NUTRITIONAL, PHYSICOCHEMICAL, AND SENSORY EVALUATION OF COMPOSITE FRUIT LEATHER DEVELOPED FROM AFRICAN STAR APPLE (*Chrysophyllum albidum*) AND BANANA

Adedayo Olubunmi ADEBOYE[1*], Oluwadamilola OGUNSADE[2], Albert Akinsola FAMUWAGUN [3], Abimbola EMMANUEL[4], Kehinde OMOWUMI [5],

[1,2,3,4,5]*Department of Food Science and Technology, Osun State University, Osogbo, Nigeria*

Corresponding Author: adedayo.adeboye@uniosun.edu.ng

Abstract
This study developed fruit leather from African star apple and banana blends to enhance the utilization of African star apple and reduce postharvest losses. The fruits were blended in varying proportions (90:10, 80:20, 70:30, 60:40, 50:50 African star apple: banana), with 100% of each fruit serving as controls. Proximate composition, textural properties, and sensory attributes of the leathers were evaluated. Results showed crude protein (8.70–12.08%), crude fat (2.00–3.18%), ash (2.41–3.03%), moisture (11.31–12.97%), and carbohydrate (66.59–67.75%) contents across the blends. Textural properties included hardness (20.91–24.06%), cohesiveness (0.32–0.42), springiness (0.65–0.76), gumminess (7.07–9.87), and chewiness (4.94–5.08 J). Incorporating up to 50% banana improved protein, fat, and ash contents, while sensory evaluation indicated maximum consumer acceptability at 30% banana inclusion. Notably, banana inclusion did not significantly alter the leathers' textural properties. This research supports Sustainable Development Goal 12 (responsible consumption and production) by improving the utilization of African star apple thus promoting food sustainability.

Keywords
Fruit Leather, Texture Profile, African Star Apple, Sustainable Development Goals

1. INTRODUCTION

Fruits are the edible and fleshy portions of plants, high in moisture, that may or may not contain seeds but they are usually rich in energy, vitamins, fibres and bioactive compounds [1, 2]. According to [3], they give diets a desirable colour, flavour, taste and fibre-rich appeal that improves the health of consumers. Fruits and vegetables are important fixtures in maintaining a balanced diet for numerous reasons ranging from nutritional benefits to improvement of satiety in consumers. Several literatures have established the importance of fruits and vegetables in the diet; however, the consumption or utilization rate is still grossly low and postharvest loss due to the high perishability is on the increase. This is observed in the volume of fruit waste particularly during seasonal glut. Moreover, some fruits have poor acceptability due to some peculiarities they possess. An example of such fruit is African Star Apple. African Star Apple (*Chrysophyllum albidum)* fruit is a member of the family, *Sapotaceae.* It has a fleshy pulp that is usually consumed while its seeds are discarded. A large amount of the fruit is lost to deterioration during postharvest handling while the slow consumption rate particularly during glut could be due to its astringent taste [4].

Fruit leather is a rolled sheet of dried fruit puree made from a single fruit or a mixture of fruits. It is often eaten as a snack or dessert. Fruit leathers are economic and convenient substitutes to consuming unprocessed fruits and they are more nutritious than other known snacks [5, 6]. Usually, other ingredients are added to give it a pleasant and acceptable taste and texture [7]. Several fruits have been explored in the production of fruit leathers [8, 9, 10, 11] thus establishing the fact that nearly all fruits can be processed into leather given the right recipe and materials. The production of fruit leather reduces fruit wastes released into the environment and also increases economic value of the fruits.

In a study by [12], low consumption of fruits and vegetables have been implicated in a worldwide micronutrient deficiency that has led to several nutritional disorders. Post-harvest losses result in food wastage and this accounts for about one-third of the entire annual harvest wasted over the years. It was also reported that African Star Apple fruits are often left unexploited and are allowed to waste due to their excess supply in their season. Due to this, rural producers are often forced to give away their produce or leave them to rot away due to the short shelf-life span after ripening [13]. This study is therefore aimed at addressing the issues of postharvest losses and underutilization of African star apple by developing a novel product that combines it with banana fruit. This combination will mask the astrigent taste associated with prematuredly harvested African star apple and at the same time improve the eating quality and nutritional properties of the final product.

2. MATERIALS AND METHOD

2.1. Production of African star apple-banana fruit leather

Ripe and matured fruits of African Star Apple and Banana were peeled and deseeded (for African Star Apple) and the resulting pulp was chopped with a stainless-steel knife. The pulp of each of the fruits were crushed/blended into puree using an electric blender [14].

Puree from the two fruits were mixed in varying proportions as shown in Table 1. To each mixture, 80 g of sugar and 16 g of gelatin dissolved in 50 ml of water was added. The purees were poured on glycerin-lined (to facilitate easy removal of the leather) parchment papers spread on a stainless-steel tray. The puree samples were dehydrated in a cabinet air dryer at 60 ^{o}C for 9 h. The trays were turned and rotated every hour throughout the drying period to ensure uniform/effective drying of the leather. After the drying operation, the edges of the leather sheet were lifted off the parchment paper. The dried fruit leather sheets were cooled and then cut into strips, rolled up and packaged using cling film.

