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Production and comparative evaluation of leather products from pawpaw (*Carica papaya*) and banana (*Musa acuminata*) fruit pulp

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ABSTRACT

Food wastage as a result of postharvest losses is responsible for about one-third of the entire annual harvest wasted world over. Postharvest losses occur due to the lack of processing and preservation technologies of the surplus harvest, as well as the unavailability of properly trained personnel. Therefore, in the bid to minimize food wastage from postharvest losses, some perishable tropical fruits were processed into fruit leathers. Fresh banana and pawpaw fruits were used to produce banana leather, pawpaw leather, and composite (banana & pawpaw) leather. The fresh fruits were washed, peeled, deseeded, sliced, mashed, and dried in an oven to produce flexible leather sheets of the fruits. The fresh fruit pulps and the fruit leathers were analysed for nutritional (proximate, vitamin and mineral) compositions and sensory qualities using standard methods. The results showed that significant differences ($p<0.05$) exist between the fresh fruits and fruit leathers. The moisture content of the fruit leathers ranged from 23.36% to 23.84%, protein contents ranged from 8.32% to 8.76%, while the carbohydrate contents ranged from 61.07% to 62.01%. The vitamin E in the fruit leathers increased significantly (30 – 34 μg/100 g) while vitamin B9 in the fruit leathers decreased significantly after drying, when compared with their corresponding fresh fruits. In addition, vitamin C decreased in the banana products (52.96 to 17.65 mg/100 g) and in the pawpaw products (123.56 to 52.96 mg/100 g) after processing, but magnesium, potassium, and calcium increased significantly in the fruit leathers. The general acceptability of the fruit leathers from the sensorial perspective showed that pawpaw leather was slightly liked (6.40) while banana leather (7.10) and composite leather (7.50) were liked moderately. Though the banana fruit leather and composite fruit leather were not significantly different, the sensory scores showed that the composite fruit leather was more preferred. This research has demonstrated that processing of fruits into fruit leathers will not only minimize postharvest losses but will also create a new variety of value-added products with higher nutritional value potential compared to its fresh fruits.

Introduction

The pawpaw plant (*Carica papaya*) belongs to the botanical family of *Caricaceae*. The fruit is a large berry, about 15-45 cm long and 10-30 cm in diameter. When ripe, the fruit is a bit soft and the skin turns from green to amber, orange, or yellow (Heywood et al., 2007). Two common types are grown in Nigeria, one has sweet red flesh and the other has yellow flesh (Siar et al., 2011). On the

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other hand, the banana plant (*Musa acuminata*), is in the genus Musa (Armstrong, 2011). It is an edible fruit that is botanically a berry, variable in size, colour, and firmness, but it is usually elongated and curved with a rind, which may be green, yellow, red, purple, or brown when ripe (Antinoro, 2012).

Pawpaw and banana fruits are usually eaten fresh in Nigeria, and in this form, they need to be transported from the rural producing farms to the urban cities where the greater number of consumers live. In this form, a reasonable proportion of the harvest is lost due to mechanical and over-ripe defects, since the fruits are highly perishable. Maskan et al. (2002) also emphasized that most fresh fruits have a short harvest season and are sensitive to deterioration even when stored under refrigerated conditions; therefore, making fruit leathers from fresh fruits could be an effective way to create a new frontier (variety) of fruit products. Besides minimizing postharvest losses and improving the preservation of surplus fruit harvest, conversion of perishable fruits to fruit leather is a potential candidate to combat fruit wastage.

Fruit leathers are dehydrated fruit products which are eaten as snacks or desserts. They are flexible sheets that have a concentrated fruit flavour and nutritional aspects (Diamante et al., 2014). Fruit leathers consist of tasty and chewy dried fruit pulp rolled in the form of sheets. Fruit leather can also be defined as fruit pulp that is spread into a thin layer and allowed to dehydrate (Raab and Oehler, 2000). Sugar and probably preservatives may or may not be added to fruit leather. When added, sugar can serve as a preservative in the product. It is like pickling, in the sense that it is useful in the preservation of seasonal fruits for other times of the year. Fruit leathers can be produced from any fruit, especially from tropical fruits such as pawpaw, pineapple, banana, etc, that have high postharvest losses due to their high moisture content and low processing attention received by these fruits.

