A STUDY OF SOME CHEMICAL, SENSORY PROPERTIES AND STORAGE TESTS OF SORGHUM STEM SHEATH-MORINGA INSTANT DRINKS

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Abstract
This research study was carried out to determine the organoleptic, antioxidant and storage properties of sorghum stem sheath-moringa instant drink stored at ambient temperature weekly for a month. The blends were produced from sorghum stem sheath and moringa leaf extractin the proportion of 100: 0, 95: 5, 90:10, 85:15 and 0:100, respectively. The antioxidant properties of the samples were in the range of 54.78-57.05%for (1, 1-diphenyl -2picryl hydrazyl) free radical (DPPH), 76.38-77.03% for Metal Chelating(MC), 172.22-173.87 GAE mg/100gfor Ferric Reducing Antioxidant Power (FRAP) and 76.38-77.03 GAE mg/100g for Total Phenol Content (TPC). The vitamin C contents ranged between 0.23 and 0.92 mg/100ml. The antioxidant properties increased significantly ($p < 0.05$) with the degree of enrichment being dependent on the increased concentration of moringa extract inclusion. The sensory evaluation revealed that the sample with 15% moringa leaf inclusion was most preferred in terms of all the sensory attributes evaluated by the panelists.Storage tests showed that total soluble solids and vitamin C decreased while titratable acidity increased throughout the period of storage. In conclusion, the inclusion of 15% moringa leaf into sorghum stem sheath flour enhanced utilization of the leaf and provision of nutritious health promoting alternative new food product that can compete with the commercial flavoured drinks.

Keywords: *organoleptic; instant drink; moringa; sorghum stem sheath*

Received: 28.09.2019 Reviewed: 18.11.2019 Accepted: 20.12.2019

1. INTRODUCTION

Sorghum (*Sorghum bicolor)* is one of the most important staple crops in Nigeria. 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).The mature black purple sheath of the stem (locally known as *poporo*) generally sold in small bundlesis used as color additives in cooking meals and also taken as beverages when steeped or boiled in water in many homes in Nigeria (Adetuyi*et al.,* 2007). 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). Adetuyi *et al., (*2007) fortified the SSS 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 *et al.* (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. The resultant solution is bright red. It is also used as a food preservative.Hence, its industrial exploitation in beverage making would be of great advantage.
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 diff parts have been reported to be rich in protein, vitamins and minerals, essential amino acids, antioxidants and antimicrobial properties (Jabeen*et al*., 2008; Anwar and Rahid 2007). *Moringaoleifera* has been used as supplements in different food products ranging from bakery products (Dachana*et al*., 2010; Ogunsina*et al*., 2011) to cereal based snacks (Ewulo, 2012) 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).The leaves (Plate 2) 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 (Moyo, 2011). 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 (Silver, 2012). However, there is a dart of information about its enrichment with moringa leaf.This study therefore aimed at enhancing the nutritional value of stem sheath drink by fortifying it with leaf extracts of moringa and also assessing the influence of fortification on the storage stability, sensory qualities as well as antioxidant and nutritional properties of the stem sheath fortified drinks.

2. MATERIALS AND METHODS

Materials

Sorghum stem sheath was purchased from Igbona market in Osogbo, Osun State, Nigeria and classified by the Dept of Botany, OAU while moringa leaves were collected from Obafemi Awolowo Teaching and Research 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).

Methods

Production of moringa leaf extract

Moringa leaf extract was produced following a modification of the method of Ilyas*et al.* (2015). Green and mature moringa leaves were desalked, 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 drying, it was milled using an electric blender (Marlex Kitchen Blender D-564, China) at maximum speed for 1 min, sieved, cooled at room temperature (27± 3^0C) and then packaged in an air-tight Ziploc bag for further use. Ten grammes of moringa leaf flour was mixed with 100ml of water, Stirred on a magnetic stirrer for 10 min and centrifuged (10 min; 3000 g).

Production of sorghum stem sheath flour

Sorghum stem sheath flourwas produced following a modification of the method of Adetuyi *et al.* (2007). Dry sorghum stem sheath was sorted and winnowed manually to remove adhering dirt and extraneous materials before drying in a laboratory oven at 55^0C for 2h. The stem sheath was then milled using Marlex blender D-564 at max speed for 1 min and packaged in an air- tight Ziploc bag for further use.

