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Physicochemical and Morphological Characterization of the Skin, Pupa, and Seeds of *Flacourtia jangomas* (Lour) Raeusch Fruit from Kindzaba, Bouenza Department

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Abstract

The fruit of *Flacourtia jangomas*, known as Indian plum, Madagascan plum, or coffee plum, is highly prized in Asian and African countries for its pleasant sweet and sour taste. Very little research has been done on this fruit in Congo, so the aim of our work is to evaluate the morphological and biochemical composition of the pulp, skin, and seeds of *Flacourtia jangomas* (Lour) Raeusch fruits harvested in the village of Kindzaba in Loutété, in the Bouenza region. Standard physicochemical methods and appropriate calibration methods were used to characterize the fruits. The results on morphology showed variation in the different structural parts of the fruit according to the three sizes identified. Furthermore, although the data on the mass percentage of pulp, skin, and seeds were significantly different ($\alpha < 0.05$), they indicate that fruit size is not an obstacle to the manufacture of value-added products. The biochemical results for the fruit showed that the pulp and skin contained a large amount of water (69.03 ± 1.19%) and soluble sugars based on glucose (0.99 ± 0.02%) compared to the seeds. However, the seeds were found to have a higher content of ash (2.86 ± 0.78%), protein (5.06 ± 0.11%), lipids (9.47 ± 0.09%), total sugars (74.63 ± 1.06%), and dry solids (92.02%). The energy value was 134.73 ± 1.03 Kcal in the pulp-skin and 403.99 ± 1.86 Kcal in the seeds. The pH of the pulp/skin (3.38 ± 0.70) is lower than that of the seeds (5.36 ± 0.04); the pulp/skin is much more acidic than the seeds. Finally, these results are conclusive and provide information on the potential of all the fruit structures of the Indian plum.

Keywords

Chemical Composition, *Flacourtia jangomas*, Skin-Pulp, Seeds, Physical Morphology

1. Introduction

Merise-pays, scientifically known as *Flacourtia jangomas*, is a tree found in lowland and mountain rainforests, belonging to the genus Flacourtia and the willow family (Salicaceae), formerly the Flacourtiaceae family, which includes 15 species of shrubs and small flowering trees [1]-[3]. The genus *Flacourtia* was formerly named in honor of Étienne de Flacourt (1607-1660), governor of Madagascar, and was placed in the now extinct family Flacourtiaceae [4]-[6] cited by Tripathi *et al.*, [1]. *Flacourtia jangomas* (Lour.) Raeusch in particular is one of the exotic fruit trees with medicinal properties, semi-wild, tropical, and native to the *Flacourtia genus*, where it is commonly known as Indian plum or Paniala, coffee plum, East Indian plum, Manila cherry [7], lubica or lovlolika [8]. It is often confused with the closely related species *Flacourtia indica*, from which it can be distinguished by its narrower, more pointed leaves [9]. It is widely cultivated in Southeast and East Asia, mainly in the northeastern states of India [10] [11] and has naturalized in a number of locations [8]. Its wild origin is unknown, but it appears to originate from tropical and subtropical regions of Africa and Asia [5].

The fruits are ellipsoid, subglobose berries, 1.5 to 2.5 cm in diameter [1], dark red or purple to almost black like cherries, harvested from June to July [10] [12] on a large upright tree or small tree 5 to 10 m tall with low branches [11] [13]. This same fruit, with a taste ranging from sour to sweet, can be eaten raw or processed into juice, syrup, jam, marmalade, pickles, and sauces, and is also used in chutneys Dubey and Pandey [14] cited by Karishma *et al.*, [15]. In the Caribbean, the fruits are particularly popular in the preparation of drinks and dishes, while in India they are of great culinary and medicinal importance, especially in Kerala [1].

The fruits are the part of the plant most commonly used for human consumption. It has been found that the edible juicy fruits are highly nutritious due to their good content of monounsaturated fatty acids, protein, vitamin C, sucrose, and considerable amounts of Ca, K, P, Fe, and Mg, fiber, and vitamin B3 [1] [16] [17]. They also contain a good amount of α-carotene (2.100 µg/g), alkaloids (254.00 µg/g), tannins (8.00 µg/g [14], total polyphenols (1,111.164 mg EAG/g DM), and total flavonoids (32.57 mg ECt/g DM) [18]. These fruits could therefore be useful as supplements to a balanced diet [16].

Congo-Brazzaville, rich in biodiversity and climate, has a wide range of plants that are not exploited or valued. *Flacourtia jangomas* (Lour.) Raeusch, which is not widely distributed throughout the country, deserves to be explored and promoted in the field of research into nutritious and therapeutic molecules. In the past, plants were used as an essential means of medication for populations [19]. The objective of our work is therefore to evaluate the morphological and nutritional composition of the pulp and skin, as well as the seeds, of *Flacourtia jangomas* (Lour) Raeusch, one of the plants cultivated in a field located in the Bouenza department, specifically in the village of Kindzaba.