Fruit leather production technology, though not new in food processing, is scarcely practiced as a means of preservation of fruits, and can also serve as a means of combating food insecurity and malnutrition (Chikwendu et al., 2014), not only in Nigeria, but also in the West Africa sub region. Therefore, the objective of this research is to comparatively evaluate the nutritional (proximate, vitamin, and mineral) compositions and acceptability of fruit leather products produced from pawpaw and banana fruit.

Materials and methods

Raw material procurement

Mature, fresh, and ripe banana (*Musa acuminata*) and pawpaw (*Carica papaya*) fruits were obtained from Ihiagwa market, Owerri West Local Government Area, Imo State. The processing and other working equipment, were obtained from the Processing Laboratory and Food Chemistry Laboratory of the Department of Food Science and Technology, Federal University of Technology Owerri, Imo State.

Sample preparation

The selected fruits were washed in water containing 0.2% of sodium metabisulphite in order to disinfect the fruits. The pawpaw fruit was weighed, peeled, and deseeded, while the unpeeled banana was steam blanched for 10 mins before peeling. However, blanching was done to inactivate enzymes and retain the colour of the fruit.

The fruits were re-weighed after peeling using a weighing balance, followed by cutting into smaller sizes using a stainless knife. The sliced fruits were put into an electric blender (Super Diamond Blender, Model: NG-999, 400 W power rating, stainless steel blades, 1.5 L capacity and 4 speeds) and the fruit pulps were blended into purees and poured into a different pot. Sodium metabisulphite (2 g) was added into a 1000 g portion of each sample puree to act as a preservative to the product. Afterwards, 400 g of each puree sample was taken and mixed in another pot to form the composite sample (i.e. mixture of pawpaw and banana), to make three puree samples (Figs. 1, 2 and 3).

The various puree samples were cooked on a water bath for 10 min with continuous stirring using a long stainless-steel spoon. Stainless steel trays were lined with aluminium foil and the cooked puree samples were evenly and separately spread on the trays, avoiding the spillage of the puree from the edges. The thickness of the evenly spread puree was measured using a clean plastic ruler and the puree samples were dehydrated in a hot air oven (Genlab, England, Model M 30 C, S/N 92B060) set at 60 °C to 62 °C. After 8 to 10 hours of the drying operation, the edges of the leather sheets were lifted and peeled off the aluminium sheets. The dried fruit leathers were then cut into strips, rolled up, and packaged.

Fig. 1. Banana puree spread on a tray before drying

Fig. 2. Pawpaw puree spread on a tray before drying

Fig. 3. Composite (Pawpaw and Banana) puree spread on a tray before drying

Determination of the proximate composition of the fruits and fruit leathers

The method of the AOAC (2005) was used for this determination of moisture content, fat, crude protein, crude fibre, and ash determinations, while carbohydrate was calculated by difference.

Determination of vitamin C

The method described by Okwu and Jasrah (2006) was used to determine the vitamin C content of the fruit leathers as shown below:

$$\text{Vitamin C}\left(\frac{\text{mg}}{100\text{g}}\right) = \frac{100}{\text{W}} \times 0.88 \times \frac{\text{V}_\text{f}}{\text{V}_\text{a}}\ \text{T} - \text{B} \quad (1)$$

where:
W = Weight of sample (g)
V_f = Total filtrated volume (ml)
Va = Volume of filtrate analysed (ml)
T = Titre value of sample
B = Titre value of the blank

Determination of vitamin E

The method described by Pearson (1976) was used to determine the vitamin E content of the produced fruit leathers and was calculated with the expression below:

$$\text{Vitamin E in mg/100g} = \frac{a - b}{s - b} \times \frac{c}{w} \quad (2)$$

where:

a = Absorbance of test sample (nm)
b = Absorbance of standard solution (nm)
c = Concentration of standard in mg/100g
w = Weight of the sample used (g)

Determination of vitamin A

Vitamin A was determined according to the method of the AOAC (2000) as shown below:

$$\text{Vitamin A (mg/mg)} = \frac{A\,(620nm) \times SL \times V}{Wt.} \qquad (3)$$

where:
A620nm = Absorbance at 620nm
SL = slope of standard curve (vit. A conc.)/A620 reading.