Plate 1: A bundle of Sorghum stem sheath

Plate 2: Moringa tree with leaves

Plate 3: Sorghum stem sheath-moringa Instant drink

Production of Sorghum Stem-Sheath Moringa Instant Drink

The method described by Adetuyi*et al.,* (2007) was adapted with some modifications. Dried sorghum stem sheath was freed from extraneous materials by manual sorting and winnowing. About 400g of the stem sheath was rinsed with water. The washed stem sheath was boiled in 6000 ml of water for 30 mins in a covered pot to aid the extraction as well as destruction of heat sensitive micro-organisms present. It was then filtered into previously sterilized bowl using a clean muslin cloth to obtain sorghum stem drink. Moringa leaf liquid extract was added at different concentrations [0, 5, 10 and 15% (v/v)] for enrichment. About 10g of sucrose was added to each moringa leaf enriched drink and then stirred to hasten the dissolution. Each sample was stirred and boiled for 5 mins to prevent post production contamination. The samples were bottled immediately, pasteurized in a covered water bath at 70^{0}C for 15 mins, cooled slowly under running water and stored at ambient temperature (27 ± 2^{0}C).
Sorghum stem sheath –moringa instant drinks and drink designation shown in Table 1.

Sensory evaluation of Sorghum stem sheath - Moringa Instant Drink

The enriched samples were presented to twenty semi-trained sensory panelists who are familiar with 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 (Ihekoronye and Ngoddy, 1985).

Table 1: Sorghum stem sheath -Moringa Instant Drink and Designation

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

Physicochemical propertiesof Sorghum Stem Sheath-Moringa Instant Drinks

pH was determined according toMeei, *et al.* (2012), titratable acidity was determined according to Dauda and Adegoke (2014) and total soluble solids was determined according to (AOAC, 2010).

Determination of Antinutritional Constituents of Sorghum Stem Sheath-Moringa Instant Drinks

Oxalate content was determined using the method of Nwinuka*et.al* (2005). Phytatecontent was determined by anion exchange method as described by Harland and Oberlaeas (1986). Tannin was determined according tothe modified vanillin – hydrochloric acid (MV – HCl) method of Price *et al.* (1978).Saponin was determined according tothe spectrophotometric method of Brunner (1984).

Storage Tests of Sorghum stem sheath - Moringa Instant Drinks

The sorghum stem sheath-moringa drinks were kept for a period of four weeks at ambient temperature (27± 2^0C) in a dark cupboard. The pH (Meei*et al.,* 2012), titratable acidity (Dauda and Adegoke*,* 2014), ascorbic acid (Hassan and Hassan, 2008) and total soluble solids (AOAC, 2010) of the samples were measured at one-week interval for a month of storage.

Statistical analysis

Experiments were run in triplicates. 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.

3. RESULTS AND DISCUSSION

Sensory Evaluation of Sorghum Stem Sheath- Moringa Instant Drinks

The results obtained from sensory evaluation of the drinks produced from sorghum stem sheath-moringa instant drinks are shown in Table 2. 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 may 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).This could be attributed to the dark wine cherry red colour of sorghum stem sheath drink which can be seen in Plate 3. 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 thequality of the products. It also influences consumer's choice and preferences (Ferial *et al.,* 2011; Pathare*et al*., 2013).

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. The result for taste showed that there was no significant difference among the enriched stem sheath drink samples while the control sample of stem sheath drink s received lower score (7.5) than the fortified sample (7.7). This could be attributed to the inclusion of moringa leaf extract. The order of the score for the taste was ST15 > ST10 > ST5 >ML> SS.

With regards to the flavour of the instant drink, sample with 15% inclusion (8.7) was most preferred while sample SS (6.0) being the least preferred. The scores increased slightly with the additions of moringa extract to sorghum stem sheath. This could 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 moringa leaf improved the flavour of the drink samples. Flavour is the main criterion that makes the product to be liked or disliked.

Table 2: Sensory Evaluation of Sorghum Stem Sheath-Moringa Instant Drink

Sample	Taste	Colour	Flavour	Ov. Accpt
SS	6.2±0.10^{d}	7.5±0.04^{b}	6.0±0.28^{d}	6.2±0.12^{d}
ML	6.3±0.01^{d}	7.3±0.06^{c}	7.4±0.10^{c}	7.0±0.08^{c}
ST5	6.9±0.07^{c}	7.7±0.02^{a}	7.5±0.01^{c}	7.5±0.14^{b}
ST10	7.6±0.02^{b}	7.7±0.02^{a}	8.0±0.42^{b}	7.6±0.05^{b}
ST15	7.9±0.15^{a}	7.7±0.02^{a}	8.7±0.34^{a}	8.4±0.20^{a}

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. Values are means ± standard deviation of triplicate determinations.The mean values along the same column with different superscripts are significantly different ($p< 0.05$

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 MLE 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.

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 (IFIC, 2011), color is the primary factor that motivates a consumer to try a product in the first place (Fernandez-Vazquez *et al.,* 2013). 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.