2. Materials and Methods

2.1. Materials

The plant material consisted of *Flacourtia jangomas* (Lour) Raeusch fruits harvested in April 2023 from Mr. TOBI-N'DZABA's experimental farm called "Kôrmo," located in the village of Kindzaba in Loutété, in the Bouenza department. These fruits, shown in **Figure 1**, were transported 72 hours after harvesting to the Agri-Food Technology Laboratory (LTA) of the National Institute for Research in Engineering Sciences, Innovation, and Technology (INRSIIT), located within the former ORSTOM scientific complex of the Ministry of Scientific Research and Technological Innovation (MRSIT) in the 1st district of Makélékélé, Brazzaville (Congo).

Figure 1. Fruit on a branch (a), harvested fruit (b); seeds (c) and pulp (d) of *Flacourtia jangomas* (Lour.) Raeusch fruit (photo by TOBI NDZABA and MOUNA T., 2023).

2.2. Methods

2.2.1. Preparation and Calibration of *Flacourtia jangomas* (Lour.) Raeusch Fruits

Immediately after the fruits were received at the laboratory, they were first sorted according to ripeness, then weighed to assess the mass of the product received. The fruit was washed with drinking water to remove any impurities, drained, and then weighed again. The fruit was then divided into two batches, one of which was stored in bags suitable for freezing at −18˚C for future work, and the other used immediately.

In recent years, studies on the physico-morphological properties of various agricultural products have been conducted to assess their processing qualities. Thus, the fruits of *Flacourtia jangomas* (Lour.) Raeusch were characterized on the basis of the physico-morphological characteristics of their structural parts (skin, pulp, and seeds). Length (L) and diameter (D) were the physical and morphological measurements taken. A sample of thirty fruits was selected at random and divided into three groups of ten fruits according to visual size (small, medium, and large). These were measured using a branded caliper (STAREX STAINLESS, 0 - 150 mm) and the average of these values was expressed in centimeters. The individual weight (m) of whole fruits was recorded using a precision scale (RADWAG AS220.R2PLUS, 0 - 210 g) and expressed in grams as the average of ten fruits for each group. The number of seeds (Npé) in the fruit was counted and the average calculated. The weight of the skin, pulp, and seeds was recorded separately on the precision scale, and the relative proportion of each component in relation to the total weight was calculated to obtain the physical composition.

2.2.2. Biochemical Analyses of Pulp and Seeds

The fresh fruits shown in **Figure 1** above were carefully divided into two structural parts (skin-pulp and seeds), which were analyzed individually due to the requirements of the determination.

Chemical properties such as pH (actual acidity), moisture content (MC), total ash content (AC), dry solid matter (SDM), carbohydrates content (CC), proteins (PC), lipids (LC), and soluble sugars (SST) were measured according to the various procedures mentioned below:

- **Moisture content (MC)**

The moisture content of each fruit sample used in the study (skin-pulp and seeds) was determined by drying in a BIOBASE laboratory oven (0˚C - 300˚C) at 103 ± 2˚C until a constant weight was obtained using the AOAC method [20]. The moisture content value was calculated and presented on the basis of wet weight (hw).

The dry matter of each fraction (pulp with skin and seeds) was ground separately and sieved through a 250 µm mesh sieve before further analysis. The dry matter fraction was determined using the differential method (100 - %MC), with values expressed on a dry basis (db).

- **Dry matter (DM)**

The dry matter of each fraction (pulp with skin and seeds) was ground separately and sieved through a 250 µm mesh sieve before further analysis. The dry matter fraction was determined using the differential method (100 - %MC), with values expressed on a dry basis (db).

- **Ash content (AC)**

Total ash was obtained after incinerating the skin/pulp and seed samples separately in a Nabertherm muffle furnace (MORE THAN HEAT 30˚C - 3000˚C) heated to 450˚C - 550˚C for 8 hours [20].

- **Protein Content (PC)**

Protein content in the seed and peel/pulp fractions was analyzed by the Kjeldahl method [21] using an Includes InKjel 1225 TCP infrared dissolution apparatus, Behrosog 3 neutralizer, and S5 water vapor distiller. The conversion to protein content of the determined nitrogen content, present as ammonia in the digested sample, was by the multiplication factor of 6.25 [22]-[24].

- **Lipid content (LC)**

The lipid content was obtained after Soxhlet extraction using a SOXTEC AVANTI 2050 device, extracting the fat from the skin/pulp and seeds with hexane as a solvent for 6 hours [20].

- **Carbohydrate content (CC)**

The carbohydrate fraction was deduced by difference by the method of Egan *et al.*, [25] according to the formula values in dry basis (d.b.):

$$\textbf{Carbohydrate rate (\%)} = 100 - [\text{PC (\%)} + \text{LC (\%)} + \text{AC (\%)} + \text{MC (\%)}] \quad (1)$$

- **Soluble sugar content (SST)**

Soluble sugars were measured using the anthrone colorimetric method in sulfuric acid medium proposed by Yemm E.W. [26]. The optical density was measured at 620 nm. A calibration curve was first produced using a solution of anhydrous α-D-glucose (reference solution) in increasing concentrations ranging from 0.25 mg/mL to 1.00 mg/mL.

