

Formulation and Profile of the Physicochemical and Sensory Properties of *Flacourtia jangomas* (Lour.) Raeusch Fruit Jam from Kindzaba

Nadia P. G. Pambou-Tobi^{1,2*}, Arnaud W. G. Tamba Sompila^{1,2}, Fanny B. Ganongo-Po², Daglish Rucia Mouna Tchibondo^{2,3}, Reyes H. Gampoula¹, Sylvia P. Ntsossani¹, Haïshat Mahoumi Souleymane¹

¹National Institute for Research in Engineering Sciences, Innovation and Technology, Brazzaville, Congo

²National Polytechnic School, Marien Ngouabi University, Brazzaville, Congo

³Laboratory for the Valorization of Aggroresources, National Polytechnic, Brazzaville, Republic of Congo

Email: *npamboutobi13@gmail.com

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Abstract

Flacourtia jangomas is a plant in the Salicaceae family whose fruit is commonly known as Indian plum, coffee plum, or Manila cherry. These fruits are eaten fresh or processed. Thus, this study aims to apply the art of sugar preservation to produce a jam made from this fruit. The jam samples were prepared according to a traditional recipe. After preparation, moisture content, pH, dry matter, ash content, sugars, dynamic viscosity, acceptability, and sensory profile were determined. The results showed that the *Flacourtia jangomas* jam was acidic, with a pH of 3.4 ± 0.00 and a titratable acidity of $2.261\% \pm 0.074\%$ citric acid. The moisture content was higher than the dry matter content, and the ash content was lower, with respective values of $50.330\% \pm 0.070\%$, $49.670\% \pm 0.040\%$, and $0.440\% \pm 0.180\%$. The jam also contains $56.600\% \pm 0.000\%$ total soluble solids. Storage of the jam under refrigerated and room-temperature conditions revealed a stable pH of 3.4, with a slight increase to 3.7 on the 27th day in the refrigerator. In contrast, an increase in total soluble solids content was observed, from 56.60 ± 0.000 to 65.19 ± 0.000 °Brix (sucrose) and from 56.60 ± 0.000 to 59.11 ± 0.000 °Brix (sucrose), respectively, in the samples stored refrigerated and at room temperature. Sensory evaluation revealed high acceptance scores for the attributes of the formulated jam. According to the sensory profile, the jam has a reddish-brown color, a sweet and balanced taste (sweet-sour), a strong honey aroma, and a slightly gelatinous or viscous texture with a moderate content of fruit chunks.

Keywords

Physicochemical Composition, Jam, Sensory Evaluation, *Flacourtia*

1. Introduction

Fruits and vegetables are essential components of a healthy diet, meeting the needs for growth, development, and maintenance throughout life [1]. They have always been considered rich sources of certain essential micronutrients and fiber [2], as well as a wide range of phytochemicals beneficial to human health [2] [3]. Thus, Mehinagic E. *et al.* [4] argue that their consumption is not only a public health issue but also an economic issue for producers and processors. Thanks to extensive research data, the nutritional benefits of fruits and vegetables are now well established in terms of their role in reducing the risk of developing noncommunicable diseases (NCDs) such as cancer, obesity, cardiovascular disease (CVD), and type 2 diabetes mellitus (T2DM) [1] [5], which account for 70% of all annual deaths worldwide [6]. Therefore, for the general population and to reap the benefits the WHO recommends consuming at least 400 g of fruits and vegetables per day, equivalent to five or more servings per day [7] [8] for optimal health and an adequate intake of essential nutrients not found in other food groups [7]. Furthermore, the recommendation excludes potatoes and other starchy tubers [1]. Due to their seasonal availability and perishable nature which stem from their high water content and the presence of various nutrients and readily available growth factors [9], cited by [10] [11]. The fruits can only be stored fresh for a few days without treatment. Hence the significant importance of combating food loss and waste through preservation techniques [12], cited by [3], which would help preserve their nutritional and physiological values. There are many ways to achieve this, including one of the oldest [13] [14] and best-known [3] [15] and, above all, considered an art: making jam [10]. Jam is a semisolid food product whose gel-like texture makes it suitable for spreading on bread. It is prepared by cooking sugar with fruit or vegetable pulp, pectin, an acid, and other ingredients until a pleasant consistency is achieved [16]. Jams are also characterized by an attractive color, a uniform consistency with indistinguishable fruit pieces, and a typical fruity flavor [17], cited by [18]. Traditionally, the fresh fruit used is first sorted, washed, peeled, and de-seeded if necessary, weighed, and then mixed with sugar syrup, and subsequently heated to 90 °C to evaporate excess water until the required sugar content in the final product is achieved [generally 60 - 65 °Brix (Codex Alimentarius) with a minimum of 55 °Brix (French legislation)]. Depending on the fruits used and/or the desired texture, it may be necessary to add an acidulant (usually citric acid) and a gelling agent such as pectin. There are many fruit trees, some of which grow wild, while others are widely cultivated and consumed in various regions of the world. *Flacourtia jangomas* (Lour.) Raeusch is an example of an exotic, domesticated, tropical, and native medicinal fruit tree, commonly known as the Indian plum or Paniala, coffee plum, East Indian plum, or Manila cherry [19]. It be-

longs to the Salicaceae family and is widely cultivated in Southeast and East Asia, primarily in the northeastern states of India [20] [21]. Its dark red or purple, almost black cherry-like fruit is harvested from June to July [20] from a tall, upright tree or a small tree 5 to 10 m tall with low-hanging branches [21] [22]. This fruit, whose taste ranges from tart to sweet, can be eaten as is or processed, and is highly nutritious thanks to its high content of macronutrients [23] and secondary compounds [24]. With this in mind, we chose to preserve the highly perishable fruits of *Flacourtia jangomas* (Lour.) Raeusch by developing a high-value-added product intended for healthy daily consumption.

2. Materials and Methods

2.1. Materials

The plant material used in this study consisted of the fruits of *Flacourtia jangomas* (Lour.) Raeusch (**Figure 1**), harvested in the village of Kindzaba, located in Lou-tété, specifically in the Bouenza Department in the southwestern part of the country. The ripe fruits (**Figure 1(b)**) of *Flacourtia jangomas* (Lour.) Raeusch were harvested between March and April 2023 from the branches (**Figure 1(a)**) of the tree. These fruits were then transported to the INRSIIT Agri-Food Technology Laboratory.