Table 1: African Star Apple – Banana Fruit Leather Composition Table

Sample Code	% African Star Apple	% Banana
ASA	100	0
BAN	0	100
FL_A	90	10
FL_B	80	20
FL_C	70	30
FL_D	60	40
FL_E	50	50

2.2. Determination of Proximate Analysis

Moisture content, Crude Protein, Crude fibre, Crude fat, Crude Ash and Total Carbohydrate were determined using standard methods. Moisture content was determined using the hot air oven method as described by [15]. One gramme of the fruit leather samples was weighed into crucibles and dried in a hot air oven (Uniscope, SM9053, England) at 105 ^{o}C for 5 hours. The dried samples were cooled in a desiccator and then weighed. Moisture content of the fruit leather was calculated as shown in equation 3.1:

$$\%\ Moisture = \frac{weight\ loss\ (g)}{weight\ of\ sample\ (g)}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.1$$

The ash content was determined using the method described by [15]. Finely ground sample (2 g) of fruit leather was weighed into a clean, previously dried and weighed crucible with lid. The sample was ignited over a low flame to char the organic matter with the lid removed. The crucible was then placed in muffle furnace (Carbolite AAF1100, United Kingdom) at 700 ^{o}C for 3 h until it ashed completely. The crucibles were transferred into desiccators, cooled and weighed. Ash content was calculated as shown in equation 3.2.

$$\%\ Ash = \frac{weight\ loss\ (g)}{weight\ of\ sample\ (g)}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots ..3.2$$

For the protein content determination, 3 g of the fruit leather samples was weighed into a Kjeldahl flask. Ten milliliter of concentrated sulphuric acid was added followed by one Kjeltec tablet (Kjeltec-Auto 1030 Analyzer, USA). The mixture was digested on heating racket to obtain a clear solution. The digest was cooled, and made up to 75 ml with distilled water and transferred onto the Kjeldahl distillation set up followed by 50 ml of 40% sodium hydroxide solution. The ammonia formed in the mixture was subsequently distilled into 25 ml, 2% boric acid solution containing 0.5 ml of the mixture of 100 ml of bromocresol green solution (prepared by dissolving 100 mg of bromocresol green in 100
ml of methanol) and 70 ml of methyl red solution (prepared by dissolving 100 mg of methyl red in 100 ml methanol) indicators. The distillate collected was then titrated with 0.05 M HCl.

Blank determination was carried out by excluding the sample from the above procedure and the crude protein content calculated using equation 3.3.

$$\%\ Protein = \frac{Titre\ Value\ x\ 0.1N\ HCl\ x\ 0.014\ x\ 6.25}{Weight\ of\ sample}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.3$$

The crude fat was determined using the method described by [15]. About 10g of the sample was weighed into a filter paper with known weight and folded neatly. The folded sample was placed inside a pre-weighed thimble (W_1). The thimble with the sample (W_2) was inserted into the Soxhlet apparatus and extraction under reflux was carried out for 6 h using n-hexane as solvent. At the end of extraction, the thimble was dried in the oven for about 30 minutes at 100 °C to evaporate off the solvent and thimble was cooled in a desiccator and later weighed (W_3). The fat extracted was then calculated as shown in equation 3.4.

$$\% \, Fat = \frac{Weight \; of \; fat}{Weight \; of \; sample} \; x \; 100 \qquad 3.4$$

Crude fibre was determined using the method as described by [15]. About 0.2 g of the fruit leather was placed in a glass crucible of known weight. 150 ml of pre-heated 1.25% H_2SO_4 was added in the extractor and the contents was boiled for 30 min at 500 °C. The acid residue was drained out from the extractor through the fiber flow system and washed with dutsilled water. Then 150 ml of pre-heated 1.25% NaOH was added to the washed residue and digested for 30 mins at 500 °C. Then the residue was washed with distilled water and dried for 2-4 h at 100 °C. It was cooled and then weighed. The fibre content was calculated as shown in equation 3.5.

$$\% \, fibre = \frac{Weight \; of \; residue}{Weight \; of \; sample} \; x \; 100 \qquad 3.5$$

The total carbohydrate content of sample was determined by summing up the percentages of moisture, ash, crude protein, fat (ether extract) and subtracting from 100 %.The difference in value (equation 3.6) was taken as the percentage total carbohydrate content of the sample.

$$Total \; carbohydrate = 100 - (\% \, fat + \% \, ash + \% \, moisture + \% \, protein + \% \, moisture \qquad 3.6$$

2.3. Determination of Textural Properties

A texturometer TA.XT (Extralab, Express Enhanced, Godalming, UK) was used. The operating conditions proposed by [16] were used, standardized as: load of 0.05 N, cylindrical specimen of P-20 stainless steel (diameter of 20 mm) with penetration depth of 5 mm, penetration speed 2 mm s^{-1} in two cycles penetration. The samples were placed in plastic containers (diameter of 50 mm and height of 55 mm), and tested 24 h after preparation, observing the maintenance of temperature (10°C). The parameters of hardness, cohesiveness, springiness, adhesiveness and gumminess were measured [17].

2.4. Sensory Evaluation

Evaluation of consumer acceptability was conducted using 20 untrained panelists (picked randomly among staff and students but conversant with consuming all the fruits used). Each panelist was asked to taste the samples of the fruit leather and score them for the following attributes (appearance, taste, texture, colour and over all acceptance) using a 9 – point Hedonic scale where 1 indicates "extremely dislike" and 9 indicates "extremely like".

