Journal of Food Technology Research
2026 Vol. 13, No. 4, pp. 139-151
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/jftr.v13i4.5331
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Proximate, physicochemical and sensory evaluation of jam produced from black plum (Vitex doniana) fruit at different stages of maturity

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Article History
Received: 8 July 2026
Revised: 11 September 2026
Accepted: 5 October 2026
Published: 29 October 2026

Keywords
Food processing
Jam
Organoleptic properties
Physicochemical properties
Vitex doniana.

ABSTRACT

This study examined the suitability of black plum (Vitex doniana) fruit for jam production using different proportions of ripe and unripe fruits. Three jam formulations were prepared: 100% ripe fruit jam (RHJ), 60% ripe and 40% unripe fruit jam (RSJ), and 40% ripe and 60% unripe fruit jam (RFJ). The jams were produced and subjected to physicochemical, proximate, and sensory analyses using standard methods. Results showed that increasing the proportion of unripe fruit significantly increased titratable acidity, pectin content, and viscosity, while reducing sugar content and total soluble solids. RFJ exhibited the highest pectin content (8.91%) and viscosity (87.47 dynes/cm^2), whereas RHJ recorded the highest reducing sugar content (54.41%) and total soluble solids (68.85 °Brix). Pectin improved the viscosity and acceptability of the jam. Similarly, the Brix and reducing sugar content increased with a higher percentage of ripe fruit, while the commercial jam (SBJ) recorded the highest Brix and reducing sugar contents. Sensory evaluation revealed that black plum jam compared favourably with commercial black currant–strawberry jam in taste and mouthfeel, while achieving superior aroma scores. However, overall acceptability was slightly lower due to the darker colour of the black plum jam. The findings demonstrate that black plum possesses adequate natural pectin and desirable sensory characteristics for jam production and represents a promising strategy for reducing post-harvest losses, as well as promoting the utilization of this underexploited indigenous fruit. Thus, further improvement in colour, formulation balance, storage stability, and shelf-life assessment is recommended.

Contribution/Originality: This study offers a fresh finding of how the proportions of ripe and unripe fruits affect the quality of black plum jam. It shows that without the use of commercial pectin, the natural pectin found in unripe fruits may increase gel strength and viscosity while preserving acceptable sensory quality.

1. INTRODUCTION

Black plum (Vitex doniana) is among the perishable fruits that, when not processed, can become contaminated by microorganisms and can be eaten whole and raw or processed into juices, jams, and concentrates (Ajenifujah-Solebo & Aina, 2011). Wild fruits, such as black plum, are articles of informal trade and, hence, sources of income for the rural population. Wild fruits have gained increased importance in the Sahel regions, where drought and other

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weather-related calamities pose a threat. There is little or no documentation on the cultivation of these indigenous trees and little progress in improving and utilising indigenous plant species for food and other uses (Dadjo, 2018). Hence, there is advocacy for the improvement of existing methods or the adoption of new methods for the greater utilisation of perishable food resources, without which nutrient depletion, quality loss, and damage to physiological structures may occur before consumption or conversion into secondary products (Aniche, 2003; McDonald, Caffin, Sommano, & Cocksedge, 2006).

The Black Plum (Vitex doniana) has over twelve varieties, and these species include Vitex barbata, Vitex campartem, Vitex cordata, and Vitex madiensis. The black plum has many names in eastern Nigeria, depending on the locality. Vitex doniana sweet is the most common of the Vitex species in West Africa (Dadjo, 2018). The fruit is from a savanna species that grows in northern, eastern, and western Nigeria. It is green when unripe and turns dark brown when completely ripe, with pulp around a hard stone that contains one to four seeds (Dadjo, 2018).In portions of Delta State and Anambra, black plum is referred to as "Mbembe." In Enugu State, it is referred to as "Erigheri" or "Mgbamgba." Abia State residents refer to it as "Uchakiri" or "Uchakoro," whilst Imo State residents refer to it as "Achakiri" or "Urobia." The Hausa in northern Nigeria refer to it as "Dinya," the Fulani as "Galbihi," and the Yoruba in western Nigeria refer to it as "Ori-nla" (Dadjo, 2018). The fruit is also referred to as the African black plum or African olive (Ajenifujah-Solebo & Aina, 2011).

Black plum contains about 77.03% moisture, 2.75% fibre, 2.9% fat, 8.10% protein, 1.65% ash content, and 7.57% carbohydrate. It also contains vitamin A (0.27), vitamins B1 (18.33), B2 (4.80), B6 (20.45), and vitamin C (35.58) (mg/100 g DW), respectively (Ajenifujah-Solebo & Aina, 2011). Minerals (mg/100 g DW) include potassium (16.5), sodium (10.40), calcium (30.27), iron (5.20), copper (2.70), magnesium (20.10), and phosphorus (16.50) (Vunchi et al., 2011). The physicochemical and sensory results indicate that the fruit has soluble solids of 18.83 °Brix, a pH of 3.85, ascorbic acid of 33.35 mg, and Na, K, and Ca contents of 0.1 mg/100 g, 1.33 mg/100 g, and 0.765 mg/100 g, respectively (Ajenifujah-Solebo & Aina, 2011). Black plum syrup can substitute for other syrups as a nutritive sweetener (Abu, 2002; Burkill, 2000; Oumorou et al., 2010).