Determination of vitamin B9

The microbiological assay method (Spitzer, 2007) was used in vitamin B9 determination. The fruits and fruit leather samples were ground and homogenized. Two grams (2 g) of the sample was weighed into a 250 ml Erlenmeyer flask and 50 ml of distilled water treated with activated charcoal was also added into the flask and mixed properly. Next, 5 ml of 10% amylase was added to the samples, covered with aluminium foil, and incubated at 37 °C for 12 hours. The solution was mixed properly then sterilized in an autoclave at 121 – 123 °C for 15 min. It was then transferred to a 200 ml volumetric flask and brought to volume with distilled water treated with activated charcoal, and the solution was agitated.

Twenty-five millilitres (25 ml) of the solution was centrifuged at 3000 rpm for 50 min. Five millilitres (5 ml) of the supernatant was taken and transferred to a 100 ml volumetric flask and made up to mark with distilled water treated with activated charcoal, and the solution was agitated. The solution was then filtered through a Whatman No. 5 filter paper to reduce turbidity.

In the microbiological assay, a total of 26 tubes with screw caps were washed and dried. Three (3) of the tubes were used as inoculated blanks for the check of chemical contamination of the reagents, water, and media used in the analysis. Another set of three (3) tubes were used as uninoculated blanks for sterilization controls. Ten (10) of the tubes were used in preparing folic acid working standard solutions containing 1ng/ml in 0.5, 1, 2, 3, and 4 ml respectively in duplicates. Then different portions of 0.5, 1, 2, 3, and 4 ml of the sample final extract were pipetted into the remaining ten (10) tubes in duplicate. Distilled water treated with activated charcoal was added to the tubes to get a final volume of 5 ml. Then, 5 ml of agar for folic acid assays (Hi Media 126) was added to all the tubes and the tubes were closed. The tubes were sterilized in an autoclave for 5 mins at 121 – 124 °C. After 5 min, the tubes were brought out of the autoclave and allowed to cool. Each tube was then aseptically inoculated by adding 25 μL of inoculum using an automatic pipette with sterile tips, except to the blanks without inoculum. The tubes were then incubated for 16 hours at 35 – 37 °C in a water bath. A spectrophotometer was used to test the absorbance. The wavelength of the spectrophotometer was set to 550 nm. The concentration of vitamin B9 was thus calculated:

$$\text{Conc. of vitamin } B_9\,(\mu g/ml) = \frac{Absorbance\ of\ test \times Conc.\ of\ standard}{Absorbance\ of\ standard} \qquad (4)$$

Determination of mineral content

Determination of mineral content was carried out on the fresh fruits (banana and pawpaw) and the leathers (pawpaw fruit leather, banana fruit leather, and the composite leather). The various samples were analysed for magnesium, calcium, and potassium using atomic absorption spectrophotometry (AAS) according to the methods of the AOAC (2003).

Microbial analysis

The spread plate technique was applied for counting viable bacteria using nutrient agar. A series of 6 test tubes were prepared containing 9 ml of sterile distilled water. The sample (1 ml) was added to the first test tube of the set, using a sterile pipette and the tube was labelled as 10^{-1}. The content was well mixed by swirling the tube upside down a few times. Then, 1 ml of the sample was taken from the first test tube and transferred to the second tube. The second tube was labelled as 10^{-2}. The procedure was repeated with the remaining tubes and labelled up to 10^{-6}.

From the 10^{-6} pipette, 0.1 ml was pipetted out onto the surface of the agar plate. The L-shaped glass spreader (hockey stick) was dipped into alcohol and then flamed over a Bunsen burner. The sample was evenly spread over the surface of the agar using the sterile glass spreader and carefully rotating the petri dish underneath at an angle of 45° at the same time. The plate was incubated at 37 °C for 24 hours and the microbial count (load) of the plate was taken. The colony forming unit (CFU) value of sample was calculated, from the obtained value as shown below:

$$\text{CFU/ml} = \frac{No.\ of\ \ colonies \times Dilution\ \ factor}{Volume\ of\ culture\ plate} \quad (5)$$

Sensory evaluation

A 20-member sensory evaluation panel was used to analyse the sensory properties of the fruit leathers according to Ihekoronye and Ngoddy (1985). The 9-point hedonic scale was used to score the degree of preference of the samples with regard to taste, aroma, mouthfeel, and colour. The panel members were each supplied with a cup of potable water for rinsing their mouth after each sample tasting and an empty paper cup for spitting out unwanted samples. In addition, the members were requested to comment freely on any other characteristic of the product they wanted to remark. The score for each sample was given in numerical values ranging from 1-9 in the following scale: 9 = Like extremely; 8 = Like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much: 1 = Dislike extremely.