Physicochemical Properties of Sorghum Stem Sheath-Moringa Instant Drink

The pH of sorghum stem sheath-moringa instant drink is presented in Table 3. The pH values of sorghum stem sheath-moringa instant drinks ranged between 6.80 and 7.60. This could be attributed to the differential pH of the two base materials which are sorghum stem sheath and moringa leaf extracts. The pH change implies that the samples are tending towards the basic / alkaline. This is good and desirable for all consumers including patients with peptic ulcer and obese patients however inclusion of preservative will be needed in order to increase its shelf stability. The pH of SS (7.10) compared favourably with the value (7.00) reported by Oluwalana *et al.,* (2013) but lower than the pH values (1.50, 1.65, 1.60) reported by Fasoyiro *et al.* (2005), Abiose and Adeniran (2010), Adeleke and Abiodun (2010) and Mgaya *et al* (2014) for roselle drink samples. The pH of instant drinks is less acidic (being alkaline in nature).

pH is a measure of the hydrogen ion concentration of a solution (Frazier and Westhoff, 1988). Solution with a high concentration of hydrogen ions has a low pH and solution with a low concentration of hydrogen ion has a high pH (Egbere *et al.,* 2007).

The titratable acidity values of the sorghum stem sheath-moringa instant drink ranged between 0.014 and 0.136) % malic acid equivalent. Sample ST15 had the lowest value (0.014%) while SS had the highest TTA value (0.136%). This implies inclusion of preservative to improve the shelf stability of the drink. The incorporation of moringa leaf had observable decrease on the titratable acidity of the ST5, ST10, ST15.

Table 3: Physicochemical properties of Sorghum Stem Sheath-Moringa Instant drinks

Sample	pH	TTA(%Malic acid)	Brix (^{0}brix)
SS	7.10±0.05^c	0.136±0.021^a	8.77±0.01^c
ML	6.80±0.02^d	0.078±0.005^c	9.03±0.18^a
ST5	7.20±0.15^b	0.107±0.003^b	8.60±0.13^c
ST10	7.30±0.04^b	0.069±0.001^d	8.70±0.02^c
ST15	7.60±0.20^a	0.014±0.026^d	8.90±0.01^b

Note: SS = sorghum stem sheath **instant** drink, ML = moringa leaf i**nstant** 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, 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 total soluble solids (degree brix) of the sorghum stem sheath-moringa instant drinks are shown in Table 3. The total soluble solid of sorghum stem- moringa instant drink ranged between (8.60 and 9.03) ^{0}brix. The values increased as the concentration of ML to sorghum stem sheath extract increased. Sample ST5 had the lowest value (8.60^{0}brix) while ML had the highest value (9.03 °brix). The increase observed could be due to the fact that moringa leaf contains more sugar than sorghum stem sheath. Addition of moringa leaf had no significant effect on the total soluble solids (^{0}brix). Depending on the type of drink, the total soluble solid has been previously linked to a more desirable good quality drinks (Balaswamy*et al.,* 2013). The total soluble solids of sorghum stem sheath drink (SS) (8.77^{0}brix) was higher than the values reported by Fasoyiro*et al.* (2005), Abiose and Adeniran (2010), Adeleke and Abiodun (2010) and Mgaya*et al* (2014) which were 8.2, 7.6, 6.2 and 5.7 °brix for roselle drink respectively. The higher the concentration of moringa, the higher the brix because degree brix is a direct function of total soluble solids.

Anti-nutrient Composition (mg/100ml) of the Sorghum Stem Sheath-Moringa Instant Drinks

The results for the anti- nutrients composition of sorghum stem sheath-moringa instant drink are represented in Table 4. The tannin content of the sorghum stem sheath-moringa instant drinks was found to range between (0.195 and 0.533) mg/100ml. For all samples, tannin contents of sorghum stem sheath-moringa instant drinks increased slightly with increase in the addition of ML to sorghum stem sheath drink. This could be attributed to low level of tannin (0.025) mg/100ml in the stem sheath (Ogunyemi, 2009). The tannin contents of enriched samples are significantly ($p < 0.05$) different from one another. Moderate levels of tannin were also found to be present in the sorghum stem sheath drink (0.025) mg/100ml which is within the safe level (5.6mg/day) (Health and Safety Publications, 2011). A tannin content up to 5.6 mg is allowed in foods, and the intake of tannins present infood is safe (EFSA, 2014). The tannin content of the stem moringa instant drink (0.025) mg/100ml was found to be much lower than that of *zobo* drink 0.035mg/100 ml (Osuntogun and Aboaba, 2004). The tannin content of the instant drink (0.025) mg/100ml was found to be much lower than 2.11mg/100ml reported for *Pensetumpurpurem* drink (Amaechi*et al.,*2009); 0.04mg/100ml, *Tridaxprocumbens* drink (Ikewuchi*et. al.,* 2009) and 0.16-0.28 mg/100ml for Olugbo leaf drink while Nchanwu leaf drink had 0.08mg/100ml (Onyeka and Nwambekwe, 2007), but comparable to 0.023mg/100ml tannin reported for bitter leaf.