In some West African countries, such as the Benin Republic, the bark and leaves are used as stimulants for impulse control. The young leaves of black plums are used as vegetables. The fruit pulp is consumable when fresh, cooked, or toasted and is locally marketed. It can be made into jam, while the leaves can be used as herbs to treat eye problems. The fruits are used to make wine (Dadjo et al., 2012). Black plum can be processed into juice and jam. Just like other fruits, it has high pectin content when unripe. Pectin is a complex polysaccharide derived from plants. It is a soluble fibre found in fruits and vegetables. It is a strong gelling agent that thickens fruit preserves, including jam, jellies, and gummy candy. This pectin can be made into a gel by heating. It can serve as a commercial thickening/gelling agent in jams and jellies and can be added to yoghurts and fruit juices as a stabilizer. Pectin can also be used as an emulsifier in ice cream (Dadjo, 2018).

In Nigeria, especially in the Eastern region, black plum has not been accorded the importance it deserves due to ignorance of its nutritive composition and a lack of knowledge of its preservation methods or conversion into value-added products (Dadjo, 2018). The usefulness of black plum has not been harnessed (Okigbo, 2001). Except a few that are retained for shelter in agricultural areas, no new plants are developed since the fully mature fruits are dispersed at the base of the tree for wild animals. Information about the nutritional value of black plums and their use in making juice, jam, and concentrate is either nonexistent or extremely limited. The black plum fruit is underutilized in Nigeria, particularly in the Eastern area. It is not easily accessible. Instead of being picked, the ripe fruit is gathered from the ground. The underutilization of this fruit was caused in part by a lack of knowledge regarding its benefits and uses in the food industry and diet. The lack of utilization has contributed to its lack of domestication, hence its gradual extinction (Dadjo, 2018).

The use of underutilized native fruits as sustainable raw materials for value-added food products has received more attention in recent years. The increasing demand for functional foods, decreased post-harvest losses, increased

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food security, and the variety of raw materials available to the fruit processing sector are the main factors driving this interest. Fruit jams continue to be one of the most popular fruit preserves because they maintain favorable nutritional and sensory qualities while extending shelf life. However, the balance of soluble solids, acidity, natural pectin concentration, and fruit maturity, all of which influence gel formation, texture, spreadability, color stability, and consumer acceptability, is crucial for the effective manufacture of jam (Dadjo, 2018).

The significance of using fruit's natural pectin to lessen reliance on commercial hydrocolloids and create cleaner-label goods with more nutritional value has also been highlighted by recent developments in fruit processing.

Compared to traditional jam fruits like strawberry, apricot, blueberry, plum, pineapple, and mixed tropical fruits, there is still little research on Vitex doniana's industrial use, despite the fact that it contains significant amounts of natural pectin, sugars, vitamins, minerals, and bioactive compounds. Few studies have assessed the fruit's aptitude for jam manufacturing; most have concentrated on its nutritional makeup, ethnobotanical significance, medicinal qualities, and general physicochemical features (Dadjo, 2018).

More significantly, prior research has mostly used fully ripe fruits to make jam without thoroughly analyzing the effects of varying ratios of ripe and unripe fruits on pectin concentration, gel formation, viscosity, sugar profile, physicochemical quality, nutritional composition, and consumer acceptability (Ofoedum et al., 2025). Additionally, nothing is known about the technological benefits of using unripe black plums that are naturally high in pectin in place of commercial pectin in jam recipes. In order to increase texture, processing efficiency, nutrient retention, and the production of clean-label products, recent food technology research has placed an increasing emphasis on formulation optimization based on fruit maturity. However, this strategy has not been sufficiently investigated for Vitex doniana (Ofoedum et al., 2025).

In order to produce high-quality jam with the desired physicochemical, nutritional, and sensory qualities, there is a significant research gap concerning the optimization of black plum maturity ratios. Closing this research gap might help reduce seasonal post-harvest losses, encourage the commercialization of this overlooked native fruit, and support the sustainable use of local biodiversity within the food processing industry.

The working hypothesis of this study is that the rheological and physicochemical properties of jam would be improved without negatively affecting customer acceptance by adding suitable amounts of unripe black plum fruit, which has a high natural pectin concentration.

Thus, the goal of this study was to make jam using various combinations of ripe and unripe Vitex doniana fruits and assess how fruit maturity affected proximate composition, physicochemical properties, viscosity, natural pectin concentration, and sensory quality. It is anticipated that the results will offer scientific proof for improving the production of black plum jam, encourage the addition of value to an underused native fruit, lower post-harvest losses, and aid in the advancement of sustainable fruit processing technology.