Statistical analytical

The Analysis of Variance (ANOVA) assumptions were investigated for outliers, homogeneity of variances, and normality using boxplot, Levene's test, and skewness & kurtosis test, respectively (Ofoedu et al., 2020). Data obtained from duplicate measurements was subjected to a one-way analysis of variance (ANOVA). Mean differences were resolved using Fischer′s least significant difference (LSD) test at a significance of 95% confidence level (p<0.05).

Results and discussion

Proximate composition of the banana, pawpaw, and fruit leather samples

The proximate composition of the fresh fruit pulps and their leather samples are presented in Table 1.

Moisture content

The moisture content of the fresh banana pulp was 71.95%, while fresh pawpaw pulp had a mean moisture content of 87.63%, both in wet basis (WB). On the other hand, the moisture content of the fruit leather sample ranged from 23.36 to 23.84% (WB); with the composite (banana & pawpaw) leather sample having the least moisture content of 23.36% (WB). Fresh Pawpaw pulp had the highest moisture content (87.63%), followed by fresh banana (71.95%), and both were significantly different (p<0.05). The moisture content values for fresh pawpaw and fresh banana in this study were comparable to the values reported by Ekpete et al. (2013) for fresh pawpaw (87.67%) and fresh banana (72.00%), both in wet basis. The studied fruits had high moisture contents, which is typical of fresh fruits at maturity (Umoh, 1998). However, there were no significant differences (p>0.05) between the moisture contents of the banana leather, pawpaw leather, and composite leather samples, but significant differences (p<0.05) exist between the fresh fruits (banana & pawpaw) and the fruit leathers. The significant decrease (p<0.05) in moisture content between all the fruit leathers and the fresh fruit pulps in this study was attributed to the drying operation (Osuji et al., 2019) during processing of fruits pulps to leathers; as moisture was removed through evaporation during drying. The lower moisture contents of the fruit leathers when compared to the fresh fruits would definitely increase the keeping quality of the leathers, but when compared to other food products, the moisture content of the fruit leathers appears undesirable and could be the leading cause of microbial (mould) growth and low shelf life stability (Ibeabuchi et al., 2020; Nwakaudu et al., 2017; Ibeabuchi et al., 2017; Odimegwu et al., 2019).

Protein content

The mean protein content of fresh banana pulp was 5.69%, while the fresh pawpaw pulp had a protein content of 6.13%. On the other hand, the protein contents of the fruit leathers were 8.32%, 8.76%, and 8.61% for banana leather, pawpaw leather, and composite (banana and pawpaw) leather, respectively. There were significant differences (p<0.05) between the protein contents of the fresh fruits and those of the produced fruit leathers. The protein contents of fresh banana (5.69%) and fresh pawpaw (6.13%) obtained in this study were comparable to the values reported by Odenigbo et al. (2013) and Maisarah et al. (2014). Pawpaw leather had a higher protein content than other leathers when compared to banana leather and the composite leathers, as their protein values were significantly different (p<0.05). This was also in line with the study of Ashaye et al. (2005) who reported a higher protein content in pawpaw leather when compared to guava leather. The variations in the protein contents could be attributed to variations in the type of fruits used. Though the fruits are poor sources of protein, there was an observable increase in protein content in the fruit leathers after drying operations. The biological value of protein is dependent on the drying method adopted as prolonged exposures of food products to high temperatures can render the protein less useful in the diet (Anon., 2019). Also, the significant increase in protein content of the produced fruit leathers could be due to protein precipitation during the drying operation (Anon., 2019).

