QUALITY EVALUATION OF JUICE BLENDS PRODUCED FROM MANGO, HOG PLUM AND GINGER

.

ABSTRACT

|  |
| --- |
| **This study assessed the quality characteristics of juice blends formulated from mango (*Mangifera indica*), hog plum (*Spondias mombin*), and ginger (*Zingiber officinale*). The objectives were to evaluate the physicochemical properties, nutrient composition, and sensory attributes of the blends. Six formulations with varying ingredient proportions were developed and subjected to comprehensive analyses, including proximate composition, physicochemical parameters, vitamin content, and antinutrient levels. All determinations were performed in triplicate.****The results revealed that the juice blends exhibited favorable nutritional profiles. Protein content ranged from 0.48% to 3.94%, carbohydrate content from 93.45% to 97.90%, and caloric values from 389.85 to 396.49 kcal/100 g. Vitamin composition varied significantly across the samples, with vitamin A ranging from 0.06 to 0.90 mg/100 g and vitamin C from 0.33 to 4.99 mg/100 g. Physicochemical analysis showed pH values between 3.6 and 4.5, total soluble solids (TSS) ranging from 12.00% to 16.00%, and syneresis between 0.00% and 1.35%.****Antinutrient concentrations were within acceptable safety limits, with oxalates ranging from 0.01 to 0.03 mg/100 g, phytates from 0.02 to 0.04 mg/100 g, and tannins from 0.19 to 0.29 mg/100 g. Sensory evaluation, using a 9-point hedonic scale, identified Sample B (90% mango, 5% hog plum, 5% ginger) as the most preferred, with an overall acceptability score of 8.10.****These findings highlight the potential of mango, hog plum, and ginger-based blends as nutrient-dense and organoleptically acceptable alternatives to synthetic beverages. Furthermore, the results contribute to sustainable food systems by offering a value-added approach to post-harvest utilization.** |

1. INTRODUCTION

Fruits constitute an essential component of the daily human diet, providing water, fiber, proteins, fats (notably from sources such as olives, avocados, and nuts), organic acids, and digestible carbohydrates (Dunlop et al., 2024).

Mango (*Mangifera indica*) belongs to the genus *Mangifera* within the family *Anacardiaceae*, which comprises several species yielding edible fruits. The mango variety employed in this study, locally referred to as “Broken” or “Brokin”, is commonly consumed by the Tiv ethnic group in Benue State, Nigeria. Hog plum (*Spondias mombin*), also known as yellow mombin, is a member of the *Anacardiaceae* family and is notable for its high concentrations of vitamins B1 and C. In addition to its vitamin content, hog plum provides essential minerals such as sodium and calcium, which are typically present in low concentrations in most fruits. Notably, its phosphorus content ranks among the highest compared to other tropical fruits, similar to levels found in *Spondias purpurea* (ceriguela), *Caryocar brasiliense* (pequi), and passion fruit (*Prudencio et al.*, 2024). Furthermore, *Cazzola et al.* (2020) reported that hog plum also possesses a high magnesium content. Ginger (*Zingiber officinale*), an underground rhizome of the herbaceous perennial species belonging to the *Zingiberaceae* family, is indigenous to various tropical and subtropical regions (*Ayustaningwarno et al.*, 2024). Ginger is commonly utilized in the form of whole juice extract or as an ingredient in beverages following blending (*Nguyen et al.*, 2023).

In Nigeria, postharvest losses of fruits and vegetables are estimated to account for 35–45% of annual production (*FAOSTAT*, 2017), severely impacting farmers' livelihoods. Despite their nutritional and medicinal significance, mango and hog plum have remained underutilized, potentially due to the limited scientific research conducted on these fruits. Recent findings reveal that postharvest losses of mangoes in Nigeria may reach up to 50–60% of total production (*Adepoju et al.*, 2022). Although data specific to hog plum are scarce, tropical fruits generally experience postharvest losses ranging from 30–50% (*Oryema et al.*, 2015). These losses are largely attributed to poor handling practices, inadequate storage infrastructure, and transportation challenges in rural communities. The growing demand for healthy and natural food products has increased consumer interest in exotic fruits, offering new opportunities for product development and innovation (*Leja & Czaczyk*, 2015). In line with this trend, fruit-based beverages with novel flavors and aromas are increasingly being developed and scientifically analyzed for their chemical, physicochemical, and sensory properties. Citrus fruit blends, such as orange–grapefruit and tangerine–grapefruit, are common examples of commercially successful mixed juices.

This study focused on the production and quality evaluation of juice blends prepared from mango, hog plum, and ginger obtained from Benue State, Nigeria. The juice blends were analyzed for proximate composition, physicochemical parameters, and nutritional properties.

Juice blends incorporating mango, hog plum, and ginger serve as rich sources of essential nutrients and bioactive compounds beneficial to human health. Mango is particularly rich in vitamins A and C, polyphenols, and dietary fiber, contributing to immune support, visual health, and digestive well-being (*Ma et al.*, 2021). Hog plum is a significant source of vitamin C, flavonoids, and carotenoids, all of which exhibit strong antioxidant properties that help alleviate oxidative stress and inflammation (*Ademiluyi et al.*, 2016). Ginger is characterized by the presence of bioactive compounds such as gingerol and shogaol, which have demonstrated anti-inflammatory, digestive, and metabolic health benefits, including improved insulin sensitivity and gastrointestinal function (*Dugasani et al.*, 2010).

The regular consumption of these juice blends may contribute to cardiovascular health by reducing oxidative stress and modulating lipid metabolism. The combined antioxidant and anti-inflammatory effects of these components could reduce the risk of chronic diseases such as diabetes, obesity, and hypertension (*Gupta et al.*, 2020). Furthermore, the dietary fiber and polyphenols present in the blends may enhance gut microbiota and improve digestive health. The synergy of vitamins, minerals, and phytochemicals found in mango, hog plum, and ginger positions this juice blend as a functional beverage with considerable health-promoting potential.

The market potential and economic viability of these juice blends are promising, owing to the increasing demand for functional beverages. Mango is widely accepted due to its palatable flavor and nutritional value, hog plum offers high vitamin C content and antioxidant capacity, while ginger contributes bioactive compounds with anti-inflammatory and digestive benefits (*Eskin & Tamir*, 2018). The combination of these ingredients results in a unique beverage with potential health benefits that appeal to health-conscious consumers. Market trends predict that the global functional beverage sector will grow at a compound annual growth rate (CAGR) of 8.6% between 2023 and 2030, driven by consumer demand for natural and nutrient-rich products (*Grand View Research*, 2023).

Economically, the production of mango, hog plum, and ginger juice blends is feasible and sustainable in tropical regions where these raw materials are abundant. The use of locally available ingredients reduces production costs and promotes supply chain sustainability. Additionally, the product may be positioned as a premium functional beverage, targeting niche markets such as wellness-focused consumers and those seeking immune-boosting drinks. Both small-scale and large-scale production are viable, with added value achievable through fortification, innovative packaging, and strategic marketing that highlights the product's health benefits. Consumer willingness to pay for functional beverages is often driven by perceived health advantages, effective branding, and taste attributes (*Kumar & Smith*, 2021), suggesting strong market prospects for this juice blend.

2. material and methods

**2.0 Sources of Raw Materials**

Freshly ripened mango (*Mangifera indica*) fruits were sourced from a local market in Ugbema, Buruku Local Government Area, Benue State, Nigeria. Mature hog plum (*Spondias mombin*) fruits were obtained from Yandev, located in Gboko Local Government Area, Benue State, Nigeria. Ginger (*Zingiber officinale*) rhizomes were purchased from the Wurukum market in Makurdi, Benue State, Nigeria. All the collected raw materials were subsequently transported to the Centre for Food Technology and Research (CEFTER) Food Laboratory, Department of Chemistry, Benue State University (BSU), for further processing and analysis.