2.5. Statistical Analyses

The data collected were expressed as mean ± standard deviation of three experiments, and subjected to statistical analysis using one- way analysis of variance (ANOVA) to determine the significance difference between mean at $P < 0.05$. Tukey significant difference (HSD) was used to compare the means. All statistical analyses were carried out using SPSS 19 software.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of African Star Apple-Banana Fruit Leather

The proximate composition of fruit leathers produced from a blend of African Star apple and banana is presented in Figure 1. The blends had lower moisture content values than the leathers made from single fruits. Among the blends, FLE (50% African star apple + 50% Banana.) had the least moisture content (11.31 %). A fruit leather with a low moisture content has a longer shelf life, as the presence of water in the leather accelerates enzymatic deterioration and spoilage [18]. The moisture content present in fruit leathers must be lower than or within the range of 10 – 20% as reported by [5]. However, several studies have revealed varying amount of moisture in fruit leathers such as 12.67-16.49 % for banana and carrageenan fruit leather as reported by [19]; 11.59 – 29.40% for mango fruit leather as reported by [20]. Nevertheless, the values obtained in this study falls below the recommended 15% value for susceptibility to microbial activity [21] and they are indicative of an appreciable quantity of total solids.

Proteins are important biologically active compounds needed by the body. There were no significant differences (p>0.05) between fruit leathers having 30 and 40% banana in their blends but the crude protein of the blends increased with increase in banana inclusion. These percentages were higher than those reported (0.58 - 0.71 % protein) for mixed fruit leather from apple, banana, and pineapple [22], and papaya fruit leather, having 1.42 - 2.25 % protein as reported by [23]. The increase in the protein composition of the African star apple-banana fruit leather could be due to the nature of nitrogen compounds present in the fruits [22]. The value of protein present in the leather is dependent on the

MC - Moisture Content
CP - Crude Protein
CFAT - Crude Fat
CF - Crude Fibre
TC - Total Carbohydrate

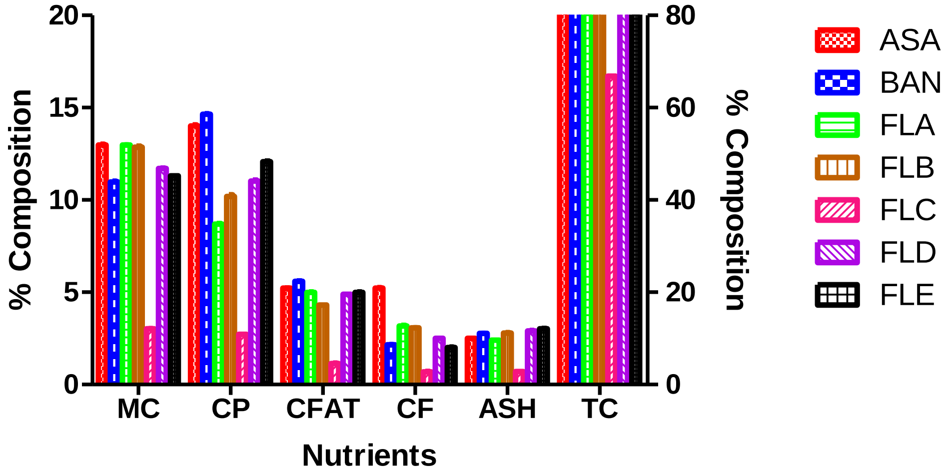

Fig 1: Proximate Composition of African Star Apple-Banana Fruit Leathers

drying method adopted (cabinet drying) as prolonged exposures of the leather to high temperatures can render the protein less useful in the diet and also, the increase in protein content of the leathers could be due to protein precipitation during the drying operation [24].

Crude fat content of the fruit leathers (4.31 – 5.60 %) were higher than that of fruit leathers from other fruits such as 0.48 - 4.06 % for *Annona muricata* L. fruit and *Avena sativa* flour fruit leather [25]; 2.18 – 2.32 for Banana-Pineapple-Apple Leather [22]. According to [24], the increase in the fat content of the fruit leathers blend could be a result of the proportionate decrease in the moisture contents during the drying operations and it could also be due to the glycerine used to grease the surface of the parchment paper to prevent the fruit leathers from sticking to the parchment paper after drying.

The crude fibre content of the fruit leather blends decreased with banana inclusion. The values (2.0 – 5.23 %) obtained in this study are comparable to the values (3.61 - 6.47 %) reported by [25] for *Annona muricata L.* fruit and *Avena sativa* flour fruit leather and lower than the value 11.50 - 22.70 % reported by [26] for edible portions of four underutilized fruits. Fibre content in the fruit leather could be used to control blood glucose levels in normal and diabetic individuals thereby protecting human against excessive weight gain and obesity and its associated diseases. According to [5], fruit leathers are expected to be rich in fibre because they are essential in food for absorbing water and providing roughage for the bowels, thereby assisting bowel movement [27].