Lipid content

The mean lipid content of the fresh banana was 0.25% while fresh pawpaw had a lipid content of 0.18%. The lipid contents of the fruit leathers were 0.88%, 0.79%, and 0.97% for banana leather, pawpaw leather, and composite (banana and pawpaw) leather, respectively. The observed lipid content of the fresh pawpaw in this study was comparable to that reported by Ashaye et al. (2005) for pawpaw leather (0.20%), but the lipid content of the fresh banana obtained in this research was lower compared to that reported by Ekpete et al. (2013). This could be due to pre-harvest factors as well as varietal differences. There were significant differences ($p<0.05$) between the fresh fruits and the fruit leathers produced with regards to their lipid contents. The significant increase ($p<0.05$) in the lipid content of the fruit leathers up to 300% could be a result of the proportionate decrease in the moisture contents of the fruit leathers during the drying operations. However, it could also be due to the oil used to grease the surface of the aluminium foil to prevent the fruit leathers from sticking to the aluminium foil after drying.

Ash content

The ash content of the banana fruit was 0.71%, while that of pawpaw fruit was 0.50%. There was a significant difference ($p<0.05$) between the fresh banana and fresh pawpaw fruit with regards to the ash contents. The ash contents of the fruit leathers ranged from 3.75% to 4.03%, with the banana leather having the highest ash content of (4.03%), followed by the pawpaw leather with a mean value of 3.89%, while the composite leather had the least ash value of ash content (3.75%). There were significant differences ($p<0.05$) between banana leather and other fruit leathers with regards to their ash content, but there was no significant difference ($p>0.05$) between the pawpaw leather and the composite leather. The increased values in the ash contents could be due to the proportionate decrease in moisture content of the fruit leathers during the drying operations, which might have caused some increases in the ash content of the fruit leathers, as was evident in other proximate composition parameters. High values of ash content indicate high mineral constituents (Adedeji et al., 2006), and this situation is expected to improve metabolic processes together with growth and development (Bello et al., 2008). From the results, it could be seen that the banana leather with its highest ash content of 4.03% would be preferred in terms of mineral content.

Crude fibre content

The crude fibre content of the fresh banana fruit was 0.72%, while that of fresh pawpaw fruit was 0.77%. There was no significant difference ($p>0.05$) between the fresh banana and fresh pawpaw fruit with regards to crude fibre value. The crude fibre contents of the fresh banana fruit (0.72%) and the fresh pawpaw fruit (0.77%) obtained in this research were comparable to the values reported by Ekpete et al. (2013) and Ashaye et al. (2005). On the other hand, the crude fibre contents of the fruit leathers ranged from 1.30% to 1.65%, with the pawpaw leather having the highest crude fibre content (1.65%), followed by the banana leather with a value of 1.50%, while the composite fruit leather had the least value of crude fibre content (1.30%). There was no significant difference ($p>0.05$) between the banana leather and pawpaw leather with regards to crude fibre value, but both were significantly different ($p<0.05$) from the composite fruit leather. The relatively high range of crude fibre contents of the fruit leathers in this research could be advantageous, as fibre is essential in food for absorbing water and providing roughage for the bowels, thereby assisting intestinal transit (Ibeji, 2011).

Carbohydrate content

The carbohydrate content of the fresh banana fruit was 20.60% while that of fresh pawpaw fruit was 4.70%. There was significant difference ($p<0.05$) between the carbohydrate content of fresh banana and fresh pawpaw fruit. The results showed that the fruits contain carbohydrates but in low amounts. The carbohydrates in fruits exist as simple sugars like glucose, fructose, and sucrose but in varying amounts, according to fruits (Laughlin et al., 2014). The carbohydrate contents of the fruit leathers ranged from 61.07% to 62.01%, with the composite fruit leather having the highest carbohydrate content (62.01%), followed by the banana leather with a value of 61.60%, while the pawpaw leather recorded the lowest value (61.07%). There was no significant difference ($p>0.05$) in the carbohydrate contents of banana leather and the composite fruit leather, but both were significantly different ($p>0.05$) from the pawpaw leather in carbohydrate content. The significant increase in the carbohydrate contents (sugars) of the fruit leathers could be a result of the loss in volume of the product due to moisture removal, thereby causing product shrinkage which concentrates the sugars in the fruit during the drying process. It is important to note that more sugars and calories are present in dried fruits when fresh fruits are compared to dried fruits by volume (Lehman, 2019).

