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INFLUENCE OF SWEETENERS AND FREEZE-DRYING ON THE QUALITY ATTRIBUTES OF SORREL (ZOBO) DRINKS

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Abstract

Aiming to add value to sorrel drink, effects of sweeteners (sugar and honey) and freeze-drying on the physicochemical properties, micronutrients and sensory attributes of sorrel drink were evaluated. Freeze-dried sorrel drink sweetened with honey was higher in yield (30% vs 10%) and solubility index (44.2 vs 44.19). Freeze-drying and sweetener type significantly ($p < 0.05$) affected the moisture (9.84-86.08%), pH (3.64-4.51), total soluble solids (8.20-15.10 ˚Brix) and ash (0.56-2.19%) contents of sorrel drink. Freeze-drying led to more concentrated calcium (0.10-1.15 mg/100g), potassium (0.80-4.30 mg/100g), magnesium (0.21-1.99 mg/100g), iron (0.07-0.10 mg/100g) and sodium (10.00-17.00 mg/100g) contents, with sugar-sweetened samples recording higher mineral contents. Both freeze-drying and honey addition resulted in increased vitamin C content, while the anthocyanin content was reduced. Sweetener type showed no significant effect on sensory attributes of the fresh and reconstituted drink samples but the mean

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sensory scores of the reconstituted drinks were significantly lower than those of fresh drink samples. Nevertheless, all the samples were accepted by the panelists. After 4 weeks of storage, 63.47% and 61.83% vitamin C losses were recorded for sugar- and honey-sweetened drink powders, respectively. This study therefore revealed the potential application of honey and freeze-drying in the production of functional instant sorrel drink powder.

Keywords: sweetener, freeze-drying, acceptability, quality attributes, instant sorrel drink powder, *Hibiscus sabdariffa*

Introduction

There is an increasing demand for functional soft drinks which are sourced from organic sources. This is in response to the growing health and economic concerns with conventional soft drinks, and dairy beverages. For instance, the presence of tartaric, phosphoric and citric acids in conventional soft drinks have been linked to ailments such as obesity, diabetes, teeth surface corrosion, and osteoporosis (Hughes *et al.*, 2000; Salami and Afolayan, 2020). As consumers are shifting towards healthy alternatives to conventional soft drinks, researchers are exploring efforts to add value to cheap plant sources with health promoting compounds for plant-based drinks.

Sorrel plant (*Hibiscus sabdariffa* L.), an annual erect herbaceous plant belonging to the Malvaceae family, is a multipurpose plant cultivated mainly for its leaves and calyces, which are being used as a healthy vegetable and as a valuable source of dietary medicines. It grows well in tropical and sub-tropical regions. Although it is said to be native to India, the plant has been introduced and grown in other parts of the world including Africa, West Indies and Central America (Fasoyiro *et al.*, 2005). The three recognized botanical varieties in Nigeria are those with red, purple and cream calyces. The red and purple varieties are used to produce sorrel drink, while the cream calyx in combination with sorrel leaf is used in preparing soup, popularly called 'Miyan Taushe' in the northern part of Nigeria (Muhammed and Umar, 2007; Olayemi *et al*., 2011). The nutrient compositions per 100 g of fresh sorrel calyces have been reported to include 84.5% water, 12.3 g carbohydrates, 2.3 g fibre, 1.2 g ash, and 0.1 g fat (Adegunloye *et al*., 1996). This also included 49 J energy, as well as micronutrients comprising 1.72 mg calcium, 57 mg phosphorus, 2.9 mg iron, 300 μg vitamin A, and 14 mg vitamin C. On the other hand, Babalola *et al*. (2001) reported 2.61 g fats, 12.0 g fibre, 6.9 g ash, 12.63 mg calcium, 1.145 g protein, 2732 mg phosphorus, 8.98 mg iron, 0.029 mg carotene, 3.765 mg niacin, 0.117 mg thiamine, 1.7 mg ascorbic acid, and 0.277 mg riboflavin in 100 g fresh calyces. Notably, the vitamin C content of sorrel calyces was reported to be 2.5-3 times higher than that of orange, blackcurrant and grapes (Ismail *et al*., 2008; M'be *et al*., 2023). The pharmacological properties (including antimicrobial, diuretic, antihypertensive, febrifugal and anthelminthic and antidiabetic properties) of the sorrel calyces and their extracts have been attributed to the presence of various bioactive constituents such as flavonoids, anthocyanins, polysaccharides and organic acids (Salami and Afolayan, 2020). Because of the aforementioned chemical compounds, *Hibiscus sabdariffa* is a suitable raw material for preparing nutritious and medicinal natural soft drinks.

