NUTRIENT COMPOSITION OF FREEZE-DRIED AND OVEN-DRIED SOURSOP (*Annona muricata*) PULP POWDERS AND SENSORY EVALUATION OF THEIR DRINKS COMPARED TO FRESH ONE

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ABSTRACT
Background: Soursop is underutilized and highly perishable, tropical fruit rich in several nutrients.
Objective: This study determined the nutrient composition of freeze-dried and oven-dried soursop (Annona muricata) pulp powders and sensory evaluation of drinks made from them compared with the fresh one.
Materials and Methods: Mature soursop fruits were purchased at a local market in Nsukka, Enugu State, Nigeria. The fruits were allowed to ripen for 5 days at room temperature (37°C). The ripe fruits were washed, peeled, seeds handpicked and the pulp dried. Freeze-drying was done at -40°C for 72 hours, oven-drying at 70° C for 48 hours. Nutrient content was determined using standard methods. Each of the freeze-dried and oven-dried soursop powders (100g) was liquefied with 500mls of water to formulate unsweetened drinks. A hundred grammes each of the dried powders were liquefied with 500mls of water and flavoured with four tablespoons (60g) of honey to formulate sweetened drinks. Fresh soursop pulp (200g) was liquefied with 400mls of water and flavoured with four tablespoons (60g) of honey to formulate sweetened fresh drink. Sensory evaluation of all the drinks was conducted using a 9-point hedonic scale. Data obtained from the study were analyzed using the Statistical Product for Service Solution (SPSS) for Windows version 21. Results were presented as means and standard deviations. The researcher used Analysis of Variance (ANOVA) and Duncan's new multiple range tests to separate and compare means at $p < 0.05$.
Results: The freeze-dried powder had higher moisture (12.86±0.01%), fat (6.66±0.01%) and carbohydrate (43.70±0.01%) contents while the oven-dried sample had higher protein (20.37±0.01%), ash (12.26±0.01%) and crude fibre (16.36±0.01%) contents. Vitamin C content was 2.76mg/100g (Freeze-dried soursop, FrDS) and 1.69mg/100g (Oven-dried soursop, ODS), vitamin B_1 was 0.05mg/100g (FrDS) and 0.04mg/100g (ODS) and vitamin B_2 was 0.09mg/100g (FrDS) and 0.05mg/100g (ODS). Ca was 1.18mg/100g and 1.46mg/100g; Fe was 24.26mg/100g and 33.35mg/100g; Mg was 42.26mg/100g and 55.58mg/100g; Na was 20.15mg/100g and 25.58mg/100g; K was 23.35mg/100g and 36.67mg/100g; Zn was 0.87mg/100g and 1.56mg/100g while P was 29.36mg/100g and 66.57mg/100g for the FrDS and ODS soursop powders respectively. The drink from fresh soursop (FSD) had the best score for overall acceptability (7.75±0.85) at $p < 0.05$ compared to the other drinks.
Conclusion: Dried soursop pulp, especially oven-dried, can be a good source of protein, fibre and minerals including K, Fe, P, Mg and Na while the freeze-dried soursop is a better source of carbohydrate, fat and vitamins than the oven-dried. Dried soursop pulp has potential in the prevention of micronutrient deficiencies as well as PEM.
KEYWORDS: Soursop, oven-dried, freeze-dried, nutrient composition, drinks.

Introduction

Micronutrients (vitamins and minerals) deficiency which is known as “hidden hunger” affects more than an estimated 2 billion people globally (1). Fruits, however, provide diversity in the diet of humans (2) and are a rich and cheap source of vitamins, minerals and fibre (3). There is, then, a need to offer consumers new products that will stimulate fruit consumption. These products need to be adapted to consumers' current states, to their sensory, nutritional and functional quality requirements (4). The challenge then is the availability of these fruits needed to constitute a diversified diet. The problem monotonous diets abound in developing countries where diets are mainly starchy staples having few fruits (5).

Many tropical fruits are grossly underutilized in the developing world. One of such underutilized fruits is the soursop fruit, scientifically known as Annona muricata (6). It is commonly called soursop in English-speaking countries, graviola in Brazil, prickly custard apple in the Caribbean and grand corossol in French-speaking countries (7). It is also known as 'Ebo or Apekan' in Yoruba, 'Fasadarur or Tuwon biri' in Hausa and 'Sawansop' in Igbo (8).