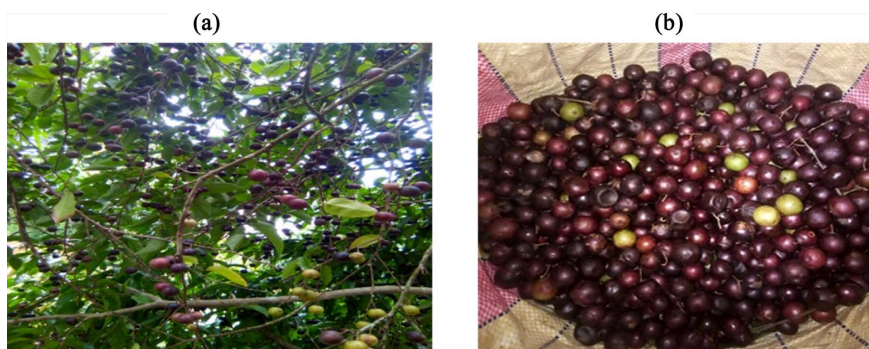


Figure 1. *Flacourtia jangomas* (Lour.) Raeusch: (a) branches bearing partially ripe, ripe, and unripe fruits; (b) ripe and unripe fruits.

2.2. Methods

2.2.1. Preparation of Fruit Jam

Before preparing the jam, the *Flacourtia jangomas* (Lour.) Raeusch were first sorted by hand according to ripeness and physical condition, then weighed on a SUNRISE commercial scale made in China (20 kg × 50 g), washed with clean tap water to remove all impurities, drained, and finally weighed again. At this stage, the fruits can be stored or used immediately to make jam (**Figure 2**).

The fruits, with their stems removed, were blanched (70 °C/10 min), peeled, cut, and seeded by hand using a knife. The fruit pulp is then mixed with an equal amount of Balbake brand granulated sugar for jam (containing 0.02 g of salt, 0.008 g of protein, 98 g of sugar, as well as a fraction of a gram of pectin as a gelling agent and citric acid as an acidulant) before being left to macerate for 24 hours.

The mixture was first briefly pre-cooked, then ground into a paste or purée, and finally brought to a boil until the desired concentration was reached. The total mass of jam obtained was 454 g, representing a yield of 50.44%. The mixture was poured directly into a pre-sterilized jar. The jar was then sealed, turned upside down immediately, and finally left to cool in the open air for 12 hours (see **Figure 2** for details).

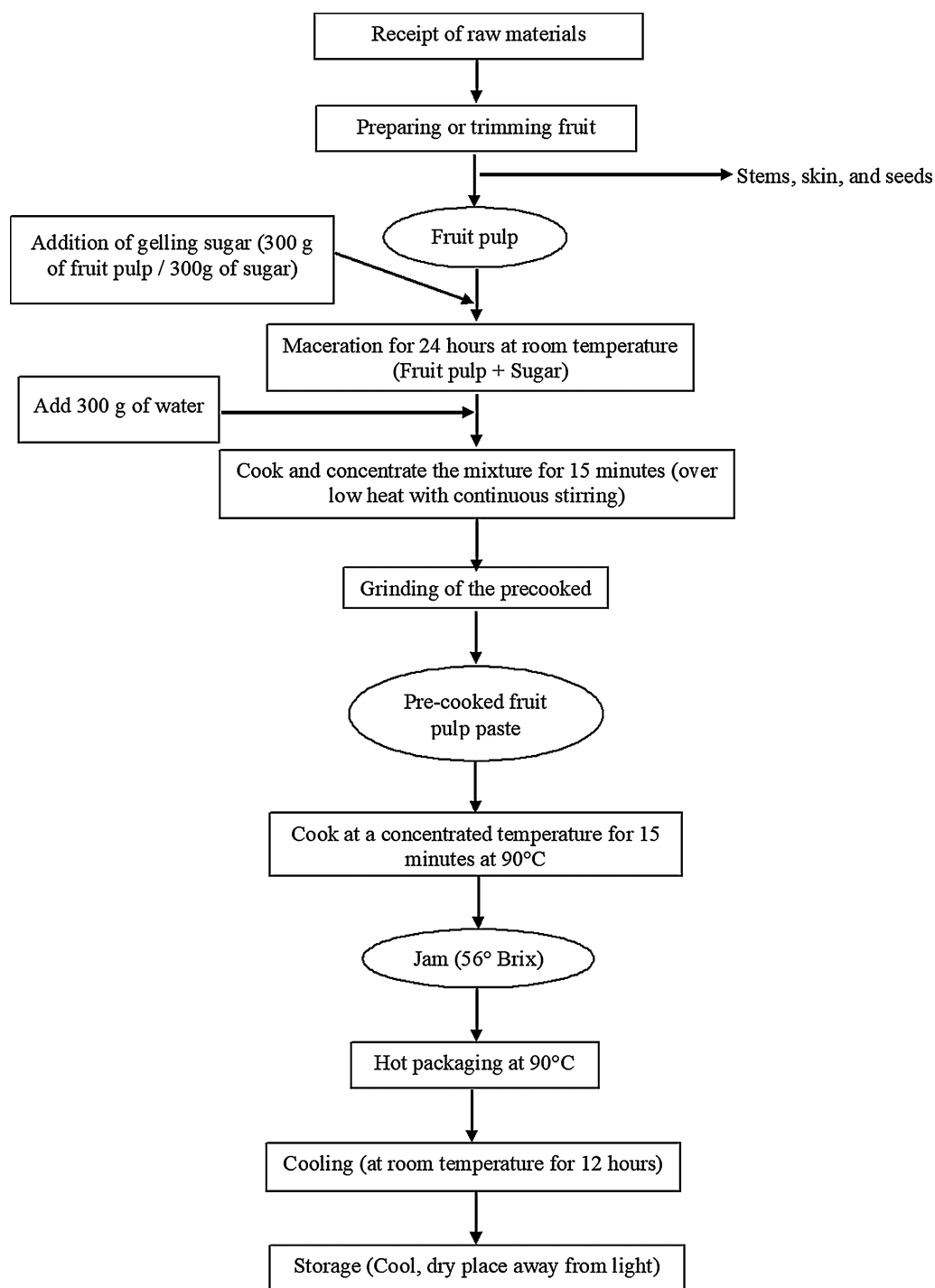


Figure 2. Flowchart for making jam from the fruit of *Flacourtia jangomas* (Lour.) Raeusch.

