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Research Article
Blends of Dehydrated Roselle Product with other Tropical Crops for Instant Sorrel Drink

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Abstract

Background and Objective: Sorrel drink is a global commercial beverage that has gained overwhelming acceptance across various tribes, socioeconomic classes, educational backgrounds and geological locations. Sorrel has been proven to have medicinal values and is a good source of natural nutrients and vitamin C. It is, therefore, apparent to investigate dehydrated sorrel blended with tropical crops such as ginger, beetroot, clove and lemon in a proportion to improve quality and to enhance storability of the sorrel tea bag products. **Materials and Methods:** Proximate analysis, physiochemical analysis and sensory acceptability were carried out on the drinks while a storage stability test was carried out on the tea bag formulations for 3 months. **Results:** The results showed that samples were in the range of (95.43-95.85%) moisture content, (0.17-0.26%) crude fat, (1.91-2.17%) crude protein, (nil) crude fibre, (0.35-0.48%) ash, (1.59-1.81%) carbohydrate, (1.02-1.16) pH, (8.99-10.50%) TA and (19.16-24.97 mg/100 mL) vitamin C. Storability test showed that microbial count was in the range of 1.27×10^{5}-7.00×10^{5} CFU g^{-1} which satisfies commercial guidelines for ready-to-drink soft drink for the aerobic count. At a 5% level of significance, there was no significant difference in all the sensory attributes of most samples. **Conclusion:** Inclusion of tropical crops improve proximate and physiochemical composition while the tea bag can be kept for a regular sorrel drink.

Key words: Product, dehydration, *Hibiscus sabdariffa*, zobo drinks, tea bag, lipid peroxidation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Dehydration is the oldest and common unit operation with overwhelming application in the food processing industry[1]. It involves the transfer of heat through the flow of hot air and the removal of moisture from food material. This is accomplished with the extension of shelf life in product[2]. Sorrel drink, a local non-alcoholic beverage manufactured by boiling and filtration from dried acidic succulent calyces of the *Hibiscus sabdariffa* flower[3]. Roselle has a floral, berry-like scent, a sour smell and an astringent, slightly mouth-drying flavour that is similar to cranberry[4]. The study showed that glucose, sucrose and fructose were found to be the main sugar in roselle calyces[5]. As a result, the calyces of sorrel are classified as a very acidic fruit with low sugar content. Investigation revealed that DP 3-sambubioside is responsible for the reddish-violet colour pigment of red and purple sorrel calyx used to produce zobo drinks. However, the red sorrel species has been approved and licensed by the United States for food and drugs administration as a colouring agent for beverage industries[6].

Research evidence showed that *Hibiscus sabdariffa* contains anthocyanins, flavonoids and protocatechuic acid, protein, b-carotene, fat, carbohydrates fibre, and vitamin C, thiamine, riboflavin, calcium, iron and phosphorus as a medicinal and dietary benefit of the crop. Roselle is capable of reducing blood pressure, lipid peroxidation, hepatoprotective effects in a variety of toxin-induced hepatitis models and antilithiatic effect[7-9]. The application of the plant in managing different medical problems including cancer, inflammatory diseases and different cardiovascular problems has been well investigated[10].

Beetroot (*Beta vulgaris* L.) is cultivated globally for its vegetable and juice benefit. It contains high amounts of betaine, carbohydrates, iron, vitamins A, B_6 and C, folic acid, protein, potassium, sodium and magnesium, as well as soluble fiber[11]. Beetroot has both nutritional and medicinal values. It helps to lower blood pressure, regulate cardiovascular health, boost endurance and muscle strength, maintain blood circulation and delay dementia development[12,13]. Beetroot contains anthocyanins which can mitigate the effects of contamination in the body[14]. Besides, it is used as a source of natural antioxidants that help protect cells against human oxidative stress[15]. Losses in beetroot nutrients occur as a result of decay inhabited during storage which consequently causes a post-harvest challenge to the crop[16-18].

