

Research Article

Quality Evaluation of Sorghum bicolor Stem Sheath Enriched with Spondias mombin Extract

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Abstract

The nutritional compositions of sorghum stem sheath-Spondias mombin extract were evaluated. The enriched stem sheath extract were obtained by mixing sorghum stem sheath and *Spondias mombin* (iyeye) extract in varied proportions at 100:0; 0:100; 95:5; 90:10 and 85:15. The five samples were subjected to analysis: proximate, mineral, vitamin C, antinutrient composition. Data obtained were analysed using descriptive and inferential statistics. The result showed that observable increases were noticed in proximate, vitamin C and mineral composition from 5% inclusion of *Spondias mombin* extract in sorghum stem sheath drinks. The anti-nutrient compositions: tannin, oxalate and saponin, ranged from (0.144 to 0.442, 0.303 to 0.385, 0.070 to 0.198) mg/100 ml, respectively for sorghum stem sheath- *Spondias mombin* extract which were within consumable safe limits. The study concluded that nutritious enriched drinks could be produced from sorghum stem sheath and *Spondias mombin* extract at ambient temperature.

Introduction

Sorghum is originally a wild plant in Africa, Sudan and central Asia which belongs to the family of Poaceae. The common names include millet, guinea corn, broom corn, sweet sorghum etc. In Nigeria languages, it is called Okababa (Yoruba), dawa/jero (Hausa) and soro (Igbo). The parts that are commonly used for herbal drugs include leaves, stem or grains. Different types of *Sorghum bicolor* are recognized including grain sorghums, sweet sorghums, and grass sorghums. It is known by a variety of names, including milo or milo-maize in the United State, dura in Sudan, great millet and guinea corn in West Africa, kafir corn in South Africa, mtama in eastern Africa and jowar in India [1]. Sorghum (*Sorghum bicolor* (L) Moench) is valued for its grain, stalks and leaves. It is one of the World's major cereal crops. Worldwide, there are a small number of grains that supply approximately 85% of the world's food energy and only four other foods (rice, wheat, maize, and potatoes) are consumed more than sorghum. For 500 million people in over 30 countries of the semi-arid tropics, sorghum is a dietary staple. Sorghum stem sheath is popularly called 'Karandasi' or 'poroporo baba' within many localities in Nigeria and being claimed by a reasonable number of herb sellers to cure anaemia. The blood "tonic" is usually prepared by boiling the karandasi in water for 20-30 min and taken between 5 and 7days. The method of production is as described by Adetuyi, et al. [2]. Sorghum stem sheath is

soaked for 10 mins at ambient temperature before boiling for 30mins. The extract is then filtered with cleaned muslin cloth to obtain clear solution. The liquid extracts were filtered through a 0.22 micron cellulose acetate filter to produce a sterile stock solution. The filtrate can be sweetened using food grade sucrose/honey according to individual's preference.

Spondias mombin tree is native and common in most lowland forests, and indigenous to tropical Africa [3]. The true yellow mombin, *S. mombin* L. (*Syn. S. lutea* L.) is most often called hog plum in the Carribean Islands [4,5]. In Jamaica, it is also known as Spanish plum, or gully plum. The yellow mombin is appreciated mostly by children and passers-by as means of alleviating thirst [6]. It is effective against anaemia, angina, anxiety, abortifacient, analgesic, anthelmintic but mostly effective against ascaris (worms). It contains carbobydrate, flavonoids, tannins, protein and sterols, it tastes sweet and sour [7]. The purple mombin (*Spondias purpurea* L.) is stewed whole, with sugar, and consumed as dessert [8], and can be preserved for future use merely by boiling and drying, which keeps the fruit in good condition for several months [8]. In Florida, yellow mombin is sold in local markets and consumed fresh; and it makes a significant contribution to the diet of people in local areas of the tropics when in season [7]. Data from various sources have identified increased consumption of the fruit of *Spondias mombin* as food in raw and processed form as a result of great taste (which ranges from sour to sour

More Information

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Submitted: 17 April 2020

Approved: 01 June 2020

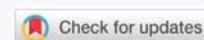
Published: 03 June 2020

How to cite this article: Adedeji TO. Quality Evaluation of *Sorghum bicolor* Stem Sheath Enriched with *Spondias mombin* Extract. Arch Food Nutr Sci. 2020; 4: 012-019.