**2.1 Preparation of Hog Plum Juice**

Juice extraction from hog plum (*Spondias mombin*) fruits was conducted following the method described by Ishak et al. (2023), with minor modifications as illustrated in Figure 1. The fruits were first sorted to eliminate extraneous materials and visibly deteriorated samples. Subsequently, the selected fruits were thoroughly washed under clean running water in the laboratory. The cleaned fruits were then processed using an electric juice extractor (Binatone Juicer 2S+P, 500W, stainless steel, JE-580, UK). The resulting juice was immediately bottled in clean, sterile plastic bottles and subjected to pasteurization at 60 °C for 10 minutes. After pasteurization, the juice was cooled to ambient temperature and stored in a refrigerator at 4 °C until further analysis.

 Fresh hog plum fruits

 Sorting

 Portable table water Washing Dirty water

 Electric juice extractor Juicing juiceless pulps

 Bottling

 Pasteurization at 60oC for 10 min

 Refrigeration

 Hog plum juice

**Figure 1; Flow chart for the preparation of hog plum fruits juice**

**2.2 Preparation of mango Juice.**

The method employed for mango juice extraction followed the procedure described by Adeola and Ogunleye (2020). Fully ripe and fresh mango (*Mangifera indica*) fruits were carefully sorted to eliminate defective samples prior to juice extraction (Figure 2). The selected fruits were thoroughly washed with potable water to remove dirt and surface contaminants. Subsequently, the mangoes were manually peeled using a stainless-steel knife, then sliced into small pieces to facilitate juice extraction. The prepared mango slices were processed using an electric juice extractor (Binatone Juicer 2S+P, 500W, Stainless Steel JE-580, UK). Following extraction, the juice was pasteurized at 60 °C for 10 minutes in sealed bottles, subsequently cooled to ambient temperature, and stored under refrigerated conditions (4 ± 1 °C) pending further analysis.

Fresh mango fruits

Sorting

 Portable table water Washing Dirty water

 Peeling

 Electric juice extractor Juicing Juiceless pulps

Bottling

Pasteurization at 60oC for 10 min

 Refrigeration

 Mango juice

**Figure 2; Flow chart for the preparation of Mango fruits juice**

**2.3 Preparation of Ginger Juice.**

The method employed for ginger juice extraction was adapted from the procedure described by Ahammed et al. (2018) and is illustrated in Figure 3. Fresh ginger rhizomes, free from visible defects and rot, were carefully selected and washed thoroughly under running potable water. The cleaned rhizomes were subsequently peeled using a stainless-steel knife and sliced into smaller pieces to facilitate juice extraction. An electric juice extractor (Binatone Juicer 2S+P, 500W, stainless steel, Model JE-580, UK) was utilized to obtain the ginger juice. The extracted juice was immediately dispensed into clean, sterilized plastic bottles, followed by pasteurization at 60 °C for 10 minutes. After pasteurization, the juice was allowed to cool to ambient temperature and subsequently stored under refrigerated conditions until further analysis.

Fresh ginger rhizome

 Sorting

Portable table water Washing Dirty water

Stainless steel knife Peeling

 Slicing

Electric juice extractor Juicing Juiceless pulps

 Bottling

 Pasteurization at 60oc for 10 min

 Refrigeration

Ginger juice

**Figure 3; Flow chart for preparation of ginger juice.**

**2.4 Formulation of the Fruit Juice Blend/Mix**

Juice extracts obtained from mango, hog plum, and ginger were systematically combined to formulate six (6) different blended juice samples, as presented in Table 1.

**Table 1 Juice mix formulation**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample** | **Mango (%)** | **Hog plum (%)** | **Ginger (%)** |
| **A** | 100 | 0 | 0 |
| **B** | 90 | 5 | 5 |
| **C** | 80 | 15 | 5 |
| **D** | 70 | 25 | 5 |
| **E****F** | 6050 | 3545 | 55 |

Prepared mango juice Prepared hog plum juice Prepared ginger juice

 Mixing

 Bottling

Pasteurization 60 °C for 10 mins

 Storage

**Figure 4: Flow chart for juice mix preparation**

**2.5 Quality Measurements**

**2.5.1 Proximate analysis**

The method described by Association of Official Analytical Chemists (AOAC, 2022) and modified by Nascimento et al., (2023) was used to evaluate the proximate composition of the juice blends from mango, hog plum and ginger.

***2.5.1.1 Determination of Moisture Content***

The moisture content was determined by drying the juice samples in an oven at 110°C until a constant weight was achieved. The weight difference before and after drying represented the moisture content. This method, along with the formula for calculating moisture content based on the weight difference before and after drying, was similarly adopted by Adepoju et al. (2019), who determined the moisture content of baobab fruit pulp using oven drying at 105–110°C until a constant weight was obtained.

Formular for moisture content

Moisture content (%) = $\frac{Initial weight-Final weight }{Initial weight}$ ×100 Eq 2.1

***2.5.1.2 Determination of Fats Content***

Fat content was determined using the Soxhlet extraction method as adopted by Fasogbon et al. (2020). After several hours of extraction using hexane as the solvent, the crude fat percentage was calculated based on the weight difference before and after extraction.

Formular for Fats content

Fats content (%) = $\frac{Weight of Fat Extracted}{ Weight of sample }×100$ Eq 2.2

***2.5.1.3 Determination of Fiber Content***

Fibre content was determined by acid and alkaline digestion as adopted by Fasogbon et al. (2020). The juice samples were digested with sulfuric acid and potassium hydroxide, followed by filtration and drying. The residue was then ashed at 550°C, and the fibre content was calculated from the weight of the residue.

Formular for moisture content

Fiber content (%) = $\frac{Weight of Residue after Ashing}{ Weight of defatted sample }×100$ Eq 2.3

***2.5.1.4 Determination of Protein Content***

Protein content was determined using the Kjeldahl method as adopted by Latimer (2023). After digestion with sulfuric acid, the nitrogen content was measured and multiplied by a conversion factor of 6.25.

Formular for protein content

Protein Content (%) = Nitrogen Content×6.25 Eq 2.4

***2.5.1.5 Determination of Carbohydrate Content***

Carbohydrate content was determined by difference as adopted by Fasogbon et al. (2020). It was calculated by subtracting the sum of ash, protein, fat, and crude fibre contents from 100, as shown in the equation 2.5 below:

Formular for carbohydrate content

Carbohydrate Content (%) =100 − (Moisture+Crude Fat+Crude Fiber+Protein+Ash) Eq 2.5

**2.5.2 Physiochemical analysis**

Physicochemical properties of the pasteurized juice samples, including total soluble solids, titratable acidity, pH, and syneresis, were determined following standard methods (AOAC, 2019; Ranganna, 2019; IFT, 2020). All analyses were carried out on the same day of juice extraction and pasteurization to maintain sample integrity. One bottle was taken from each sample for the analyses as described below.

***2.5.2.1Titratable acidity test***

In each fruit juice sample, titratable acidity were analysed using 0.1 N NaOH solution as described by AOAC (2022). To this end, 5 mL of the mixed juice sample were diluted to 50 mL using distilled water and then poured into a 250 mL volumetric flask. Three drops of phenolphthalein indicator were added and the sample titrated with 0.1 N NaOH solution until an endpoint of pink colour were observed. Titratable acidity was calculated as shown in Equation (2.6).

100 N acid$=\frac{NNaOH×VNaOH×Facid }{Vjuice}×100$ Eq (2.6)

Where: NNaOH is the normality of NaOH used (g L-1), *V*NaOH is the volume of NaOH solution consumed (L), *F*acid is an equivalent factor of the acid in the fruit juice sample = 0.067 equivalent weight of malic acid, and *V*juice is the volume of the juice sample (L).

***2.5.2.2 Total Soluble Solids and pH Test***

Total soluble solids (TSS) in the mixed fruit juice samples were measured as °Brix using a digital pocket refractometer (ATAGO, Japan) with TSS ranging between 0 and 88 °Brix and a precision of 0.1 °Brix. The refractometer was tested for distilled water before each TSS measurement. The pH of the juice samples was measured as described by Potǎrniche *et al*. (2023). It involved using a digital pH meter (HI98129, Hanna Instruments Inc., Limena, Italy) with a precision of ±0.01. Calibration of the pH meter was carried out using standard buffer solutions (pH 4.01 and pH 7.00) prior to each measurement to ensure accuracy.

***3.7.2.3 Determination of pH.***

pH was determined in ten milliliters of the juice dispensed into a beaker after calibration with phosphate buffer of PH 4.0 and 7.0 as described by Adepoju *et al.,* (2021).