The soursop tree is prevalent in the rainforests of Africa, especially in Eastern Nigeria, South America and Southeast Asia (9). The fruit is very delicate, dark green but firm especially when unripe, and covered with spines. It is relatively large, and has a very thin, leathery skin, and can weigh about 2.5kg to more than 4kg (10). The pulp is white, creamy, meaty, juicy and slightly acidic having many seeds (10). The fruit spines become smooth, its green colour slightly pale, and yields to touch as the fruit matures (11). They are eaten as food with its stems and leaves employed in orthodox medicine to cure symptoms of inflammation and infection. Soursop fruit is also used as a dietary supplement and is widely promoted as an effective cancer treatment (12).

Soursop has been reported to be a fruit of great nutritional importance having low sodium content, very low saturated fat and cholesterol, and contains dietary fibre, potassium, B-vitamins, and vitamin C (13). The fruit pulp has been reported useful in producing concentrated juice, frozen pulp, nectar, jam, ice cream, alcoholic beverages, diuretic drinks and anti-scorbutic syrup (14). Domestically, soursop pulp is strained and used as a drink or eaten as dessert (15). Fruits, however, are known to be short-lived due to seasonality and their perishable nature (7). Soursop is highly susceptible to quality deterioration after harvest if not well preserved (6). Utilization of fruits in many developing countries is restricted as a result of inadequate processing and preservation methods (16).

Soursop pulp could be preserved dry by oven-drying the pulp (18) or by spray-drying, vacuum-drying and freeze-drying, (17). Drying is an excellent way to preserve fruits (such as soursop) which can add variety to meals and also provide delicious, nutritious snacks (19). Oven-drying with a simple kitchen oven is the easiest way to dry foods in many households. It is faster and safer than sun-drying and is useful for drying a small quantity of food. This process does reduce the heat labile nutrients such as vitamin C (19). However, the substantial decrease in moisture levels results generally in higher nutrient content (18). Conversely, freeze-drying involves placing the food to be dried on large racks inside a vacuum chamber. Temperature is decreased below freezing then gradually increased so that the water in the product goes from a solid state to a gaseous state, leaving the food structure intact. This process produces higher-quality products with little or no shrinkage, minimal changes in colour and nutrients (18). Apart from fewer nutrient losses, freeze-drying also results in a product that can be more successfully rehydrated in the future (19). The soursop fruit pulp concentrated into powder will increase its commercial value and demand in Nigeria, make it available during its off-season, and encourage its inclusion in our diets. The aim of this study, therefore, was to determine the nutrient content of freeze-dried and oven-dried soursop pulp and acceptability of drinks made from them via sensory evaluation.

Materials and Methods

Procurement of Materials

Fresh, mature (fruit skin becomes smooth, its green colour slightly pale) soursop fruits were selected and purchased from a local market in Nsukka, Enugu State, Nigeria.

Preparation of samples

The soursop fruits were allowed to ripen (until they were soft and yielding to touch) at room temperature (37°C) for about five days. Below is the flow chart showing the steps involved in the extraction of the soursop pulp for freeze-drying and oven-drying.

Fresh, ripe soursop fruit
↓
Washed with cold tap water
↓
Peeled (manually)
↓
Seed removal (manually)
↓
Spread out (manually on drying containers)
↙ ↘
Freeze-dried (FrDS) (at -40°C for 72 hours) | Oven-dried (ODS) (at 70ºC for 48 hours)

Figure 1: Flowchart for the preparation of soursop pulp for freeze-drying and oven-drying

Figure 2: Soursop pulp in the form it was dried

Freeze-drying was done at -40°C for 72 hours (18) using a freeze-dryer, Virtis (Genesis 25, USA), with an average freezing speed of 2.04°C min-1, a plate temperature between 10°C and 80°C, and a maximum product temperature of 60 ± 5°C (17). The freeze-dried soursop samples (FrDS) were homogenized by blending them into a fine powder using a kitchen blender (Sonik® Japan, SB-1212 model). The powder was very similar in colour to that of the fresh soursop pulp.

Oven-drying was done at 70° C for 48 hours in a single layer on oven trays. The dried fruit was then ground into fine flour using a kitchen blender (Sonik® Japan, SB-1212 model) (18). The powdered oven-dried soursop (ODS) flour was yellowish brown in colour. The freeze-dried and oven-dried samples were packaged in air-tight bags prior to use for analysis.