2.2.2. Physicochemical Analyses of the Fruit and the Prepared Jam

The analyses performed focused on:

- Dry matter (DM): This was determined after drying by placing 5 g of the sample in a drying oven (model DHP9052-INDELAB) at 105°C for 24 hours [25];
- Total ash (TA): This was obtained by incinerating the jam sample in a muffle furnace (Nabertherm, MORE THAN HEAT 30°C - 3000°C) heated to 450°C - 550°C for 8 hours [25];
- Active acidity (pH): The pH was determined according to the method [26] using a pH meter (HANNA Instruments, model EcoTestrpH1). The pH meter was calibrated using standard reference solutions of 4.01 and 7.0 at 25°C. The pH of the fruit jam samples was measured on the filtrate obtained from 2 g of material weighed on a precision balance (RADWAG AS220.R2PLUS) with 20 mL of distilled water and centrifuged at 3000 rpm for 10 min. The sample was measured in triplicate by inserting the pH electrode directly into a beaker containing the samples;
- Total acidity (TA) also known as titratable acidity was determined using the modified method described by Adetoro, L. M. O., *et al.* [11]. Briefly, 5 grams of fruit jam were dissolved in 50 mL of distilled water and centrifuged at 3000 rpm for 10 minutes. To the filtrate (25 mL), three drops of phenolphthalein indicator were added, and the mixture was titrated with a 0.1 N sodium hydroxide (NaOH) solution until a light pink color appeared and persisted for 15 seconds. This procedure was repeated three times. The total titratable acidity was calculated as a percentage of citric acid (Equation (1)) and malic acid (Equation (2)) using the following formulas:

$$TA\left(g_{C_6H_8O_7}/L\right) = V_{NaOH \text{ titrated}} \times 0.64 \quad (1)$$

$$TA\left(g_{C_4H_5O_5}/L\right) = V_{NaOH \text{ titrated}} \times 0.67 \quad (2)$$

- Viscosity: The viscosity of the formulated fruit jam was determined using a Bostwick Consistometer. This test measures the distance traveled by a liquid over a given surface. Approximately 100 mL of the formulated fruit jam was poured into the viscometer's container and allowed to flow down the slope, which is graduated in centimeters, for 30 seconds. The resulting value was then recorded as the consistency of the product at room temperature.
- Brix degree: The total soluble solids (TSS) content of the fruit and the formulated fruit jam was determined. A drop was placed on the prism of the digital refractometer (Automatic Abbe Refractometer SGW-733 User Manual) to obtain the total soluble solids content in Brix (sucrose).

2.2.3. Shelf-Life Studies of *F. jangomas* Fruit Jam

For the preservation study, a jar of jam was stored at room temperature between 27 and 30°C, on the one hand, and another was stored in a cool place at a temperature between 4°C and 5°C, on the other hand. These two jars of jam were tested under real-life conditions of daily household use by opening and closing them before re-

turning them to storage. A physicochemical evaluation of a test sample of the stored jams was conducted every three days during the first two weeks and then on the 27th day of storage (limited to the sample stored under refrigerated conditions) to assess biochemical characteristics such as total soluble solids (TSS), precisely sucrose and glucose content, as well as pH, in order to determine the best-before date.

2.2.4. Sensory Analyses of the Prepared Jam

A selected group of 36 volunteers (composed of men and women, aged 18 to 60 and older, who work at the Brazzaville Science Park and students doing internships in the laboratories) participated as members of the hedonic evaluation panel and in the descriptive testing of the jam. This group was trained to describe the attributes of *F. jangomas* jams. All evaluation sessions took place at the laboratory of the Institute for Research in Engineering Sciences, Innovation, and Technology. The sensory evaluation of the *F. jangomas* jam was conducted two days after it was made and at two separate times in order to complete both sensory tests. Color, taste, odor, and texture were evaluated using a 9-point hedonic scale [where 9 = love it very much, 8 = like it a lot, 7 = like it moderately, 6 = like it a little, 5 = indifferent (neither like nor dislike), 4 = don't like very much, 3 = don't like, 2 = don't like at all, 1 = hate]. As for the overall acceptability of the jam, it was evaluated using a five-point (05) smile scale ranging from don't like at all (1) to love it very much (5), with indifferent (3). All jams were presented to the panelists at room temperature, under normal lighting, in transparent plastic containers coded with random three-digit numbers.

With regard to the sensory profile of the jam, four descriptors rated on an intensity scale ranging from 1 (very faintly perceived) to 7 (very strongly perceived) were selected for 3 to 7 target criteria. These include taste or flavor (sweet, sour, balanced, and aftertaste), color or appearance (red, brown, and purple), texture or consistency (presence of fruit chunks or fiber, viscous, pasty, velvety, gelatinous, thick), and finally, odor (aroma): fruity, caramelized (cooked sugar), and honey (floral). Each taster could check more than one perceived sub-descriptor at a given intensity level.

The scores from all sensory evaluations were used for the mathematical analysis.

2.2.5. Statistical Analyses

The data analysis software Excel (version 2007) and Minitab (version 2017) [27] were used to perform the statistical analyses. Excel was used to calculate sums, means, and standard deviations, as well as to plot graphs. Minitab software (version 2017) [27] was also used for analysis of variance (ANOVA) and descriptive statistical analysis.

3. Results and Discussion

3.1. Physicochemical Properties of *Flacourtia jangomas* (Lour) Raeusch Jam

Several physicochemical properties of *F. jangomas* jam (**Figure 3(a)** and **Figure**

3(b)) such as moisture content, ash content, dry matter content, total soluble solids expressed in Brix as sucrose, as well as pH and titratable acidity, were measured using various standard procedures listed above, and the resulting data are presented in **Table 1**.



Figure 3. *Flacourtia jangomas* (Lour) Raeusch fruit jam: before (a), after 12 hours of packaging (b–c), after 27 days of storage in the refrigerator (d), and after 12 days at room temperature (e).

Table 1. Physicochemical Composition of *Flacourtia jangomas* (Lour.) Raeusch Fruit Jam.

Parameters	Average Values
WC (%)	43.078 ± 0.040
DM (%)	56.922 ± 0.040
AC (%)	0.440 ± 0.180
SC (°B) at 27.4°C	56.600 ± 0.000
pH	3.400 ± 0.000
TA (% citric acid)	2.261 ± 0.074
TA (%malic acid)	2.367 ± 0.077
Viscosity (cm/30s)	1.000 ± 0.000

Legend. WC: water content; DM: dry matter; AC: ash content; SC: sucrose content; TA: titratable acidity.