DOI: 10.29328/journal.afns.1001022

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Keywords: Proximate; Extract; *Spondias mombin*; Sorghum stem sheath



sweet), good levels of minerals, vitamins, low levels of lipids and reducing sugars [8-12]. Recent studies also suggest that the fruit of *Spondias mombin* is a rich source of antioxidants and phenols, minerals, phytonutrients, organic acids, phytosterols, terpenoids, and carotenoids [13-15]. Findings have established it as a potential source of highly nutritious feed stuff, folk medicine and phytomedicine as a result of its aromatic, astringent and refrigerant nature [8,13,16-18]. The tree exudes gum used as glue; root and bark decoctions are used as purgatives and remedies for diarrhea, dysentery and haemorrhoids [8], while leaves extract have been reported to have anxiolytic [19], anathematic, sedative, antiepileptic and antipsychotic [16], hypoglycaemic [20], in vitro antioxidant [21], and antimicrobial effects [22].

Research efforts are being directed towards utilizing locally available raw materials in food and beverage formulation. Indigenous beverages have been developed with great success and these include zobo and kunnu zaki [23,24]. With increased awareness of the consumers of diet related health problems, the emphasis has been to reduce chemical addition in food formulation including beverage. In the last few decades, interest in scientific research has shifted to plant materials having nutraceutical properties [25]. Recently, emphasis has been placed on foods that are useful in the prevention and treatment of diseases. The native plants like sorghum stem sheath and *Spondias mombin* fruits are usually under-explored in spite of their enormous nutritional and medicinal benefits in many countries. Adetuyi, et al. [2] reported that sorghum stem sheath lacks vitamin C which is abundant in *Spondias mombin* fruits. So, it is essential to explore the potential of indigenous plants through the development of innovative functional drinks. The established data on the nutritional composition of *Spondias mombin* fruits is an indication that they have potential to be used as a food additive with multiple purposes [5]. *Spondias mombin* can also serve as a protein, antioxidants, and fatty acid, mineral and vitamin sources for drink formulation. Although considerable amount of literature exists on the nutrient composition of sorghum stem sheath, however, there is a dearth of information about its enrichment with *Spondias mombin* extract. This study therefore seeks to investigate its possible proximate and nutrient compositions so as to unravel new information to improve health and nutrition (Plates 1,2).

Materials and methods

Materials

Sorghum stem sheath was purchased from Oja-oba market in Akure, Ondo State, Nigeria while *Spondias mombin* (iyeye) fruits were collected from a local farm in Akure, Ondo 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 *Spondias mombin* extract: The method

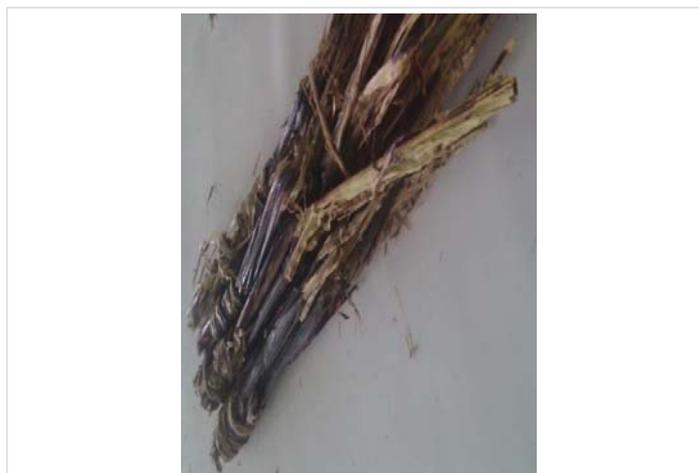


Plate 1: Sorghum stem sheath.