2. MATERIALS AND METHODS

2.1. Material Procurement

The black plum (Vitex doniana) fruits used for this study were collected from naturally grown trees on Urobia farms in Umuchima Community, Ideato South Local Government Area, Imo State, Nigeria, during the peak fruiting season (June to July). Figures 1 and 2 illustrate ripe black plum fruit and unripe black plum fruit, respectively, sourced from Urobia farmland in Umuchima Community. To guarantee consistency across treatments, sound fruits selected based on precisely established ripeness indices were harvested. Unripe fruits were distinguished by their green skin color, hard texture, stronger acidity, and higher natural protopectin concentration, whereas ripe fruits had a distinctive dark purple-to-black skin color, soft flesh, pleasant scent, and advanced physiological maturity. Before processing, all gathered fruits were meticulously sorted to remove any samples that were bruised, infected, insect-infested, overripe, or mechanically damaged. To reduce physical damage and field heat accumulation, the selected fruits were transported in ventilated plastic crates to the Food Science and Technology Laboratory of the Federal

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University of Technology, Owerri, after being thoroughly cleaned with potable water, sanitized with a food-grade chlorinated solution, and rinsed with distilled water. To minimize enzymatic degradation and microbiological growth, the fruits were kept at 4 ± 1°C prior to processing, which took place within 24 hours of harvest.

Other ingredients for fruit preserves, such as white granulated sugar, lime (citric acid), and containers, were purchased at Ochanja Market, Onitsha, Anambra State, Nigeria.



Source: Urobia farmland, Umuchima.

Figure 1. Ripened black plum fruit.



Figure 2. Unripe black plum fruit.

2.2. Methods

2.2.1. Experimental Design

Three black plum jam formulations made from varying ratios of ripe and unripe plums were used in the experiment, which was carried out using a completely randomized design (CRD). The formulations were as follows:

RHJ: 100% ripe fruit.

RSJ: 40% unripe fruit and 60% ripe fruit.

RFJ: 60% unripe fruit and 40% ripe fruit.

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Nine experimental units were created by independently producing each formulation in triplicate (n = 3) as a single treatment. To guarantee that the fruit maturity ratio was the sole experimental element, all batches were manufactured under the same processing settings, including ingredient quantities, heating temperature, cooking time, and packing techniques.

The percentage of ripe and unripe black plum fruits served as the independent variable, whereas proximate composition, physicochemical characteristics, pectin content, viscosity, reducing sugar, total soluble solids, and sensory characteristics were the dependent factors.

2.3. Replication Strategy

For every composition, three unique manufacturing batches were made on different occasions utilizing freshly made fruit pulp. For every batch, all physicochemical and proximate analyses were carried out in triplicate, and the mean values and their standard deviations were shown. Twenty untrained panelists participated in a single sensory examination, and each panelist independently assessed all coded samples. This replication technique reduced experimental variability and enhanced the analytical data's repeatability and dependability.

2.4. Randomization

A random-number sequence was used to randomize the order of sample preparation and laboratory analysis in order to reduce systematic bias. To avoid positional and carry-over effects, jam samples were coded with randomly generated three-digit numbers throughout sensory evaluation, and each panelist's presentation sequence was randomized. In order to wipe the palate before further assessments, water was given between samples.

2.5. Justification for Selecting Fruits and Formulation Ratios

The ripe-to-unripe fruit ratios of 100:0, 60:40, and 40:60 were selected to examine the technical impact of fruit maturity on jam quality. Due to enzymatic breakdown during ripening, fully ripe fruits often have lower pectin levels but higher quantities of soluble sugars and desirable flavor compounds. On the other hand, unripe fruits have increased levels of organic acids and protopectin, which enhance gel formation and product viscosity. To find out if natural pectin, acidity, sweetness, and sensory acceptability could all be balanced without the use of commercial pectin, the intermediate formulation (60:40) was added. Studies looking into optimizing natural pectin in fruit preserves have used similar formulation techniques.

2.6. Precautions Taken

All ingredients were weighed using calibrated analytical balances; laboratory equipment was standardized prior to use, and all processing parameters, such as cooking temperature, heating time, ingredient composition, and storage conditions, were maintained uniformly throughout all treatment batches in order to increase experimental reproducibility. Throughout the production process, quality control methods were used to reduce batch-to-batch variance.