3.1.1. Water Content (WC)

Jam is a food product with an intermediate water content [18] [28] or a semisolid product [16]. This content can be influenced by the quantity and nature of the ingredients as well as the cooking temperature. It is also a parameter that indicates the shelf life of the products. The higher the water content, the shorter the shelf life [29]. A moisture content of $43.078\% \pm 0.040\%$ (Table 1) was recorded in our jam. Based on the results obtained, we observe that the moisture content of our jam exceeds the standards, which require that the moisture content of jam range between 30% and 40% [30] [31]. This high moisture content may be due to the nature of the gelling sugar or to the water-to-sugar ratio used in our formulation to achieve the desired product texture. This high moisture content could affect the jam's shelf life, as it falls outside the range (averaging 31.23% to 33.36%) of moisture content values for commercially available jams, as stated by Chalchisa, T., *et al.* [32].

Furthermore, our results were higher and not comparable to those obtained by several authors, such as Teixeira, F. *et al.* [33], who found average values ranging from 30.50 ± 0.02 to 30.52 ± 0.02 in four orange jam formulations; and Negrea, M. *et al.* [29], who reported a moisture content ranging from 27.723 to 28.697 g/100 g in six jams made from citrus byproducts including pomelo (PPJ), lime (LIPJ), lemon (LEPJ), clementine (CPJ), orange (OPJ), and grapefruit (GPJ); or by Chalchisa, T., *et al.* [32], where the moisture content ranged from 29.23% to 32.98% in pineapple jams.

3.1.2. Dry Matter (DM)

According to Stamatovska, V. *et al.* [34], the total dry matter content of processed jams depends on several factors, including the sugar used during production, the amount of total dry matter, soluble solids, and total sugars contained in the fruit, as well as the influence of heat treatment. With regard to our results, the average DM content is $56.922\% \pm 0.040\%$ (Table 1). However, this value is not comparable to that obtained by Abid, M *et al.* [14] for one of the pomegranate jams (formulation G) (49.70 ± 0.30). In addition, some authors have obtained relatively low values, such as Stamatovska, V. *et al.* [34] (43.29% - 44.36%) for jams made from Stanley plums; while others have obtained relatively high values, such as Abid, M. *et al.* [14], who found average contents ranging from 1.15 ± 0.35 to 59.40 ± 0.90 for the eight other pomegranate-based jam formulations.

Furthermore, the dry matter content in our jam can be considered high. And when it is high, it can be directly linked to the jam's shelf life during storage and to a longer shelf life [14], ranging from 7 to 15 months, or even longer [35].

3.1.3. Ash Content (AC)

Ash content provides relevant information on the product's mineral content [29], which is very important in many biochemical reactions that contribute to the proper physiological functioning of the body's major metabolic processes [36]. The ash content of the *F. jangomas* jam obtained averages approximately $0.440 \pm 0.180\%$ (Table 1), which is comparable to that of orange jams (0.41 ± 0.01) for-

mulated by Teixeira, F., *et al.* [33]. In contrast, Chalchisa, T., *et al.* [32] found lower ash content values ranging from 0.166 to 0.387% in pineapple jam compared to Negrea, M., *et al.* [29], who reported very high ash contents ranging from 2.717 ± 0.091 to 4.133 ± 0.132 in six jams made from citrus byproducts notably pomelo (PPJ), lime (LIPJ), lemon (LEPJ), clementine (CPJ), orange (OPJ), and grapefruit (GPJ).

3.1.4. Total Sugar and Soluble Solids Content (Brix)

As the main components of jams, sugars give them their taste, aroma, texture, and color [16]. Furthermore, the total soluble solids (TSS) and total sugar content is a refractometric index that indicates the percentage (%) of solids dissolved in a solution [11]. Just like dry matter (DM), the total soluble solids (TSS) content of processed jams is influenced by the type of sugar used; most often, sucrose acts as a natural preservative and inhibits microbial growth by binding water in the jam, thereby making it unavailable for microbial activity and extending its shelf life [11]. Adegbanke, O. R. [37], however, notes that the higher the Brix degree, the better the taste (or sweetness) and the greater the nutritional density of the food.

The total sugar content, expressed as sucrose, in the jam made from *Flacourtia jangomas* fruit was estimated at 56.60 ± 0.000 °B (Table 1). However, our results are lower than those obtained by Teixeira, F. *et al.* [33], who found average values ranging from 63.00 ± 0.0 to 64.01 ± 0.00 in four orange jam formulations, as well as those reported by Negrea, M. *et al.* [29], who found sugar content ranging from 65.540 - 67.246 g/100 in six jams made from citrus byproducts (notably pomelo (PPJ), lime (LIPJ), lemon (LEPJ), clementine (CPJ), orange (OPJ), and grapefruit (GPJ)).

According to the Codex Alimentarius standard [38], standard fruit jams must contain at least 60% soluble solids. However, our results are in line with French regulations, which require a sugar content of 55% in jams.

3.1.5. pH

The pH of processed foods plays a crucial role in maintaining their taste, flavor, color, and texture ([39], cited by [18]).

In jam formulation, pH is a key parameter that must be controlled and lowered [14] to improve the microbial stability of food products ([40], cited by [13]). However, the pH of the jam should not be lowered too much, as this can lead to the deterioration of organoleptic qualities such as glucose crystallization, a grainy texture, an excessively sour flavor, and seepage [13]. International standards require a relatively acidic pH of 2.8 to 3.5 [41] at the end of the process (final jam). Experimental results show that our jam meets this international standard for jam, with our results (pH 3.4 see Table 1) being close to those obtained by Maimaitiyiming, R *et al.* [13], who found values of 3.41 and 3.25, respectively, for the mixed jam made from frozen *Morus nigra* L. fruit and dried *Prunus domestica* L. fruit (4:1 ratio) and for the jam made from frozen *Morus nigra* L. fruit. Azzouzi H. *et al.* [31] also obtained similar values of 3.03 and 3.35 for jams made from Moroccan

clementines; Adetoro, L. M. O. *et al.* [11] found a value of 3.07 ± 0.06 in a standard plum jam (NPJ); Degmara Nihal *et al.* [42] reported a value of 3.5 for strawberry jam; Teixeira, F. *et al.* [33] found values ranging from 3.30 to 3.50 in four orange jams; and finally, Abid, M. *et al.* [14] reported values of 3.11 (formulation A), 3.08 (formulation C), and 3.06 (formulation E) for pomegranate jams, respectively. Adegbanke, O. R. [37] found higher values ranging from 4.17 ± 0.01 to 4.56 ± 0.01 for mixed jams made from apples, oranges, bananas, and papayas. Furthermore, gel formation occurs only within a specific range of hydrogen ion concentration (2.7 - 3.6), where the optimal pH range for proper jam gelling [18] is around 3.0 [43]. Above a value of 4, no gel formation occurs [43].