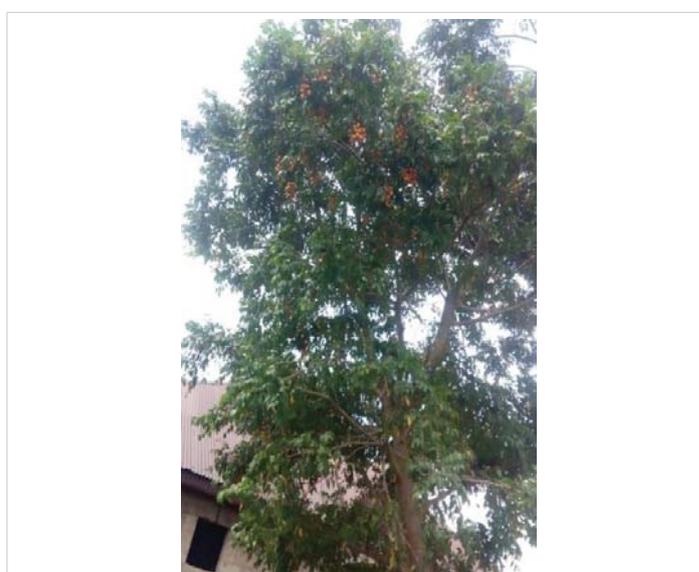


Plate 2: *Spondias mombin* tree with fruits.

described by Tiburski, et al. [14], was adapted with some modifications. About 200 g of *Spondias mombin* fruits were sorted and washed to remove extraneous materials. The pulps were extracted with 3000 ml of water manually by hand and sieved with a clean muslin cloth. The liquid extract was decanted into sterilized bottles and kept in a refrigerator for further use.

Production of sorghum stem-sheath-*Spondias mombin* extract: The method described by Adetuyi, et al. [2] was adapted with some modifications. Dried sorghum stem sheath was freed from extraneous materials by manual sorting and winnowing. About 400 g of the stem sheath was weighed and washed slightly with water. The washed stem sheath was boiled thoroughly in 6000 ml of water for 30 mins 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. *Spondias mombin* extract was added at different concentrations [0, 5, 10 and 15% (v/v)] for enrichment. Each sample was stirred and boiled for 5 mins to prevent

post production contamination. The samples were bottled immediately, pasteurized at 70 °C for 15 mins, cooled slowly under running water and stored at ambient temperature (27 ± 2 °C). Sorghum stem sheath – *Spondias mombin* extract and sample designation is shown in table 1.

Proximate analysis of sorghum stem sheath- *Spondias mombin* extract

The samples were analyzed for moisture content, crude fat, crude protein, ash content, crude fibre based on the method of analysis of the association of official analytical chemists [26]. Carbohydrate content was calculated by difference.

Mineral element and vitamin C analysis of sorghum stem sheath- *Spondias mombin* extract

The analysis for essential mineral elements was carried out by atomic absorption spectrophotometric using the method of Fashakin, et al. [27]. Ascorbic acid concentration in the enriched drink was determined using the method of Hassan and Hassan [28].

Determination of anti-nutritional constituents of sorghum stem sheath- *Spondias mombin* extract

Oxalate content was determined using the method of Edet, et al. [29]. Tannin was determined according to the modified vanillin – hydrochloric acid (MV – HCl) method of Price, et al. [30]. Saponin was determined according to the spectrophotometric method of Brunner [31].

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. The flow chart for the production of sorghum stem sheath- *Spondias mombin* drink is shown in figure 1.

Results and discussion

Proximate compositions (%) of sorghum stem sheath- *Spondias mombin* extract

The proximate composition of the sorghum stem sheath -*Spondias mombin* extracts are presented in table 2. This showed increases in crude fat, ash, protein and moisture content with decrease in carbohydrate content of the enriched extract. The moisture content of the enriched sorghum stem sheath increased insignificantly ($p > 0.05$) from (87.71%