3. SAMPLE PREPARATION

3.1. Production of Jam Samples

The black plum jam samples were produced using the methods outlined by Ajenifujah-Solebo and Aina (2011) and Ofoedum et al. (2025). Freshly harvested black plum fruits, including ripe and mature unripe fruits, were obtained from the bush farm. They were sorted and washed with water. The kernels were removed and discarded, leaving only the pulp and skin. Three formulations were made from the pulp and skin obtained. Three different containers were used: 100% ripe black plum pulp was placed in the first container; 60% ripe and 40% mature unripe black plum pulp by mass were placed in the second container; and 40% ripe and 60% unripe black plum pulp by mass were placed in

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the third container, respectively. The pulps in each container were then blended, and 49% by weight of the puree (blended pulp and skin) was combined with 50% by weight of sugar, while 1% citric acid was added. The mixtures were boiled in a pot and allowed to simmer at 165°C for 15 min, after which each was bottled. The jams were filled hot into sterilized glass jars, leaving headspace, and sealed. The jams produced from 100%, 60%, and 40% ripe black plums were labelled RHJ, RSJ, and RFJ, respectively. The flowchart is shown in Figure 3.

The labelled jam samples were then stored in the refrigerator at 4°C until further analysis.

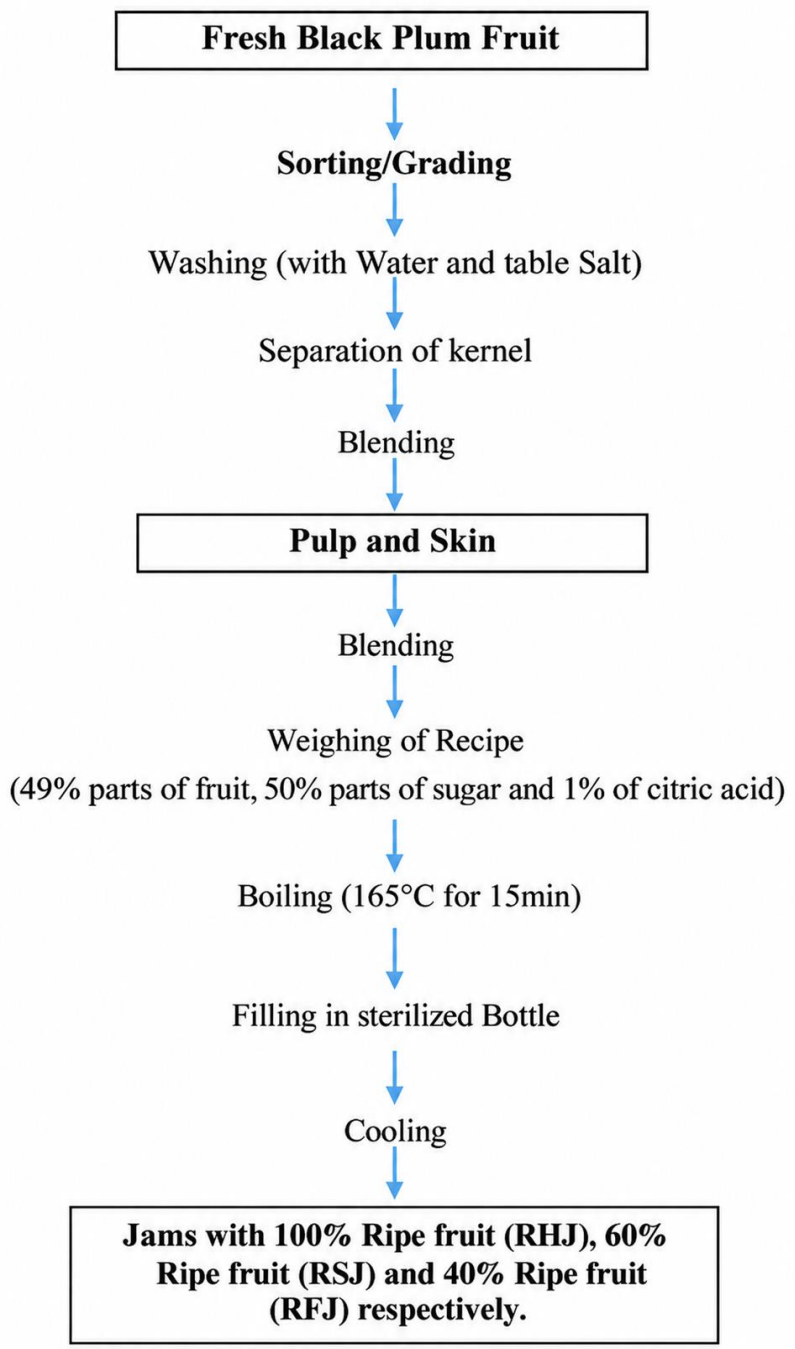


Figure 3. Production of various jam samples from fresh fruit of Vitex doniana.

4. ANALYSES CONDUCTED

4.1. Analytical Replication

In order to increase analytical accuracy and lower measurement error, all physicochemical and proximate analyses were carried out in triplicate for each biological replicate. Thus, three replicates were biological, and three

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were laboratory replicates. Each reported result represents the mean ± standard deviation of three biological replicates, each examined three times.

