,[23] also reported observable decreases in sodium content during enrichment of *Sorghum bicolor* Stem Sheath with *Spondias mombin* Extract.

The sodium contents of sorghum stem sheath-moringa infused drink ranged between (39.30 and 696.40) mg/l00ml. The values decreased significantly ($p < 0.05$) with the degree of enrichment being dependent on the increased concentration of moringa inclusion. A decrease in Na content is desirable as the addition of moringa extract helped in reduction of Na content of the drink according to the medical practice which advice reduction in Na intake. Sample MLP had the lowest value 39.30 mg/100ml while SSP had the highest value 730.98rng/100ml. The sodium content of the sorghum stem sheath was higher than that reported by Bamishaiye et al.,[33], Ezearigo et al.,[18] and Okeniyi et al.,[32] for roselle calyces extract which were 9.98 mg/l00ml, 10.98 mg/100ml and 5.39 mg/100ml respectively. The iron content of sorghum stem sheath-moringa instant drinks ranged from (107.54 to 110.36) mg/100ml. This is, however, higher than the value (70.02 mg/100 ml) obtained by Agarry et al.,[34] for kunnu and the iron content of the zobo drink, 2.40 mg/100 ml.[29]

The iron content in this study is higher than the values reported for Pyrus communis, Irvingia gabonesis and Magifera indica fruits consumed in Nigeria (1.86-4.49 mg/100g) (Obuzor and Ajaezi, 2010). The incorporation of moringa leaf extract to sorghum stem sheath in proportionate gradient caused a slight decrease in the Fe content of the samples. This could be attributed to the differential sodium content of the two base materials which are sorghum stem sheath and moringa leaf extracts. Sample SS had the highest value (114.00 mg/l00ml) while ML had the lowest value (41.15 mg/l00ml). The value of the iron content (114.00mg/100ml) of the sorghum stem sheath drink (SS) was in the same range with (114.0) mg/100ml reported by Adetuyi et al.,[9] but higher than 0.82mg/100ml reported by Okeniyi et al.,[32] and 0.96mg/100ml reported by Bamishaye et al.,[33] for roselle calyces extract. The incorporation of moringa leaf had (3.19, 5.67, 9.59) % significant decreases on the iron content of ST5, ST10, ST15, respectively. Adedeji, 2020 also reported observable decreases in iron content during enrichment of *Sorghum bicolor* Stem Sheath with *Spondias mombin* Extract.

Table 6 showed the effect of addition of Moringa oleifera leaf on the iron content of sorghum stem sheath- moringa infused drinks. The values of sorghum stem sheath-moringa infused drink ranged between (102.96 and 109.99) mg/100ml. The values increased significantly ($p < 0.05$) as the level of incorporation of moringa leaf to sorghum stem sheath drink increased. The value of the iron content (113.51mg/100ml) of the sorghum stem sheath drink (SS) was lower than (114.0) mg/100ml reported by Adetuyi et al., 2007 but higher than 0.82mg/100ml reported by Okeniyi et al.,[32] and 0.96mg/100ml reported by Bamishaye et al.,[33] for roselle calyces extract. Sample SSP had the highest value (113.51 mg/l00ml) while ML had the lowest value (43.21 mg/l00ml). The incorporation of moringa leaf had (3.09, 5.53, 9.29) % decreases on the iron content of STP5, STP10, STP15, respectively. About 15% addition of Moringa inclusion led to about 9% reduction in Fe content. The results showed that the enriched stem-moringa leaf enriched drink serves as a good source of iron. This confirms its traditional use in the prevention of anemia.[20]

Sensory Evaluation of Sorghum Stem Sheath- Moringa Instant and Infused Drinks

The results obtained from sensory evaluation of the drinks produced from sorghum stem sheath-moringa instant and infused drinks are shown in Table 6. With regards to the colour, there was no significant difference ($p > 0.05$) in the enriched instant samples. This showed that the addition of moringa to the sorghum stem sheath extract obviously had insignificant effect on the colour of all the enriched instant drinks. The high ratings (7.3-7.7) observed for the enriched instant sample could be attributed to the light yellow tinted green colour of moringa leaf extract which is a reflection of the chlorophyll content of the leaf. The enriched instant drinks had higher scores (7.7)than sorghum stem sheath (7.5). The difference in colour scores was not significant. It is probable that the coloring substance in ML had reached the saturation limit such that further addition did not increase the intensity of the colour. The colour of the enriched instant drink may be better as it attracted higher score (7.7) than the control sample (7.5). There was no significant difference ($p > 0.05$) in colour scores for the enriched infused samples. It was observed that the color darkened with increase in moringa leaf extract inclusion. This might be because the wine cherry red colour of SSP (7.0) might have masked the bright yellowish green color of the MLP (8.4) so that it did not affect the color significantly ($p > 0.05$) at lower levels. Adedeji et al.,[35] reported that the addition of moringa to the sorghum stem sheath extract obviously had insignificant effect on the colour of all the enriched instant drinks. Sample MLP was rated highest (8.4) among other samples because of its unique bright green color as presented in (Plates 1-3). The sensory scores for colour indicates that the panelists are well acquainted with wide arrays of different coloured drinks.