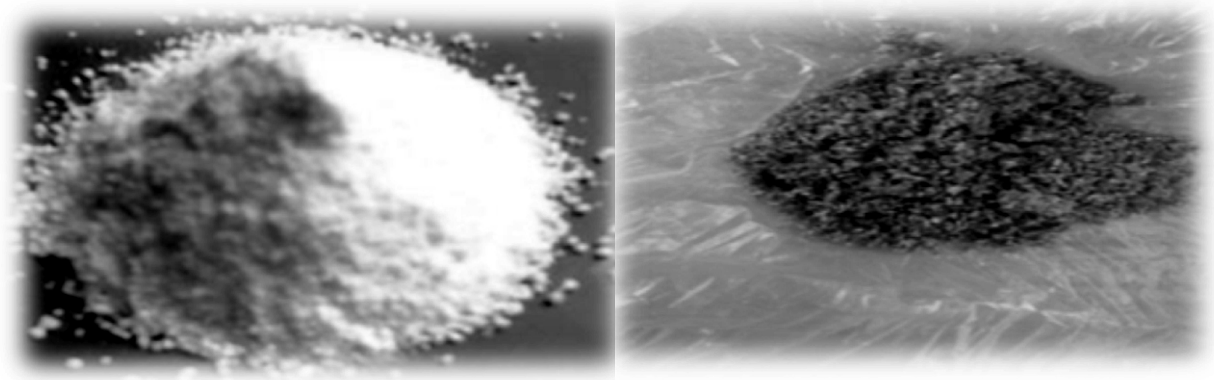

Figure 3 and 4: Freeze-dried and oven-dried soursop pulp

Chemical analysis

The moisture content, crude ash, crude fibre, crude protein, and fat content of the samples were all determined using the methods of AOAC (20). Carbohydrate content was obtained by difference. The AOAC (20) method was used to determine calcium, magnesium, sodium, potassium, iron, zinc and phosphorus using the atomic absorption spectrophotometric method. Vitamin C content was determined using the titration method by AOAC (21), thiamine and riboflavin content of the samples was determined using the spectrofluorometric method of AOAC (20).

Preparation of soursop drinks

Soursop drinks were prepared from fresh soursop pulp, oven-dried pulp and freeze-dried pulp using the following recipes adapted from Onyechi et al. (22).

Table 1: Preparation of fresh sweetened soursop pulp drink (FSD)

Ingredients	Quantity
Honey	4 table spoons
Water	400mls
Freshsoursop pulp	200g

Method of Preparation

a. Two hundred grammes (200g) of soursop pulp were weighed out into an electric blender (Sonik® Japan, SB-1212 model).

b. Four hundred millimetres (400mls) of drinking water was added into the blender and then blended for 4 minutes to homogenize the drink.

c. Four tablespoons (60g) of honey was added into the blender and then blended for 2 minutes.

d. The homogenized drink was poured into different clean bottles, cooled and was ready for drinking.

Recipe for Oven-dried soursop pulp drink (sweetened) (ODS)

Table 2: Preparation of sweetened oven-dried soursop pulp drink

Ingredients	Quantity
Honey	4 table spoons
Water	500mls
Oven-dried soursop pulp	100g

Method of Preparation

a. One hundred grammes (100g) of the oven-dried pulp were weighed out into an electric blender (Sonik® Japan, SB-1212 model).

b. Five hundred millimetres (500mls) of drinking water was added into the blender and then blended for 5 minutes to homogenize the drink.

c. Four tablespoons (60g) of honey was added into the blender and then blended for 2 minutes.

d. The homogenized drink was poured into different clean bottles, cooled and was ready for drinking.

Recipe for Freeze-dried soursop pulp drink (sweetened) (FrDS)

Table 3: Preparation of sweetened freeze-dried soursop pulp drink

Ingredients	Quantity
Honey	4 table spoons
Water	500mls
Freeze-dried soursop pulp	100g

Method of Preparation

a. One hundred grammes (100g) of the freeze-dried pulp were weighed out into an electric blender (Sonik® Japan, SB-1212 model).

b. Five hundred millimetres (500mls) of drinking water was added into the blender and then blended for 5 minutes to homogenize the drink.

c. Four tablespoons (60g) of honey was added into the blender and then blended for 2 minutes.

d. The homogenized drink was poured into different clean bottles, cooled and was ready for drinking.