3.1.6. Titratable Acidity (TA)

pH and total titratable acidity are important parameters for optimal gelling, for preventing the growth of microorganisms that cause food poisoning, and for maintaining the quality of jam [11]. It has been noted that the presence of organic acids contributes to a long shelf life for jams [35]. Furthermore, Uddin, M. R., *et al.* [44] note that sugars and fruit acids are the main contributors to the total soluble solids (TSS) content of fruit-based products, hence their evaluation.

In our study, the titratable acidity in the jam made from *Flacourtia jangomas* fruit was quantified and expressed as a percentage of malic acid, firstly because it is assumed to be rich in malic acid since it is a plum species, in which malic acid is the predominant acid; and second, as a percentage of citric acid due to the tart gelling sugar used in the jam's preparation. It was observed that the values were similar regardless of the organic acid in question, at 2.261 ± 0.074 and 2.367 ± 0.077 (Table 1), respectively, as a percentage of citric acid and malic acid. These values are similar to those obtained by Emelike, N. J. T., & Akusu, O. M. [45] in guava ($2.60\% \pm 0.01\%$) and mango (2.78 ± 0.00) jams among the six formulations tested. Our results for titratable acidity, expressed as acid. Total acidity, expressed as malic acid in accordance with STAS 5952-71, is a maximum of 0.5% for products preserved with sugar [46]. Thus, the titratable acidity, expressed as a percentage of malic acid, in our analyzed jam sample does not comply with the limits set by current standards and is significantly higher—a value far removed from those obtained by other researchers, who reported a total acidity range of 0.31% to 0.48%, for different types of mango jam (MJ) and mixed mango-pineapple jam (MPJ) [46]. In contrast, Viana, E.S., *et al.* [47] found that the titratable malic acidity (AT) of different formulations ranged from 1.07% [F1: 70% banana extract (BE): 30% Araçá-boi (AB)] to 1.94% [F4: 30% banana extract (BE) and 70% Araçá-boi (AB)], which fell within the predetermined acidity range for fruit jams.

Finally, the high acidity values observed in our study, although lower (ranging from 2.60% to 4.63%) than those obtained by Emelike, N. J. T., & Akusu, O. M. [45], indicate that the jam can be stored for a long time ranging from 7 to 15 months, or even longer thanks to the presence of organic acids [35] and that the growth of microorganisms can be inhibited (technological aspect), in addition to the impact on taste (sensory aspect) [29].

3.1.7. Dynamic Viscosity

Viscosity is the measure used to assess a jam's resistance to flow [11]. It depends on the pectin concentration in the fruit and the production temperature [45] which is one of the most important parameters [36] [45] as well as pH and sugar [11]. To achieve the desired consistency and firmness, the addition of sugar primarily refined sugar or white sugar (sucrose) [16] is essential for the gelling of jams. Numerous models have been developed to predict the flow properties of food products. Thus, we evaluated the apparent viscosity of the formulated *Flacourtia jangomas* fruit jam, which was found to be approximately 1 cm/30 s (Table 1). Based on the Bostwick viscosity test, this value indicates that the jam has a thick or nearly gelling texture or consistency. Furthermore, according to Awolu, O. O., *et al.* [36], high viscosity could be attributed to a high fiber content and, above all, to the concentration of pectin. It should also be noted that viscosities can vary depending on the presence of added sugars and sugars naturally present in the fruit, processing conditions, and the specific jam formulations.

This is the case with Adetoro, L. M. O. *et al.* [11], who observed viscosities ranging from 204.30 ± 2.97 Pa·s in date and apple jam (DSAJ) to 401.00 ± 1.41 Pa·s in kola nut and sugar-sweetened monkey fruit jam (SSMJ). This is also the case for Awolu, O. O., *et al.* [36], who reported viscosities measured at 30°C ranging from 90.33 ± 0.58 dPa/sec in the Banana: watermelon: pineapple in a 25:25:50 ratio to 300.00 ± 0.00 dPa/sec in the banana: watermelon: pineapple jam in a 50:25:25 ratio.

3.2. Stability of *Flacourtia jangomas* (Lour) Raeusch-Based Jam

Parameters such as moisture content [29] [44], dry matter content, the presence of organic acids [35], and pH [13] influence shelf life. In our study, only pH and soluble dry matter content expressed as a percentage of sucrose were measured.

Table 2 and Table 3 present the results obtained.

The average sucrose content was 56.60 ± 0.000 °Brix at the start of storage, immediately after formulation. After approximately 15 days of storage, and every three days when the samples undergoing stability testing were opened and closed, it was observed that both dry matter (DM) values increased from 56.60 ± 0.000 to 59.11 ± 0.000 °Brix (Table 2) for the sample stored in the open air (after 12 days); and from 56.60 ± 0.000 to 65.19 ± 0.000 °Brix for the sample stored in a cool place (Table 3). The results obtained are consistent with several research studies that have reported a continuous increase in the TSS content of jam when evaluating its storage stability: Masih S. *et al.* [18], for jams prepared from four varieties of jujube, ranging from 69.92 to 70.20 °Brix; Ullah, N., *et al.* [28] for a mixed carrot-and-apple jam, where the average TSS value was 67.45 at the start of storage and 70.40 after 90 days. The same applies to Shah, W., *et al.* [48] (69.37 to 70.43) for apple- and olive-based jams, as well as Rana, M. S., *et al.* [49], where the initial soluble solids content (TSS) of the mixed coconut and pineapple jam samples increased from 67.0 °Brix, 67.7 °Brix, and 67.5 °Brix to 69 °Brix, 68.9 °Brix, and 69

°Brix, and then to 68.5 °Brix, 68.8 °Brix, and 68.7 °Brix after packaging in glass containers and storage at room temperature and in the refrigerator, respectively.

Table 2. Effect of storage on the pH and soluble dry matter of jam stored at room temperature.