Sorrel drink, popularly known as *zobo* in Nigeria, *Orselle* in France and *Karkade* in Arab-speaking countries, is a non-alcoholic, refreshing, nutritious and medicinal drink mainly produced from the acid-succulent calyces of *Hibiscus sabdariffa.* Sorrel drink is prepared by boiling and steeping sorrel calyces in water. The obtained extract is usually flavoured with fruit components (juice or peel) and spices before being sweetened with sugar or any other sweetener such as honey (Salami and Afolayan, 2020). Sorrel drink is now becoming a global commercial beverage, gaining notable acceptance across people of all ages. However, stability and safety concerns pose a major limitation to the large-scale production of sorrel drink. The drink has a shelf life of about 24 hours when stored at ambient temperature, or a few days when refrigerated (Jimoh, 2022). Sorrel drink is susceptible to microbial spoilage, especially due to microbial contamination from the ingredients and materials used in its production (Salami and Afolayan, 2020; Jimoh, 2022). Although several preservation techniques such as the use of pasteurization, carbonation, chemical and natural preservatives have been reported, much is still left to be desired, particularly in terms of convenience, product qualities and consumers' safety (Izah *et al*., 2015; Chukwu *et al*., 2020; Salami and Afolayan, 2020). This calls for the adoption of new technology to extend the shelf life and add value to sorrel drink.

Dehydration is a veritable processing technique which can be used to extend the shelf life and improve the handling convenience and transportation of indigenous drinks. Few studies have attempted adding value to sorrel drink using drying technology. For instance, Mohammed *et al*. (2017) studied the proximate, nutritional and microbiological properties of pulverized sorrel powder, while Sulieman (2014) investigated the physical properties, chemical composition, and microbiological characteristics of spray-dried *karkade* powder. Builders *et al*. (2010) studied the phytochemicals, as well as physical and physicochemical properties of liquid and freeze-dried extract of *Hibiscus sabdariffa.* However, there is a paucity of information on the effect of sweeteners and freeze-drying on the quality attributes of sorrel drinks.

The choice of freeze-drying in the current study was informed by its relatively minimal effect on the nutrients and quality attributes of food. Even though freeze-drying may be considered an expensive technology, it is still being widely employed in basic research. Honey, the only insect-derived natural product, has been reported to be of high nutritional, cosmetic, industrial and therapeutic values. Its use as a sweetener in this study was based on its sweetness, which is 25% more than that of table sugar as a result of its high fructose content (Samarghandian *et al*., 2017). This study was therefore designed to examine the effect of sweeteners (sugar and honey) and freeze-drying on the physicochemical properties, micronutrients and sensory attributes of sorrel drink with the aim of developing a value-added, shelf-stable functional, sorrel-based drink.

Materials and methods

Materials

Mature dried red sorrel (*Hibiscus sabdariffa*) calyces and other ingredients (sugar, pineapple, ginger, cloves) used were purchased from Ipata market in Ilorin, Nigeria and they were immediately transported to the Food Processing Laboratory of the Department of Home-Economics and Food Science, University of Ilorin, Nigeria for processing. Pure honey (Mutifloral table honey) was purchased from University of Ilorin Apiary (Ilorin, Kwara State, Nigeria). All the chemicals and equipment used were of analytical grade.

Preparation of spices' extracts and pineapple juice

Ginger (50 g) was peeled and chopped into small pieces using a clean, stainless-steel knife. The resulting pieces were then blended with 50 mL deionized water using a Kenwood blender (Kenwood Limited, Havant, Hampshire, UK) with stainless steel blades until a smooth paste was obtained. The paste was further diluted with 100 mL deionized water and then filtered using a clean sterile muslin cloth. The same procedure was used to obtain cloves' extract. Pineapple juice was produced from fresh matured ripe pineapple fruit using electric juice extractor as described by Ahaotu and Ekpemagha (2024).