***2.5.2.4 Determination of syneresis***

Syneresis is an important physical test of juice quality. Water separation from juice samples was performed according to the method described by Yasmin *et al.,* (2022) with some modifications. 10 mL of juice samples was spread in a thin layer to cover the Whatman No.1 filter paper. The juice was filtered for 15 minutes. Then, the filtrate was collected, and the weight was recorded. The percentage syneresis was calculated using Equation 2.7:

Syneresis (%) = $\frac{Wt. of filtrate}{Total wt. of juice}$ × 100 Eq (2.7)

**2.3 Vitamin Analysis**

**2.3.1 Betacarotene**

Betacarotene is a provitamin A carotenoid, meaning it's a precursor that the body can convert into Vitamin A. Betacarotene is commonly measured in Vitamin A research because it is one of the main dietary sources of provitamin A, which can then be converted to active Vitamin A in the body. Vitamin A was determined by the calorimetric method described by García-Romero et al. (2023) and Khalil & Hassan (2022). Approximately 1 g of the sample was mixed with 30 ml of absolute alcohol and 3 ml of 5 % KOH solution was added to it and boiled for 30 min under reflux. After washing the sample with distilled water, provitamin A was extracted with 150 ml of diethyl ether. The extract was evaporated to dryness at low temperature and then dissolved in 10 ml of isopropyl alcohol. Exactly 1 ml of standard Vitamin A solution was prepared and that of the dissolved extract was transferred to separate cuvettes and their respective absorbance were read in a spectrophotometer at 325 nm with a reagent blank at zero. Betacarotene was then calculated using Equation 2.8

$Conc. of vit A in sample=\frac{Absorbance of sample}{Absorbance of standard} X conc. of standard $ Eq (2.8)

**2.3.2 Determination of thiamine (VitaminB1)**

The spectrophotometric method, described by Hamad and Hassan (2023), was used for determination of the B Vitamins. Exactly 5ml of each sample was homogenized with 50 ml of 1M ethanolic sodium hydroxide and the homogenate was filtered to obtain the filtrate to be used for the analysis. An aliquot (10 ml) of the filtrate was treated with equal volume of 0.1M K2Cr2O7 solution in a flask. Standard thiamine solution was prepared and diluted to a chosen concentration (0.5). An aliquot of the standard thiamine solution was also treated with 10 ml of the dichromate solution (K2Cr2O7) in a separate flask while a reagent blank was set up by treating l0 ml of the ethanolic sodium hydroxide with the potassium dichromate solution. The absorbance of the sample and the standard solutions was measured in a spectrophotometer at a wavelength of 360 nm with the reagent blank to be used to calibrate the instrument at zero. The thiamine content was calculated using Equation 2.9.

$Thiamine\frac{mg}{100}=\frac{100}{W}X\frac{Au}{As}X\frac{C}{1}X\frac{Vf}{Va}X D$ Eq(2.9)

where:

W - Weight of sample analysed

Au = Absorbance of sample

As = Absorbance of standard solution

C = Concentration (mg/ml) of standard solution

Vf= Total volume of filtrate

Va = Volume of filtrate analysed

D = Dilution factor where applicable

**2.3.3 Determination of riboflavin (Vitamin B2)**

Riboflavin (Vitamin B2) content was determined spectrophotometrically as described by Omodara et al. (2021). Approximately 1 ml of sample was weighed into a conical flask and was dissolved with 100 ml of deionized water. This was shaken thoroughly and heated for 5 min and allowed to cool and then filtered. The filtrate was poured into cuvettes and their respective wavelengths for the vitamins set to read the absorbance using spectrophotometer.

Vitamin B1 = 261 nm

Vitamin B2 = 242 nm

Vitamin conc. (mg/%) = A x Df x Vol. of cuvette

Where:

A = Absorbance

E = Extinction co-efficient = 25 for B1 and B2

Df = Dilution factor

**2.3.4 Determination of niacin (Vitamin B3)**

Vitamin B3 content was determined spectrophotometrically as adopted by Omodara et al. (2021). Approximately 1 mL of the juice sample was weighed into a conical flask and dissolved in 100 mL of deionized water. The mixture was shaken thoroughly, heated for 5 minutes, and allowed to cool before filtration. The filtrate was collected, and aliquots were transferred into cuvettes. The respective wavelengths specific to each vitamin were set, and the absorbance was read using a UV-visible spectrophotometer

$Niacin\frac{mg}{100}=\frac{100}{W}X\frac{Au}{As}X\frac{C}{1}X\frac{Vf}{Va}X D $ Eq (2.10)

where;
W - Weight of sample analysed

Au = Absorbance of sample

As= Absorbance of standard solution

C = Concentration (mg/ml) of standard solution

Vf = Total volume of filtrate

Va = Volume of filtrate analysed

D = Dilution factor where applicable

C =Concentration of standard solution

**2.3.5 Determination of ascorbic acid (Vitamin C)**

The method described by Annor *et al.,* (2021) was used. Exactly 10 ml of the sample was extracted with 50ml EDTA/TCA (50g in 50 ml of water) extracting Solution for I hour and filtered through a Whatman filter paper into a 50 ml volumetric flask and made up to the mark with the extracting solution. Twenty (20 ml) of the-extract was pipetted into a 250 ml conical flask and 10 ml of 30 % KI was added and also 50 ml of distilled water added. This was followed by 2 mL of 1 % starch indicator. This was titrated against 0.01 mL CuSO4 solution to a dark end point.

$Vit.C \frac{mg}{100g} =0.88 X\frac{100}{5}X\frac{Vf}{20}X\frac{T}{1} $ Eq (2.11)

Where:

Vf = Volume of extract

T = Sample titre – blank titre.

**2.4 Anti-nutritional Properties**

The following anti-nutrients were analysed in the mango, hog plum and ginger juice extracts.

**2.4.1 Oxalates**

Oxalate were determined using Dye method (Wang et al. 2023). Exactly 2.5 g of the sample were extracted with dilute HCl, 5 mL of concentrated ammonia and precipitated with CaCl2 as calcium oxalate. The precipitate is washed with 20 mL of 25 % H2SO4 and dissolved in hot water before titrating with 0.05 N KMnO4 to determine the concentration of oxalate.

**2.4.2 Tannins**

Tannins were determined using Burn method (Wilson *et al.,* 2020), with 5g of the dried sample treated with 50ml methanol and kept for 24 hours before filtration. 5mL of freshly prepared vanalin hydrochloric acid is added and the solution is allowed to stand for 20 minutes for color development. The absorbance is measured at 550 nm using spectronic 20 and the machine value is used in calculating the tannin content.

**2.4.3 Phytate**

0.2 g of the sample were weighed into 250 mL conical flask. It were soaked in 100 mL of 20 % concentrated HCl for 3 hours, the sample will then be filtered 50 mL of the filtrate were placed in a 250 mL beaker and 100 mL distilled water added to the sample. Then 10 mL of 0.3 % ammonium thiocyanate solution were added as indicator and titrated with standard Fe3Cl+ (iron(III) chloride) solution which contains 0.00195 g iron per 1 mL (Wilson *et al.,* 2020).

Phytic acid = $\frac{titre value ×0.00195×1.19×100}{2}$ Eq(2.12)

**2.5 Sensory Evaluation Test**

Sensory acceptance of all the mixed juice samples were evaluated by 20 panellists of both genders (aged from 18 years and above) who were randomly selected students of CEFTER Makurdi. The panelist team was trained before assessing the sensory acceptance of the mixed juice samples, they evaluated for colour, flavour, sweetness, and overall acceptability. The sensory analysis was based on a 9-point hedonic scale following the method described by (Sanz-Maldonado *et al.,* 2023). The hedonic scoring scale was arranged such that: 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. Organoleptic acceptance was carried out using the mixed juice samples stored at 4 °C. The panellists were randomly served with 30 mL of each juice mix in transparent plastic cups for evaluation. They were asked to drink water before tasting the next sample. Sensory acceptance assessment were performed at day one of production.

**2.6 Data Analysis**

Data obtained from the study were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) version 26 software, as described by Field (2020).. Mean and standard deviation was calculated where appropriate. Analysis of variance (one way ANOVA) was used to determine the treatment that was different from the others in the various parameters tested; differences were considered at 95% (*P*>0.05) significant. Means were separated using the Duncan Multiple Range Test.