Physicochemical Parameters	Initial (Day 0)	Day 3	Day 6	Day 9	Day 12
pH	3.40 ± 0.00	3.40 ± 0.00	3.40 ± 0.00	3.40 ± 0.00	
Sacch. (°Brix)	56.60 ± 0.00	56.56 ± 0.00	58.70 ± 0.00	59.10 ± 0.00	Presence of Mold
Temp. (°C)	27.4°C	21.2°C	22.7	25.1	

Legend: Sacch.: Sucrose; Temp.: Temperature.

Table 3. Effect of storage on the pH and soluble dry matter of jam stored in a cool place (refrigerator).

Physicochemical Parameters	Initial (Day 0)	Day 3	Day 6	Day 9	Day 12	Day 27
pH	3.40 ± 0.00	3.30 ± 0.00	3.30 ± 0.00	3.40 ± 0.00	3.40 ± 0.00	3.70 ± 0.00
Sacch. (°Brix)	56.60 ± 0.00	60.85 ± 0.00	60.43 ± 0.00	65.19 ± 0.00	62.16 ± 0.00	60.36 ± 0.00
Temp. (°C)	27.4	22.7	25.5	23.0	20.5	20.5

Legend: Sacch.: Sucrose; Temp.: Temperature.

The increase in total soluble solids (TSS) content could be due to the formation of mono- and disaccharides resulting from the hydrolysis of polysaccharides [49] in the presence of acid [48], and to the fermentation of sugars [50]. Furthermore, according to Uddin, M. R. *et al.* [44], this increase in total soluble solids (TSS) indicates a reduction in moisture content, thereby improving the nutritional quality of the jam samples.

The pH of the *F. jangomas* fruit jam remained stable at 3.4 throughout the stability test period for the sample stored at room temperature (Table 2). In contrast, in the sample stored in the refrigerator, a slight decrease in pH (to 3.3) was observed after six days. This decrease in pH can be attributed to pectin hydrolysis, the formation of free acid [48] [50] during sugar degradation, and to changes in composition [50]. However, a rise in pH to 3.7 was observed on the 27th day, following a period of stability (3.4) between the 9th and 15th days (Table 3). Our results do not align with those of previous studies on jujube jam (3.84 to 3.76, [18]); coconut and pineapple jam (2.95 to 2.85, [49]); carrot jam (3.34 to 2.62, [50]); mixed carrot and apple jam (3.63 to 3.44, [28]); and finally, apple-olive jam (3.57 to 3.40, [48]), which showed a decrease in the pH of the fruit jams during storage.

In addition, we observed the appearance of a layer of mold on the sample stored at room temperature after 15 days. These results underscore the recommendation to consume opened jam quickly—ideally within two weeks. In contrast, we did not observe any mold growth in the sample stored in a cool place for more than 15 days.

3.3. Sensory Evaluation of Jam Made from *Flacourtia jangomas* (Lour.) Raeusch

In accordance with Adegbanke, O. R. [37], sensory analysis is an integral part of food evaluation because it engages the human senses of sight, smell, taste, touch, and hearing, thereby providing essential information about food products. Sensory characteristics such as texture, flavor, aroma, shape, and color are considered key quality attributes valued by consumers [44]. One of the most important factors that consumers consider when choosing foods is color [14] [18]. Taste, on the other hand, is a key factor in determining consumer preference for a product. It encompasses flavor, texture, aroma, and visual appearance [18].

Table 4 below presents the scores obtained from the hedonic test.

Table 4. Sensory evaluation of *F. jangomas* fruit jam.

Descriptors	Mean $\pm$ SD	% approval	% indifference	% rejection
Color	7.944 $\pm$ 1.013 ^A	97.220	2.780	0.000
Odor	7.444 $\pm$ 1.576 ^{AB}	94.440	0.000	5.560
Flavor	7.250 $\pm$ 1.663 ^{AB}	86.110	2.780	11.110
Texture	6.944 $\pm$ 1.999 ^B	86.110	0.000	13.890

Values are expressed as mean $\pm$ standard deviation. Means followed by the same letter in the same column, for each attribute, do not differ according to Tukey's test ($p > 0.05$), % approval percentage of scores 6 through 9; % of indifference percentage of scores of 5; % of rejection percentage of scores from 1 to 4.

Table 4 shows the mean sensory scores for jam prepared using *Flacourtia jangomas* fruits. Mean scores for color, taste, aroma and texture reveal that no significant difference (P -value = 0.064) was observed between attributes of jam. Since the P -value of the controlled one-way analysis of variance is greater than 0.05, there is no statistically significant difference between the means of the 4 organoleptic attributes at the 5% significance level.

However, when clustering information was taken into account using Tukey's method at a 95% confidence level ($p < 0.05$), and since the factors "color" and "texture" did not share any common letters, this indicates that the mean for color is significantly higher than that for texture.

3.3.1. Hedonic Test

The results regarding the color of the jam showed that the formulation received a higher score (7.944), with an acceptability rate of 97.22% and a rejection rate of 0% (**Table 4**). These data are based on 36.11% (data not shown) of tasters who assigned a maximum score of 9 (love it) and 2.78% (data not shown) who assigned the minimum score of 5 (indifferent) on the hedonic scale. Results similar to those of the present study were reported by Teixeira, F. *et al.* [33], who obtained a score of 7.82 ± 1.28 for one (OP0) of the four orange jam formulations. Adetoro, L. M. O., *et al.* [11] obtained a score of 8.14 ± 0.90 for the color of classic apple jam. In

contrast, Machalela, A. A., *et al.* [51] obtained average scores ranging from 6.24 to 6.58 for tomato jam, results that were lower than those found in the present study.

The aroma or odor can be influenced by the composition of the fruit and/or additives. Regarding the aroma of the jam, we obtained a score of 7.444, with an acceptability rate of 94.44% and a rejection rate of 5.56% (Table 4). These data are based on 27.78% (data not shown) of tasters who reported a maximum score of 9 (love it) and 2.78% (data not shown) who gave the minimum score of 2 (“don’t like it at all”) on the hedonic scale. Results similar to those of the present study were reported by Teixeira, F. *et al.* [33], who obtained a score of 7.55 ± 1.35 for an orange jam formulated with 4% orange peel (OP4). In contrast, Machalela, A. A., *et al.* [51] obtained average scores ranging from 5.96 to 6.42 for tomato jam, results lower than those found in the present study. Adetoro, L. M. O., *et al.* [11], in their study on orange jam, reported higher averages of 8.25 ± 0.50 ; 8.00 ± 0.82 , and 8.50 ± 0.57 for commercial fruit jam (CFJ), regular monkey nut jam (NMJ), and regular plum jam (NPJ), respectively.