Clove (*Syzygium aromaticum*, *Eugenia aromaticum* or *Eugenia caryophyllata*) is the aromatic dried flower buds, widely used in biryanis, salads, pickles and garam masala. Clove buds have a pungent smell with a sour aftertaste. It is dark brown, a strong fragrant odour that is hot, pungent, very sweet and slightly astringent[19]. Dried cloves contain carbohydrate, steam-volatile oil, fixed oil, resins, proteins, tannins, cellulose, pentosate and minerals such as potassium, sodium. It also consists of sterols such as isobiflorin, triterpenes, sitosterol, stigmasterol, campesterol, flavonoids. Clove is considered to have antibacterial qualities due to its high flavonoid content. Thus, it is used in various dental creams, toothpaste, mouthwashes and is also used as an inflammatory agent[20]. Clove is used to increase hydrochloric acid (HCl) in the stomach as a carminative and to strengthen peristalsis, treat flatulence, loose movements, indigestion and nausea[19]. It also helps in the treatment of diarrhoea, gastric irritability and vomiting[20].

The underground stem (rhizome) of ginger (*Zingiber officinale* Roscoe) is used in several ways such as the production of syrup, volatile oil and oleoresin. It has a different useful variety among other spices that constituted its global relevance in dietary supplements, drinks and food products such as curry powder, soups, jams, confectionaries and baked goods[21]. The crop is used in therapeutic procedures in Asia, India, Europe and the Middle East for the treatment of diseases such as arthritis, upset stomach, asthma, diabetes and menstrual irregularities[22]. Fresh ginger pungency is caused by a group of phenols, gingerols from which the most prevalent is 6-gingerol[23]. A 5-deoxy derivative of ginger, paradol can also be a component of fresh ginger. Shogaols, which are dehydrated forms of thermal processing of gingerols gives dried ginger its pungency[24]. Bioactive diarylheptanoids and zingerone are also suspected to contribute to its supposed health benefits in addition to the pungent phenolic compounds like gingerols and shogaols.

The health-promoting effects of citrus have been primarily related to the antioxidant content of vitamin C and flavonoids[25]. Citrus fruits and co-products containing phenolic have recently gained significant attention in human nutrition for their health benefits[26]. Flavonoids have medicinal properties in citrus fruits and these include anti-inflammatory, anti-atherogenic and antitumor activity, blood clot inhibition and high antioxidant activity[27]. The most common citrus flavonoids are flavanones majorly found in the peels[28].

The tendency for a sorrel drink to quickly deteriorate limits large-scale production, If not refrigerated, it has a shelf life of about 24 hrs after production and when refrigerated it can only last for a few days. The beverage is susceptible to microbial contamination, which can result in food spoilage.

Because of this challenge, coupled with post-harvest problems associated with crops, it is imperative to investigate

the nutritional, physicochemical, microbial and storage stability of non-alcoholic drinks made from blends of dehydrated Roselle and other tropical crops.

MATERIALS AND METHODS

Study area: The study was carried out in the Food Science and Technology laboratory, Bells University of Technology, Ota, Nigeria between January and August, 2021.

Specimen collection: Roselle calyces (*Hibiscus sabdariffa*), fresh beetroot (Beta vulgaris L.), clove bud (*Syzygium aromaticum*), fresh ginger rhizome (*Zingiber officinale*) and lemon fruit (*Citrus limon*) were purchased at popular Oja Ota market, Ogun state, Nigeria.

Methods: The beetroot tubers were sorted, washed and peeled. It was weighed with the aid of a digital weighing scale. The tubers were cut into thin slices, dried in a laboratory oven at 60°C for 8 hrs and milled with a blender. The clove buds were sorted, weighed and sterilized for 3 min. Afterwards, it was milled into powder. Ginger tubers were sorted, washed, peeled, cut into slices, dried at 60°C for 9 hrs and milled into powder. The Lemon fruits were 1st sorted and weighed, then washed with potable water and peeled. The lemon peel and the lemon flesh were dried at 60°C for 8 hrs and 60°C for 20 hrs, respectively and they were milled separately to a fine powder. Roselle was sorted to remove dirt and unwanted materials, weighed and washed with potable water and dried in a laboratory oven at 6060°C for 10 hrs. It was milled with a blender and all the milled samples (roselle powder, ginger powder, beetroot powder, clove powder, lemon powder) were mixed at different ratios (60:10:10:10:10, 70:10:10:5:5, 75:10:5:5:5, 80:5:5:5:5), respectively. The blended samples were thoroughly sieved and packaged in tea bags. The homogenous sorrel drink was prepared from various blended sorrel powders.