Recipe for Oven-dried soursop pulp drink (unsweetened) (ODSp)

Table 4: Preparation of unsweetened oven-dried soursop pulp drink

Ingredients	Quantity
Water	500mls
Freeze-dried soursop pulp	100g

Method of Preparation

a. One hundred grammes (100g) of the oven-dried pulp were weighed out into an electric blender (Sonik® Japan, SB-1212 model).

b. Five hundred millimetres (500mls) of water was added into the blender and then blended for 5 minutes to homogenize the drink.

c. The homogenized drink was poured into different clean bottles, cooled and it was ready for drinking.

Recipe for Freeze-dried soursop pulp drink (unsweetened) (FrDSp)

Table 5: Preparation of unsweetened freeze-dried soursop pulp drink

Ingredients	Quantity
Water	500mls
Oven-dried soursop pulp	100g

Method of Preparation

a. One hundred grammes (100g) of the freeze-dried pulp were weighed out into an electric blender (Sonik® Japan, SB-1212 model).

b. Five hundred millimetres (500mls) of water was added into the blender and then blended for 5 minutes to homogenize the drink.

c. The homogenized drink was poured into different clean bottles, cooled and it was ready for drinking.

Sensory evaluation

A nine-point hedonic scale was used to evaluate the soursop drinks for colour, taste, aroma and general acceptability where nine (9) was the highest score (like extremely) and one (1) the lowest (dislike extremely). The sensory evaluation was done at the diet therapy laboratory of the Department of Nutrition and Dietetics, University of Nigeria, Nsukka. The five different soursop drinks were coded and kept cool in a refrigerator. A twenty-man panel randomly selected from students of the Department of Nutrition and Dietetics, University of Nigeria Nsukka, were arranged in such a way as to avoid interactions that will introduce bias. The panel was provided with five (5) plastic, transparent, white cups each containing thirty millimetres (30mls) of the five soursop pulp drinks. They were also provided with 0.5 litres of potable water for mouth rinsing in between samples.

Statistical analysis

Data obtained from this study were analyzed using the Statistical Product for Service Solution (SPSS) for Windows version 21. Analysis of Variance (ANOVA) and Duncan's new multiple range test were used to separate and compare means at P<0.05.

RESULTS

Table 6 shows the results of the nutrient composition of the freeze-dried and oven-dried soursop samples. The moisture content of the freeze-dried soursop (12.86%) was significantly (P<0.05) higher than that of the oven-dried soursop (7.59%). The crude protein content of the samples was 17.59% for the freeze-dried soursop and 20.37% for the oven-dried soursop which was significantly (P<0.05) different. The fat content of the samples was 6.66% for the freeze-dried and 2.29% for oven-dried which was also significantly (P<0.05) different). The crude ash content of the freeze-dried and oven-dried soursop was 6.64% and 12.26% respectively showing a significant (P<0.05) difference. The crude fibre content of the freeze-dried and oven-dried soursop was 12.59% and 16.36% each showing a significant (P<0.05) difference. Carbohydrate values were 43.70% for the freeze-dried and 41.15% for the oven-dried soursop which was also significantly (P<0.05) different. Vitamin content of the samples showed that vitamin C was 2.76mg/100g for freeze-dried and 1.69mg/100g for the oven-dried soursop showing a significant (P<0.05) difference. Vitamin B_1 content of the samples was 0.05mg/100g for freeze-dried and 0.04mg/100g for the oven-dried soursop showing a significant (P<0.05) difference. Vitamin B_2 content of the samples was 0.09mg/100g for the freeze-dried and 0.05mg/100g for the oven-dried soursop also showing a significant (P<0.05) difference.