4.2. Proximate Analysis

The methods of Latimer (2019) were used to determine the proximate composition of the black plum samples. The measurable parameters included ash content, moisture, crude fat, protein content, and carbohydrates.

Standard analytical procedures were used for their estimation, and the readings obtained were calculated and recorded.

4.3. Determination of the Physicochemical Properties of Jam Samples Made from Black Plum

Latimer (2016) method was used to determine the physicochemical properties of the samples.

4.4. Determination of Total Phenols

A 0.2 g portion of the sample was mixed with 10 ml of concentrated methanol. The intensity of the resulting blue colouration was measured as absorbance using a colorimeter at a wavelength of 540 nm (Latimer, 2019). The percentage phenol content was calculated as follows;

$$\%\text{Phenol} = \frac{100}{w} \times \frac{au}{as} \times \text{C} \times \frac{Vt}{Va} \times \text{D} \qquad (1)$$

Where;

W = weight of the sample.

a_u = Absorbance of the test sample.

a_s = Absorbance of standard phenol solution.

C = Concentration of standard phenol solution.

Vt = Total volume of extract.

Va = Volume of analytes.

D = Dilution factor.

4.5. Viscosity

This procedure is described by Onwuka (2005). In a beaker, 15 g of the sample was made into a slurry in 300 ml of water. The mixture in the beaker was fixed below the impeller blade of the Brookfield viscometer, model LVT (Brookfield Engineering Laboratories Inc., Middleboro, MA 0234, USA), for rheological measurements.

4.6. Determination of pH

After the pH meter electrode was properly cleaned with distilled water, the reading was set to zero. After that, the meter was standardized at 25°C using buffer 4, 7, and 9 solutions. After pipetting 25 milliliters of each sample into three separate beakers, the pH electrode (probe) was dipped into the samples, and the readings from each sample were allowed to stabilize before being recorded.

4.7. Determination of Soluble Solids (°Brix)

A portable VBR32T Brix/ATC -32% refractometer was used to measure the Brix of the various jam samples. The digital refractometer's glass prism was wiped clean after being cleaned with distilled water. Using a micropipette, a few drops of the test sample were applied to the optical (sensitive) area of the refractometer. The reading was then observed on the visual display and recorded.

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4.8. Total Titratable Acidity

The method of Ajenifujah-Solebo and Aina (2011) was adopted for this determination. To ensure complete mixing of the sample and the indicator, 5 milliliters of the sample and 0.5 milliliters (3 drops) of 5% phenolphthalein indicator were added to the same conical flask and gently shaken. A 0.1 N sodium hydroxide solution was used to titrate the contents of the conical flask against a white backdrop. The titration was continued until the burette reading was recorded and a persistent pink coloration was observed. The endpoint was determined by taking the burette reading. This is how the total acidity was determined:

Total titratable acidity is equal to $(V \times N \times 75)/(1000 \times v) \times 100$.

V is the milliliters of sodium hydroxide solution used in the titration.

N is the sodium hydroxide solution's normality, and v is the sample volume (ml).

4.9. Sensory Evaluation

The sensory evaluation involved twenty (20) untrained panelists, including staff members and undergraduate and graduate students from the Federal University of Technology Owerri's Department of Food Science and Technology. The panelists had no known fruit product allergies, were between the ages of 20 and 45, and regularly consumed fruit jams using the methodology outlined by Chukwu et al. (2017). Using a nine-point hedonic scale, each participant was asked to score the juice and jam samples according to appearance, taste, flavor, texture, and overall acceptability with 9 as extremely liked and 1 as extremely disliked.

4.10. Statistical Analysis

The individually manufactured batch of jam served as the experimental unit, and laboratory measurements were repeated analytical assessments of each experimental unit. The biological replicate means were used in statistical studies to prevent pseudoreplication.

The mean ±standard deviation (SD) was used to express the experimental results in triplicate. One-way Analysis of Variance (ANOVA) was used to analyze the data obtained which was a method adopted from, Chukwu et al. (2017). The following assumptions were assessed before ANOVA: independence of observations through separate batch preparation, homogeneity of variances using Levene's test, and normality of residuals using the Shapiro-Wilk test. ANOVA was conducted at the 95% confidence level when these assumptions were met ($p > 0.05$). Fisher's least significant difference (LSD) test was used to separate the means at $p < 0.05$. IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis.

5. RESULTS AND DISCUSSION

The results of the proximate, physicochemical, and sensory analyses of the black plum jam samples are as follows:

Table 1. The Proximate composition of the Jam samples (%).