Proximate analysis of sorrel samples: The proximate composition of the sorrel drink samples was determined using methods as described by Pasha *et al.*[29] for parameters such as moisture, ash, protein, crude fat, crude fibre and carbohydrate, respectively.

Determination of moisture content: The moisture content of each sample was determined by weighing 5 g of the sample and placed in a dry Petri dish. The lid of the dish was then loosened and heated, in an oven at 105°C for 1 hr. The dish from the oven was removed and cooled in the desiccator and weighed. The sample was then heated in the oven for a further period of 3 hrs, cooled and weigh. This procedure was continued until the difference in weight between 2 consecutive observations was less than 1 mg[29]:

$$\text{Mositure content}\,(MC_{wb})\,(\%) = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (1)$$

Where:

W_1 = Weight of empty Petri dish
W_2 = Weight of Petri dish and weight of the sample before drying
W_3 = Weight of Petri dish and weight of the sample after drying

Determination of ash content: The ash content of each sample was determined by weighing 5 g of the sample and put in a clean dried and weighed out crucible. The sample was then evaporated to dryness in an oven for 100°C. The dried sample was then placed in a muffle furnace and ignited at 550°C. It was then transferred into desiccators to cool. The weight of the ash and crucible was taken:

$$\text{Ash content}\,(\%) = \frac{W_2 - W_1}{\text{Weight of samples used}} \times 100 \quad (2)$$

Where:

W_1 = Weight of crucible
W_2 = Weight of crucible and ash

Determination of crude protein: The protein content of each sample was determined using KJECTEC 2200 distillation apparatus (Kjeldahl method) according to the procedure of AOAC[29]. The reagent includes concentrated H_2SO_4 (12 cm^3), 2 tablets of catalyst copper sulphate, 50 g and potassium sulphate, 4% boric acid, 20% sodium hydroxide solution and 0.1 M of hydrochloride:

$$\text{Crude protein} = \text{Titre of samples} - \text{Titre of blanks} \times 1000 \times \frac{\text{Weight of samples}}{\text{Value obtained} \times \text{conversion factor}} \quad (3)$$

Determination of crude fat: The crude fat of each sample was determined using the soxhlet method. One gram of each dried sample was weighed into a fat-free extraction thimble and gently clogged with cotton wool. The thimble was then placed

in the extractor, fitted up with a reflux condenser and a 250 mL soxhlet flask which has been dried in the oven, cooled in the desiccator and weighed. The soxhlet flask was then filled to 3/4 with petroleum ether (40-60°C) and the soxhlet flask. Extractor plus condenser set was then placed on the heater. The heater was put on for 6 hrs with constant running water from the tap for condensation of ether vapour. The set was constantly watched for leakages and the heat source was adjusted appropriately for the ether to boil gently. The ether was then left to siphon completely. The ether content of the extractor was carefully drained into the ether stock bottle. The thimble containing the sample was then dried on a clock glass on the benchtop. The distillation continues until the flask is practically dried. The flask which contains the fat was detached, cleaned and dried to a constant weight in the oven[29]:

$$\text{Crude fat (\%)} = \frac{W_2 - W_1}{\text{Weight of samples used}} \times 100 \quad (4)$$

Where:

W_1 = Initial weight of dried soxhlet flask

W_2 = Final weight of oven-dried flask+fat

Determination of crude fibre: The crude fibre content of the sample was determined by weighing 2 g of each sample and transferring it into a 1 L conical flask. One hundred mL of sulphuric acid 0.255 M was heated to a boil and then introduced into the conical flask containing the sample. The content was boiled for thirty minutes and the level of acid was maintained by adding distilled water. After 30 min, the content was filtered through a muslin cloth held inside a funnel and the residue was rinsed thoroughly until it was no longer acidic to litmus and then transferred into a conical flask[29]. One hundred 100 mL of NaOH 0.313 M was boiled and introduced into the conical flask containing the sample. The content was boiled for thirty minutes and the level of acid was maintained by adding distilled water. After thirty minutes, the content was filtered through muslin cloth held in a funnel. The residue was then rinsed thoroughly until its washing was no longer alkali. The residue was introduced into an already dried crucible and ash at 600°C:

$$\text{Crude fibre (\%)} = \frac{W_2 - W_1}{\text{Weight of samples used}} \times 100 \quad (5)$$

Where:

W_1 = Initial weight of crucible

W_2 = Final weight of the crucible

Determination of carbohydrate content: This was done by summing up the percentage of moisture, ash, protein, fat (ether extract) and fibre for each of the samples and subtracting it from 100. The difference in value was taken as the percentage of total carbohydrates of the sample:

$$\text{Crude carbohydrate (\%)} = 100 - (\text{moisture} + \text{ash} + \text{crude protein} + \text{fat} + \text{fibre}) \quad (6)$$

Physiochemical analysis of sorrel samples pH determination: The pH of each sorrel sample was determined using a pH meter. The pH meter was turned on and allowed to warm up for 5 min and then calibrated with a pH buffer solution to assure the sensitivity and accuracy of the meter. This was done by submerging the electrode of the meter into each buffer solution with a thorough washing with distilled water. The pH readings of the sorrel samples (which were 1st produced by pouring 10 mL of sample into a beaker) were obtained one at a time by dipping the pH meter electrode into the sample and thoroughly washing with distilled water after each dip.

Titratable acidity determination: Standard method of Horwitz[30] was used to measure TA (titratable acidity). The sample was homogenized in 20 mL of distilled water and filtered using Whatman number 1 filter paper. Phenolphthalein was used on the filtrate as an indicator and titrated against 0.05 M NaOH. The titration was continued until a faint and persistent pink colour (onion pink) was obtained which signified the endpoint. Titratable acidity was calculated using the Eq.:

$$\text{TA} = \frac{\text{M} \times \text{NaOH} \times 0.09 \times 100}{\text{V}} \quad (7)$$

where, M is the molar value of NaOH used and V is the volume of the sample.

Microbiological analysis: Microbiological analysis of sorrel drink samples was carried out according to the Official Methods of Analysis reported by Yang and Li[31]. The total aerobic count of bacteria was determined by weighing 1 mL of each already serial diluted sample and inoculating it into a sterile dish, nutrient agar was poured into the petri dish after allowing it to solidify and then incubated at 37-45°C for 24 hrs:

$$\text{CFU g}^{-1} = \frac{\text{Noumber of colony} \times \text{dilute factor}}{\text{Volume inoculated}} \quad (8)$$

Determination of vitamin C: Five grams of each sorrel sample was put in a flask and 25 mL of 5% metaphosphoric acid and 10% acetic acid was added and agitated severally. It was then transferred using a pipette into a 50 mL volumetric flask and mixed by gently shaking to obtain a homogenous mixture. Each solution was then filtered and used for ascorbic acid determination, 0.3 mL of 3% bromine water was added to 4 mL of each filtrate from the solution till the solution becomes coloured which confirms the oxidation of ascorbic acid to dehydroascorbic acid is complete. About 0.2 mL of thiourea solution was then added to remove excess bromine water to obtain a clear solution after which it was titrated with 2,4-dinitrophenylhydrazine dye and kept in a water bath at 37°C for 3 hrs after which it was cooled and 5 mL of very cold 85% H_2SO_4 was added and stirred. The reading was carried out afterwards at a wavelength of 521 nm:

$$\frac{\text{Ascoribic acid}}{(\text{mg kg}^{-1})} = \frac{\text{Con.}\left(\text{mg L}^{-1}\right) \times \text{volume of extract} \times \text{dilute factor}}{\text{Samples weight}} \quad (9)$$