Sorrel drinks and their freeze-dried powders preparation

Sorrel drinks were prepared using the method described by Bolade *et al*. (2009) with some modifications. The dried red sorrel calyces (200 g) were sorted and cleaned of dirt and other foreign materials before being cleaned in potable water. The cleaned calyces were added to boiling water (1:52 w/v) and heated for 5 minutes. Pineapple peel (9 g) was added and the mixture was allowed to boil for 30 minutes. Thereafter, the resulting hot red-coloured aqueous extract was allowed to cool and then filtered using a piece of white sterile muslin cloth. The extracts of ginger (100 mL) and clove (130 mL), as well as pineapple juice (280 mL), were added to the sorrel drink and thoroughly mixed. The sorrel drink was divided into two portions which were sweetened with sugar (60 g) and honey (340 mL), respectively, based on our preliminary investigation. Each of the portions was further divided into two and a portion of the samples sweetened with sugar and honey was packaged in sterile plastic bottles and immediately subjected to analyses, while the second portion of the samples were freeze-dried at -56° C. The freeze-drying process took 4 days for sugar-sweetened sorrel drink and 7 days for the honey-sweetened sorrel drink. The freeze-dried sorrel drink pellets are shown in Figure 1.

Determination of yield and solubility index of sorrel drink powder

The yield of the sorrel drink powder was calculated by dividing the weight of the dried sorrel drink by the weight of the dried calyces used on dry basis, while the solubility index of the sorrel drink powder was determined by dividing the weight of soluble fraction by the weight of sample, as described by Kolawole *et al*. (2024).

Determination of physicochemical properties

Moisture (925.09) and ash (936.03) content were determined using the method of AOAC (2000). Briefly, oven drying method at 103.5˚C for 5 hours for moisture determination and the ash content was obtained by igniting 2 g sample at 550 ˚C for 4 hours using muffle furnace. The pH of sorrel drink was determined using electrically calibrated digital pH meter (Mettler Delta 340, Leicester, England, UK), and the same meter was used for the powders, following the procedure described by Kolawole *et al*. (2024). The total soluble solids of the sorrel samples were determined using a refractometer, as described in method 932.12 (AOAC, 2000). For the powders, 10 g of sample was first homogenized in 40 mL of water and centrifuged (Model 4515 Sigma, Osterode Am Harz, Germany) at 3000 rpm for 20 min and the supernatant was used for soluble solids measurement. After sterilizing the refractometer with distilled water and cotton wool, three drops of well homogenized sample were put on prism of refractometer and direct reading was taken.

Mineral analysis

The calcium, potassium, magnesium, sodium and iron composition of the sorrel samples were determined after ashing and digestion using Perkin Elmer atomic absorption spectrophotometer (Model No. 311, Perkin Elmer Company, Shelton, Connecticut, USA) as described by Oyeyinka (2016).

Determination of vitamin C and anthocyanin

Vitamin C content was determined using the 2, 6-dichlorophenol indophenol titration method described in method 967.21 of AOAC (2005), while anthocyanin was determined using UV-spectrophotometer according to the pH differential method described by Abu Bakar *et al*. (2009).

Vitamin C stability study

Representative samples from each sorrel drink powder were packaged separately in an airtight sterile plastic bottles and stored at room temperature (27 ± 2 ◦C) for 4 weeks and vitamin C analysis was conducted every two weeks.

Sensory evaluation

The instant sorrel drink powders were reconstituted and all the sorrel drink samples in identical bowls were coded before being randomly presented to a 50-member semi-trained panel (21 males and 29 females with average age of 26 years) comprising the students and members of staff of the University of Ilorin in well-illuminated booths. The panel selection was based on their familiarity with the sensory attributes of sorrel drink and their interest in participating in this study. Each panelist was given a questionnaire with instructions to score the appearance, aroma, taste, mouthfeel and overall acceptability of the samples based on a 9-point hedonic preference scale (9 = like extremely and 1 = dislike extremely) and multiple comparison test (Kolawole *et al*., 2024). The panelists were provided with potable water to rinse their mouth after tasting each sample. This study proposal was approved by the Research and Ethical committee of the Department of Home Economics and Food Science, University of Ilorin, Nigeria, following its presentation. The assessors are regular consumers of sorrel drink and they gave their informed consent to participate in the sensory evaluation with the ability to withdraw from the study at any point in time.

Statistical analysis

Experiments were conducted in triplicate, except where it is stated otherwise, and the generated data were analyzed using one-way analysis of variance (ANOVA) of the Statistical Package for Social Sciences (SPSS, version 20.0). Duncan's Multiple Range Test ($p<0.05$) was used to separate the means.