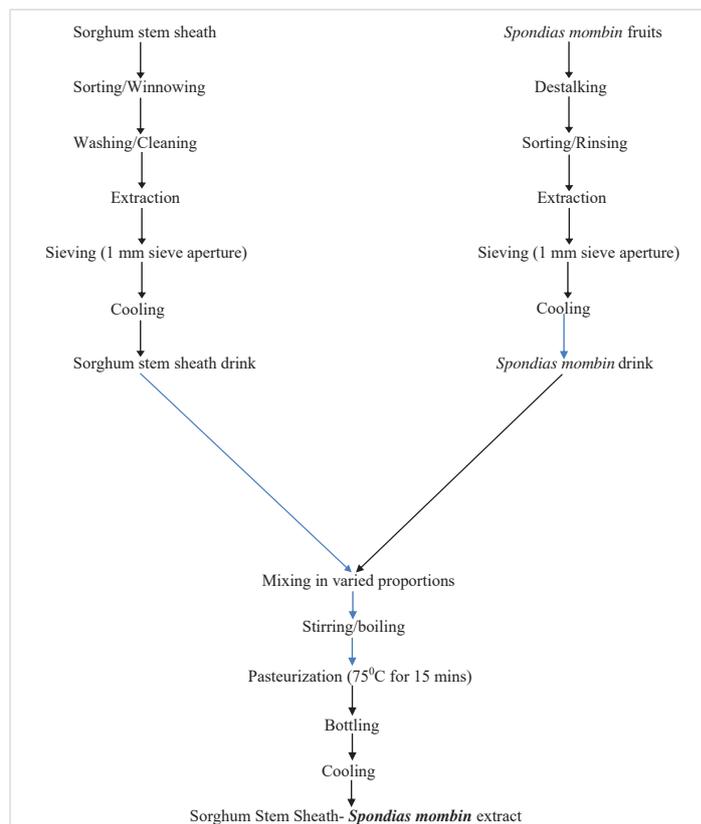


Figure 1: Flow chart for the production of Sorghum stem sheath-*Spondias mombin* Extract.

Source: Tiburski, et al. (2011); Adetuyi, et al. (2007) modified.

to 87.01%) with increased inclusion of *Spondias mombin* extract. The moisture content of the stem sheath (88.00%) was relatively lower than other recorded values like *Moringa oleifera* extract (90.00%) [32]. The high moisture content of enriched samples may be due to high amount of water used for the extraction which underpins its role as thirst quenching characteristics [33,34].

The ash content increased insignificantly ($p > 0.05$) from (0.34% to 0.42%) with increased inclusion of *Spondias mombin* extract. The ash content of the stem sheath (0.30%) was relatively higher than *Moringa oleifera* extract (0.20%) [35]. The ash in food determines largely the extent of mineral matters likely to be found in the food substance which nutritionally aids the metabolism of other organic compounds, such as protein and fat [36]. Plant materials are known to be rich sources of mineral elements. Ashing is usually carried out in order to evaluate the mineral matter of food [37].

The fat content increased insignificantly ($p > 0.05$) from (0.109% to 0.340%) with increased inclusion of *Spondias mombin* extract. The fat content of the stem sheath (0.009%) was relatively lower than other recorded values like *Piliostigma thonningii* extract (1.42%) [38]. However, the lower amount of fat (0.109% to 0.340%) in the samples can be used as diet drink and preventive measures for other chronic diseases [39]. The koronye and Ngoddy [40] reported that fat should be less than 5% in juices and drinks since this could

Table 1: Sorghum stem sheath - *Spondias mombin* Extract and Sample Designation.

Sample Code	Sample Designation
SS100SM0	Sorghum stem sheath Extract- Control
SM100SS0 SS95SM5	<i>Spondias mombin</i> Extract-Control 95% Sorghum stem sheath + 5% <i>Spondias mombin</i> Extract
SS90SM10	90% Sorghum stem sheath + 10% <i>Spondias mombin</i> Extract
SS85SM15	85% Sorghum stem sheath + 15% <i>Spondias mombin</i> Extract

Table 2: Proximate Composition (%) of Sorghum Stem Sheath- *Spondias mombin* Extracts.

Sample	Moisture	Fat	Protein	Ash	CHO
SS100SM0	88.00 ± 0.01 ^a	0.009 ± 0.004 ^d	0.050 ± 0.005 ^d	0.30 ± 0.05 ^d	11.64 ± 0.01 ^a
SM100SS0	82.28 ± 0.05 ^d	2.00 ± 0.03 ^a	2.60 ± 0.02 ^a	1.00 ± 0.01 ^a	8.00 ± 0.05 ^d
SS95SM5	87.71 ± 0.03 ^c	0.109 ± 0.003 ^c	0.178 ± 0.004 ^c	0.34 ± 0.04 ^c	11.46 ± 0.02 ^b
SS90SM10	87.43 ± 0.02 ^c	0.208 ± 0.002 ^c	0.305 ± 0.002 ^c	0.37 ± 0.03 ^c	11.27 ± 0.03 ^b
SS85SM15	87.01 ± 0.04 ^b	0.340 ± 0.001 ^b	0.495 ± 0.003 ^b	0.42 ± 0.02 ^b	10.99 ± 0.04 ^c

Note: SS100SM0 = sorghum stem sheath extract, SM100SS0 = *Spondias mombin* extract, SS95SM5 = 95% sorghum stem sheath + 5% *Spondias mombin* extract, SS90SM10 = 90% sorghum stem sheath + 10% *Spondias mombin* extract, SS85SM15 = 85% sorghum stem sheath + 15% *Spondias mombin* extract, Values are means ± standard deviation of triplicate determinations. The mean values along the same column with different superscripts are significantly different ($p < 0.05$).

result to rancidity leading to the development of unpleasant and odorous compounds.