Mineral content of the samples indicated that calcium was 1.18mg/100g for the freeze-dried and 1.46mg/100g for the oven-dried soursop. The oven-dried sample had significantly (P<0.05) higher calcium content than the freeze-dried sample. The iron content of the freeze-dried and oven-dried soursop was 24.26mg/100g and 33.35mg/100g respectively showing a significant (P<0.05) difference. Magnesium content of the samples was 42.26mg/100g for the freeze-dried and 55.58mg/100g for the oven-dried soursop, showing also a significant (P<0.05) difference. The sodium content of the freeze-dried and oven-dried soursop was 20.15mg/100g and 25.58mg/100g respectively, also showing significant (P<0.05) difference. Potassium content of the samples was 23.35mg/100g for the freeze-dried and 36.67mg/100g for the oven-dried soursop showing significant (P<0.05) difference Zinc content of the freeze-dried and the oven-dried soursop were 0.87mg/100g and 1.56mg/100g respectively, also showing significant (P<0.05) difference. The phosphorus content of the samples was 29.36mg/100g for the freeze-dried and 66.57mg/100g for the oven-dried soursop also showing a significant (P<0.05) difference in the potassium content of the freeze-dried and oven-dried soursop samples.

Table 6: Nutrient composition of the freeze-dried and oven-dried soursop pulp powders (per 100g)

Variables	Samples FrDS	ODS
Proximate (per 100g)		
Moisture	12.86 ± 0.01	7.59 ± 0.01
Protein	17.59 ± 0.01	20.37 ± 0.01
Fat	6.66 ± 0.01	2.29 ± 0.01
Ash	6.64 ± 0.01	12.26 ± 0.01
Crude fibre	12.59 ± 0.01	16.36 ± 0.01
Carbohydrate	43.70 ± 0.01	41.15 ± 0.04
Vitamins (mg/100g)		
Vitamin C	2.76 ± 0.01	1.69 ± 0.01
Vitamin B_1	0.05 ± 0.00	0.04 ± 0.00
Vitamin B_2	0.09 ± 0.00	0.05 ± 0.00
Minerals (mg/100g)		
Calcium	1.18 ± 0.01	1.46 ± 0.01
Iron	24.26 ± 0.01	33.35 ± 0.01
Magnesium	42.26 ± 0.01	55.58 ± 0.01
Sodium	20.15 ± 0.01	25.58 ± 0.01
Potassium	23.35 ± 0.01	36.67 ± 0.01
Zinc	0.87 ± 0.01	1.56 ± 0.01
Phosphorus	29.36 ± 0.02	66.57 ± 0.01

Mean ± SD of three determinations.

Key:

FrDS=Freeze-dried soursop

ODS=Oven-dried soursop

Table 7 shows the mean sensory scores of the fresh soursop drink and the dried soursop samples that were reconstituted into drinks. The score for appearance ranged from 6.10 ± 2.75 (Freeze-dried soursop drink, FrDS) to 7.35 ± 0.75 (unsweetened freeze-dried soursop drink, FrDSp). There was no significant ($p>0.05$) difference in the appearance of the samples. The values for taste/flavour varied from 5.90 ± 2.10 (sweetened, freeze-dried soursop drink, FrDS) to 8.00 ± 0.92 (fresh, sweetened soursop drink, FSD). Taste/flavour score was significantly ($P<0.05$) higher in the fresh, sweetened soursop drink (FSD) than in the other samples. Scores for texture/consistency were significantly ($P<0.05$) higher in the FrDSp (7.55 ± 0.76) and in the fresh soursop drink (6.75 ± 1.25) than in the other samples. The score for aroma/smell was significantly ($P<0.05$) higher in the FrDS drink (8.75±0.44) than in all the other samples. FSD had the best rating for overall acceptability. Its score (7.75±0.85) was significantly ($P<0.05$) higher than those of the other samples.

Table 7: Sensory qualities of the fresh, freeze-dried and oven-dried soursop drinks

Parameter	FSD	ODSp	FrDS	ODS	FrDSp
Appearance	$6.25^{a}\pm2.81$	$6.35^{a}\pm1.53$	$6.10^{a}\pm2.75$	$6.10^{a}\pm1.80$	$7.35^{a}\pm0.75$
Taste/ Flavour	$8.00^{b}\pm0.92$	$6.20^{a}\pm2.12$	$5.90^{a}\pm2.10$	$6.65^{a}\pm1.42$	$6.35^{a}\pm1.53$
Texture/ Consistency	$6.75^{bc}\pm1.25$	$6.00^{ab}\pm1.69$	$5.35^{a}\pm1.42$	$5.70^{a}\pm1.78$	$7.55^{c}\pm0.76$
Aroma/ Smell	$7.65^{c}\pm1.04$	$6.45^{a}\pm1.05$	$8.75^{d}\pm0.44$	$6.70^{ab}\pm1.75$	$7.45^{bc}\pm1.57$
Overall Acceptability	$7.75^{b}\pm0.85$	$6.50^{a}\pm1.00$	$6.65^{a}\pm1.42$	$6.20^{a}\pm1.01$	$6.85^{a}\pm0.81$

Different superscripts (a, b, c, d) within each row in the same group indicate significant ($p < 0.05$) difference

Key:

Mean ± SD of three determinations.