3 results and discussion

3.1 Results

3.1.1Proximate composition of juice and their blends.

The result of the proximate composition of the individual juice samples and their blends is shown on table 2. The moisture content ranged from 86.87 to 88.87 %, ash content from 0.47 to 1.11%, protein content from 1.52 to 3.35 %, fat content from 0.01 to 0.02 %, fibre content from 1.23 to 2.13 % and carbohydrate content from 5.03 to 9.05%.

Table 2 proximate composition of juice and their blends



*Values within the same column with the same superscripts are not significantly different (P>0.05)*

*A=100% Mango juice, 0% Hog plum juice and 0% Ginger juice*

*B=90% Mango juice, 5% Hog plum juice and 5% Ginger juice*

*C=80% Mango juice, 15% Hog plum juice and 5% Ginger juice*

*D=70% Mango juice, 25% Hog plum juice and 5% Ginger juice*

*E=60% Mango juice, 35% Hog plum juice and 5% Ginger juice*

*F=50% Mango juice, 45% Hog plum juice and 5% Ginger juice*

*GG: Ginger juice*

*HP: Hog plum*

3.1.2 Vitamin content of juice samples blends

Table 3 shows the results obtained for the vitamins present in the juice samples and their blends. Vitamin a ranged from 0.63 to 0.83 mg/100g, vitamin c from 3.35 to 4.40 mg/100g, vitamin b1 from 0.56 to 0.93 mg/100g, vitamin b2 from 0.67 to 0.84 mg/100g and vitamin b3 from 0.12 to 0.19 mg/100 g.

Table 3 vitamin content of the juice blends



*Values within the same column with the same superscripts are not significantly different (P>0.05)*

*A=100% Mango juice, 0% Hog plum juice and 0% Ginger juice*

*B=90% Mango juice, 5% Hog plum juice and 5% Ginger juice*

*C=80% Mango juice, 15% Hog plum juice and 5% Ginger juice*

*D=70% Mango juice, 25% Hog plum juice and 5% Ginger juice*

*E=60% Mango juice, 35% Hog plum juice and 5% Ginger juice*

*F=50% Mango juice, 45% Hog plum juice and 5% Ginger juice*

*GG: Ginger juice*

*HP: Hog plum*

3.1.3 Physicochemical analysis of juice blends

The result of the physicochemical composition of the individual juice samples and their blends is shown on table 4 below. The PH ranged from 3.6 to 4.5, TTA ranged from 0.44 to 0.61 °brix, TSS from 0.08 to 16.00 %, syneresis from 0.00 to 16.00.

Table 4 Physicochemical analysis of juice blends



*Values within the same column with the same superscripts are not significantly different (P>0.05)*

*A=100% Mango juice, 0% Hog plum juice and 0% Ginger juice*

*B=90% Mango juice, 5% Hog plum juice and 5% Ginger juice*

*C=80% Mango juice, 15% Hog plum juice and 5% Ginger juice*

*D=70% Mango juice, 25% Hog plum juice and 5% Ginger juice*

*E=60% Mango juice, 35% Hog plum juice and 5% Ginger juice*

*F=50% Mango juice, 45% Hog plum juice and 5% Ginger juice*

*GG: Ginger juice*

*HP: Hog plum*

3.1.4 Antinutrient content of juice blends

Table 5 shows the results of the antinutrient present in mango, hog plum and ginger juice together with their blends before pasteurization. Results showed there was significant difference (p <0.05) in the oxalate, phytate and tannins concentration among the samples. Oxalates ranged from 0.01 to 0.03 mg/100g, phytates ranged from 0.02 to 0.04 mg/100g and tannins from 0.19 to 0.29 mg/100g.

**Table 5 Antinutrient content of juice samples blends**. 

*Values within the same column with the same superscripts are not significantly different (P>0.05)*

*A=100% Mango juice, 0% Hog plum juice and 0% Ginger juice*

*B=90% Mango juice, 5% Hog plum juice and 5% Ginger juice*

*C=80% Mango juice, 15% Hog plum juice and 5% Ginger juice*

*D=70% Mango juice, 25% Hog plum juice and 5% Ginger juice*

*E=60% Mango juice, 35% Hog plum juice and 5% Ginger juice*

*F=50% Mango juice, 45% Hog plum juice and 5% Ginger juice*

*GG: Ginger juice*

*HP: Hog plum*

3.1.5 Sensory Evaluation of the Juice

In the sensory evaluation, the overall acceptability of the various samples was assessed based on sensory scores for color, aroma, texture, tartness sweetness. The colour ranged from 4.00 to 7.40, aroma from 4.45 to 7.00, texture from 4.55 to 7.90, tartness from 4.45 to 7.00, sweetness from 4.60 to 7.50 and the overall acceptability from 4.58 to 8.10. There was a significant difference among all parameters. The results are presented on Table 6.

Table 6 Sensory evaluation of the juice blends

 

*Values within the same column with the same superscripts are not significantly different (P>0.05)*

*A=100% Mango juice, 0% Hog plum juice and 0% Ginger juice*

*B=90% Mango juice, 5% Hog plum juice and 5% Ginger juice*

*C=80% Mango juice, 15% Hog plum juice and 5% Ginger juice*

*D=70% Mango juice, 25% Hog plum juice and 5% Ginger juice*

*E=60% Mango juice, 35% Hog plum juice and 5% Ginger juice*

*F=50% Mango juice, 45% Hog plum juice and 5% Ginger juice*

3.2 Discussion

**3.2.1 Proximate composition of juice blends**

The moisture content of the juice blends ranged from 86.87% in Sample D to 88.67% in Sample F. The highest moisture content was recorded in Sample F, formulated with 50% mango juice, 45% hog plum juice, and 5% ginger juice. This observation is consistent with the findings of Ohwesiri et al. (2016). A progressive increase in moisture content was observed from Samples A to F, corresponding to the increasing proportion of hog plum juice in the blends. The measured moisture contents fall within the acceptable range of 80–95% reported for fruit and vegetable juices (*Kumar et al.*, 2023). Elevated moisture content is generally indicative of freshness but may also enhance susceptibility to microbial spoilage, as highlighted by Fasuan et al. (2022).

Ash content exhibited a significant increase from 0.47% in Sample A to 1.11% in Sample F as the proportion of hog plum juice increased. This suggests that hog plum contributes a higher mineral content relative to mango and ginger. The observed ash content (0.47–1.11%) is comparable to the range of 0.55–1.25% previously reported by Ibrahim et al. (2019) for tropical fruit juice blends, although slightly lower than the 0.68–1.98% range observed by Kumar et al. (2022) in mixed fruit beverage formulations.

Protein content varied significantly among the samples, ranging from 1.52% to 3.35%. The highest protein content was observed in blends with elevated ginger concentrations, indicating ginger’s superior protein contribution compared to mango and hog plum. These values exceed those reported by Ani and Abel (2018) for *Citrus maxima* juice (0.42–1.76%), suggesting a potential nutritional advantage of these juice blends due to their higher protein content.

The fat content across the juice blends was generally low, ranging from 0.01% to 0.14%, with the highest value recorded in Sample GG (100% mango juice). This range is lower than the 0.83% reported by Ani and Abel (2018) for *Citrus maxima* juice but is within the range of 0.14–0.47% as reported by Masresha et al. (2020) for other fruit juice blends.

Fibre content showed notable variation across the samples, ranging from 1.17% in Sample HP to 2.25% in Sample GG. A positive correlation was observed between fibre content and increasing ginger proportion, confirming ginger’s higher dietary fibre contribution. These values are considerably higher than the 0.32–0.58% reported by Deepa et al. (2017) but remain lower than the range of 2.56–6.53% documented by Olaoye et al. (2021) in studies involving other fruit juice blends.

Carbohydrate content ranged from 5.03% in Sample F to 9.05% in Sample A, with a decreasing trend as the proportion of mango juice declined. This suggests that mango contributes a higher carbohydrate content relative to hog plum and ginger. This pattern is consistent with the observed energy values, although specific energy values were not provided in this section. The carbohydrate levels reported in this study are lower than those recorded by Fasuan et al. (2022) for certain tropical fruit juice blends, which ranged from 13.26% to 14.98%.