Results and discussion

Effect of sweetener on the yield and solubility index of freeze-dried instant sorrel drink powders

The yield of sugar-sweetened sorrel drink powder was 10%, and three times this amount was obtained for the sample sweetened with honey (Figure 1b). Lower yield recorded for the sample sweetened with sugar could be attributed to its relatively higher moisture removal efficiency, compared to the sugar-sweetened sample, in which honey appeared to be more humectant. A major factor that could have also contributed to the higher yield of the honey-sweetened sample is the high total solids of honey which has been reported to be over 80% (Kamal *et al*., 2019). Solubility index is a reconstitution property of powders which depend largely on their soluble components such as sugars. The solubility indices of the instant sorrel drink powders were significantly ($p<0.05$) different, with honey-sweetened sample having higher value (44.20%) than its sugar-sweetened counterpart (Figure 1c). This can be explained by factors such as difference in the types of simple sugars present in the sweeteners. This is possible because of the higher fraction of simple sugars in honey such as the monosaccharides like fructose (Khan *et al*., 2018), with easier solubility than sucrose, which is typically found in table sugar. The fact that solubility index may influence the mouthfeel of reconstituted drinks from the instant sorrel drink powder, makes it an important property.

Effect of sweetener on the physicochemical properties of sorrel drinks and their freeze-dried powders

The moisture content, pH, total soluble solids and ash contents of sorrel drinks sweetened with sugar and honey, as well as their corresponding freeze-dried powders are presented in Table 1. The moisture content of the sorrel samples ranged between 9.84% and 86.08%. Freeze-drying resulted in loss ($p<0.05$) of 88% and 86% moisture in sugar- and honey-sweetened freeze-dried sorrel drinks, respectively. Sulieman (2014) has also reported a significant reduction in the moisture content of *Hibiscus sabdariffa* extract from 96% to 6.7-8.2% following spray-drying. The variation in the moisture content of the sorrel samples obtained in this study and that of the previous study could be due to the differences in the ingredients, method of production as well as the method and condition of drying employed. Moisture content of the freshly prepared sorrel drink was not significantly influenced by the type of sweetener used, but the honey-sweetened freeze-dried sorrel drink powder showed significantly ($p<0.05$) higher moisture content than its sugar-sweetened counterpart. Moisture removal was more effective and faster from sorrel drink sweetened with sugar than the sample sweetened with honey. The higher amount of moisture present in the honey-sweetened freeze-dried sample may be due to the characteristic sticky/viscous nature of honey, which probably restricted moisture removal during drying (Hebbar *et al*, 2008). Also, the fact that honey was used in its original wet form compared to sugar that was in dry form might be responsible for the inability of the honey-sweetened sorrel drink to dry to a very low moisture content within the same period with sugar-sweetened counterpart. The lower moisture content obtained for the freeze-dried samples is an indication of shelf stability and convenience.