FSD=Fresh soursop drink

ODSp=Oven-dried soursop drink (unsweetened)

FrDS=Freeze-dried soursop drink

ODS=Oven-dried soursop drink

FrDSp=Freeze-dried soursop drink (unsweetened)

DISCUSSION

The moisture content of the oven-dried soursop pulp (ODS, 7.58%) was significantly (P<0.05) lower than that of the freeze-dried (FrDS, 12.86%). This indicates that freeze-drying is not as effective in decreasing the moisture content of soursop pulp as the oven-drying method. This result agrees with those of Iombor et al (18) (oven-dried soursop, 8.10% and freeze-dried soursop, 12.40%) who also reported lower moisture content of oven-dried soursop. These authors concluded that oven-drying is a better method in the preservation, shelf life and keeping quality of soursop pulp. Low moisture level inhibits the multiplication of spoilage organisms (23). The moisture content for freeze-dried soursop is similar to the value obtained for sun-dried Annona senegalensis (African custard-apple) (12.2%) (24). The lower protein content (17.58%) of the freeze-dried soursop could be as a result of its higher moisture content as seen in the result. Conversely, the higher protein content (20.36%) of the oven-dried soursop could be as a result of its lower moisture content (7.58%). The low moisture content of a food has been shown to result in the concentration of its nutrients as observed by Gbeyonron (25). This author worked on sun-dried pawpaw and garden egg fruits and reported that drying causes nutrient concentration in food samples. This study also shows that the oven-dried soursop can contribute significantly to the protein needs of consumers in promoting growth and repair of worn-out tissues (3). The crude fibre content of the freeze-dried and oven-dried samples showed appreciable amounts of fibre. This agreed with the study by Iombor et al. (18) (Freeze-Dried Soursop, 12.30% and Oven-Dried Soursop, 16.20%). Fibre helps maintain good health in the human digestive system. The freeze-dried flour, however, had a significantly lower value than the oven-dried flour which agrees with the study carried out by Abe-Inge et al. (26) on African Palmyra palm fruit flour. Crude ash provides an approximate measure of the total mineral composition of foods. Thus, the higher ash content of the oven-dried sample (12.26%) compared to the freeze-dried sample (6.63%) as shown in the result is indicative of good deposit of minerals in the oven-dried fruit sample. The difference in the ash content of the samples could be related to the difference in their moisture contents. The moisture content of the freeze-dried sample was higher which resulted in lower ash content. This agrees with the fact that removal of moisture increases the concentration of nutrients in foods (27). The fat content, as well as the carbohydrate of the freeze-dried sample, was significantly (P<0.05) higher than those of the oven-dried sample. This is probably because freeze-drying as a drying treatment has been reported to give the highest final product quality compared to other thermal drying methods. Its characteristics are similar to those of the fresh plants (28). Low crude fat content (as in the oven-dried) indicate that the powder is less susceptible to quick rancidity (29). The values for the fat content of the freeze-dried (6.66%) and oven-dried (2.29%) samples were low compared to 24.0% reported for