The protein content increased insignificantly ($p > 0.05$) from (0.178% to 0.495%) with increased inclusion of *Spondias mombin* extract. Although the crude protein of sorghum stem sheath (0.050) % was lower compared to the *Abelmoschus esculentus* extract (41.1%) [41] and *Adasonia digitata* extract (21.8%) [42] and *Bombax glabra* extract (34.1%) [14], it is also lower than the results of other tropical plant seeds extract like the *Sesemum indicum* (11.6%) [43] and *Annona muricata* (2.4%) [44]. Protein is an essential building material in food necessary for the maintenance of all body parts, such as blood, hair, bones, brain, nails, skin muscles and body fluid (Ayo, et al. 2007).

Carbohydrate content of the enriched samples was obtained by difference which decreased insignificantly ($p < 0.05$) from (11.46% to 10.99%) with increased inclusion of *Spondias mombin* extract. The total carbohydrate of the stem extract (11.64%) content is lower than *Cola millenii* extract (37.8%) [14], *Annona muricata* extract (47.1%) [44] and *Adasonia digitata* extract (52.5%) [42]. The stem samples submits as potential source of carbohydrates that could be used as a good supplement to the scarce cereal grains in Nigeria as sources of energy in diet.

Mineral compositions (mg/100 ml) of sorghum stem sheath- *Spondias mombin* extracts

The mineral compositions of sorghum stem sheath- *Spondias mombin* extract are shown in table 3. The calcium contents of the enriched samples decreased insignificantly ($p < 0.05$) from (601.99 to 526.97) mg/100 ml with increased inclusion of *Spondias mombin* extract. The calcium content of the stem sheath (632.00) mg/100 ml was significantly higher when compared with *Moringa oleifera* leaf extract (84.73) mg/100 ml [32], *Piliostigma thonningii* extract (43.11

mg/100 ml) [38], *Lophira lanceolata* extract (30 mg/100 ml) [45]. *Sesemum indicum* extract (281 mg/100ml) [43] and *Cola millenii* extract (168.35 mg/100 ml) [46]. The increased Ca content suggests that the enriched extract may be useful for the transport of oxygen and cellular activity. The Recommended Daily Allowance (RDA) ranged between 400 and 1200 mg per day for infants, children and young adults [47]. Consumption of the enriched samples will definitely contribute to the RDA of calcium in infants and adults and enhance the health status of the consumers. Functions of calcium include bone mineralization, muscle contraction, cell signaling and regulation of cell metabolism. It can also mediate the death of a cell or a group of cells [47].

The sodium contents of sorghum stem sheath- *Spondias mombin* extract decreased insignificantly ($p < 0.05$) from (761.01 to 713.50) mg/100 ml with increased inclusion of *Spondias mombin* extract. The sodium content of the stem sheath (780.00) mg/100 ml was relatively higher than *Moringa Oleifera* extract (40.10 mg/100 ml) [35]. Sodium intake in the enriched drink may activate, the Na^+/K^+ pump. This may cause influx of K^+ into the intracellular fluids and efflux of Na^+ , accompanied with Cl^- and water, thereby resulting in possible reduction in blood pressure. This could account for the acclaimed diuretic effect and consequently the antihypertensive effects of sorghum stem sheath extract as claimed by Adedayo, et al. and Awika, et al. [48,49].