The total acceptable tannin daily intake for a man is 5.6 mg (Gbadamosi and Famuwagun, 2015). However, the presence of tannin is not desired in foods when it is above the Recommended Daily Intake (RDI). If tannin concentration in the diet becomes too high (above 5.6mg), it can decrease protein digestibility in humans and animals.In the case where tannin content is below the recommended consumable limit, it has been reported to have possible anticarcinogenic effects (Soetan, 2008). It also contributes to foaming activities in drinks. The level of this tested anti-nutrient in the enriched samples were low and within the tolerable (safe) levels for man (5.60 mg/day) (Health and Safety Publications, 2011).

The oxalate level of the sorghum stem sheath – moringa instant drinks ranged between (0.375 and 0.684) mg/100ml. The increase in oxalate content of the enriched drinks (0.375 and 0.684) mg/100ml could be attributed to the low oxalate content of sorghum stem sheath (0.220) mg/100ml extracts. The enriched samples are significantly ($p < 0.05$) different from each other. SS (0.220) mg/100ml is higher than (0.180) reported for *Pensetumpurpurem* drink, (0.159mg/100ml) for B. coyicea seeds drink (Amaechi*et al.,*2009) but lower than (58.81mg/100gml) reported for *Solanumnigrum* drink and 109.80mg/100ml reported for *Gentumaficanum* seeds drink (Chinma and Igyor, 2007). The oxalate content (0.375-0.684) mg/100ml of the stem-moringa instant drink was found to be lower than the oxalate content of *zobo* drink (0.615 mg/100ml) (Adanlawo and Ajibade, 2006). The oxalate content of the stem drink (0.375 and 0.684) mg/100ml was within the safe level of consumption in humans since the lowest dose reported is 5 g (about 70 mg/kg) (Tsai, 2005; UPMC, 2017).

Mubarak (2005) and Fasoyiro (2006) reported that processing techniques could inactivate some food enzymes and degrade the anti-nutrients by leaching the toxic component into hot water. Albihn and Salvage (2001) reported that boiling may cause considerable skin (epidermal) rupture and facilitate the leakage of soluble oxalate into boiling water. The levels of this tested anti-nutrient in the enriched samples were low and within the tolerable (safe) levels for man (10mg/day) (Health and Safety Publications, 2011).

The saponin level of the sorghum stem sheath – moringa instant drinks ranged between (0.390 and 0.412) mg/100ml. Thesaponin content of sorghum stem sheath is (0.018) mg/100ml and moringa leaf extracts (2.500) mg/100ml. The enriched samples are significantly ($p > 0.05$) different from one another. Moringa leaf extract 2.500mg/100ml is comparable with 2.5mg/100ml reported by Makkar and Becker (1997) and 3.0mg/100ml reported by Foidl*et al.,* (2001) for saponins in *Moringaoleifera* leaf extract. Saponin content of sorghum stem sheath –moringa instant drinks (0.390 and 0.412) mg/100ml was lower than (0.88%) reported for tigernut drink by (Ade-Omowaye*et al.*, 2009). The incorporation of moringa leaf extracts had ($p < 0.5$) % significant increase of (95.63, 95.54, 95.38) on the saponin contents of ST5, ST10, ST15, respectively.

Saponins have been found to cause hemolytic activity by reacting with the sterols of erythrocytes membrane (Gbadamosi and Famuwagun, 2015).

The bitter taste of *Moringaoleifera* leaf has been attributed to saponins because of its structural complexity, foaming and emulsifying, pharmacological, medicinal and haemolytic properties, as well as antimicrobial and insecticidal activities, (Ogbe and Affiku, 2012; Gbadamosi and Famuwagun, 2015). The level of this tested antinutrient in the enriched samples were low and within the tolerable (safe) levels for man (10mg/ day) (Health and Safety Publications, 2011).

Table 4: Anti nutrient Composition (mg/100ml) of Sorghum Stem Sheath-Moringa Instant drinks

Sample	Tannin	Oxalate	Saponin
SS	0.025 ± 0.055^{d}	0.220 ± 0.042^{d}	0.018 ± 0.045^{d}
ML	3.410 ± 0.061^{a}	3.310 ± 0.091^{a}	2.500 ± 0.050^{a}
ST5	0.195 ± 0.077^{c}	0.375 ± 0.082^{c}	0.412 ± 0.001^{c}
ST10	0.279 ± 0.003^{c}	0.452 ± 0.001^{c}	0.404 ± 0.008^{c}
ST15	0.533 ± 0.023^{b}	0.684 ± 0.026^{b}	0.390 ± 0.002^{b}

Note: SS = sorghum stem sheath **instant** drink, ML = moringa leaf i**nstant** 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, Values are means ± standard deviation of triplicate determinations. The mean values along the same column with different superscripts are significantly different ($p< 0.05$).