In terms of taste, the jam received a score of 7.250, with an acceptability rate of 94.44% and a rejection rate of 11.11% (Table 4). These results are based on 27.78% (data not shown) of tasters who gave a maximum score of 9 (love it) and 2.78% (data not shown) who gave the minimum score of 3 (“don’t like it”) on the hedonic scale. Teixeira, F. *et al.* [33] obtained similar scores (7.07 ± 1.36 - 7.71 ± 1.51) for orange jams formulated with varying percentages (4% - 12%) of orange peel.

As for texture, in the evaluation conducted by Teixeira, F. *et al.* [33] in their study on orange jam, they reported obtaining the highest averages, ranging from 7.44 ± 1.24 to 7.75 ± 1.19 for formulations containing 0.4% and 8% orange peel, whereas the formulation containing 12% orange peel had a score of 7.10 ± 1.52 , which is close to the results (6.944) of the present study, where the acceptability and rejection rates were 86.11% and 13.89%, respectively (Table 4). These data were obtained based on 25% (data not shown) of evaluators who reported a maximum score of 9 (love it) and 2.78% (data not shown) who gave the minimum score of 1 (hate it) on the hedonic scale. It can be suggested that the average score of 6.944 ± 1.999 indicates a pleasant mouthfeel, likely due to the balanced textural properties of the fruit, as stated by Adegbanke, O. R. [37] in his recent work. Machalela, A. A. *et al.* [51], on the other hand, obtained average and lower scores for the texture descriptor, ranging from 6.1 to 6.56, in tomato jam.

Overall acceptability scores (Figure 4(a)) showed that *F. jangomas* fruit jam received ratings of 5 (like very much), 4 (like somewhat), and 2 (do not like very much) on the five-point rating scale, corresponding to 44%, 50%, and 6%, respectively.

3.3.2. Descriptive Analysis

To analyze the results obtained from the sensory profile of the jam, we chose to perform a descriptive statistical analysis of the responses; and the average numbers of participants who perceived a sub-descriptor are presented graphically in

Figure 4(b) through Figure 4(f).

Referring to **Figure 4(a)**, we note that the colors red and brown were most frequently perceived at the same four intensity levels (from 2 = very faintly perceived to 5 = perceived) by the assessors, whereas the color purple was perceived by only one assessor at an intensity of 4 (perceived). For the color red, three (3), eight (8), two (2), and four (4) evaluators assigned intensity levels of 5 (Perceived), 4 (Moderately perceived), 3, and 2 (Weakly perceived), respectively. Regardless of the intensity level, a total of 19 assessors or 53% perceived the jam as having a red color. On average, the red intensity was perceived by 3.80 ± 2.49 individuals. As for brown, three (3), one (1), three (3), and five (5) raters as opposed to four (4) rated the intensity as 5 (perceived), 4 (moderately perceived), 3, and 2 (weakly perceived), respectively, as well as 1 (very weakly perceived). As with the color

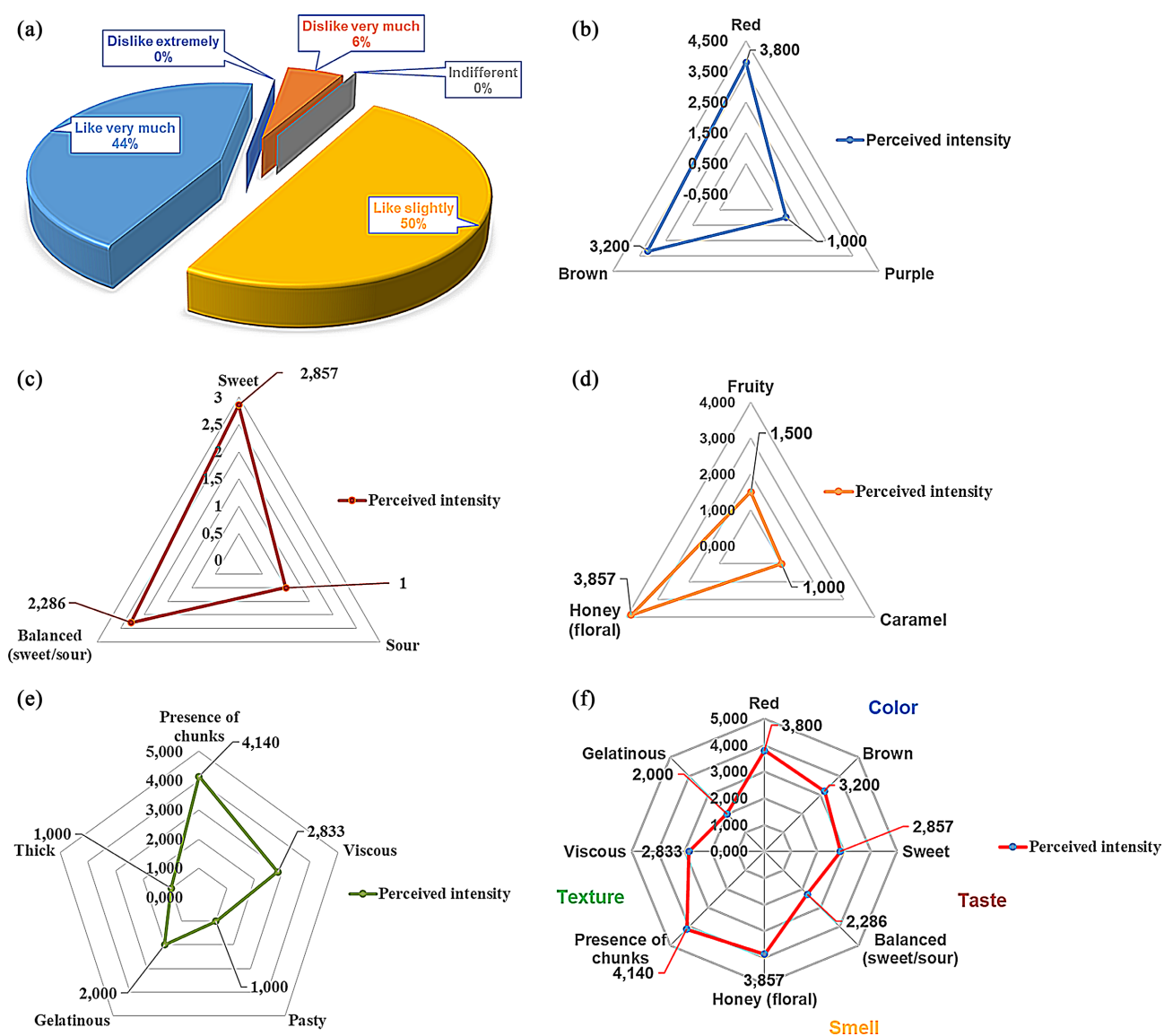


Figure 4. Overall acceptability of the hedonic test (a) on a scale of 1 - 5 and sensory profiles of the descriptors for color (b), taste (c), odor (d), texture (e), and the overall set of descriptors (f).

red, and regardless of the intensity level, a total of 16 assessors or 44% perceived the jam as brown. On average, the red intensity was perceived by 3.20 ± 1.483 individuals.