**3.2.2 Vitamin content of juice blends**

The vitamin A content of the juice blends ranged from 0.06 mg/100 g in the pure mango juice (Sample GG; 100% mango) to 0.83 mg/100 g in Sample F (50% mango, 45% hog plum, 5% ginger). Notably, the 100% mango juice exhibited the lowest vitamin A content, whereas blends containing hog plum showed significantly higher levels. This observation suggests that hog plum is a substantial contributor to the vitamin A content in the blends. A progressive increase in vitamin A content was observed from Samples A to F, corresponding to increasing proportions of hog plum. The recorded range exceeds the 0.02–0.45 mg/100 g reported by Adepoju and Oyewole (2018) for similar fruit-based beverages, indicating that the mango–hog plum blends formulated in this study may serve as a richer source of vitamin A.

Vitamin C content varied from 0.33 mg/100 g in the pure mango juice (Sample GG) to 4.40 mg/100 g in Sample F. A clear trend of increasing vitamin C content was observed as the proportion of hog plum increased within the blends. This range is considerably higher than the 0.01–0.12 mg/mL reported by Tiencheu et al. (2021) for comparable beverages, suggesting that the mango–hog plum–ginger blends could serve as superior sources of vitamin C.

Vitamin B1 (thiamine) content ranged from 0.05 mg/100 g in the pure mango juice (Sample GG) to 0.93 mg/100 g in Samples E and F, both characterized by higher hog plum proportions. The positive correlation between thiamine content and hog plum concentration indicates that hog plum contributes more significantly to vitamin B1 content than mango. Notably, the highest thiamine levels (0.93 mg/100 g) exceeded the 0.55 mg/100 g previously reported by Ani and Abel (2018) for *Citrus maxima* juice.

Vitamin B2 (riboflavin) content varied between 0.07 mg/100 g (Sample GG) and 0.84 mg/100 g (Sample F). Similar to other vitamins, riboflavin levels increased progressively with higher hog plum concentrations, although this trend slightly deviated from earlier references suggesting that mango possessed higher B2 concentrations.

Vitamin B3 (niacin) content ranged from 0.02 mg/100 g (Sample GG) to 0.19 mg/100 g (Sample F), with a consistent increase observed as hog plum proportions increased. However, these values were significantly lower than the 14.42 mg/100 g reported by Ani and Abel (2018) for *Citrus maxima* juice. Despite this, the relative increase attributable to hog plum remains noteworthy.

Overall, the results indicate that the incorporation of hog plum and ginger into mango juice substantially enhanced the vitamin composition of the blends across all measured vitamins. The formulation containing 50% mango, 45% hog plum, and 5% ginger (Sample F) consistently exhibited the highest vitamin concentrations, suggesting that this blend offers the most nutritionally balanced profile among the samples evaluated.

**3.2.3 Physicochemical analysis of juice blends**

The pH values of the blended juice samples (A to F) ranged from 3.6 to 4.5, with a consistent decline observed as the proportion of hog plum juice increased. This inverse relationship between pH and hog plum concentration indicates that hog plum significantly contributes to the acidity of the blends. These findings are consistent with those reported by Rahman et al. (2019), who documented pH values between 3.8 and 4.2 for different mango cultivars. However, the broader pH range observed in the present study is likely attributable to the inclusion of hog plum, recognized for its high organic acid content. The pH values obtained are critical for ensuring microbial safety and modulating enzymatic activity in fruit-based beverages. According to Keerthirathne et al. (2019), fruit juices with pH values below 4.6 inhibit the proliferation of most pathogenic bacteria, suggesting that these blends may possess inherent shelf-stability without the need for intensive preservation measures.

The total titratable acidity of the juice blends varied from 0.44% to 0.61%, exhibiting a proportional increase with the rising concentration of hog plum juice. This trend further supports the role of hog plum in enhancing the acidity of the blends. Compared to the TTA values reported by Curi et al. (2017) for mango pulp (0.35% to 0.45% citric acid equivalent), the values obtained in this study were relatively higher, which is consistent with the acidic nature of hog plum. Elevated TTA levels are known to contribute to enhanced flavor complexity and may also improve microbial stability, as supported by Zhang et al. (2019) in their study on mixed fruit juice formulations.

The TSS content across the juice blends ranged from 12.00% to 16.00%, showing an overall increasing trend with higher hog plum proportions. These results are comparable to the findings of Hossain et al. (2023), who reported TSS values between 14.5% and 17.2% in mango-based functional beverages. The observed variation in TSS across the samples indicates differential sugar content, which directly influences sweetness perception. As highlighted by Singh and Sharma (2023), TSS is a key parameter affecting not only sensory attributes but also the osmotic balance and microbial resistance of fruit juices. The relatively higher TSS observed in samples with greater hog plum content may be due to the presence of additional soluble solids such as pectin and organic acids contributed by the hog plum.

Syneresis values among the juice blends ranged from 0.00% to 1.35%, with sample E exhibiting the highest value. This variation suggests that the colloidal stability of the blends is influenced by the specific compositional ratios of the constituent fruits. These findings align with those of Hossain et al. (2016), who reported on the physicochemical and sensory changes in mixed fruit juices during storage and identified syneresis as a critical stability factor. The elevated syneresis observed in some samples may indicate potential instability issues that could be mitigated by the incorporation of stabilizers or the application of homogenization techniques. As described by Hassan et al. (2022), factors such as pectin content, pH, and processing methods significantly influence syneresis behavior in fruit-based beverages.

The physicochemical characteristics of the mango, hog plum, and ginger juice blends exhibit both congruencies and deviations when compared to existing literature on fruit juices. The trends observed in pH and TTA conform to general expectations for fruit-based beverages, consistent with findings by Ahmed et al. (2020) on multi-fruit juice blends. However, the distinctive influence of hog plum, particularly on acidity and soluble solid content, resulted in a unique physicochemical profile not commonly reported. The elevated TSS values observed surpass typical values for single-fruit juices and align with those reported by Egbuta and Chima (2022) in studies on multi-fruit blends, where synergistic interactions between different fruit constituents elevated the TSS levels. Furthermore, the variation in syneresis observed underscores the complexity of colloidal interactions within the blends, consistent with observations by Emelike and Ebere (2015) in their evaluation of cashew apple-based juice blends.

In summary, the findings from this study provide valuable insights into the interactions between mango, hog plum, and ginger in juice formulations. The results demonstrate that varying fruit ratios significantly influence the physicochemical characteristics of the final product, offering prospects for the development of customized juice blends tailored to meet specific sensory and stability requirements.

**3.2.4 Antinutrient content of juice blends**

The oxalate content of the juice blends ranged from 0.01 to 0.03 mg/100 g across samples A to F. Samples A and B, composed of 100% and 90% mango juice, respectively, exhibited the lowest oxalate concentration (0.01 mg/100 g). In contrast, samples D, E, and F, which contained higher proportions of hog plum juice, recorded the highest oxalate levels (0.03 mg/100 g). These values are substantially lower than those reported by Rahman et al. (2019), who documented an oxalate content of 0.31 mg/100 g in mango pulp. The relatively low oxalate concentrations in the present blends are desirable, as excessive oxalate intake is implicated in the pathogenesis of kidney stone formation (Wilson et al., 2023).
The observed increasing trend in oxalate content with higher hog plum proportions suggests that hog plum is a significant contributor to oxalate levels within the blends. This finding is consistent with previous reports by Bishir et al. (2024) on tropical fruits, which identified plum varieties as having generally higher oxalate contents compared to mango.

Phytate concentrations in the juice blends ranged from 0.02 to 0.04 mg/100 g. A gradual increase in phytate levels was observed with increasing hog plum juice proportions, with sample F (50% mango, 45% hog plum) exhibiting the highest phytate content.
Compared to the findings of Madalageri et al. (2017), who reported phytate levels of 0.27 mg/100 g for mango pulp, the values obtained in this study were markedly lower. This reduction may be attributed to varietal differences or to the specific processing methods employed in the juice preparation. Although phytates are recognized for their capacity to chelate minerals and reduce their bioavailability (Martinez et al., 2023), the low phytate levels observed in the juice blends suggest that any adverse impact on mineral absorption is likely to be minimal.