Shelf Life Study of the Stored Sorghum Stem Sheath-Moringa Instant Drinks

Changes in Vitamin C Contents of the Stored Enriched Instant Drinks

Vitamin C content of the enriched drink samples is presented in Table 5 which varied between (0.00 and 4.43) mg/100ml throughout the period of storage. SSS drink on its own had no Vitamin C while ML has 4.43mg/100ml. Addition of ML to SSS increased the Vitamin C content of the enriched drink and the higher the proportion of ML added, the higher the Vitamin C content (at week 0). Vitamin C loss is known to increase with exposure to heat, light and oxygen (Bamishaye*et al.,* 2011).

There was significant progressive reduction ($p < 0.05$) in the vitamin C content of the enriched samples as the storage period increased. However, significant higher losses of (82.61, 54.32, 35.55) % in vitamin C content were observed in the enriched samples by the 4th week of storage compared to the fresh samples. The decrease observed may be attributed tooxidation and fermentation reaction which might have occurred in the drinks during storage and is highly dependent on the presence of oxygen in the head space or dissolved 0_2 in the drink samples (Ozmianski *et al.* 2007). Similar results were reported by Egbere*et al.,* (2007) during the storage of roselle drink.

Table 5: Effect of Storage Time on Some Properties of Sorghum stem sheath -Moringa Instant Drinks

Sample	Wk0	Wk1	Wk2	Wk3	Wk4
SS	7.1 ± 0.08^a	6.9 ± 0.10^a	6.6 ± 0.23^a	6.1 ± 0.42^a	5.3 ± 0.34^a
ML	6.7 ± 0.01^c	6.5 ± 0.11^d	6.1 ± 0.13^d	5.5 ± 0.31^d	4.6 ± 0.02^d
ST5 Ph	6.9 ± 0.01^b	6.8 ± 0.01^b	6.3 ± 0.01^b	5.6 ± 0.01^b	4.7 ± 0.01^b
ST10	6.8 ± 0.10^b	6.7 ± 0.10^b	6.0 ± 0.20^b	5.1 ± 0.40^b	3.9 ± 0.30^b
ST15	6.5 ± 0.03^d	6.6 ± 0.02^c	5.5 ± 0.02^c	4.2 ± 0.03^c	2.6 ± 0.32^c
SS	0.134 ± 0.035^a	0.160 ± 0.023^a	0.188 ± 0.012^a	0.223 ± 0.007^a	0.265 ± 0.041^a
ML	0.080 ± 0.011^c	0.106 ± 0.014^c	0.134 ± 0.010^c	0.169 ± 0.011^c	0.211 ± 0.012^c
ST5TTA (% Malic acid)	0.107 ± 0.001^b	0.133 ± 0.002^b	0.184 ± 0.001^b	0.244 ± 0.012^b	0.332 ± 0.046^b
ST10	0.067 ± 0.040^b	0.109 ± 0.025^b	0.170 ± 0.014^b	0.256 ± 0.001^b	0.377 ± 0.002^b
ST15	0.014 ± 0.032^d	0.075 ± 0.012^d	0.162 ± 0.003^d	0.282 ± 0.013^d	0.444 ± 0.035^d
SS	8.8 ± 0.01^c	8.6 ± 0.01^a	8.2 ± 0.01^a	7.5 ± 0.01^a	6.5 ± 0.01^a
ML	9.0 ± 0.01^a	8.5 ± 0.01^b	7.9 ± 0.02^b	7.1 ± 0.03^b	6.0 ± 0.02^b
ST5^{0}Brix	8.6 ± 0.03^e	8.2 ± 0.02^c	7.6 ± 0.01^c	6.7 ± 0.01^c	5.5 ± 0.01^c
ST10	8.5 ± 0.02^d	8.0 ± 0.03^d	7.2 ± 0.03^d	6.2 ± 0.02^d	4.9 ± 0.03^d
ST15	8.3 ± 0.01^b	7.9 ± 0.01^e	6.8 ± 0.01^e	5.6 ± 0.01^e	4.1 ± 0.01^e
SS	0.00 ± 0.00^e	0.00 ± 0.00^e	0.00 ± 0.00^e	0.00 ± 0.00^e	0.00 ± 0.00^e
ML	4.43 ± 0.01^a	3.83 ± 0.01^a	3.12 ± 0.01^a	2.22 ± 0.01^a	1.11 ± 0.01^a
ST5Vit C (mg/100ml)	0.23 ± 0.02^d	0.20 ± 0.03^d	0.16 ± 0.04^d	0.11 ± 0.02^d	0.04 ± 0.02^d
ST10	0.46 ± 0.04^c	0.42 ± 0.02^c	0.37 ± 0.03^c	0.30 ± 0.04^c	0.21 ± 0.03^c
ST15	0.92 ± 0.03^b	0.86 ± 0.04^b	0.79 ± 0.02^b	0.71 ± 0.03^b	0.60 ± 0.04^b