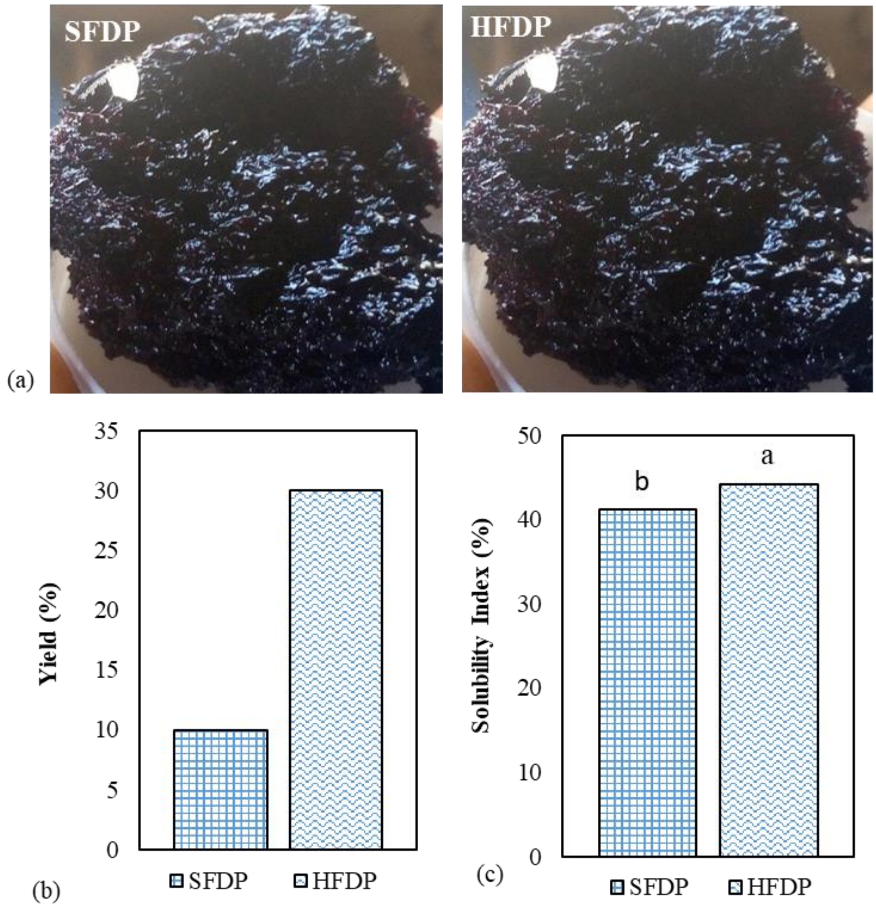

Figure 1. Physical appearance of sugar- and honey-sweetened freeze-dried sorrel drink pellets and yield (a) and solubility index (b) of their powders. Error bars indicate standard deviation (N = 3). Charts with different alphabet are significantly (P<0.05) different. SFDP–Sugar-sweetened freeze-dried sorrel drink powder, HFDP–Honey-sweetened freeze-dried sorrel drink powder.

The pH values of the sorrel drinks and their freeze-dried powders ranged from 3.64 to 4.50, indicating that the samples were acidic (Table 1). The generally low pH of the samples might be attributed to the acidic nature of *Hibiscus sabdariffa* calyces which has been reported to be rich in organic acids such as oxalic, succinic, tartaric and malic acids (Wong *et al*., 2002). This could partly explain the characteristic tart taste of sorrel drink. The use of sugar and honey showed no significant effect on the pH of the fresh sorrel drinks. However, freeze-drying resulted in significant ($p<0.05$) decrease in pH of the sorrel drink samples and a significant difference also existed between the pH values of the powdered samples with the honey-sweetened sample having the lowest. Nevertheless, the pH values recorded in this study are comparable to pH value of 3.80 reported by Ajala *et al*. (2013). The presence of other ingredients such as spices and pineapple products might have increased the pH of the sorrel drink samples.

The total soluble solids, which can be described as the amount of solids dissolved within a liquid, ranged from 8.20 to 15.10 ˚Brix for the sorrel samples. This is comparable to the 11.00 ˚Brix reported for *zobo* drink by Chukwu *et al*. (2020) and 11.20-13.30 ˚Brix reported by Bolade *et al*. (2009). The results showed that the type of sweetener and freeze-drying had significant ($p<0.05$) influence on the total soluble solids of the sorrel samples. The total soluble solids of the freshly prepared sorrel drinks were higher ($p<0.05$) than those of freeze-dried samples, presumably as a result of loss of some volatile dissolved components during drying. Honey addition appeared to resultant in higher total soluble solids in both freshly prepared and freeze-dried sorrel samples. This may be due to the presence of several kinds of sugar dissolved in honey unlike table sugar that is majorly made up of sucrose. This is plausible since honey has been shown to contain over 22 other sugars apart from fructose, glucose, sucrose and reducing sugars (Khan *et al*., 2018). Bolade *et al*. (2009) previously documented comparable 11.2-13.3 ˚Brix as the common denominator of the total soluble solids of *zobo* drinks studied. Total soluble solids are a good representation of sugar quantity in drinks and fruits**.**

Table 1. Physicochemical properties of sorrel drinks and their freeze-dried powders sweetened with sugar and honey.