The iron content of sorghum stem sheath-moringa instant extract decreased insignificantly ($p < 0.05$) from (108.46 to 94.61) mg/100 ml with increased inclusion of *Spondias mombin* extract. The iron of the stem sheath extract (114.00) mg/100 ml was higher compared to *Lophira lanceolata* extract (40 mg/100 ml) [45], *Cola millenii* extract (48 mg/100 ml) [46], *Sesemum indicum* extract (38.3 mg/100 ml) [43] and *Piliostigma thonningii* extract (78.70 mg/100 ml) [38]. The results showed that the enriched samples serve as good

Table 3: Minerals and Vitamin C Composition (mg/100ml) of Sorghum Stem Sheath- *Spondias mombin* Extracts.

Sample	Na	Ca	K	Fe	Vit C
SS100SM0	780.00 ± 0.01 ^a	632.00 ± 0.02 ^a	123.04 ± 0.06 ^d	114.00 ± 0.03 ^a	0.00 ± 0.00
SM100SS0	400.10 ± 0.05 ^d	31.80 ± 0.05 ^d	270.02 ± 0.01 ^a	3.18 ± 0.09 ^d	34.01 ± 0.01 ^a
SS95SM5	761.01 ± 0.03 ^b	601.99 ± 0.01 ^b	130.39 ± 0.02 ^c	108.46 ± 0.05 ^b	1.70 ± 0.04 ^c
SS90SM10	742.01 ± 0.04 ^b	571.96 ± 0.03 ^b	137.74 ± 0.03 ^c	102.92 ± 0.06 ^b	3.40 ± 0.03 ^c
SS85SM15	713.50 ± 0.02 ^c	526.97 ± 0.04 ^c	148.77 ± 0.04 ^b	94.61 ± 0.07 ^c	5.19 ± 0.02 ^b

Note: SS100SM0 = sorghum stem sheath extract, SM100SS0 = *Spondias mombin* extract, SS95SM5 = 95% sorghum stem sheath + 5% *Spondias mombin* extract, SS90SM10 = 90% sorghum stem sheath + 10% *Spondias mombin* extract, SS85SM15 = 85% sorghum stem sheath + 15% *Spondias mombin* extract, Values are means ± standard deviation of triplicate determinations. The mean values along the same column with different superscripts are significantly different ($p < 0.05$).

sources of iron. This confirms its traditional use of sorghum stem sheath in the prevention of anemia [50]. The values are in accordance to RDA 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 16 mg/100 g for women and feeding mothers [51]. It is also important for cytochrome activity, urea cycle, lipogenesis and cholesterologenesis [52].

The potassium contents of sorghum stem sheath- *Spondias mombin* extract ranged from 130.39 to 148.77 mg/100 ml which increased insignificantly ($p > 0.05$) with increased inclusion of *Spondias mombin* extract to sorghum stem sheath extract. The potassium content of the stem sheath (123.04) mg/100 ml was relatively higher than *Moringa Oleifera* extract (178.24 mg/100 ml) [35]. Therefore, *Spondias mombin* extract is a potassium rich product. The increasing trend observed in this study also suggests that both *Spondias mombin* and sorghum stem sheath are good sources of mineral elements. Potassium is the principal intracellular cation of most body tissues [36]. Potassium rich diet is used therapeutically in patients with uncomplicated essential hypertension. Natural potassium sources such as food and drinks are used for treatment or supplement [54]. The results suggest that *Spondias mombin* could be a good source of calcium, magnesium, iron, where intakes of 150 - 1000 g, 160- 850 g, 8-32 g would meet the Adequate Intake (AI) and Recommended Dietary Allowance for these minerals respectively [55].

The vitamin C contents of the enriched samples are shown in table 3 which increased insignificantly ($p > 0.05$) from (0.00 to 5.19%) with increased inclusion of *Spondias mombin* extract. The vitamin C content of the stem sheath (0.00) mg/100 ml was relatively lower than *Moringa Oleifera* extract (4.43 mg/100 ml) [35]. Lack of vitamin C in the stem sheath is in agreement with the report of USDA Nutrient data base [56] that sorghum stem sheath does not contain vitamin C. Gbadegesin, et al. [57] reported that the vitamin C status of beverages (such as *zobo*) can be improved by blending with plant materials and fruits. Adetuyi, et al. [2] obtained a similar result for vitamin C content of sorghum stem sheath extract (0.00%) when fortified with 50%, 60%, 70%, 80% and 90% orange and pineapple juices and reported proportionate values of 0.7, 1.3, 2.1, 2.8 and 3.5 mg/100 ml and (0.5, 0.9, 1.2, 1.7 and 2.1) mg/100 ml in the vitamin C content of the

blends, respectively. Vitamin C is a powerful water-soluble antioxidant that boosts the immune system and helps prevent cancer and heart disease [58]. Vitamin C requirements may be higher in stressed or traumatized persons or in persons with diabetes mellitus [52]. The RDA ranged between 30 to 60 mg per day for infants, children and adults. Consumption of the enriched drink will help provide some of the needed nutrients to meet the Recommended Daily Intake (RDI).