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. Values are means ± standard deviation of triplicate determinations.The mean values along the same column with different superscripts are significantly different ($p< 0.05$)

Dauda and Adegoke (2014) also reported a similar trend of results during the storage of soy-milk based juice at ambient temperature. Sample ST15 had the highest vitamin C content (0.92) mg/100ml and followed by ST10 (0.46) mg/100ml and ST5 (0.23) mg/100ml among the enriched samples. The increase can be attributed to the notable contribution of ascorbic acids from the ML. A similar magnitude of vitamin C depletion during storage was reported by Ibrahim (2016) on fruit blends. A loss of 35- 82.60% ascorbic acid was noted after 4 weeks at ambient storage. Ozmianski*et al.,* (2007) reported losses in Vitamin C as 58%, 39% and 25% in apple, apple juice with blackcurrant and blackcurrant juices respectively during 6 months' storage at 4^0C. This result is also similar to the report of Burdulu*et al.,* (2006) who reported high ascorbic acid destruction in lemon and orange juice concentrate and established that ascorbic acid decomposes easily in acidic solution. Being a potent antioxidant, factors such as oxidative enzyme, molecular oxygen, alkaline pH metal ions and temperature are capable of influencing the depletion of vitamin C in drinks and fruits (Herbig and Renard, 2017).

The effects of storage time on the vitamin C of the instant drinks were monitored for the duration of four-weeks. Data from 4 weeks were programmed into different equations to develop a mathematical relationship between variables (vitamin C and time). The quadratic equations gave highest R^2 values hence these were used to predict the duration till twenty-four weeks, for samples with 5% moringa leaf inclusion (Table 6). The R^2 values for quadratic equation of samples in ST5 was 0.9995 while for samples ST10 and ST15 had their R^2 values ranged between 0.0993and 0.9917. This suggests that regression equation gave a better fit for the set of data generated for sample ST5 compared to those of sample ST10 and ST15. The vitamin C content of the instant drinks (ST5, ST10, ST15) stored at ambient temperature from week 0 - 4 ranged between (0.04-0.23), (0.21-0.46) and (0.60-0.92) mg/100ml respectively. This suggests a percentage decrease (82.61%, 54.32% and 35.55%) by 4^{th} week of storage, respectively. The vitamin C content of the enriched samples will be 0 when the storage period is above 8 weeks.

pH and Titratable acidity (TTA, % malic acid) of Sorghum stem sheath -Moringa Instant Drink with Storage Time

The results of pH and titratable acidity (% malic acid) during storage are shown in Table 5. This indicated a general significant decrease ($p < 0.05$) in pH and corresponding significant increase ($p < 0.05$) in titratable acidity of the enriched samples with storage days. The pH of the beverage samples varied between 2.60 to 7.10 while the TTA varied between 0.014 to 0.444 % malic acid throughout the period of storage. This observation agreed with the report that % TTA and pH are inversely related (Nwafor and Ikenebomeh, 2009).Decrease in Ph and increase in acidity implies that the drink is becoming more acidic (not conducive for microbial growth) (Prescott *et al.,* 1999; Doughari *et al.,* 2007). Similar results of decrease in pH and corresponding increase in titratable acidity was reported by Egbere *et al.* (2007) during the storage of roselle drink with ethanol extracts of alligator pepper and ethanol at ambient temperature. Dauda and Adegoke (2014) also reported a similar trend of results during storage of soy- milk based juice at ambient temperature. pH and titratable acidity of drink and fruits are primarily used to assess some intrinsic quality attributes, which may determine the degree of acceptability of the products to the consumers. There was an observable decrease in pH with storage time in all the enriched samples. However, by the end of the 4^{th} week at ambient storage conditions, there were significant higher losses/ decreases of (31.88, 42.65, 60.60) % in pH and increases of (210.28, 462.69, 3071.43) % in titratable acidity of the enriched drink samples. This observation compared favourably with results of some ealier studies (Cortes *et al.,* 2005; Rivas *et al.,* 2006) reporting a decrease in pH of fruit juices during storage. However, a 10% decrease in pH could have significantly altered the quality acceptability of the drink.