Evaluation of sensory attributes: Consumer assessment of overall acceptability of sorrel drink was done according to Jimoh[32]. Forty students of Bells University of Technology, Ota Nigeria was chosen. These are regular consumers of sorrel drinks and were randomly selected for the evaluation. There were 5 samples and each sample was placed in a separate identical, transparent and covered cup. The cups were coded as ZC, RGB+1, RGB+2, RGB+3 and RGB+4, respectively and placed on a clean table. A questionnaire was designed and distributed among the 40 respondents to score attributes namely colour, aroma, taste, mouth feel and overall acceptability on a Hedonic scale of 9 points, 9 was like extremely, 8 like very much, 7 like moderately, 6 like slightly, 5 neither like nor a dislike, 4 dislike slightly, 3 dislike moderately, 2 dislike very much and 1 dislike extremely. Each of the samples was presented at different times to each of the respondents to avoid any bias in judgement. The responses were collated to compare the consumer preferences of the sorrel drink.

Storability test: A storage stability test was carried out on the sorrel tea bag samples produced at the different formulations in an airtight container (Ziplock). The samples were stored at ambient conditions and a microbial test was carried out on each product for 3 months.

Statistical analysis: Statistical analysis was conducted with the SPSS software version 22.0. The mean and standard deviation of duplicate of the parameters was calculated and differences between the means were evaluated by analysis of variance (ANOVA) with a significant level being considered at $p<0.05$. The mean comparison was assessed by Duncan's multiple range test and the values were expressed as Means±Standard deviations.

RESULTS AND DISCUSSION

Proximate compositions of sorrel drink samples: The results of proximate analysis for sorrel drink samples are shown in Table 1. The moisture content of the sorrel drink ranged from 95.43% in RGB+1 to 95.85% in RGB+4. The moisture content of the control sample with 100% roselle calyx was 97.73%. This is closely related to Adeniji[27], which reported that the moisture content of the sample was 82.42%. The high moisture content implies that the sorrel drinks blends are likely to be capable of quenching thirst. At a 5% level of significance, the moisture content of the samples was observed to be a significant difference except for RGB+3 and RGB+4. The crude protein of the sorrel drink samples ranged from 1.91% in RGB+4 to 2.17% in RGB+2 while roselle calyx was 0.73%. RGB+2 shows the highest protein level at least proportion (5%) of glove and lemon, but as beetroot reduces, protein content reduces. The implication of this is that beetroot is the potential source of protein. This work contradicts the result presented by Adesokan *et al.*[33], who reported a protein value of 6.20-9.10%. This could be due to drying temperature (60°C) since the average protein denaturation temperature is 45°C[34]. There was a significant difference in the protein content of the samples except for RGB+1 and RGB+3.

The crude fibre was not detected in any of the samples. This finding is similar to the result of Adeniji[27], who reported that crude fibre was nil. This finding contradicts the result of Ajayi and Oyerinde[35], who reported that fibre content in sorrel samples containing ginger and lemon ranged from 8.70-10.30%. This might be a result of the processing method since the same material under different processing methods gives different results. The fat content of the sorrel samples ranged from 0.17% in RGB+4 to 0.26% in RGB+1 while roselle calyx was0.05%. This finding contradicts the results of Ajayi and Oyerinde[35], who reported that 100% of roselle had 0.54% fat content. This could be as a result of a plant variety or material handling during processing. The crude fat content of the samples was observed to be a significant difference ($p<0.05$). The ash content of the sorrel samples ranged from 0.35% in RGB+4 to 0.48% in RGB+1 while roselle calyx was 0.10%. In other words, the inclusion of tropical crops increases the ash content significantly. The carbohydrate content of the sorrel samples ranged from 1.59% in RGB+2 to 1.81% in