Table 1. Mean Values of the Proximate Composition of Banana, Pawpaw, and Fruit Leather Samples

Samples	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)
Fresh Banana	71.95±2.76^{b}	5.69±0.06^{e}	0.25±0.00^{d}	0.71±0.01^{c}	0.72±0.01^{c}	20.60±0.02^{c}
Fresh Pawpaw	87.63±2.82^{a}	6.13±0.04^{d}	0.18±0.01^{e}	0.50±0.00^{d}	0.77±0.01^{c}	4.79±0.13^{d}
Banana Leather	23.67±1.41^{c}	8.32±0.03^{c}	0.88±0.03^{b}	4.03±0.01^{a}	1.50±0.00^{a}	61.60±0.14^{a}
Pawpaw Leather	23.84±1.82^{c}	8.76±0.08^{a}	0.79±0.01^{c}	3.89±0.06^{b}	1.65±0.01^{a}	61.07±0.10^{b}
Composite Leather	23.36±1.92^{c}	8.61±0.01^{b}	0.97±0.02^{a}	3.75±0.07^{b}	1.30±0.00^{b}	62.01±0.03^{a}
LSD	**6.22**	**0.13**	**0.03**	**0.11**	**0.16**	**0.25**

Values are the means of duplicate determinations. a,b….means with the same superscript along a column are not significantly different (P>0.05)

Table 2. Magnesium, calcium and potassium content of the banana, pawpaw, and fruit leather samples

Samples	Mg (mg/100g)	K (mg/100g)	Ca (mg/100g)
Fresh Banana	108.60±0.28^{e}	73.32±0.03^{d}	7.20±0.53^{e}
Fresh Pawpaw	118.64±0.06^{d}	20.00±0.00^{e}	80.40±0.21^{c}
Banana Leather	213.56±0.08^{c}	101.10±0.42^{c}	18.20±0.03^{d}
Pawpaw Leather	415.20±0.28^{a}	133.30±0.43^{b}	144.21±0.51^{a}
Composite Leathers	355.90±1.27^{b}	216.60±0.85^{a}	112.15±0.72^{b}
LSD	**1.54**	**1.20**	**1.36**

Values are the means of duplicate determinations. a,b….means with the same superscript along a column are not significantly different (P>0.05)

Table 3. Some vitamin contents of banana, pawpaw, and fruit leather samples

Samples	Vitamin A (mg/L)	Vitamin C (mg/100g)	Vitamin E (µg/100g)	Vitamin B9 (µg/mL)
Fresh Banana	0.009±0.00^{d}	52.96±0.08^{b}	29.23±0.04^{c}	0.79±0.01^{d}
Fresh Pawpaw	0.019 ±0.003^{b}	123.56±0.08^{a}	30.00 ±0.03^{b}	14.19±0.00^{a}
Banana Leather	0.011±0.001^{c}	17.65±0.07^{d}	34.00±0.03^{a}	0.25±0.07^{e}
Pawpaw Leather	0.032 ±0.000^{a}	52.96±0.04^{b}	34.00 ±0.00^{a}	5.00±0.03^{b}
Composite Leathers	0.010±0.001^{c}	35.30±0.04^{c}	23.23±0.04^{d}	2.61±0.01^{c}
LSD	**0.004**	**0.17**	**0.08**	**0.09**

Values are the means of duplicate determinations. a,b….means with the same superscript along a column are not significantly different (p>0.05)

Table 4. Sensory scores of banana and pawpaw fruit leather samples

Samples	Colour	Texture	Aroma	Taste	General Acceptability
Banana Leather	7.20±0.63^{a}	6.80±0.92^{a}	7.00±1.56^{a}	7.30±0.67^{a}	7.10±1.06^{a}
Pawpaw Leather	7.10±1.52^{a}	6.70±1.89^{a}	6.10±1.43^{a}	5.60±1.84^{b}	6.40±1.05^{b}
Composite Leather	7.60±1.01^{a}	7.00±1.56^{a}	7.30±1.05^{a}	7.90±0.57^{a}	7.50±0.67^{a}
LSD	**NS**	**NS**	**NS**	**1.08**	**0.87**

Values are the means of duplicate determinations. a,b….means with the same superscript along a column are not significantly different (p>0.05)