Table 6: Regression Equations and R^2 Values for Vitamin C content (mg/100ml) of the enriched drinks at ambient temperatures

Sample	Best Fit Equation	Linear R^2	Logarithmic R^2	Quadratic R^2	At 8th week
SS	$y = 0$	N/A	N/A	N/A	N/A
ML	$y = -0.0864x^2 - 0.3064x + 4.812$	0.9847	0.8821	0.9998	-3.154
ST5	$y = -0.0064x^2 - 0.0084x + 0.244$	0.974	0.8577	0.9995	-0.838
ST10	$y = -0.0086x^2 - 0.0106x + 0.478$	0.9737	0.8565	0.9997	-0.157
ST15	$y = -0.0079x^2 - 0.0319x + 0.958$	0.9856	0.8866	0.9993	0.197

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. 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 7: Regression Equations and R^2 Values for pH values of Sorghum stem sheath -Moringa Instant Drink at ambient temperatures.

Sample	Best Fit Equation	Linear R^2	Logarithmic R^2	Quadratic R^2	At 8th week
SS	$y = -0.1x^2 + 0.16x + 7.02$	0.9308	0.781	0.9981	1.90
ML	$y = -0.1143x^2 + 0.1657x + 6.64$	0.9363	0.7864	0.9996	0.65
ST5	$y = -0.1286x^2 + 0.2114x + 6.84$	0.9300	0.7714	0.9986	0.30
ST10	$y = -0.1714x^2 + 0.2886x + 6.72$	0.9281	0.7683	0.9979	-1.94
ST15	$y = -0.2571x^2 + 0.5229x + 6.34$	0.9104	0.7401	0.9914	-5.93

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. 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 8: Regression Equations and R^2 Values for Total Titratable Acidity (% malic acid) values of Sorghum stem sheath -Moringa Instant Drink at ambient temperature

Samples	Best Fit Equations	Linear R^2	Logarithmic R^2	Quadratic R^2	At 8th week
SS	$y = 0.0028x^2 + 0.0158x + 0.116$	0.9896	0.8962	0.9997	0.422
ML	$y = 0.0028x^2 + 0.0158x + 0.062$	0.9896	0.8962	0.9997	0.368
ST5	$y = 0.0095x^2 - 0.0009x + 0.0982$	0.9609	0.8289	0.9994	0.699
ST10	$y = 0.0131x^2 - 0.0017x + 0.0572$	0.9605	0.8300	0.9996	0.882
ST15	$y = 0.0168x^2 + 0.006x - 0.0072$	0.9663	0.8407	0.9998	1.073

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. Values are means ± standard deviation of triplicate determinations.The mean values along the same column with different superscripts are significantly different ($p< 0.05$).

Conversely, titratable acidity of the drink samples increased with storage which is consistent with other studies (Mgaya-Kilima*et al.,*2014). Acid hydrolysis of polysaccharides leading to the depletion of acidity in drinks and fruit juices has been suggested to be responsible for the decline in acidity during storage (Mgaya-Kilima *et al.,* 2015). Higher increases in acidity were observed between 2nd and 4th week of storage in all the samples. This may be due to oxidation, hydrolysis and putrefaction by fermenting microorganisms during storage.

The effects of storage time on the pH of the instant drinks were monitored for the duration of four-weeks. Data from 4 week were subjected to different equations to develop a mathematical relationship between the variables (pH and time). The quadratic equations gave the highest R^2 values hence these were used to predict the duration till twenty-four weeks (Table 7). The R^2 values for quadratic equation of samples in ST5 was 0.9986 while for samples ST10 and ST15 had their R^2 values ranged between 0.09971 and 0.9914. This suggests that regression equation gave a better fit for the set of data generated for sample ST5 compared to those of sample ST10 and ST15. The pH of the instant drinks (ST5, ST10, ST15) stored at ambient temperature from week 0 - 4 ranged between (6.9-4.7), (6.8-3.9) and (6.5-2.6) respectively. This suggests a percentage increase (31.88%, 42.65% and 60.60%) by 4th week of storage, respectively. The pH of the enriched drink stored at ambient temperature had no significant difference ($p > 0.05$) with increase in time from week 1 to week 8 (Fig. 4.4) and had a significant increase from week 16 to 24.