Sample	**Moisture content (%)**	**pH**	**TSS (^{0} Brix)**	**Ash (%)**
SFSD	$86.08±0.01^a$	$4.50±0.04^a$	$14.25±0.08^b$	$0.72±0.08^b$
HFSD	$85.82±0.86^a$	$4.51±0.08^a$	$15.10±0.04^a$	$0.56±0.13^b$
SFDP	$9.84±0.19^c$	$3.82±0.10^b$	$8.20±0.02^d$	$1.78±0.28^a$
HFDP	$11.73±0.15^b$	$3.64±0.02^c$	$9.90±0.04^c$	$2.19±0.12^a$

Values are means (N = 3) ± SD. Means with different superscript within the same column are significantly ($p<0.05$) different. SFSD–Sugar-sweetened fresh sorrel drink; HFSD–Honey-sweetened fresh sorrel drink; SFDP–Sugar-sweetened freeze-dried sorrel drink powder; HFDP–Honey-sweetened freeze-dried sorrel drink powder.

Values in the range of 0.56-2.19% were obtained for the ash content of the sorrel drink samples with freeze-dried samples having significantly ($p<0.05$) higher values (1.78-2.19%). This was expected as the ability of drying to concentrate nutrients such as minerals, is a well-known phenomenon. However, it was observed that the type of sweetener used in this study had no significant effect on the ash content of both the liquid and the powdered sorrel samples. Ash is the remaining inorganic residue after water and organic matter have been removed from food by heating such food in the presence of an oxidizing agent and it is a good representation of the total mineral composition of the food (Kolawole *et al*., 2016).

Effect of sweetener on the mineral composition of fresh and freeze-dried sorrel drinks

The calcium (0.10-1.15 mg/100g), potassium (0.80-4.30 mg/100g), magnesium (0.21-1.99 mg/100g), sodium (10.00-17.00 mg/100g) and iron (0.07-0.10 mg/100g) contents of the sorrel drink samples are presented in Table 2. The results showed that the freeze-dried sorrel drink samples contained higher ($p<0.05$) calcium, potassium, magnesium, sodium and iron than the freshly prepared samples. The higher ash content of the freeze-dried samples (Table 1) could be responsible for their higher mineral compositions. The type of sweetener significantly affected the potassium and iron contents of the sorrel drinks as well as the calcium, potassium, magnesium and sodium composition of their freeze-dried powders. The higher values recorded for the mineral elements of the sugar-sweetened sorrel samples compared to the honey-sweetened samples and the trend in the results obtained for the mineral composition of the sorrel drink samples followed the same trend as that of the ash content of the sorrel drink samples (Table 1). This indicated that the examined mineral elements of the sorrel samples are a good representation of their crude ash contents. Mohammed *et al*. (2017) previously reported the iron content of instant sorrel drink powder to be 0.60 mg/100g but powder was made from dehydrated purple sorrel calyx which could account for variation in the results obtained in this study.

Table 2. Mineral composition (mg/100g) of fresh sorrel drinks and their freeze-dried powders sweetened with sugar and honey.

Sample	**Calcium**	**Potassium**	**Magnesium**	**Sodium**	**Iron**
SFSD	0.15 ± 0.07^{c}	1.0 ± 0.01^{c}	0.21 ± 0.04^{c}	10.65 ± 0.21^{c}	$0.10\pm0.\ 01^{a}$
HFSD	0.10 ± 0.01^{c}	0.80 ± 0.01^{d}	0.21 ± 0.01^{c}	$10.00\pm0.\ 28^{c}$	0.07 ± 0.02^{b}
SFDP	1.15 ± 0.07^{a}	4.30 ± 0.01^{a}	1.99 ± 0.06^{a}	17.00 ± 0.13^{a}	0.10 ± 0.01^{a}
SFDH	0.45 ± 0.07^{b}	3.15 ± 0.07^{b}	1.06 ± 1.06^{b}	$14.90\pm0.\ 57^{b}$	0.10 ± 0.01^{a}

Values are means (N = 3) ± SD. Means with different superscript within the same column are significantly ($p<0.05$) different. SFSD–Sugar-sweetened fresh sorrel drink; HFSD–Honey-sweetened fresh sorrel drink; SFDP–Sugar-sweetened freeze-dried sorrel drink powder; HFDP–Honey-sweetened freeze-dried sorrel drink powder.

Other factors that could account for variations in the mineral content between the current and the previous studies include varietal differences of *Hibiscus sadarriffa* (Olayemi *et al*., 2011), variation in processing methods and the choice of sweeteners used. The rich mineral composition of the sorrel drinks could be mostly attributed to the high mineral content in the calyces of *Hibiscus sadarriffa*. This is plausible since *zobo* calyces have been reported to contain mineral elements such as potassium, calcium, magnesium, and iron (Babalola *et al*., 2001).