Table 1: Proximate compositions of sorrel drink samples

Samples	Moisture content (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	CHO (carbohydrate) (%)
ZC	97.73±0.11^{c}	0.73±0.01^{a}	0.05±0.01^{a}	0.00±0.00	0.10±0.01^{a}	0.99±0.04^{a}
RGB+1	95.43±0.06^{a}	2.03±0.04^{c}	0.26±0.02^{d}	0.00±0.00	0.48±0.01^{d}	1.81±0.01^{c}
RGB+2	95.66±0.06^{ab}	2.17±0.04^{d}	0.21±0.01^{c}	0.00±0.00	0.38±0.01^{bc}	1.59±0.00^{b}
RGB+3	95.74±0.06^{b}	2.01±0.04^{c}	0.25±0.01^{cd}	0.00±0.00	0.40±0.02^{c}	1.61±0.13^{bc}
RGB+4	95.85±0.16^{b}	1.91±0.03^{b}	0.17±0.02^{b}	0.00±0.00	0.35±0.01^{b}	1.73±0.11^{bc}

Values are Means±Standard deviation of duplicate determinations, mean values of the samples within a column with different superscripts (letters) are significantly different ($p<0.05$), ZC: 100% roselle calyx, RGB+1: 60% roselle+10% ginger+10% beetroot+10% clove+10% lemon, RGB+2: 70% roselle+10% ginger+10% beetroot+5% clove+5% lemon, RGB+3: 75% roselle+10% ginger+5% beetroot+5% clove+5% lemon and RGB+4: 80% roselle+5% ginger+5% beetroot+5% Clove+5% lemon

Table 2: Physiochemical analysis of sorrel drink samples

Samples	pH	Titratable acidity (%)	Vitamin C (g/100 mL)
ZC	0.84±0.01^{a}	7.83±0.25^{a}	13.48±0.06^{a}
RGB+1	1.16±0.01^{d}	10.11±0.06^{c}	19.16±0.31^{b}
RGB+2	1.11±0.03^{c}	9.08±0.04^{b}	20.37±0.08^{c}
RGB+3	1.11±0.01^{c}	10.50±0.00^{d}	23.43±0.23^{d}
RGB+4	1.02±0.02^{b}	8.99±0.02^{b}	24.97±0.18^{e}

Values are Means±Standard deviation of duplicate determinations, mean values of the samples within a column with different superscripts (letters) are significantly different ($p<0.05$), ZC: 100% roselle calyx, RGB+1: 60% roselle+10% ginger+10% beetroot+10% clove+10% lemon, RGB+2: 70% roselle+10% ginger+10% beetroot+5% clove+5% lemon, RGB+3: 75% roselle+10% ginger+5% beetroot+5% clove+5% lemon and RGB+4: 80% roselle+5% ginger+5% beetroot+5% clove+5% lemon

RGB+1 while roselle calyx was 0.99%. RGB+1 shows the highest carbohydrate level at uniform proportion (10%) of other crops blends with 60% roselle. In another word, the uniform proportion of ginger, beetroot, clove and lemon enhances high carbohydrate content. However, Atta *et al.*[36] reported a high level of carbohydrate content of 7.29%. This could be due to the addition of pineapple, orange and sweetener. The carbohydrate content of the sorrel samples was noticed to be a significant difference except RGB+3 and RGB+4.

Physiochemical compositions of sorrel drink samples: The results of the physiochemical composition of sorrel drink samples are shown in Table 2. The pH of the samples ranged from 1.02 in RGB+4 to 1.16 in RGB+1 while roselle calyx was 0.84. It was noticed that as percentage inclusion in tropical crops increases, the pH increases. However, the result is at variance with Adelekan *et al.*[37], who reported a pH range of 4.04-4.58, the increase in pH could be as a result of the high pH level of the fruits added. At a 5% level of significance, the samples were significantly different except RGB+2 and RGB+3. The titratable acidity of the sorrel samples ranged between 8.99% in RGB+4 and 10.50% in RGB+3 while roselle calyx was 7.83%. The Titratable Acidity (TA) values of the samples were higher than 3.19 and 4.23% reported by Gbadegesin *et al.*[2]. The high TA values might be a result of very low pH due to the inclusion of lemon and clove.