Tannin content varied between 0.19 and 0.29 mg/100 g across the samples, displaying a general increasing trend with higher hog plum juice inclusion. Sample F, with 50% mango and 45% hog plum, recorded the highest tannin concentration.
The tannin content detected in the present study was lower than that reported by Kumar et al. (2022) for mango pulp (0.45 mg/100 g). The observed trend suggests that hog plum is a major contributor to the tannin content in the blends. While tannins are often associated with reduced protein digestibility and mineral bioavailability, they also exhibit notable antioxidant properties (Zhang et al., 2021), which may impart health benefits.

The antinutrient profile of the juice blends revealed several noteworthy patterns. Firstly, all three antinutrients (oxalates, phytates, and tannins) exhibited increasing concentrations with higher hog plum juice content, confirming hog plum as the principal contributor to the antinutrient load. Secondly, among the antinutrients, tannins were present in the highest concentrations, followed by phytates and oxalates. This distribution contrasts with findings from Anderson and Lee (2023), who reported oxalates as the predominant antinutrient in other fruit juices.
Importantly, the antinutrient levels recorded in this study were generally lower than those reported in the literature for the individual fruits, which may be attributed to varietal characteristics, the blending ratio, or processing techniques applied.
From a nutritional standpoint, although antinutrients are known to potentially impair nutrient bioavailability, the low levels identified in these blends suggest minimal negative impacts on nutrient absorption. Moreover, as noted by Madalageri et al. (2023), low to moderate levels of certain antinutrients, particularly tannins, may confer antioxidant benefits.

In conclusion, the antinutrient composition of mango–hog plum–ginger juice blends was strongly influenced by the formulation, with higher hog plum content resulting in elevated antinutrient concentrations. However, the overall low levels of oxalates and phytates, and the moderate presence of tannins, indicate that these blends are unlikely to adversely affect mineral bioavailability and may, in fact, offer potential health benefits related to their antioxidant properties and sensory characteristics.

**3.2.5 Sensory evaluation of the juice blends**

The colour scores of the juice blends ranged from 4.00 to 7.40, with Sample B (90% mango, 5% hog plum, 5% ginger) recording the highest score (7.20) and Sample F (50% mango, 45% hog plum, 5% ginger) the lowest (4.00). These values are consistent with the range of 4.40 to 6.85 reported by *Ohwesiri et al.* (2016). The observed decrease in colour scores with increasing hog plum concentration suggests a panelist preference for the characteristic yellow-orange hue of mango juice. The statistically significant differences between the samples indicate that blend composition markedly influences visual appeal.

Odour scores ranged from 4.45 to 7.00, with Samples A (100% mango) and B (90% mango, 5% hog plum, 5% ginger) achieving the highest scores (7.00), while Sample F recorded the lowest (4.45). The absence of a significant difference between Samples A and B suggests that moderate inclusion of hog plum and ginger does not adversely affect the aroma of the juice blends. The declining trend in odour scores with increasing hog plum content may indicate that the aroma profile of hog plum is less preferred compared to that of mango.

Texture scores varied between 4.55 and 7.90, with Sample B exhibiting the highest score (7.90) and Sample F the lowest (4.55). This range exceeds the 3.91 to 5.53 reported by *Adubofuor et al.* (2016) for pumpkin–pineapple juice blends, suggesting that the mango-based blends in this study possess superior textural properties. The elevated texture score for Sample B may be attributed to the improved viscosity or mouthfeel imparted by the incorporation of small amounts of hog plum and ginger.

Tartness scores ranged from 4.45 to 7.00, with Sample A recording the highest and Sample F the lowest scores. Contrary to expectations, tartness scores declined with increasing hog plum content despite its known tart flavor. This phenomenon may be attributed to potential interactions between hog plum and ginger at higher concentrations, possibly masking or altering the panelists' perception of tartness.

Sweetness scores ranged from 4.60 to 7.50. Samples A and B exhibited the highest sweetness scores (7.50), while Sample F scored the lowest (4.60). The progressive decline in sweetness scores with increasing hog plum content is consistent with its lower intrinsic sugar content relative to mango. The comparable sweetness scores of Samples A and B indicate that minimal additions of hog plum and ginger do not significantly affect perceived sweetness.

Overall acceptability scores ranged from 4.50 to 8.10, with Sample B receiving the highest score (8.10) and Sample F the lowest (4.50). This suggests that the blend comprising 90% mango, 5% hog plum, and 5% ginger (Sample B) achieved the most favorable balance of sensory attributes. The significant differences observed among samples emphasize the critical role of blend formulation in determining consumer acceptability.

Comparative Analysis:

1. Blend Optimization: Sample C (30% Mango, 65% Hog plum, 5% Ginger) is most preferred, data shows Sample B (90% Mango, 5% Hog plum, 5% Ginger) as the overall favorite. This discrepancy highlights the importance of considering multiple sensory attributes in product development.
2. Impact of Hog Plum: While the reference suggests that higher hog plum content improved certain attributes, our data shows a general decline in sensory scores with increasing hog plum proportion. This difference could be due to variations in hog plum varieties or processing methods.
3. Ginger Effect: The consistent 5% ginger across samples B-F allows us to isolate its impact. The data suggests that small amounts of ginger can enhance overall acceptability when combined with predominantly mango juice, but higher proportions (as in Sample F) negatively impact all sensory attributes.
4. Texture-Flavour Interaction: The high texture score for Sample B, combined with its high scores in other attributes, suggests a potential synergy between textural properties and flavor perception in juice blends.

The sensory evaluation highlights the intricate interaction between the components of the juice blends and consumer perception. The findings indicate that mango juice serves as a favorable base, while the incorporation of moderate quantities of hog plum and ginger enhances the overall sensory appeal. However, increased concentrations of these additives were associated with a general decline in sensory scores across all evaluated attributes.

The optimal formulation (Sample B: 90% mango, 5% hog plum, 5% ginger) successfully balances the familiar and desirable characteristics of mango with the subtle, complementary flavors of hog plum and ginger. This result offers valuable insights for product development within the fruit juice industry, emphasizing the potential for formulating novel and consumer-acceptable beverages through the strategic combination of familiar and underutilized exotic fruits.

4. Conclusion

Juice was successfully formulated from a blend of mango (*Mangifera indica*), hog plum (*Spondias mombin*), and ginger (*Zingiber officinale*). Both mango and hog plum exhibited high moisture content, making them suitable for juice production. The resulting juice blends were nutritionally rich, containing appreciable levels of proteins, fiber, carbohydrates, and energy, while exhibiting low fat content. Although the presence of antinutritional factors was detected, their concentrations remained within the permissible limits for human consumption.

Samples with higher proportions of hog plum showed increased acidity, likely attributable to the inherent organic acid content of the fruit. Total soluble solids (TSS) were consistently high across all samples, indicating substantial levels of soluble sugars. Syneresis varied among the formulations, with sample E exhibiting the highest value, suggesting potential variations in water-holding capacity due to compositional differences.

Microbiological assessment revealed low microbial loads across all samples, which could be attributed to the combined effects of pasteurization, the antimicrobial properties of ginger, and adherence to hygienic processing conditions. The shelf-life evaluation demonstrated that the juice blends maintained microbiological stability for a minimum of three weeks at both 4°C and 37°C, with microbial counts remaining within acceptable safety limits. Notably, refrigeration (4°C) significantly enhanced the microbial stability, underscoring the importance of adequate storage conditions in preserving product quality.

Sensory evaluation indicated that Sample B (90% mango, 5% hog plum, 5% ginger) was the most preferred by panelists, achieving the highest scores in both overall acceptability and individual sensory attributes. This finding emphasizes the critical role of flavor balance in consumer acceptance of fruit-based beverages.

Overall, this study successfully developed and characterized juice blends derived from mango, hog plum, and ginger, providing valuable insights into their nutritional, physicochemical, and sensory properties. The juice blends were notably rich in fiber, carbohydrates, and energy, and contained significant levels of vitamins, particularly vitamin C, contributed mainly by mango and hog plum. Although antinutrients were present, their levels did not exceed safe consumption thresholds, confirming the nutritional safety and potential functional benefits of the juice blends.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

References

Dunlop, E., Cunningham, J., Adorno, P., Fatupaito, S., Johnson, S. K., & Black, L. J. (2024). Development of an updated, comprehensive food composition database for Australian-grown horticultural commodities. arXiv preprint arXiv:2402.06169.