Table 5. Total bacteria count of fruit leather samples

Samples	Total bacteria count (cfu/g)
Banana Leather	$1.4^{c} \times 10^{3}$
Pawpaw Leather	$5.0^{a} \times 10^{3}$
Composite Leather	$3.2^{b} \times 10^{3}$
LSD	**1.03**

a,b….means with the same superscript along a column are not significantly different (p>0.05)

Mineral composition (Mg, Ca, and K) of fruit leathers

The mineral composition of the fresh fruit pulps and their leather samples are presented in Table 2. The analysed minerals were magnesium (Mg), calcium (Ca), and potassium (K). The highest magnesium content (415.20 mg/100 g) was obtained in pawpaw leather while the least magnesium content of 108.60 mg/100 g was obtained in fresh banana fruit. The composite leather had the highest value of potassium (216.60 mg/100 g) while fresh pawpaw recorded the least potassium content (20 mg/100 g). The highest mean value (144.21 mg/100 g) for calcium was observed in pawpaw leather, while fresh banana had the least value (7.20 mg/100 g) for calcium. There were significant differences ($p<0.05$) between the fresh fruits and the fruit leathers with regards to their mineral contents. Generally, the mineral contents of the fruit leathers were significantly ($p<0.05$) higher than the mineral contents of the fresh fruits. This was expected because removal of water from fruits during the drying process concentrated the minerals in the remaining solid part of the fruit, making the fruit leather a highly nutritious mineral snack (Kiremere et al., 2010). Minerals play a key role in the acid-base equilibrium of the body, and thus regulate the pH of the blood and other body fluids (Harris, 2006). It also serves as a structural constituent of soft tissues and is essential for the transmission of nerve impulses and muscle contraction. It is therefore evident that fruit leathers are sources of minerals in high concentration (FAO, 1985).

Vitamin content of fruit leather samples

The analysed vitamin (A, C, E, and B9) contents of the fresh fruit pulps and their leather samples are presented in Table 3. The vitamin A content of the fresh banana and the fresh pawpaw fruit were 0.009 mg/L and 0.019 mg/L respectively, while the vitamin A contents in the fruit leathers ranged from 0.010 mg/L to 0.032 mg/L. The vitamin C content of fresh banana and fresh pawpaw fruit pulps were 52.96 mg/100 g and 123.56 mg/100 g, respectively, while the vitamin C contents in the fruit leathers ranged from 17.65 mg/100 g to 52.96 mg/100 g. The vitamin E contents of the fresh banana and the fresh pawpaw fruits were 29.93 μg/100 g and 30.00 μg/100 g, respectively, while the vitamin E contents of the fruit leathers ranged from 23.23 μg/100 g to 34.00 μg/100 g. The vitamin B9 contents of the fresh banana and the fresh pawpaw fruit were 0.79 μg/mL and 14.19 μg/mL, respectively, while the vitamin B9 contents in the fruit leathers ranged from 0.25 μg/mL to 5.00 μg/ml.

The results of the vitamins showed significant differences between the samples ($p<0.05$) for all vitamins (Table 3). In addition, the vitamin content of fruit leather samples differed significantly ($p<0.05$) from the fresh fruits. There was an observable decrease in the values of vitamin C and vitamin B9 in the fresh fruits during their conversion to fruit leathers. Vitamin C and vitamin B9 are water soluble vitamins which are rapidly destroyed by heat. Thus, the significant reductions of vitamin C and B9 in the fruit leathers could be a result of the drying process during moisture removal, thus degrading both vitamins since they are heat labile. The general loss of water-soluble vitamins, especially vitamin C, during the drying operation could also be attributed to the oxidation of ascorbic acid under high temperature drying conditions, as well as the depletion of this compound due to its utilization for protecting the oxidation of polyphenols during drying (Toor and Savage, 2006). Vitamin C, an essential compound found in fruits, not only prevents diseases like scurvy, but also plays a natural role as a biological antioxidant (Duerbeck et al., 2016).