Ash content in foods is related to the mineral content [28], and the values (2.41 – 3.03 %) obtained in this study increased with banana inclusion. These values exceed those reported for persimmon fruit leather [29], which contains ash in the range of 1.1 - 1.12 %, and papaya fruit leather, which contains ash in the range of 0.94 - 2.08 % [23]. An increase in the ash content of banana-pineapple-apple fruit leathers due to banana inclusion was also reported by [22].

Carbohydrates present in fruits exist as simple sugars like glucose, fructose, and sucrose but in varying amounts, according to fruits. All the samples of fruit leather produced showed a high level of carbohydrate content. The high carbohydrate contents could be because of the loss in volume of the leather due to moisture removal, thereby causing product shrinkage, which concentrates the sugars in the fruit during the drying process. More amount of sugars and calories are present in dried fruits when compared to fresh fruits by volume. In addition, [30] reported that high carbohydrate diets provide the energy needed to do work; however, low amount of carbohydrate content in diets is also of advantage for diabetic patients.

3.2. Textural Properties of the Fruit Leathers

Texture analyzer is a powerful tool for correctly evaluating the textural properties of fruits and vegetables particularly because it can simulate the chewing process of the human mouth [31]. The results obtained from instrumental testing of the leathers for hardness, cohesiveness, springiness, gumminess and chewiness are presented in Fig. 2.

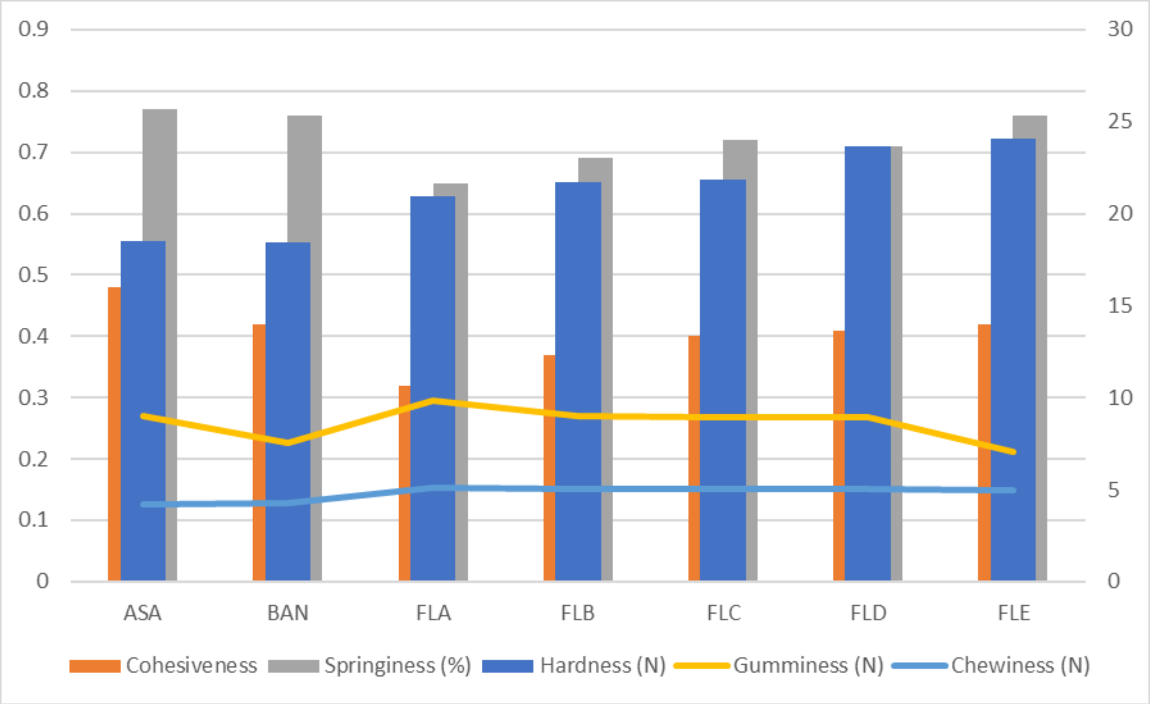

Fig. 2: Textural Properties of Africa Star Apple-Banana Fruit Leathers

Hardness is the force required to break a food material into smaller sizes [17]. The values for hardness of African star apple - Banana fruit leather blends ranged from 20.91 N - 24.06 N with the values increasing with banana inclusion. The leather, FLE containing 50 % Africa star apple and 50 % Banana had the highest level of hardness which was higher than values reported for leathers from various fruits in Indonesia by [5]. [32] reported a higher range of 51.48 - 62.08 N for fruit leather produced from dragon fruit. Among the fruit leather blends, sample FLA (90 % African star apple and 10% Banana) had the lowest value for hardness and this implies that the sample is less resistance to deformation and only a little force is needed to break it during chewing or handling as compared to other fruit leather samples. Thus, making it easy to roll during processing and more chewable for the consumer. According to [33], consumer's preference in fruit leather has revealed that aside from a gummy texture, a soft texture is desired. The hardness of the leathers from the blends increased with decreasing moisture and carbohydrate levels thus agreeing with the report that moisture, carbohydrate levels and heat treatment are responsible for the hard texture of fruit products.