Cazzola, R., et al. (2020). Going to the roots of reduced magnesium dietary intake: A tradeoff between soil depletion and food processing. *Frontiers in Nutrition*, 7, 577. <https://doi.org/10.3389/fnut.2020.00077>

Prudencio, C.V., Silva, M.A., & Oliveira, A.C. (2024). Fruits of the Brazilian Cerrado: Possibilities of uses for the manufacture of food products. *Brazilian Archives of Biology and Technology (Curitiba, Brazil)*, 67, e20230212.

Nguyen, T.M., Hoang, M.L., & Nguyen, L.T. (2023). The utilization of ginger in beverages: Processing, health benefits, and functional applications. *Journal of Food Science and Technology (New York, USA)*, 16(3), 245-258.

Ayustaningwarno, A., Anjani, D., Ayu, S., & Fogliano, V. (2024). A critical review of Ginger's (*Zingiber officinale*) antioxidant, anti-inflammatory, and immunomodulatory properties. *Frontiers in Nutrition*, 11, 1364836. <https://doi.org/10.3389/fnut.2024.1364836>.

Food and Agriculture Organization (FAO). (2017). General Standard for Fruit Juices and Nectars CXS 247-2005. FAO/WHO Codex Alimentarius. Retrieved from [https://www.fao.org/fao-who-codexalimentarius/sh-proxy/jp/?](https://www.fao.org/fao-who-codexalimentarius/sh-proxy/jp/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXS%2B247-2005%252FCXS_247e.pdf)

Adepoju, O. T., & Karim, S. A. (2021). Nutrient composition, anti-nutritional factors, and jam preparation from *Spondias mombin* (hog plum, "iyeyb") fruit pulp. *Nigerian Journal of Nutritional Sciences, 25*(1), 2004.

Oryema, C., Oryem-Origa, H., & Nana, R. (2015). Influential factors to the consumption of edible wild fruits and products in the post-conflict district of Gulu, Uganda. *Journal of Natural Sciences Research, 5*(10), 132-143.

Ishak, N. A., Muhammad, N., Gani, S. S. A., & Mohamad, H. (2023). Characterization and antioxidant properties of underutilized hog plum (Spondias cytherea) fruit extract obtained through ultrasound-assisted extraction. *Food Research*, 7(1), 146-154.

Adeola, T., & Ogunleye, A. (2020). Physicochemical properties of mango juice during storage. *International Journal of Food Science and Technology, 45*, 120–130.

Nascimento, R. Q., Silva, J. K. R., Barros, M. E. S., & Lima, M. A. C. (2023). Quality control parameters and analytical methods for fruit juice analysis: A comprehensive review. *Food Analytical Methods*, 16(4), 1141-1163.

AOAC. (2022). *Official Methods of Analysis* (21st ed.). Association of Official Analytical Chemists.

García-Romero, Y., Alejo-Armenta, L. N., García-Galindo, H. S., López-Vidal, O., & Ramírez-Mares, M. V. (2023). Analytical methods for the determination of vitamin A in food matrices: A systematic review. *Food Analytical Methods*, 16(4), 1075-1092.

Khalil, M. M., & Hassan, H. M. (2022). Modern analytical methods for determination of fat-soluble vitamins: A comprehensive review. *Critical Reviews in Analytical Chemistry*, 52(8), 2471-2495.

Hamad, G. M., & Hassan, M. H. (2023). Development and validation of a novel spectrophotometric method for determination of B vitamins in food supplements. *Journal of Food Composition and Analysis*, 116, 104962.

Annor, G. A., Tyl, C., Shahidi, F., Mondor, M., Udenigwe, C. C., & Ramdath, D. D. (2021). Antioxidant vitamins and phenolics in raw and processed Canadian lentils. *LWT-Food Science and Technology*, 143, 111116.

Wang, H., & Zhang, M. (2023). Folate intake during pregnancy: Impact on birth outcomes and neural tube defects*. Journal of Maternal-Fetal & Neonatal Medicine*, 36(3), 312-324.

Wilson, D. R., & Thompson, K. L. (2020). Material considerations in fruit juice processing equipment: Effects on product quality. Journal of Food Engineering, 277, 109891.

Ohwesiri, M. A., David, B. K.-K., & Caroline, O. E. (2016). Quality characteristics of orange/pineapple fruit juice blends. *American Journal of Food Science & Technology, 4*(2), 43–47.

Kumar, S., Patel, R., & Thompson, M. (2023). Temperature-dependent microbial dynamics in fruit beverages: A comprehensive analysis. *Food Microbiology Research*, 45(2), 178-192.

Ibrahim, M. A., Ahmed, S. F., & Rahman, M. S. (2019). Physicochemical and sensory evaluation of mixed tropical fruit juice blends. *International Journal of Food Science and Technology*, 54(8), 2647-2658.

Kumar, N., Singh, R. K., & Kumar, P. (2022). Recent advances in fruit juice processing and preservation techniques: A comprehensive review. Food Research International, 152, 110846.

Ani, P. N., & Abel, H. C. (2018). Nutrient, phytochemical, and antinutrient composition of *Citrus maxima* fruit juice and peel extract. *Food Science & Nutrition, 6*(1), 1–6. <https://doi.org/10.1002/fsn3.604>

Masresha Minuye Tasie, Ammar B. Alemimi, Rawdah Mahmood Ali, & Gary Takeoka. (2020). Study of physicochemical properties and antioxidant content of mango (*Mangifera indica* L.) fruit. *Eurasian Journal of Food Science and Technology, 4*(2), 91–104.

Olaoye, I. O., Salako, Y. A., Odugbose, B. D., & Owolarafe, O. K. (2021). Effect of processing conditions on the quality of juice extracted from hog plum fruit. *Ife Journal of Science, 23*(1).

Deepa, M. M., Bharati, P., & Kage, U. (2017). Physicochemical properties, nutritional, and antinutritional composition of pulp and peel of three mango varieties. *International Journal of Educational Science and Research, 7*(3), 81–94. https://doi.org/xxxxx

Rahman, M. S., Hossain, M. A., & Ahmed, M. (2019). Post-harvest handling and processing of mangoes: A comprehensive review. *Journal of Food Processing and Technology*, 10(4), 789-798.

Curi, P. N., Almeida, A. D., Tavares, B. S., Nunes, C. A., Pio, R., Pasqual, M., & Souza, V. D. (2017). Optimization of tropical fruit juice based on sensory and nutritional characteristics. *Journal of Food Science and Technology, 37*(2), 308–314. https://doi.org/xxxxx

Hossain, M. M., Rahman, M. M., & Ali, M. A. (2023). Nutritional composition and bioactive properties of tropical fruits: Implications for functional food development. *International Journal of Food Science and Technology (London, UK)*, 58(9), 1412-1423.

Singh, B., Kumar, A., & Sharma, P. (2023). Economic aspects and quality management in fruit juice processing: Current scenario and future prospects. Journal of Food Processing and Preservation, 47(2), e16542.

Hassan, W., Malik, A., & Ahmad, S. (2022). Antioxidant potential of gingerols and related compounds in ginger: Biochemical and molecular mechanisms. *Antioxidants*, 11(4), 678-692.

Ahmed, J., Ramaswamy, H., & Kashaninejad, M. (2020). Thermal and non-thermal processing of juice blends for quality retention. *Food Processing and Preservation, 34*(2), 90–105.

Rahman, M. S., Hossain, M. A., & Ahmed, M. (2019). Post-harvest handling and processing of mangoes: A comprehensive review. *Journal of Food Processing and Technology*, 10(4), 789-798.

Wilson, R.B., Anderson, J.C., Taylor, M.K. (2023). Novel food applications and processing technologies for Spondias mombin products. *Food Research International*, 165: 112289.

Martinez, R., Chen, K., & Wong, P. (2023). Advanced techniques in small-scale beverage processing and packaging. Journal of Food Processing Technology, 14(3), 245-259.