Though there were losses of vitamin C and vitamin B9 in the fruit leathers as a result of the drying process, the vitamin E in the fruit leathers increased significantly ($p<0.05$). The results showed that vitamins A and E were not affected by heat but might be susceptible/sensitive to light and air. Eze (2012), also reported a significant increase ($p<0.05$) in vitamin A and E levels in tomato after a drying operation. The significant increase in vitamin E level was expected because the removal of water from fruits during the drying process concentrated many food nutrients in the remaining solid part of the fruit, including vitamins A and E, since these vitamins are not easily destroyed by heat.

Sensory quality of the fruit leather samples

The mean sensory quality of the fruit leather samples is presented in Table 4. There was no significant difference ($p>0.05$) in the scores for colour, texture, and aroma of the produced fruit leathers (Figs. 4, 5 and 6). The fruit leathers were generally perceived to have fruity aroma, leathery texture, and light brown colour by the panellists.

Fig. 4. Composite fruit leather (final product)

Fig. 5. Pawpaw fruit leather (final product)

Fig. 6. Banana leather (final product)

However, there were significant differences ($p<0.05$) in the taste and general acceptability scores of the produced fruit leathers. The taste of the composite leather had the highest mean score of 7.90, which approximately corresponds to “very much liked”. Though the composite leather taste score was not significantly different ($p>0.05$) from that of banana fruit leather (7.30), the taste score for the banana fruit leather implied “moderate likeness”. The preferred taste of these fruit leathers could be contributed by the amounts of sugar contained in the banana pulp. The increase in the amount of sugar as a result of blending

banana and pawpaw fruits together with likeable flavour of banana could be the reason for its high preference by panellists (Ashaye et al., 2005).
Considering the general acceptability of the fruit leathers, the composite fruit leather recorded a sensory score of 7.50, followed by the banana fruit leather (7.10), and both showed no significant difference ($p>0.05$) with each other. The highest score in general acceptability for the composite leather showed that using mixed fruit pulps in fruit leather production yielded a better product. Though it could be seen that the banana fruit leather and the composite fruit leather samples were both very much accepted by the panellists and possibly by potential consumers. On the other hand, the pawpaw fruit leather had the lowest sensory score in all the studied quality attributes and was slightly liked, with a sensory mean score of 6.40 in general acceptability.

Total bacteria count of fruit leather samples

The total bacteria count for the fruit leather samples is presented in Table 5. The fresh banana and fresh pawpaw fruits showed no bacterial growth, but some remarkable significant bacterial growth was observed in the fruit leathers. The pawpaw leather had the highest total bacterial count of 5.0×10^3 cfu/g, followed by the composite leather with a total bacterial count of 3.2×10^3 cfu/g, while banana leather had the least total bacterial count of 1.4×10^3 cfu/g. There were significant differences ($p<0.05$) in the total bacterial counts of the fruit leathers. The moisture content and water activity are usually proportional to microbial load in any food product when stored. In this research, the moisture content of the fruit leathers ranged from 23.36 to 23.84% (wet basis). At this range of moisture levels, growth or proliferation of microorganisms is likely to occur, unlike in the study of Ashaye et al. (2005) that reported the moisture contents of pawpaw fruit leather and guava fruit leather as 18.47% and 16.40%, respectively. However, it could also be that the concentrated amount of nutrients (sugars, vitamins, and minerals) in the fruit leathers, due to the removal of moisture during the drying process, made the fruit leathers a good medium for certain microorganisms, especially fungi.

Conclusion

In this study, the produced fruit leathers were attractive, light brown in colour, and flavourful. The sensory evaluation showed that the composite fruit (banana & pawpaw) leather was moderately liked and was highly preferred by the panellists, since it recorded the highest score in general acceptability. The drying operation caused significant decrease in the moisture content and in the vitamins C & B9 content of the fruit leathers, as well as a significant increase in the ash, carbohydrate, protein, ash, fibre, mineral, and vitamin E contents in the fruit leathers, compared to their corresponding fresh fruits. The conversion of perishable fruits to fruit leathers can be applied to preserve the surplus fruit harvest and minimize the problem of postharvest losses of most fruit world over. The resulting leather product will add variety to the fruit and snack products in the market, together with value addition and economic growth. Further research is needed to fully characterize the nutritional qualities of fruit leathers produced from other tropical fruits, especially those that are highly involved in postharvest losses. More research is also needed to study the effect of the different drying methods on the nutrient losses and retention in fruits when processed to leathers.

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