The effects of storage time on the titratable acidity of the instant drinks were monitored for the duration of four-weeks. Data for 4 weeks were subjected to different equations to develop a mathematical relationship between variables (titratable acidity and time). The quadratic equations gave highest R^2 values hence these were used to predict the duration till twenty-four weeks, for samples with 5% moringa leaf inclusion (Table 8). The R^2 values for quadratic equation of samples in ST5 was 0.9994 while for samples ST10 and ST15 had their R^2 values ranged between 0.09996 and 0.9998. Thissuggests that regression equation gave a better fit for the set of data generated for sample ST5 compared to those of sample ST10 and ST15. Thetitratable acidity of the instant drinks (ST5, ST10, ST15) stored at ambient temperature from week 0 - 4 ranged between (0.107-0.332), (0.067-0.377) and (0.014-0.444) respectively. This suggests a percentage increase (210.28%, 462.69% and 3071.43%) by 4th week of storage, respectively.

Total Soluble Solids of Sorghum stem sheath – MoringaInstant Drink

The results of the total soluble solids of the samples during storage is shown in Table 5. Total soluble solids (TSS) of the samples were in the range of 4.1 to 9.0 ^{0}brix over the storage period. There was 14% significant decrease ($p < 0.05$) in the ^{0}brix of all the samples from week 1 to 4 during storage days which ranged from 36.05 and 50.60%. The TSS values showed a controlled reduction in the enriched samples. A similar trend of results as influenced by storage was reported by Abiose and Adeniran (2010) andEgberee*t al.* (2007) for roselle drink with percentage reduction of 19.74, 24.13 and 35.02% at the end of the 4th week of storage. Also, a similar trend of result was also reported by Dauda and Adegoke (2014) of soy-milk based juice with percentage decrease of 24.12, 30.05 and 42.31% during the storage at ambient temperature.

The sweet taste, flavour and dark red colour characteristics of sorghum stem sheath-moringa instant drink were not maintained during storage.

Table 9: Regression Equations and R^2 Values for ^{0}brix of Sorghum stem sheath -Moringa Instant Drink at ambient temperature

Samples	Best Fit Equations	Linear R^2	Logarithmic R^2	Quadratic R^2	At 8th week
SS	$y = -0.1357x^2 + 0.2443x + 8.68$	0.9262	0.7698	0.9997	1.950
ML	$y = -0.1x^2 - 0.14x + 9.22$	0.9744	0.8596	0.9993	1.700
ST5	$y = -0.1357x^2 + 0.0443x + 8.68$	0.9581	0.8246	0.9998	0.350
ST10	$y = -0.1286x^2 - 0.1286x + 8.76$	0.9722	0.851	0.9999	-0.500
ST15	$y = -0.1643x^2 - 0.0843x + 8.6$	0.966	0.8364	0.9979	-2.590

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. 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 storage studies of the samples showed that there was continuous reduction and gradual decrease in pH which accounts for an observable increase in titratable acidity characterized with sourness, development of offensive, alcoholic odour, cloudy appearance, gas bubbles and colour change from wine cherry red to deep blackish colour. This might be due to the pooled effects of metabolism and increase in acidity produced by spoilage bacteria.Preservatives like Sodium benzoate and EDTA could be added to sorghum stem sheath-moringa instant drink in order to preserve the flavour, taste and dark red colour of the drink and elongate its shelf life during storage. Oluwalana*et al.* (2015) reported that there was no observable bacteria growth in the pasteurized and preserved sorghum stem sheath sample with 0.1% sodium benzoate after 28 days of storage. This shows the effectiveness of preservatives in prolonging the shelf life of the drink. Ade-Omowaye*et al.*(2015) also reported that nutritious and relatively shelf stable non-alcoholic drink could be produced for two weeks from sorghum stem sheath with 0.5% ginger extract (spice) inclusion without the use of chemical preservative.The effects of storage time on ^{0}brix of the instant drinks were monitored for the duration of four-week. Data from 4 weeks were subjected to different equations to develop a mathematical relationship between the variables (^{0}brix and time). The quadratic equations gave highest R^2 values hencethese were used to predict the regression analysis for the duration till twenty-four weeks, forthe enriched samples. The R^2 values for quadratic equation of samples in ST5 was 0.9998 while for samples ST10 and ST15 had their R^2 values ranged between 0.9979 and 0.9999 (Table 9). This suggests that regression equation gave a better fit for the set of data generated for sample ST5 compared to those of sample ST10 and ST15. The^{0}brix of the instant drinks (ST5, ST10, ST15) stored at ambient temperature from week 0 - 4 ranged between (5.5-8.6), (4.9-8.5) and (4.1-8.3) respectively. This suggests a percentage increase (36.05%, 42.35% and 50.60%) by 4th week of storage, respectively.

4. CONCLUSION

The storage stability studies of the enriched instant drink samples revealed that the pH, total soluble sugar and vitamin C decreased while the total titratable acidity of the enriched sample increased gradually with storage time. Based on the above findings, the shelf life of sorghum stem sheath cannot go beyond 24hrs after production without refrigeration or inclusion of preservatives.

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