Vitamin C in sorrel drinks samples: The vitamin C content of the sorrel samples ranged from 19.16 mg/100 mL in RGB+1 to 24.97 mg/100 mL in RGB+4 as shown in Table 2 while roselle calyx was 13.48±0.06. As the proportion of the tropical crops in the formulation becomes uniform to counter the over whelming effect on each other, vitamin C level increases. The results contradict 2 mg/100 mL reported by Mohammed *et al.*[38]. The increase in vitamin C could be a result of the inclusion of crops. There was a significant difference in the vitamin C content of the samples.

Sensory evaluation of sorrel drinks samples: Sensory evaluation of the samples was carried out at ambient temperature (30-34°C) as shown in Fig. 1. There was no significant difference ($p>0.05$) in overall acceptability, mouth feel, taste, aroma and colour for RGB+1, RGB+2, RGB+3 and RGB+4 samples. However, looking at individual attributes, ZC showed the best acceptable colour (7.65) among other samples. This is an indication that tropical crops blended with roselle calyx change the natural colour of the drink. RGB+1 gave the best aroma (6.75) as a result of the combined effect of tropical crops in their respective highest proportion (10%). RGB+4 offered the best taste (6.35) at the lowest proportion of tropical crops (5%). In another word, the interaction of the crops at reduced proportion with a high level of roselle calyx influences the taste. RGB+3 showed the best mouth feel and overall acceptability of 6.45 and 6.60, respectively. This could be as a result of the overwhelming effect of 10% ginger over 5% of each other crops.

Storability of sorrel tea bag samples: Total Plate Count (TPC) is the number of bacteria able to grow in an aerobic environment at moderate temperature. It is proof of quality and cannot in any way provide a safety assessment of

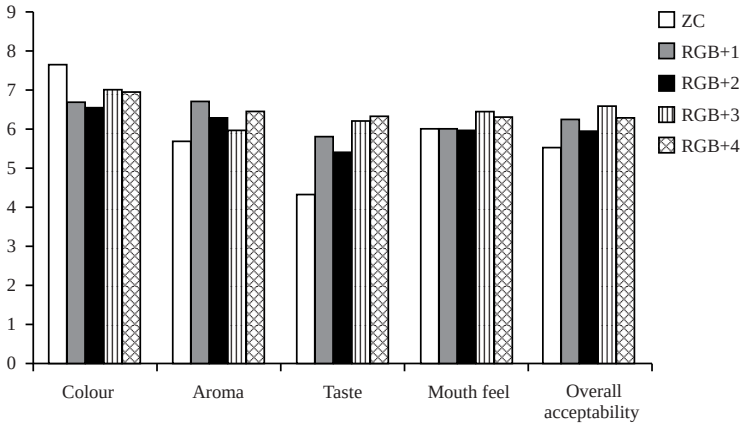

Fig. 1: Sensory evaluation of sorrel drinks samples

ZC: 100% roselle calyx, RGB+1: 60% roselle+10% ginger+10% beetroot+10% clove+10% lemon, RGB+2: 70% roselle+10% ginger+10% beetroot+5% clove+5% lemon, RGB+3: 75% roselle+10% ginger+5% beetroot+5% clove+5% lemon and RGB+4: 80% roselle+5% ginger+5% beetroot+5% clove+5% lemon

Table 3: Storability of sorrel tea bag samples for three months at ambient condition

Samples	Parameters	Month 0 ($\times 10^5$ CFU g^{-1})	Month 1 ($\times 10^5$ CFU g^{-1})	Month 2 ($\times 10^5$ CFU g^{-1})	Month 3 ($\times 10^5$ CFU g^{-1})
RGB+1	TPC	TFTC	3.78 ± 0.13^c	4.19 ± 0.05^c	7.00 ± 0.16^b
RGB+2	TPC	TFTC	4.05 ± 0.10^d	6.28 ± 0.04^d	6.92 ± 0.04^b
RGB+3	TPC	TFTC	3.06 ± 0.06^b	3.16 ± 0.02^b	5.03 ± 0.03^a
RGB+4	TPC	TFTC	1.27 ± 0.02^a	2.03 ± 0.42^a	5.15 ± 0.07^a