The values for cohesiveness of the blends ranged from 0.32 - 0.42 with cohesion increasing with banana inclusion. Cohesiveness refers to mutual attraction within a product when simulating mastication [34], this is the chewy characteristic of the fruit leather. It is also referred to as the limit to which a food sample deforms before it breaks. [35] reported a higher cohesiveness value for date-mango fruit leather. According to [36], cohesiveness is influenced by the amount of starch, moisture content, the type of hydrocolloid used and drying temperature during processing. More so, the starch present in the fruit puree affects the thickening of the product by binding some of the water present and also prevents the fruit leather from drying out completely thereby creating a better mouthfeel. The increase in the degree of cohesiveness of the blends as banana inclusion increased could be attributed to the high starch composition in banana.

The values obtained for springiness of the samples ranged from 0.65 - 0.77%, with sample FLA (90 % African star apple and 10 % Banana) having the lowest level of springiness and sample ASA (100% African star apple) having the highest level of springiness. Springiness is the degree to which a sample can recover after the deformation force is removed following the first compressive deformation [37]. It is associated with the elasticity of the fruit leather. The results obtained in this study were lower compared to that reported for Date-mango fruit leather by [35]. These values implied that the fruit leather samples for all the blends do not spring back to their original form once force is applied on them.

The values obtained for gumminess ranged from 7.07 - 9.87 N, with sample FLA (90 % African star apple and 10 % Banana) having the highest level of gumminess and FLE having the lowest level of gumminess. This result is lower compared to 50.144 N - 96.438 N for date-mango fruit leather reported by [35]. Gumminess is a measure of the energy required to overcome the surface attraction when masticated (Yang *et al.*, 2023), thus sample FLA (90 % African star apple and 10 % Banana) having the highest value for gumminess, will require more energy for mastication. The African Star Apple is naturally a gummy food material, often regarded by consumers as a local alternative to bubble gum. This characteristic explains the observed increase in gumminess as the proportion of African Star Apple in the formulation increases.
The values obtained for chewiness ranged from 4.22 - 5.08 N, with sample FLA (90 % African star apple and 10 % Banana) having the highest level of chewiness. These values are lower compared to 95.518 - 45.129 N reported by [35] for Date-mango leather. Chewiness is the product of hardness, cohesiveness, and springiness and is a comprehensive indicator of product quality [38]. This relationship explains the similar trends observed between chewiness and gumminess in the results. The findings for chewiness align closely with those for gumminess, further confirming this correlation.

3.3. Sensory Evaluation of the Fruit Leathers

The radar plot of the mean sensory scores for the fruit leathers is presented in Figure 3 and it showed that up to 40% inclusion of banana resulted in leathers with nearly similar sensory characteristics. Leather made from 100% African Star Apple (ASA) distinctly stood out in nearly all attributes examined thus confirming the poor consumer perception of the fruit. FLC containing 30% Banana and 70% ASA had the highest scores for appearance, taste, colour and overall acceptability. Since the aim of the fruit leather production is to make an alternative, acceptable fruit snack from ASA which is usually less consumed for its astringent taste, the mean scores obtained indicate that the consumers are opened to exploring African Star Apple combined with banana leather as an alternative way of consuming the fruit. This is reflected in the blends having mean scores above 5 (Table 2).
For appearance, the scores for the blends ranged from 6.0 – 8.0 and at higher levels of banana inclusion, the scores were significantly different ($P<0.05$). For taste (5.8 – 7.1), there was significant difference among the blends with fruit leather containing 30% banana having the highest score for taste. Giving the extreme dislike for ASA's taste, there may be a need to improve the taste of the blends with another sweeter fruit or addition of more sugar. [7] opined that the quantity of sugars in the fresh fruit pulp and amount added during preparation affects the taste and flavour of the final product. Drying of fruits into leathers has also been reported to reveal the actual taste of fruits [33]. When compared with the single strength leathers (ASA and BAN), ASA had a poor taste while BAN which is naturally sweet had the highest score for taste. The scores obtained for taste in this study were higher than that reported for African star apple and plum blends by [13].
For texture (6.7 – 7.0), there was no significant difference amongst the scores for the blends but leather with 20% banana had the highest score. According to [39], fruit leathers are expected to have elastic texture which is determined by the composition of pectin, sugar, acid and water. Addition of humectants also contribute to the texture as it regulates the extent of moisture removal during drying. The texture values obtained in this study were much lower than values reported for mango leather by [20] possibly due to the nature of the fruits and the use of hydrocolloids like CMS and gum Arabic.
Sensory scores for colour (6.1 – 7.7) reduced with banana inclusion but they were still higher than the scores for ASA alone. According to [5], the final colour of fruit leather is largely dependent on the initial colours of the raw fruits and it is an index of quality. The colour changes are largely due to the initial brown-orange colour of ASA and further browning due to caramelization during drying. Colour has also been implicated as a quality parameter in organoleptic assessment of food products particularly as a browning index [14].
Overall acceptability scores ranged from 5.8 – 7.3 with fruit leather containing 30% banana having blends the highest overall acceptability with significant difference existing among them. This indicates that, varying the proportion of African star apple and Banana during blending with a constant percentage of sugar and gelatin does have an effect on the overall acceptability of the samples in agreement with the report for jam produced from African star apple and plum blend according to [13].