Effect of sweetener on the Vitamin C and anthocyanin contents of sorrel drinks and their freeze-dried powders

The results presented in Table 3 indicate that the type of sweetener used in this study and the freeze-drying significantly ($p<0.05$) influenced the vitamin C (215.81-756.24 mg/100g) and anthocyanin (0.63-1.20 mg/100g) contents of the sorrel drink samples. The honey-sweetened sorrel drink samples had higher vitamin C, but lower anthocyanin content than their corresponding sugar-sweetened counterparts. Similarly, freeze-drying increased the vitamin C but decreased the anthocyanin content of sorrel drink samples. Generally, sorrel drink samples sweetened with honey had a higher vitamin C content (389.02 and 756.24 mg/100g) than those sweetened with sugar (362.74 and 215.81 mg/100g) (Table 3). *Zobo* calyx is known to be rich in vitamin C. The values were generally higher than 26 mg/100g reported by Mohammed *et al*. (2017). This could be attributed to the inclusion of pineapple products (juice and peel extract) and the methods of drying adopted. The authors used spray drying which works at a very high temperature of 130-200^{0}C. This presumably led to substantial loss of vitamin C, being very heat sensitive in nature. As an antioxidant, vitamin C has the capacity to boost body immunity against various diseases and ailments such as colon cancer and scurvy (Mohammed *et al*., 2017; Kolawole *et al*., 2024). The liquid samples recorded higher anthocyanin contents than their freeze-dried counterparts. This was expected since some of the anthocyanin contents might be lost during period of freeze-drying. The values in this study ranged from 0.63-1.20 mg/100g. Anthocyanins are known to give sorrel drink its characteristic color. The anthocyanins that have been identified in sorrel include delphinidin-3-sambubioside, cyaniding-3-sambubioside and delphinidin-3-glucose (Hong and Wrostlad, 1990).

Table 3. Vitamin C and anthocyanin content of sorrel drinks and their freeze-dried powders sweetened with sugar and honey.

Sample	Vitamin C (mg/100g)	Anthocyanin (mg/100g)
SFSD	215.81±23.48^d	1.20±0.02^a
HFSD	389.02±23.92^b	1.09±0.01^b
SFDP	362.74±27.00^c	0.83±0.01^c
HFDP	756.24±6.75^a	0.63±0.01^d

Values are means (N = 3) ± SD. Means with different superscript within the same column are significantly ($p<0.05$) different. SFSD–Sugar-sweetened fresh sorrel drink; HFSD–Honey-sweetened fresh sorrel drink; SFDP–Sugar-sweetened freeze-dried sorrel drink powder, HFDP–Honey-sweetened freeze-dried sorrel drink powder.

Sensory attributes of fresh and freeze-dried sorrel drinks sweetened with sugar and honey

The mean sensory scores for the appearance (6.94-8.02), aroma (6.44-7.44), taste (5.90-7.66), mouthfeel (6.10-7.52) and overall acceptability (6.50-7.90) of the freshly prepared and the reconstituted sorrel drinks are shown in Table 4. The type of sweetener had no significant effect on the sensory ratings of the sorrel drink samples with the exception of the mean scores for the mouthfeel of reconstituted sorrel drinks. Also, the mean scores for the sensory characteristics of the sugar-sweetened sorrel drinks were generally higher than those of their honey-sweetened counterparts. However, the sensory characteristics of the reconstituted drinks were rated lower than that of their freshly prepared counterparts, indicating the significant ($p<0.05$) impact of freeze-drying on the sensory characteristics of sorrel drink. Nevertheless, the results showed that all the sorrel drink samples were accepted by the panelists. Freshly-prepared sorrel drinks were more accepted than the freeze-dried samples in all sensory parameter assessed. Freeze-drying took time which could have caused oxidation reaction and affected the color pigments such as anthocyanin. This probably influenced the judgements of the panelists. In both fresh and dry forms, samples sweetened with sugar had higher preference than those sweetened with honey but the difference was not significant except in mouthfeel of freeze-dried sample. Although freeze-drying significantly reduced the sensory properties of sorrel drinks, all the freeze-dried samples were still generally accepted. The familiarity of the consumers with the taste of sugar might also explain why samples sweetened with sugar were better accepted. This presumption is in line with the comments of some of the panelists on the noticeable characteristic taste of honey in honey-sweetened samples. This is also in line with the perception that consumers do not readily accept newly introduced food products due to their familiarity with the characteristic nature of the already existing one.