Sample	Moisture	Ash	Dietary Fibre	Fat	Protein	Carbohydrates
RHJ	$26.46^{a}\pm1.68$	$1.17^{a}\pm0.02$	$0.44^{c}\pm0.04$	$0.43^{a}\pm0.03$	$0.83^{b}\pm0.11$	$70.67^{c}\pm1.69$
RSJ	$23.16^{b}\pm0.92$	$1.15^{a}\pm0.02$	$0.96^{b}\pm0.09$	$0.48^{a}\pm0.05$	$1.04^{a}\pm0.03$	$73.21^{b}\pm0.94$
RFJ	$18.09^{c}\pm0.91$	$1.03^{b}\pm0.09$	$1.02^{b}\pm0.04$	$0.49^{a}\pm0.04$	$1.16^{a}\pm0.08$	$78.21^{a}\pm0.85$
SBJ	$24.31^{b}\pm0.80$	$0.41^{c}\pm0.03$	$1.29^{a}\pm0.08$	$0.09^{b}\pm0.01$	$0.31^{c}\pm0.06$	$73.59^{b}\pm0.82$
$LSD_{(0.05)}$	2.13	0.09	0.13	0.07	0.14	2.12

Note: The "a, b, c, d, …" means values with the same superscripts in the same are not significantly different, while those means with different superscripts (a, b, c, d, …) are significantly different.
RHJ =Jam formulated with 100% ripened black plum fruit.
RSJ = Jam formulated with 60% ripened and 40% unripe black plum fruit.
RFJ = Jam formulated with 40% ripened and 60% unripe black plum fruit.
SBJ = Commercial Jam.

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Table 2. The Physicochemical composition of the Jam samples.

Samples	TTA (%)	pH	Viscosity (Shear stress dynes/cm^2)	Pectin content (%)	Reducing Sugar (%)	Brix (^{o}B)
RHJ	$0.4^b \pm 0.06$	$3.40^b \pm 0.10$	$74.62^d \pm 2.08$	$5.64^c \pm 0.79$	$54.4^b \pm 1.11$	$68.85^a \pm 2.28$
RSJ	$0.59^a \pm 0.07$	$3.10^c \pm 0.10$	$80.13^c \pm 1.68$	$7.55^{bc} \pm 0.47$	$43.09^c \pm 1.75$	$60.41^b \pm 3.34$
RFJ	$0.64^a \pm 0.02$	$3.10^c \pm 0.10$	$87.47^b \pm 1.47$	$8.91^b \pm 1.99$	$37.35^d \pm 3.76$	$54.39^c \pm 2.54$
SBJ	$0.55^a \pm 0.03$	$4.90^a \pm 0.20$	$94.12^a \pm 3.88$	$14.08^a \pm 1.30$	$62.18^a \pm 2.32$	$71.33^a \pm 2.12$
$LSD_{(0.05)}$	0.1	0.25	4.65	2.41	4.6	4.92

Note: The "a, b, c, d, …" means values with the same superscripts in the same are not significantly different, while those means with different superscripts (a, b, c, d, ….) are significantly different.
RHJ =Jam formulated with 100% ripened black plum fruit.
RSJ = Jam formulated with 60% ripened and 40% unripe black plum fruit.
RFJ = Jam formulated with 40% ripened and 60% unripe black plum fruit.
SBJ = Commercial Jam.

Table 3. The Sensory evaluation of the Jam samples.

Samples	Taste	Aroma	Appearance	Mouthfeel	Texture	Overall Acceptability
SBJ	$7.35^a \pm 0.93$	$7.15^b \pm 1.31$	$6.70^a \pm 1.30$	$7.85^a \pm 1.37$	$7.20^a \pm 1.01$	$7.80^a \pm 0.55$
BPJ	$7.25^a \pm 0.85$	$8.05^a \pm 1.05$	$6.30^b \pm 1.17$	$7.10^a \pm 1.17$	$6.15^b \pm 1.19$	$7.05^b \pm 0.51$
$LSD_{(0.05)}$	0.55	0.74	0.27	0.79	0.58	0.33

Note: Each value is the mean of 20th panelists. The "a, b, c, d" means: values with the same superscripts in the same are not significantly different, while those means with different superscripts (a, b, c, d, …) are significantly different.
SBJ= Store bought jam (black currant-strawberry Jam), BPJ= Black plum jam.

5.1. Proximate Composition of the Jams

The results of the proximate composition of the three jam samples produced and the commercially produced black currant jam are shown in Table 1. The jam samples were produced from the same quantities of black plum pulp and skin (45 parts) and sugar (55 parts). Sample RHJ was produced from 100% ripe black plum fruit, RSJ from 60% ripe and 40% unripe fruit, and RFJ from 40% ripe and 60% unripe black plum fruit, respectively. Sample SBJ is the commercially purchased black currant jam. According to the results, the moisture content of the jam samples ranges from 18.09 (RFJ) to 26.46 (RHJ). The moisture content of RHJ is significantly higher, followed by that of the commercially produced jam (SBJ, 24.30). There was no significant difference ($P \geq 0.05$) in the moisture content of the commercially produced jam (SBJ) and jams RSJ and RFJ. The moisture content of sample RFJ is much lower. Sample RHJ, which has 100% ripe fruit, had a higher moisture content than the others. This suggests that the pectin in the 40% ripe fruit jam, RFJ, did not hold as much moisture as in the other samples. The moisture may have evaporated during the boiling process.