4. CONCLUSION

This study demonstrated the feasibility of producing fruit leather from African Star Apple with up to 50% banana inclusion. Blending African Star Apple with banana (up to 30%) enhanced the nutritional composition of the leather without significantly affecting its texture, while maintaining good textural properties. Sensory evaluation results indicated that the blend containing 30% banana received the highest scores for certain attributes (Appearance, taste, colour, overall acceptability), making it the most acceptable formulation. This product presents an alternative form for banana and African star apple utilization thus promoting sustainability and reducing wastage.

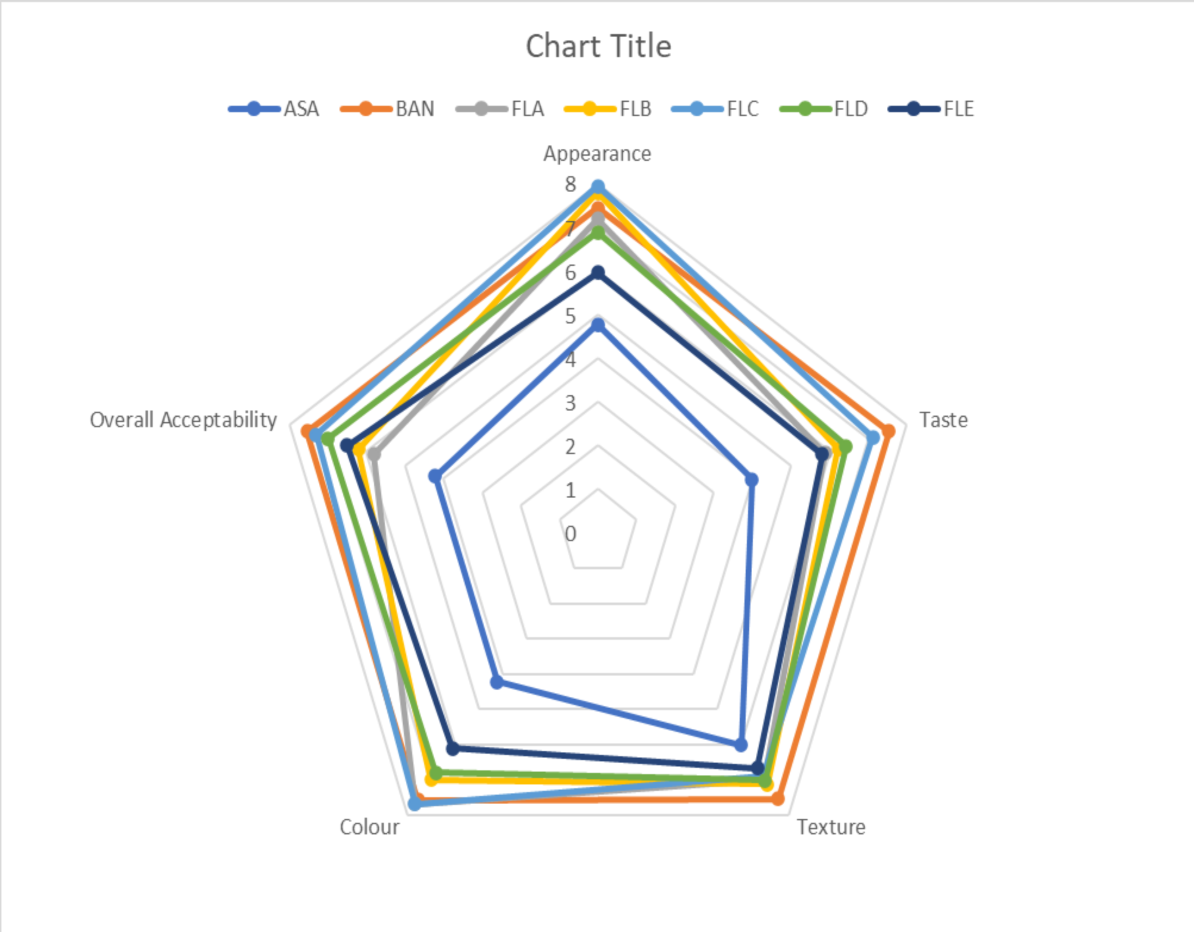

Fig. 3: Radar Plot Showing Sensory Scores for Africa Star Apple-Banana Fruit Leathers

Table 2: Sensory Evaluation of Fruit Leather produced from African Star Apple and Banana blends

Samples	Appearance	Taste	Texture	Colour	Overall acceptability
ASA	4.8±0.23e	4.0±0.02d	6.0±0.21c	4.2±0.07c	4.2±0.08e
BAN	7.5±0.31abc	7.5±0.23a	7.5±0.45a	7.6±0.41a	7.5±0.07a
FLA	7.2±0.11bc	5.9±0.05c	7.0±0.01ab	7.7±0.05a	5.8±0.55d
FLB	7.8±0.52ab	6.2±0.34bc	7.1±0.05ab	7.0±0.03ab	6.2±0.07cd
FLC	8.0±0.09a	7.1±0.11a	6.9±0.23b	7.7±0.09a	7.3±0.15a
FLD	6.9±0.14c	6.4±0.09b	7.0±0.11ab	6.8±0.14b	7.0±0.12ab
FLE	6.0±0.21d	5.8±0.03c	6.7±0.06b	6.1±0.27b	6.5±0.07bc

Values are the means of triplicate determinations ± Standard deviation. Means with the same superscript along a column are not significantly different (p>0.05).
ASA = 100 % African star apple
BAN = 100 % Banana

FLA= 90 % African star apple + 10 % Banana
FLB = 80 % African star apple + 20 % Banana
FLC = 70 % African star apple + 30 % Banana
FLD = 60 % African star apple + 40 % Banana
FLE = 50 % African star apple + 50 % Banana.
This fruit leather offers an alternative consumption method for African Star Apple, helping to reduce its perceived astringency while promoting sustainability and improving post-harvest utilization. To further enhance consumer acceptability, incorporating a naturally sweeter fruit like pineapple could improve flavor, while the use of hydrocolloids may enhance texture. Future research should explore these modifications to optimize product quality and market potential.