Table 4. Sensory properties of fresh and freeze-dried sorrel drinks sweetened with sugar and honey.

Sample	Appearance	Aroma	Taste	Mouthfeel	Overall acceptability
SFSD	8.02 ± 0.89^{a}	7.44 ± 0.91^{a}	7.66 ± 0.98^{a}	7.52 ± 0.79^{a}	7.90 ± 0.86^{a}
HFSD	7.88 ± 0.96^{a}	7.18 ± 1.22^{a}	7.16 ± 1.35^{a}	7.10 ± 1.25^{a}	7.54 ± 1.01^{a}
SFDP	7.18 ± 0.94^{b}	6.50 ± 1.27^{b}	6.28 ± 1.43^{b}	6.60 ± 1.23^{b}	6.64 ± 1.24^{b}
HFDP	6.94 ± 1.04^{b}	6.44 ± 1.31^{b}	5.90 ± 1.37^{b}	6.10 ± 1.37^{c}	6.50 ± 1.17^{b}

Values are means (N = 50) ± SD. Means with different superscript within the same column not significantly ($p<0.05$) different. SFSD–Sugar-sweetened fresh sorrel drink; HFSD–Honey-sweetened fresh sorrel drink; SFDP–Sugar-sweetened freeze-dried sorrel drink powder, HFDP–Honey-sweetened freeze-dried sorrel drink powder.

Storage stability of vitamin C content of freeze-dried sorrel drink powders sweetened with sugar and honey

The vitamin C content of the freeze-dried sorrel drink powders stored for four weeks generally decreased (p<0.05), irrespective of the type of sweetener used (Table 5). The sugar-sweetened and the honey-sweetened sorrel drink powders recorded high losses (57.28% and 51.58%, respectively) of vitamin C after the first two weeks of storage, but only 6.19% and 10.25% losses of vitamin C were recorded in the sugar- and honey-sweetened samples, respectively after additional two weeks of storage. Overall, the results showed higher total loss of vitamin C in case of sugar-sweetened sample (63.47%) compared to the honey-sweetened sample (61.83%) after four weeks of storage. The general high loss of vitamin C recorded for the sorrel drink powders during storage agreed with the report of Kolawole *et al*. (2024), which showed a significant loss in vitamin C content of trona-treated okra powder stored for six weeks at room temperature. The authors linked the loss in vitamin C to the possible conversion of vitamin C to dehydroascorbic acid by the action of the enzyme ascorbate oxidase during storage.

Table 5. Storage stability of vitamin C content (mg/100g) of freeze-dried sorrel drink powders sweetened with sugar and honey.

Sample	Week 0	Week 2	Week 4
SFDP	756.24±0.02[a]	323.07±0.01[b] (-57.28%)	303.07±0.01[c] (-6.19%)
HFDP	362.74±0.05[a]	175.63±0.03[b] (-51.58%)	157.63±0.02[c] (-10.25%)

Values are means (N = 3) ± SD. Means with different superscript within the same row are significantly (p<0.05) different. SFDP–Sugar-sweetened freeze-dried sorrel drink powder, HFDP–Honey-sweetened freeze-dried sorrel drink powder.

Conclusions

This study presents freeze-drying as a way to add value as well as convenience to sorrel drink. The type of sweetener and freeze-drying influenced the quality attributes of sorrel drink. The yields of the instant sorrel drink powders obtained from the sugar- and the honey-sweetened sorrel drink samples were 10 and 30%, respectively. Moisture removal during freeze-drying was more efficient with sugar-sweetened sorrel drink than with honey-sweetened sample, resulting in lower moisture content and lower water activity in the former. Honey-sweetened sorrel powder demonstrated a better vitamin C retention during four weeks of storage. Although the sugar-sweetened freshly prepared and reconstituted sorrel drinks had relatively higher sensory ratings than their honey-sweetened counterparts, all the sorrel drinks were accepted by the panelists. Therefore, honey can be used in place of sugar to sweeten and produce functional sorrel drink. Investigation on the health benefits of the value added sorrel drinks and the influence of addition of sweeteners to sorrel drink after drying are recommended for further studies.

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