Annona senegalensis (African custard-apple) (24). On a general note, however, only a few fruits are known to be rich in fat (18). Fats from plant sources are unsaturated and so the freeze-dried sample will serve as a healthy fat source for optimum health (3). The high carbohydrate content of the samples suggests the potential of the fruit as a rich source of energy in the diet of the consumers (30). The oven-dried soursop had lower fat and carbohydrate content probably due to drying at 70C (31). The results of the proximate composition of soursop (Annona muricata) showed that it is a nutritious fruit. The vitamin C content of the freeze-dried and oven-dried samples agrees with the work by Onimawo (13) who reported that soursop is a good source of vitamin C, dietary fibre, potassium and B-vitamins. Vitamin C is an antioxidant which contributes to wound healing; promotes iron absorption as well as the synthesis of hormones and neurotransmitters (32). The freeze-dried sample had significantly ($P<0.05$) higher vitamin C content (2.76mg/100g) than the oven-dried sample (1.68mg/100g) which may be because ascorbic acid content decreases in high-temperature treatments (33). In addition, Castaneda et al (34) observed that the chalarina, a Peruvian fruit, retained a larger proportion of the volatile and thermo-sensitive compound, vitamin C when dehydrated through freeze-drying. Vitamins B_1 (thiamine) and B_2 (riboflavin) are water-soluble vitamins essential for the metabolism of the energy-giving nutrients, functioning mainly as coenzymes. The thiamine content of the oven-dried sample was significantly ($P<0.05$) lower than that of the freeze-dried. This is obviously because thiamine is partly destroyed by heat and alkali (3). This result compares with the value (0.06 ± 0.00 mg) observed by Johnson et al. (36) for oven-dried watermelon pulp. Riboflavin content of the freeze-dried sour-sop (0.09 ± 0.00 mg) was higher than the oven-dried sample (0.05 ± 0.00 mg). This is because heat treatment results in the loss of vitamin C, thiamine, riboflavin and niacin (35). Johnson et al (36) observed an even lower value of riboflavin (0.02 mg) for oven-dried watermelon pulp compared to 0.05 mg for the oven-dried sour-sop pulp. Enzymatic activity and balance of electrolytes in the blood fluid are related to adequate sodium, potassium, magnesium and zinc since they are required most in living cells. The values for all minerals from the oven-dried sample (calcium, iron, magnesium, sodium, potassium, zinc, phosphorus) were all observed to be significantly ($P<0.05$) higher than those from the freeze-dried sample; which agrees with the fact that the crude ash content of the oven-dried sample was found to be higher than that of the freeze-dried sample. These values observed were higher than the values observed for African custard-apple (Annona senegalensis) except for calcium and zinc which are comparable to those of the custard-apple (24). These minerals are relatively inert and are not sensitive to degradation by thermal processes used in food preservation (37). Phosphorus was the most abundant mineral found in the oven-dried sample (66.58 mg). This is important because phosphorus is a component of deoxyribonucleic acid (DNA), ribonucleic acid (RNA) and the coenzyme forms of vitamins B_1 and B_6 (38). Magnesium was the most abundant (42.25 mg) in the freeze-dried sample. It is involved in more than 300 different enzymatic reactions and also in adenosine diphosphate (ADP) and adenosine triphosphate (ATP) processes (32). The significant ($P<0.05$) difference for taste/flavour between the fresh soursop drink (FSD) and the other drinks from the dried samples is probably because most of the subjects were more familiar with the fresh soursop compared to the dried samples. The unsweetened freeze-dried soursop drink (FrDSp) had a significantly ($P<0.05$) higher score for texture/consistency than the other samples which agrees with the work by Serna-Cock et al (39). They observed that in many fruits, properties such as shape and texture are retained after freeze-drying. The sweetened freeze-dried soursop drink (FrDS) was rated significantly ($P<0.05$) higher than the other samples for aroma/smell in agreement with the fact that the freeze-drying technology offers advantages in aroma retention caused mainly by a lower product temperature (40). The significantly ($P<0.05$) higher rating of the FSD for overall acceptability is obviously due to the fact that the panel was not used to the other novel drinks from dried soursop. The result from the mean sensory scores, however, showed that the drinks from the dried sour-sop samples (especially, the unsweetened freeze-dried soursop drink) were liked moderately in all the attributes. This is an indication that the drinks from dried sour-sop were not completely rejected and could be improved, either by adding sugar to further cover the acid/sour taste and also finer filtration to produce smoother and more preferable drinks.

CONCLUSION

This study has shown that dried soursop (Annona muricata) pulp is highly nutritious and is rich in several macro and micronutrients including carbohydrate, fibre, protein, fat, potassium, iron, phosphorus, magnesium and sodium, as well as vitamin C, thiamine and riboflavin. Thus, it can be used in dietary diversification programme to combat micronutrient deficiencies using locally available fruits. It will help promote the nutritional status of consumers. Also, dried soursop pulp and drinks from it will help improve the dwindling consumption of the fruit all year round. Drying will allow the production of powdered fruit that can make the fruit available during its off-season. More research work is needed to improve the flavour, taste and general acceptability of the drinks from dried sour-sop powders. There is a need for further investigations on the nutritional, biochemical and physiological functions of the active compounds of dried soursop in vitro and in vivo.

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