REFERENCES

[1] Mintah, B.K., Eliason, A.E., Nsiah, M., Baah, E.M., Hagan, E. and Ofosu, D.B. Consumption of fruits among students: A case of Public University in Ghana. *African Journal of Food, Agriculture, Nutrition and Development,* 12(2), 2012, pp 5979-5993. ISSN: 1684 5374.
[2] Singh, R., Kaushik, R. and Gosewade, S. Bananas as underutilized fruit having huge potential as raw materials for food and non-food processing industries: A brief review. *The Pharmaceutical Innovation Journal*; 7(6), 2018, 574-580.
[3] Chavan, U.D. and Shaik, J.B. Standardization and Preparation of Guava Leather. *International Journal of Advanced Research in Biological Sciences,* 2(11), 2015, pp.102-113.
[4] Amusa, N. A., Ashaya, O. E., and Oladapo, M. O. Biodeterioration of the African star apple (Chrysophyllum albiddum) and the effect on its food value. *African Journal of Biotechnology, 11(3)*, 2005, pp.56-59.
[5] Sukasih, E. and Widayanti, S.M. Physicochemical and Sensory Characteristics of fruit leather from various indonesian local fruits. *IOP Conference Series, Earth and Environmental Science, 1024 012035, 2022.*
[6] Huang, X. and Hsieh, F. Physical Properties, Sensory Attributes, and Consumer Preference of Pear Fruit Leather. *Journal of Food Science,* 70(3), 2005, pp.E177-E186.
[7] Madhav, K. and Parimita. Studies on Development of Tomato Leather Prepared for Geriatric Nutrition, *Journal of Nutrition and Food Sciences,* 6:1, 2016. DOI: 10.4172/2155-9600.1000446
[8] Singh, A., Sonkar, C. and Shingh, S. Studies on development of process and product of plum fruit leather. *International Journal of Food Science and Nutrition*, 4(5), 2019, pp.74 – 79.
[9] Yadav, K.C., Dangal, A., Thapa, S., Rayamajhi, S., Chalise, K., Shiwakoti, L.D., Shiwakoti, R., and Katuwal, N. Nutritional, phytochemicals, and sensory analysis of *Lapsi* (*Choerospondias axillaris*) fruit leather. *International Journal of Food Properties,* 25(1), 2022, pp.960-975, DOI: 10.1080/10942912.2022.2070203.
[10] Mounika, M and Mashewari, K. U. Development and sensory evaluation of value added mixed fruit leather. *International Journal of Chemical Studies*; 7(4), 2019, pp.590-593.
[11] Kashyap, S. and Sharma, N. New insights in the production of fruit leather. *The Pharma Innovation Journal*; 12(5), 2023, pp.1140-1151.
[12] Ruel, M.T., Nicholas, M. and Lisa, S. Patterns and determinants of fruit and vegetable consumption in Sub-Saharan Africa. FAO/WHO workshop on fruits and vegetables for health, 1–3 September, 2004. http://dx.doi.org/10.5772/intechopen.7447249
[13] Ogunlade, A.O. and Oluwafemi, G.I. Production and evaluation of jam produced from plum and African Star apple blends. *Food Research*, 5 (4), 2021, pp.93 – 98
[14] Madusanka, D.B.G., Sarananda, K.H., Mafeendran, T. and Hariharan, G. Development of Tropical Fruit Leather and Quality Evaluation during Storage at Ambient Conditions. *International Symposium on Agriculture and Environment, University of Ruhuna, Sri Lanka. 2017.*
[15] AOAC. Association of Official Analytical Chemists. *Official methods of analysis* (18th ed.). 2005. AOAC International.
[16] Lobato, L.P., Grossmann, M.V.E. and Benassi, M.T. Inulin addition in starch-based dairy desserts: instrumental texture and sensory aspects. *Food Science and Technology International,* 15, 2009, pp.317–323.
[17] Szczesniak, A.S. Texture is a sensory property. *Food Quality and Preference,* 13(4), 2002, pp.215 – 225.
[18] Singh, R., and Anderson, B. The major types of food spoilage: an overview. Understanding Measuring the Shelf-life of Food, 2004, pp.3–23.
[19] Setiaboma, W., Fitriani, V. and Mareta, D.T. Characterization of fruit leather with carrageenan addition with various bananas. *IOP Conference Series, Earth and Environmental Science,* 258 012004, 2018. DOI 10.1088/1755-1315/258/1/012004
[20] Wati, A.T. and Puspasari, D.A. Characteristics of mango fruit leather (*Mangifera indica*) with the addition of lime (*citrus aurantiifolia*) in variation of drying temperature. *Jurnal Pangan dan Agroindustri Vol.11* No.1, 2023, pp.30-36.