Anti- nutrient composition (mg/100 ml) of sorghum stem sheath-*Spondias mombin* extract

The result for the anti- nutrients composition of sorghum stem sheath- *Spondias mombin* samples is represented in table 4. Moderate levels of tannin were also found to be present in the enriched samples (0.025) mg/100 ml which is within the safe level (5.6 mg/day) [59]. A tannin content up to 5.6 mg is allowed in foods, and the intake of tannins present in the sorghum stem sheath extract (0.025) mg/100 ml was found to be much lower than that of *zobo* drink 0.035 mg/100 ml [60] and *Moringa Oleifera* extract (0.3410 mg/100 ml) [32]. The tannin content of the enriched extracts ranged between (0.144 and 0.442) mg/100 ml which increased insignificantly ($p > 0.05$) with increased inclusion of *Spondias mombin* extract. The levels of this tested anti-nutrient in the enriched samples were very low and within the tolerable (safe) levels for man (5.60 mg/day) [61].

The oxalate content of the enriched stem samples (0.303 and 0.385) mg/100 ml which increased insignificantly ($p > 0.05$) with increased inclusion of *Spondias mombin* extract was within the safe level of consumption in humans since the lowest lethal dose reported is 5 g (about 70 mg/kg) [62] and so therefore 40 – 50 mg/day is recommended [63]. The oxalate content of the stem sheath (0.220) mg/100 ml was relatively lower than *Moringa Oleifera* extract (3.3 10mg/100 ml) [32]. Mubarak, and Fasoyiro [64,65] 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 [66] 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 (10 mg/day) [59].

Table 4: Anti nutrient Composition (mg/100ml) of Sorghum Stem Sheath- *Spondias mombin* Extract.

Sample	Tannin	Oxalate	Saponin
SS100SM0	0.025 ± 0.005 ^d	0.220 ± 0.004 ^d	0.018 ± 0.002 ^d
SM100SS0	2.40 ± 0.02 ^a	1.88 ± 0.03 ^a	1.05 ± 0.01 ^a
SS95SM5	0.144 ± 0.004 ^c	0.303 ± 0.003 ^c	0.070 ± 0.004 ^c
SS90SM10	0.263 ± 0.003 ^c	0.336 ± 0.002 ^c	0.121 ± 0.003 ^c
SS85SM15	0.442 ± 0.002 ^b	0.385 ± 0.001 ^b	0.198 ± 0.001 ^b

Note; SS100SM0 = sorghum stem sheath extract, SM100SS0 = *Spondias mombin* extract, SS95SM5 = 95% sorghum stem sheath + 5% *Spondias mombin* extract, SS90SM10 = 90% sorghum stem sheath + 10% *Spondias mombin* extract, SS85SM15 = 85% sorghum stem sheath +15% *Spondias mombin* extract, 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 saponin level of the sorghum stem sheath – *Spondias mombin* extract ranged between (0.070-0.198) mg/100 ml which increased insignificantly ($p > 0.05$) with increased inclusion of *Spondias mombin* extract. The saponin content of the stem sheath (0.018) mg/100 ml was relatively lower than *Moringa Oleifera* extract (2.500 mg/100 ml) [32]. Saponins have been found to cause haemolytic activity by reacting with the sterols of erythrocytes membrane [61]. The levels of this tested antinutrient in the enriched samples were low and within the tolerable (safe) levels for man which may not constitute any health hazard or mal-absorption of other nutrients when taken in large quantity (10 mg/ day) [59].

Conclusion

Data indicated higher nutritional compositions with low concentrations of anti-nutrients within consumable safe limits. This shows that the enriched samples can be potential sources of nutrients.

Recommendation

The physicochemical and antioxidant properties of the enriched samples could be studied for further research work.

Also, the shelf life of the extract under different preservative techniques could be evaluated.

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