Three jam samples produced from black plum fruit had higher ash contents than the commercially produced jam. The higher ash content in the produced jam samples suggests that pectin from fruits contributes to the higher ash content, whereas the commercial pectin used in the commercial juice (black currant-strawberry) has lower ash content. There was no significant difference ($P \geq 0.05$) in the ash content of jam produced with 60% ripe fruit (RSJ) and 40% ripe fruit (RFJ). The results obtained in this work are related to the results obtained by Amah and Okogeri (2019).

5.2. Physico-Chemical Composition of Jam Sample

The results of the physicochemical composition are shown in Table 2. The titratable acidity of the jam samples ranges from 0.4 to 0.64, with the jam made with 40% ripened and 60% unripe black plum fruit (RFJ) giving the highest value and the jam made from 100% ripened black plum having the lowest value. This implies that the higher the percentage of unripe fruit in the jam formulation, the greater the titratable acidity, and that ripening reduced the acid values. There is no significant difference in the titratable acidity content of the jams that contained 60% and 40% ripened juice and the store-bought jam. The pH level increases with ripening. Thus, as the fruit ripens, the acidity

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decreases. However, there is also a significant increase in the pH of the store-bought jam (SBJ) compared with the jam made from 100% ripened fruit (RHJ).

Thus, pH measures the concentration of hydrogen ions in a solution (Ofoedum et al., 2024). The viscosity of the jam samples ranged from 74.62 (shear stress/dryness/cm2) in RHJ to 87.47 (shear stress/dryness/cm2) in RFJ. The viscosity of RSJ jam was significantly higher than that of RHJ jam but lower than that of RFJ jam. This implies that the higher the proportion of unripe fruit in the jam, the higher the pectin content and viscosity. Pectin content tends to decrease as fruit ripens. The store-bought jam (SBJ) had the highest viscosity among the other jam samples. The high viscosity and pectin content of SBJ may be due to the commercial pectin added during production. When there are sufficient soluble solids and acidity, high-methoxyl pectin creates junction zones through hydrophobic interactions and hydrogen bonding. The greater viscosity in formulations with more unripe fruit can be explained by this continuous gel network, which traps water molecules and increases flow resistance. Stronger gels also result from decreased pectin breakdown during ripening. According to Chan, Choo, Young, and Loh (2017), pectin is the main rheology modifier that causes fruit preserves to become viscous.

The pectin content of the fruit reduces as it ripens. The pectin from black plum improved the viscosity and acceptability of the jam. Similarly, the Brix and reducing sugar content increased with the higher percentage of ripened fruit, while the commercial jam (SBJ) recorded the highest Brix and reducing sugar content, possibly due to the type of fruit used for the jam and the type of sugar contained. This suggests why the organoleptic analysis of the syrup produced by the concentration of black plum juice compares favourably with sucrose in sensory properties in model foods (Abu, 2002; Jat et al., 2018). During ripening, complex carbohydrates are hydrolyzed by natural invertase and amylolytic enzymes into glucose and fructose. During cooking, these sugars take part in Maillard reactions that affect customer choice, color development, and flavor complexity. Sweetness and total soluble solids are also improved by increased reducing sugars.

5.3. Sensory Evaluation of Jam Samples

The results of the sensory evaluation comparing a store-bought jam (SBJ) and a jam produced with fully ripe black plum fruit (BPJ) are shown in Table 3. There is no statistically significant difference in the taste of the two jams. However, there is a significant difference ($P \leq 0.05$) in their aroma, with black plum jam (BPJ) rated higher (8.05), while blackcurrant-strawberry jam (SBJ) scored 7.15. In appearance, the store-bought jam rated higher (6.70), and the 100% ripe black plum jam rated lower (6.30). Also, there is no significant difference in the taste and mouthfeel of the black plum jam produced with 100% ripe fruit (BPJ) and the store-bought (commercial) jam (SBJ). However, the commercial jam was more accepted than the black plum jam because of the latter's dark colour. This implies that the taste of the two jam samples was statistically the same, but the black plum jam was rated lower in appearance, perhaps because of its very dark colour (black-brown), which may result from high-heat treatment, caramelization, and the Maillard reaction. When subjected to high temperatures, sugars in the presence of ascorbic acid turn brown. They also caramelize during high-heat treatment. The mouthfeel evaluation of the jam samples was statistically the same because the taste and flavour were rated highly, although the flavour of the black plum jam was rated higher than that of the store-bought jam. In terms of texture, consistency, and spreadability, the store-bought jam differed significantly from the black plum jam. In overall acceptability, the store-bought jam rated higher (7.80) than the black plum jam (7.05), which was accepted but not as much as the store-bought jam. The black plum jam is very dark, and its appearance may have repelled some panelists, even though it tasted good. The use of mixed fruit in this formulation to augment colour acceptance is highly advocated. Agbede and Ibitoye (2007) and Ofoedum et al. (2025) also reported similar results in the sensory evaluation of jam from sycamore fruits. Due to its higher concentration of reducing sugars, lower acidity, and stronger fruit fragrance that develops during ripening, the formulation with a larger proportion of ripe fruit has a better taste score. As volatile esters, alcohols, and aldehydes that give fruit its distinctive flavour are produced, starch hydrolysis raises the sugar concentration throughout maturity. On the other hand,