[21] Suna, S., Tamer, C.E., Inceday, B., Sinir, G.O. and Copur, O.U. Impact of drying methods on physicochemical and sensory properties of apricot pestil. *India Journal of Tradition Knowledge,* 13(1), 2014, pp.47-55.
[22] Offia-Olua, B. I. and Ekwunife, O. A. Production and evaluation of the physico-chemical and sensory qualities of mixed fruit leather and cakes produced from apple (Musa Pumila), banana (Musa Sapientum), pineapple (Ananas Comosus). *Nigerian Food Journal,* 33, 2015, pp.22–28
[23] Ghimire, R., and Ojha, P. Preparation and physiochemical evaluation of papaya-soy fruit leather. *Golden Gate Journal of Science Technology*, 2016, pp.1–6.
[24] Ofoedu, C.E., Ubbaonu, C.N., Agunwah, I.M., Obi, C.D., Odimegwu, N.E., and Okeke, F.K. Production and comparative evaluation of leather products from pawpaw (*Carica papaya*) and banana (*Musa acuminata)* fruit pulp. *Croatian Journal of Food Science and Technology,* 12 (2), 2020, pp.218-228. DOI: 10.17508/CJFST.2020.12.2.10
[25] Ayalew, G. M., and Emire, S. A. (2020). Formulation and characterization of fruit leather based on Annona muricata L. fruit and Avena sativa flour. Journal of Food Processing and Preservation, 44(1), 2020, pp.: 14284.
[26] Boakye, A.A., Wireko-Manu, F. D., Agbenorhevi, J.K. and Oduro, I. Dietary fibre, ascorbic acid and proximate composition of tropical underutilised fruits. *African Journal of Food Science,* Vol. 8(6), 2014, pp.305-310. DOI: 10.5897/AJFS2014.1165.
[27] Ibeji, C.C. (2011). Effect of Different Processing Methods on the Nutritional Composition of Three Different Cultivars of *Dioscorea bulbifera,* Unpublished B.Sc. Thesis. Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Abia State.
[28] Kurniadi M, Parnanto, N.H.R., Saputri, M.W, Sari, A.M., Indrianingsih, A.W. and Herawati, E.R.N. The effect of kappa-carrageenan and gum Arabic on the production of guava-banana fruit leather. *Journal of Food Science and Technology;* 9(11), 2022, pp.4415-4426.
[29] Mohamed, A.H.A., Ragab, M., Siliha, H.A.I. and Haridy, L.A.M.M.. Physicochemical, microbiological and sensory characteristics of Persimmon fruit leather. *Zagazig Journal of Agricultural Research,* Vol. 45 No. (6A), 2018.
[31] Zhang, Y., Wang, H., Chen, H., Liu, R., Chen, H., Fang, X., Xiao, J., Wu, W., and Gao, H. The crucial evaluation indexes and relative measurement methods of edible value for fresh fruits and vegetables: A review. *Future Postharvest and Food*, 1(2), 224, pp. 222–236. https://doi.org/10.1002/fpf2.12026
[32] Raj, B. and Dash, K.K. Development of Hydrocolloids Incorporated Dragon Fruit Leather by conductive hydro drying: Characterization and Sensory Evaluation. *Food Hydrocolloids for Health*, 2(1), 2022, pp.100086. DOI:10.1016/j.fhfh.2022.100086
[33] Fauziyah, E. Towards Fruit Consumer Preference Leather Attributes of Madurese Exotic Tropical Fruits. International Research Journal of Business Studies, 10(2), 2017, pp.111-122
[34] Xie, D., Liu, X., Zhang, H., Xia, W., Huang, X., Bi, D., and Pan, S. Textural properties and morphology of soy 7S globulin-corn starch (amylose, amylopectin). *International Journal of Food Properties, 20*(10), 2017, pp.197–2205. https://doi.org/ 10.1080/10942912.2016.1233430
[35] Patil, S., Shere, P., Sawate, A. and Mete, B. Effect of hydrocolloids on textural and sensory quality of date-mango leather. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 2017, pp.399–402.
[36] Talay R., Erdogan, U. The Effect of Hydrocolloids on Texture of Fruit Leathers. 3rd International Conference on Advanced Engineering Technologies. 19-21 September 2019 (ICADET)
[37] Fox, P. F., Guinee, T. P., Cogan, T. M., and McSweeney, P. L. Cheese: Structure, rheology and texture. In *Fundamentals of Cheese Science* (2017, pp.475-532). Springer, Boston, MA. doi: 10.1007/978-1-4899-7681-9-14.
[38] Yang, F., Sun X., Hu, J., Honghong C., Xiao, H., Wu, X., Liu, C. and Wang, H. Edible gum addition improves the quality of freeze-dried restructured strawberry blocks, *Food Chemistry*, X(18), 2023, 100702. https://doi.org/10.1016/j.fochx.2023.100702
[39] Raab, C. and Oehler, N. Oregon State University, Extension Service 1-4, 2000. Available on https://ir.library.oregonstate.edu. Accessed on 15th May 2025.