Values are Means±Standard deviation of duplicate determinations, mean values of the samples within a column with different superscripts (letters) are significantly different ($p<0.05$). ZC: 100% roselle calyx, RGB+1: 60% roselle+10% ginger+10% beetroot+10% cloves+10% lemon, RGB+2: 70% roselle+10% ginger+10% beetroot+5% cloves+5% lemon, RGB+3: 75% roselle+10% ginger+5% beetroot+5% cloves+5% lemon, RGB+4: 80% roselle+5% ginger+5% beetroot+5% cloves+5% lemon, TFTC: Too few to count and TPC: Total plate count

ready-to-eat food/drink. However, it only gives valuable information about the quality and shelf life of any food/drink to harness the storage and handling potential of such a product. The sorrel tea bag samples were stored at ambient temperature for 3 months and the results of the microbial analysis are shown in Table 3.

Month 0 result of microbial analysis during storage shows that there were too few nutrient agar plate counts. Month 1 result for microbiological analysis during storage depicts that the total plate count of the sorrel samples increased to 3.78×10^5 CFU g^{-1} in RGB+1, 4.05×10^5 CFU g^{-1} in RGB+2, 3.06×10^5 CFU g^{-1} in RGB+3 and 1.27×10^5 CFU g^{-1} in RGB+4. There was a significant difference ($p<0.05$) in the microbial level of the samples in the 1st month. In month 2, microbial count increased to 4.19×10^5 CFU g^{-1} in RGB+1,6.28×10^5 CFU g^{-1} in RGB+2, 3.16×10^5 CFU g^{-1} in RGB+3 and 2.03×10^5 CFU g^{-1} in RGB+4. There was a significant difference in the microbial count of the samples in the 2nd month. In month 3, the result of microbiological analysis carried out during storage stability shows that the total plate count of the sorrel samples increased to 7.00×10^5 CFU g^{-1} in RGB+1, 6.92×10^5 CFU g^{-1} in RGB+2, 5.03×10^5 CFU g^{-1} in RGB+3 and 5.15×10^5 CFU g^{-1} in RGB+4. At a 5% level of significance, there was no significant difference in samples RGB+1 and RGB+2 and RGB+3 and RGB+4. The highest microbial count of 4.05×10^5 and 6.28×10^5 CFU g^{-1} in the 1st and 2nd month, respectively were found in RGB+2 and 7.00×10^5 CFU g^{-1} was found in RGB+1 in the 3 month.

In general, the microbial growth shows that micro-organisms increased over the months but within the limit of $<10^8$ CFU g^{-1} set as a target in commercial guidelines for ready-to-drink soft drink products[39] and less than 10^6 CFU g^{-1} for the aerobic count in foods[40]. There were only a few microbial counts in month zero. It gradually increased and for 3 months, the count was within the standard of microbial specification of food. Thus, within this period of the experiment, the products are safe.

CONCLUSION

The inclusion of these selected tropical crops in the production of hydrated sorrel drinks improves the physicochemical and nutritional quality of the products. Preservative attributes of these crops influence the storability of the samples at ambient conditions. The products are stable and safe. The overall acceptability of the products was high. At $p>0.05$ significant level, there was no significant difference in the sensory attributes considered for the samples. Thus, the products are recommendable to all ages.

SIGNIFICANCE STATEMENT

This study discovered non-alcoholic drinks made from blends of dehydrated roselle and other useful tropical crops. The nutritional befit could guarantee good health and long shelf life is beneficial to prevent post-harvest losses. However, there are numerous challenges encountered in the production of instant sorrel drink that is safe. This study will help the researchers to uncover the effect of the inclusion of tropical crops in the production of sorrel in tea bags for an instant drink that many researchers were not able to explore.

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