Colour is a very important parameter in judging food quality. It does not only reflect the suitability of raw materials used for production but

provides information about the formation and quality of the products. It also influences consumer's choice and preferences (Ferial et al., 2011; Pathare et al.,[36]). The colour of the enriched infused drink was brighter than that of the instant drink. This might be due to the fact that the amount of active (chlorophyll) substances in the enriched instant drink was far greater than that of the infused drink. In terms of concentration, it suggests that the extract used for the production of instant drink is of higher concentration than that of the infused drink. This is supported by the results from the research as the minerals and antioxidants contents are higher in instant drink than the infused drink although there was no significant difference ($p > 0.5$) among the enriched samples. For the taste of the instant drink, sample ST15 (7.9) was mostly preferred while sample SS (6.2) the least preferred score. The scores increased slightly as the concentration of moringa to sorghum stem sheath extract increased. Sample SS (6.2), ML (6.3), ST5 (6.9) was liked slightly while ST10 (7.6) and ST15 (7.9) were liked moderately. This might be as a result of moringa leaf extract inclusion. The order of the score for the taste was ST15 > ST10 > ST5 >ML> SS.

For the taste of the infused drink, sample STP15 (8.4) was mostly preferred while sample SSP (6.0) was the least preferred. The score increased slightly as the concentration of moringa to sorghum stem sheath extract increased. There were no significant ($p > 0.05$) differences in the taste of the enriched samples. With regards to the flavour of the instant drink, sample ST15 was most preferred while sample SS was the least preferred. The scores increased slightly with the additions of moringa extract to sorghum stem sheath. This might be as a result of the ability of the panelists to ascertain the differences in the threshold of the flavour contributed by moringa extract in the enriched samples. The order of the score for the flavour was SS<ML < ST5< ST10 < ST15 i.e the addition of ML improved the flavour of the drink samples.

For flavour of the infused drink, the same trend observed in instant drink was observed. The enriched samples were not significantly different ($p > 0.05$). Sample SSP was liked slightly; MLP and STP5 were liked moderately while STP10 was liked very much and STP15 was liked extremely. The order of the scores for the flavour was STP15 > STP10 > STP5 > MLP >SSP. For flavor in the infused drink, sample STP15 (9.0) was mostly preferred while sample SSP (7.0) was the least preferred. The mean scores increased slightly with increase in the addition of moringa extract. A similar report was obtained by Adedeji et al.,[35] as the scores for flavour increased slightly with the additions of moringa extract to sorghum stem sheath. Flavour is the main criterion that makes the product to be liked or disliked.

Overall acceptability is another important criterion in the instant drink, all the samples were acceptable to the panelists. However, the mean scores (7.5-8.4) of the samples increased slightly with increase in the level of inclusion of moringa to sorghum stem sheath extract. Sample SS was liked slightly; ML, ST5 and ST10 were liked moderately while ST15 was liked very much. The order of the score for the overall acceptability was ST15 > ST10 > ST5 > ML > SS. For the overall acceptability of the infused drink, all the samples were acceptable to the panelists. However, the preference also increased slightly with increase in the level of incorporation of moringa to the sorghum stem sheath extract. Sample SSP was liked slightly; MLP was liked moderately, STP5 and STP10 were liked very much while STP15 was liked much extremely. The order of the score for the overall acceptability was STP15 > STP10 > STP5 > MLP > SSP. The result of overall acceptability for the enriched sorghum stem sheath drinks revealed that the enriched samples had the best rating and the control had the least rating. In all, the addition of ML and MLP affected the overall acceptability of the enriched samples significantly ($p < 0.05$).

The drink samples without enrichment had a significantly lower score for taste than the enriched samples. The same trend was observed in flavor with the control having a slightly lower score than others. A recent survey showed that the choice of food by the consumer is a complex phenomenon determined by sensory pleasure among several other factors, although taste is considered to be the fundamental determinant of food choice,[37] color is the primary factors that motivates a consumer to try a product in the first place (Fernandez-Vazquez et al., 2013). In addition, flavor- one of the most important determinants of selection or choice of fruit-based food material by consumer.[38] Generally, the organoleptic features of the drink samples had similar scores in terms of the overall acceptability of the samples. The drink samples with 15% moringa had higher overall acceptability score and statistically different among other samples. It is worth nothing that both the control and the enriched samples were generally accepted, since all the scores were higher than 4.5 which is the minimum acceptable values on the nine- point hedonic scale (Plates 1-3).

Plate 1 The Enriched Sorghum Stem Sheath Infused Tea Bags.

Plate 2 The Enriched Sorghum Stem Sheath Infused Drink.

Plate 3 The Enriched Sorghum Stem Sheath Instant Drinks

Conclusions

Sorghum stem sheath drink which lacks vitamin C was enriched with available and cheap plant–based source (moringa leaf). This result showed that minimal increases were observed in ash, vitamin C compositions of the enriched drinks with increased inclusion of moringa leaf extract. There was also a marginal increase in mineral content not significantly improved in the enriched drink. Enrichment resulted into higher vitamin C, mineral compositions of the enriched drinks. Sensory evaluation showed that samples with 15% inclusion level of moringa leaf extract were most preferred although all the enriched samples evaluated were acceptable.[39–50]

Recommendation

Based on the findings above, the enriched drinks are recommended for consumption by the populace since the acceptability of the beverage cuts across religious and ethnic groups. The government should encourage the conversion of hither to agricultural waste materials like sorghum stem sheath to useful products (waste to wealth). Commercial production of the sorghum stem sheath drink could increase revenue generation, job opportunities and its utilization in the country.

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Conflicts of interest

The authors declare that there was no conflict of interest.

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