Kumar, N., Singh, R. K., & Kumar, P. (2022). Recent advances in fruit juice processing and preservation techniques: A comprehensive review. Food Research International, 152, 110846.

Zhang, R., McClements, D. J., & Sun, J. (2021). Bioactive compounds in ginger: Chemistry, stability, and biological activities. *Comprehensive Reviews in Food Science and Food Safety*, 20(2), 1213-1244.

Anderson, K., Lee, S., & Wang, Y. (2023). Analysis of fruit juice consumption and dental caries in preschool children: A multi-center study. Journal of Pediatric Dentistry, 45(3), 178-189.

Ohwesiri, M. A., David, B. K.-K., & Caroline, O. E. (2016). Quality characteristics of orange/pineapple fruit juice blends. *American Journal of Food Science & Technology, 4*(2), 43–47.

Ahammed, S., Talukdar, M. M. H., & Kamal, M. S. (2015). Processing and preservation of ginger juice. *Journal of Environmental Science and Natural Resources*, 7(1), 117–120.

Latimer, G. W., Jr. (Ed.). (2023). *Official Methods of Analysis of AOAC INTERNATIONAL* (22nd ed.). AOAC INTERNATIONAL.

Adepoju, A.A., Adeniji, O.A., Akinola, O.A., & Adepoju, O.A. (2021). Nutritional, sensory, physico-chemical, phytochemical, microbiological and shelf-life studies of natural fruit juice formulated from orange (*Citrus sinensis*), lemon (*Citrus limon*), honey and ginger (*Zingiber officinale*). *Journal of Food Processing and Preservation*, 45(6), e15467. https://doi.org/10.1111/jfpp.15467

Yasmin, S., Shaheen, G., Rani, D., Roy, C., Akhter, M. J., Shakil, M., Mahomud, M., & Sohany, M. (2022). Physicochemical and sensory characteristics of orange juice supplemented yogurt. *Fundamental and Applied Agriculture*, 7(1), 1–10. <https://doi.org/10.5455/faa.139528>

Fasuan, A. A., Akin-Obasola, B., & Abiodun, B. O. (2022). Water activity relations of spoilage fungi associated with smoke-dried catfish (*Clarias gariepinus*) sold in some open markets in Nigeria. *Journal of Food Science and Technology*, 59(6), 2168–2176. <https://doi.org/10.1007/s13197-021-05229-8>

Adepoju, O.T., & Oyewole, E.O. (2008). Nutrient composition and acceptability of fortified jam from Spondias mombin (Hog plum, 'Iyeye') fruit pulp. *Nigerian Journal of Nutritional Sciences*, 29(2), 180-189.

Tiencheu, B., Nji, D. N., Achidi, A. U., Egbe, A. C., Tenyang, N., Ngongang, E. F. T., *et al.,* (2021). Nutritional, sensory, physico-chemical, phytochemical, microbiological and shelf-life studies of natural fruit juice formulated from orange (*Citrus sinensis*), lemon (*Citrus limon*), honey and ginger (*Zingiber officinale*). *Heliyon, 7*(6), e07177. <https://doi.org/10.1016/j.heliyon.2021.e07177>

Fasuan, A. A., Akin-Obasola, B., & Abiodun, B. O. (2022). Water activity relations of spoilage fungi associated with smoke-dried catfish (*Clarias gariepinus*) sold in some open markets in Nigeria. *Journal of Food Science and Technology*, 59(6), 2168–2176. <https://doi.org/10.1007/s13197-021-05229-8>

Zhang, Y., Li, Q., Xing, C., & Gao, R. (2019). Effects of raw materials proportions on the sensory quality and antioxidant activities of apple/berry juice. *Food Science and Technology*, 39(2), 361-368.

Hossain, M. M., Shishir, M. R. I., Saifullah, M., Sarker, K. U., Safeuzzaman, & Rahman, M. A. (2016). Production and Investigation of Biochemical and Organoleptic Changes of Mixed Fruit Juice during Storage. *Indian Journal of Nutrition*, 3(1), 119.

Egbuta, C.K., & Chima, J.U. (2022). "Physicochemical and Sensory Characteristics of Mixed Fruit Juices Prepared from Blend of Pineapple, Pawpaw and Watermelon Fruits Juices." *Asian Food Science Journal*, 21(12), 28-35

Emelike, N. J. T., & Ebere, C. O. (2015). Effect of Packaging Materials, Storage Time and Temperature on the Colour and Sensory Characteristics of Cashew (Anacardium occidentale L.) Apple Juice. *Journal of Food and Nutrition Research*, 3(7), 410-414.

Bishir, B. B., Adamu, H. Y., Abdu, S. B., & Aliyu, A. M. (2024). Evaluation of phytochemical and nutrient compositions of hog plum (*Spondias mombin*). *Nigerian Journal of Animal Production*, 1639–1641. <https://doi.org/10.51791/njap.vi.5995>

Madalageri, D. M., Bharati, P., & Kage, U. (2017). Physicochemical Properties, Nutritional and Antinutritional Composition of Pulp and Peel of Three Mango Varieties. *International Journal of Educational Science and Research (IJESR)*, 7(3), 81-94.

Madalageri, D. M., Bharati, P., & Kage, U. (2023). A comprehensive review of bioactive tannins in foods and beverages: Functional properties, health benefits, and sensory qualities. *Molecules, 30(4), 800.* <https://www.mdpi.com/1420-3049/30/4/800>

Adubofuor, J., Amoah, I., & Agyekum, P. B. (2016). Physicochemical Properties of Pumpkin Fruit Pulp and Sensory Evaluation of Pumpkin-Pineapple Juice Blends. *American Journal of Food Science and Technology*, 4(4), 89-96.

Ademiluyi, A. O., Oboh, G., Boligon, A. A., & Athayde, M. L. (2016). *Effect of hog plum (Spondias mombin) fruit on oxidative stress and hyperlipidemia in high-fat diet-fed rats.* Pharmaceutical Biology, 54(10), 2156-2163.

Dugasani, S., Pichika, M. R., Nadarajah, V. D., Balijepalli, M. K., Tandra, S., & Korlakunta, J. N. (2010). *Comparative antioxidant and anti-inflammatory effects of ginger varieties (Zingiber officinale).* Food and Chemical Toxicology, 48(10), 2638-2644.

Gupta, S. C., Sung, B., Kim, J. H., Prasad, S., Li, S., & Aggarwal, B. B. (2020). *Regulation of survival, proliferation, invasion, angiogenesis, and metastasis of tumor cells through modulation of inflammatory pathways by nutraceuticals.* Cancer Metastasis Reviews, 39, 631–664.

Ma, X., Zheng, C., Hu, C., Rahman, K., Qin, L., & Qin, B. (2021). *The genus Mangifera (Anacardiaceae): Ethnopharmacology, phytochemistry, and pharmacology.* Phytotherapy Research, 35(3), 1272-1300.

Eskin, N. A. M., & Tamir, S. (2018). *Functional Foods and Biotechnology: Biotransformation and Analysis of Functional Components in Foods*. CRC Press.

Grand View Research. (2023). *Functional Beverages Market Size, Share & Trends Analysis Report, 2023-2030*.

Kumar, P., & Smith, J. (2021). "Consumer Preferences for Functional Beverages: A Market Analysis." *Journal of Food Science and Technology*, 58(7), 1023-1035.

Fasogbon, M. B., Akinwande, B. A., Olaniran, A. F., & Olanrewaju, S. A. (2020). Proximate composition, mineral content and antioxidant activities of baobab (Adansonia digitata) pulp and kernel from Nigeria. Heliyon, **6**(10), e05262.
<https://doi.org/10.1016/j.heliyon.2020.e05262>

Adepoju, O. T., Olusola, A. O., & Owolabi, A. O. (2019). Chemical, mineral composition and functional properties of baobab pulp from different locations of Nigeria. African Journal of Food Science, **13**(9), 189-197.
<https://doi.org/10.5897/AJFS2019.1829>

Omodara, M. A., Akinoso, R., & Adebowale, A. A. (2021). Effect of processing methods on vitamin composition of fruit juices. *International Food Research Journal*, **28**(3), 543–550.

Field, A. (2020). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). Sage Publications.