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because of higher concentrations of organic acids and phenolic compounds, formulations with more unripe fruit showed greater acidity and astringency, which probably decreased the perception of sweetness and overall flavour acceptance. Similar sensory reactions have been noted for black plum jam and other fruit preserves; whereas excessive ripeness decreased gel strength, increasing fruit maturity enhanced flavour acceptability (Ajenifujah-Solebo & Aina, 2011). These results emphasize the significance of striking a balance in ripeness to maximize both technical functioning and sensory quality.

6. CONCLUSIONS

This study offers fresh scientific proof of how fruit ripeness affects the qualitative characteristics of jam made from the underappreciated native fruit Vitex doniana. The study shows that fruit maturity is a crucial driver of physicochemical properties, natural pectin concentration, viscosity, reducing sugars, and sensory quality through a methodical assessment of various ratios of ripe and unripe fruits. The results demonstrate that while greater quantities of ripe fruit improve sweetness and flavor, increasing the amount of unripe fruit increases natural pectin availability and gel strength. This provides a useful foundation for optimizing jam formulation without depending on commercial pectin. This facilitates the creation of clean-label fruit preserves utilizing naturally occurring hydrocolloids and adds to the expanding body of information regarding the technical functioning of native tropical fruits.

6.1. Contribution to Knowledge

From an industrial standpoint, the study shows that Vitex doniana may be used as a substitute raw material for commercial jam manufacturing, providing processors with an affordable way to increase product uniformity by exploiting the fruit's natural pectin. In addition to encouraging sustainable processing of locally accessible fruit resources, the improved formulations may lower manufacturing costs related to imported commercial pectin. Additionally, small and medium-sized food businesses, cottage industries, and commercial fruit processors can diversify their product portfolios, add value to an underutilized indigenous crop, and lower seasonal post-harvest losses by successfully producing acceptable black plum jam. These results are consistent with international efforts supporting circular bioeconomy, sustainable food systems, and greater use of underutilized and neglected plant species. Black plum jam's commercialization potential is especially important in tropical areas where Vitex doniana is widely available but still mostly untapped. Creating commercially viable jam products from this fruit might boost local value chains, boost farmers' earnings, promote domestication and cultivation of the species, enhance food security, and lessen reliance on imported fruit preserves. Black plum-based goods are now more competitive in the market because of the use of naturally produced pectin, which also satisfies customer desires for clean-label foods made with fewer artificial ingredients.

7. RECOMMENDATIONS

Future studies should concentrate on improving processing conditions to enhance color retention and antioxidant preservation, assessing packaging systems, microbial safety, storage stability, and shelf life under various storage conditions, and looking into consumer acceptance across larger demographic groups. Additional research should measure the antioxidant potential and bioactive components of black plum jam, evaluate the viability of producing it on an industrial scale, and investigate the use of Vitex doniana in other high-value goods like fruit spreads, jellies, candies, drinks, and functional foods. Together, these initiatives will make black plum more commercially viable and enhance its role in agro-industrial growth, nutritional diversity, and sustainable food processing.

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8. LIMITATIONS

This study was limited to three jam formulations prepared from ripe and unripe black plum fruit. Storage stability, shelf life, microbial quality, antioxidant activity, and colour parameters were not fully reported. The sensory evaluation used a limited panel size and compared only one black plum jam sample with a commercial product. Processing conditions, pectin determination, and formulation basis require clearer reporting. Further studies should include standardized processing, larger sensory panels, and detailed shelf-life evaluation.

Funding: This study received no specific financial support.
Institutional Review Board Statement: This study was approved by the Federal University of Technology, Owerri, Nigeria under protocol number [FUTO/FST/IRB/2026/010].
Informed Consent Statement: Informed verbal consent was obtained from all participants, and all data were anonymized to protect participant confidentiality.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. However, this study followed all writing ethics.
Competing Interests: The authors declare that there are no competing interests.
Authors' Contributions: All authors contributed equally to the conceptualization and design of the study. All authors have read and agreed to the published version of the manuscript.
Disclosure of AI Use: The authors admit using Grammarly and ChatGPT for reference formatting, grammar checking, and language editing. The intellectual contributions and academic judgment of the authors were not replaced by these AI-assisted technologies. They thoroughly evaluated, revised, validated, and approved all AI-assisted outputs, including content, references, and interpretations.

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