As with color, in terms of taste and referring to **Figure 4(c)** we observe that the sweet and balanced (sweet/sour) tastes were the most frequently perceived by the tasters across all seven (7) intensity levels. In contrast, the sour taste was perceived by only one taster at an intensity of 4 (moderately perceived). The aftertaste was not perceived by any taster. Regarding the sweet taste, intensities 3 (weakly perceived), 4 (moderately perceived), and 5 (perceived) were mentioned by a group of three (3) tasters for each intensity cited. Furthermore, four (4) and five (5) tasters rated the intensity at levels 6 (extremely noticeable) and 7 (very, very noticeable), respectively. In total, 20 tasters, or 54%, reported that the jam tasted rather sweet. On average, the sweet taste was perceived by 2.857 ± 1.464 individuals, although a total of 13 tasters reported the highest sweetness intensities (6 and 7). Regarding the “balanced taste” descriptor, intensities 5 (perceived), 6 (extremely perceived), and 7 (very extremely perceived) were rated by two (2) tasters for each intensity. In contrast, four (4) and three (3) tasters rated intensities 4 (moderately perceived) and 3 (weakly perceived), respectively. For this sub-descriptor, there were 16 evaluators in total, 43% of whom reported perceiving the jam as having a balanced flavor. The average number of evaluators who perceived the intensity levels for the “balanced” and “acidic” tastes were approximately 2.286 ± 0.951 and 1.000 ± 0.000 , respectively.

As for the aroma, the honey (floral) aroma was the one most frequently perceived (see **Figure 4(d)**) by the majority of tasters (27 tasters or 75%), at across all intensity levels (from 1 = very faintly perceived to 7 = very strongly perceived), where it was noted that seven (7) tasters perceived a honey (floral) at an intensity of 3 (moderate) and five (5) tasters at intensities of 6 and 7 (very strong) and three (3) tasters at intensities of 1 and 2 (very faintly perceived), whereas the caramelized (one assessor for each intensity level or 17%) and fruity (2 tasters or 8%) scents were perceived only weakly. The average perceived intensity in terms of an assessor for the floral, fruity, and caramelized odors was 3.857 ± 1.864 , 1.500 ± 0.707 , and 1.000 ± 0.000 , respectively.

Finally, for the texture descriptor (**Figure 4(e)**), we found that the criteria “presence of chunks” (29 tasters or 32%) and “viscous sensation” (26 tasters or 28%) were rated highest by the tasters for all seven (7) intensity levels, except for level 2 for the viscous sensation. On average, $4,140 \pm 3,13$ and $2,833 \pm 2,229$ tasters perceived the “presence of chunks” and the “viscous” texture, respectively, in the jam. Furthermore, the pasty (9 tasters or 10%), gelatinous (18 tasters or 20%), and thick (9 tasters or 10%) textures were, on average, perceived as low, with average intensities of approximately 1.000 ± 0.000 , 2.000 ± 0.000 , and 1.000 ± 0.000 , respectively. The “velvety” response was not perceived by any taster.

Ultimately, by grouping the sub-descriptors of the sensory profile of *Flacourtia jangomas* jam as perceived by the tasters (see **Figure 4(f)**), we can conclude that

the jam made from *Flacourtia jangomas* fruit has a reddish-brown color, a sweet and balanced taste (sweet and tart), a strong honey-like aroma, and a slightly gelatinous or viscous texture with a pronounced presence of fruit chunks.

4. Conclusion

The objective of this study on the formulation of jam made from *F. jangomas* fruit using traditional methods was achieved. The methodology employed was based on a comprehensive evaluation of physicochemical parameters, including pH, acidity, total soluble solids (TSS), ash content (TC), moisture content (TE), and apparent viscosity, as well as sensory analysis. The results indicated, among other things, low acidity (pH 3.4), a moderate total soluble solids (TSS) content (56.57 ± 0.00) within the French standard range, and high apparent viscosity. The shelf-life study showed that the jam may be edible for up to 27 days after opening if stored at 4°C (no visible mold). After about two weeks at 27°C - 32°C, it was no longer safe for consumption. Nevertheless, sensory analysis which is essential for understanding consumer preferences showed that the jam excelled in terms of color, taste, aroma, texture, and overall acceptability. This study demonstrated that *F. jangomas* fruit jam has promising physicochemical and sensory properties, offering practical implications for the food industry. This could help explore the possibility of processing the fruit into other products such as jam, thereby contributing to the reduction of post-harvest fruit losses, the improvement of the population's diet, and promising opportunities in the market.

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Use of Artificial Intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

Glossary

Moisture Content (Moisture)

Ash Content (Ash)

Soluble Dry Matter (SDM)

Total Titratable Acidity (TTA)

pH: Hydrogen Ion Concentration

Solid Dry Matter (SDM)

Author Contributions

Conceptualization, N.P.G. Pambou-Tobi; methodology, N.P.G. Pambou-Tobi, Arnaud W.G. Tamba Sompila, Daglish Rucia Mouna Tchibondo, Reyes H. Gampoula and Haïshat Souleymane Mahoumi; software, N.P.G. Pambou-Tobi and

Daglish Rucia Mouna Tchibondo; validation, N.P.G. Pambou-Tobi and Arnaud W.G. Tamba Sompila; formal analysis, Arnaud W.G. Tamba Sompila; data curation, Daglish Rucia Mouna Tchibondo; writing—original draft preparation, N.P.G. Pambou-Tobi; writing—review and editing, N.P.G. Pambou-Tobi and Arnaud W.G. Tamba Sompila; visualization, Fanny B Ganongo-Po; supervision, Ntsossani Sylvia Petronille; project administration, N.P.G. Pambou-Tobi. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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