- **Actual acidity: pH**

The pH was evaluated according to the protocol established by the **DGCERF** [27], in which a test sample of 2 g of fruit powder was dissolved in 20 mL of distilled water, then filtered, left to stand for 1 hour, and finally, the reading was taken on the device screen (EcoTestrpH1) after inserting the probe and stabilizing the measurement.

- **Energy value (EV)**

To determine the theoretical caloric value of the skin, pulp, and seeds of *F. jangomas* fruit, the elements of the main constituents (carbohydrates, proteins, lipids) were added to their Atwater thermal coefficients [28] according to the following formula:

$$\text{Energy value (kcal)} = [(\%\ \text{carbohydrates} \times 4) + (\%\ \text{proteins} \times 4) + (\%\ \text{lipids} \times 9)] \quad (2)$$

2.2.3. Statistical Analysis

All measurements in the study were performed in triplicate (n = 3), with the exception of the proportion of fruit parts (n = 30). The results will be presented as mean values with the corresponding standard deviation (SD). ANOVA and Tukey's multiple comparison test (using Minitab 2017 software) were used as statistical tools to evaluate significant differences at $p < 0.05$.

3. Results and Discussion

3.1. Physico-Morphological Analysis of *Flacourtia jangomas* (Lour) Raeusch Fruits

F. jangomas fruits are round and measure approximately 15 to 25 mm in diameter [7] [17]. According to [29] cited by Utpal Barua *et al.*, [30] fruit size is one of the most important characteristics of a fruit crop, and larger fruits are generally preferred in most fruit species.

We therefore divided the fruits with approximately the same visual size into three batches. The results of the fruit size grading of *F. jangomas* are shown in **Table 1**.

Table 1. Physico-morphological analysis of *Flacourtai jagoams* (Lour) Raeusch fruits.

Sample	Physical parameters	MFE (g)	Ef (cm)	Lf (cm)	Mpe (g)	Mpé (g)	Npé	Mpu (g)
F. jangomas small caliber	Minimum	1.726	1.200	1.200	0.324	0.265	7.000	1.015
	Maximum	2.296	1.500	1.500	0.487	0.410	10.000	1.564
	Average	**2.097A**	**1.380B**	**1.360B**	**0.388B**	**0.319C**	**7.800B**	**1.390C**
	Ecartype	0.185	0.092	0.107	0.047	0.046	1.135	0.168
F. jangomas medium-caliber	Minimum	3.131	1.400	1.440	0.461	0.471	9.000	2.090
	Maximum	4.365	1.700	1.700	0.890	0.806	14.000	2.891
	Average	**3.720B**	**1.520B**	**1.564B**	**0.689AB**	**0.610B**	**10.700A**	**2.422B**
	Ecartype	0.431	0.089	0.090	0.130	0.131	1.418	0.330
F. jangomas large caliber	Minimum	4.700	1.800	1.800	0.696	0.695	8.000	3.182
	Maximum	7.100	2.100	2.100	1.193	1.313	15.000	4.220
	Average	**5.518C**	**2.020A**	**2.030A**	**0.860A**	**0.876A**	**11.200A**	**3.766A**
	Ecartype	0.777	0.123	0.095	0.156	0.190	2.440	1.253

MFE: mass of whole fruit; Ef: fruit thickness; Lf: fruit length; Mpe: skin mass; Mpé: seed mass; Npé: number of seeds; Mpu: pulp mass. Means with different upper cases in a column (comparison between *F. jangomas* fruit) are statistically significant at 5% probability level.

The shape of the fruit is determined by its length and width and is one of the most important quality parameters for consumers. From a test sample of 10 specimens for each category or batch of *F. jangomas* fruit, we found that the average length, weight, and thickness of small Indian coffee cherries were 1.360 ± 0.107 cm, 2.097 ± 0.185 g, and 1.380 ± 0.092 cm, respectively. The average values for Mpe, Mpé, Mpu, and Npé for Indian coffee cherries were 0.388 ± 0.047 g; 0.319 ± 0.046 g; 1.390 ± 0.168 g; and 7.800 ± 1.135, respectively.

For medium-sized fruits, out of the ten samples analyzed, we obtained average values of 3.720 ± 0.431; 1.52 ± 0.08; 1.564 ± 0.090; 0.689 ± 0.130; 0.610 ± 0.130; 2.422 ± 0.330, and 10.700 ± 1.418, respectively, for the weight of whole fruit, thickness, length, skin weight, seed weight, pulp weight, and total number of seeds.

For large fruits, we obtained an average value of 2.020 ± 0.120 cm for thickness; 2.030 ± 0.095 cm for length; 5.518 ± 0.777 for whole fruit weight; 0.860 ± 0.156 g for skin weight; 3.766 ± 1.253 g pulp mass; 0.876 ± 0.190 g seed mass; and finally, 11.200 ± 2.440 total number of seeds. To conclude this first section, the dimensional characteristics of the fresh fruits of *F. jangomas* of different sizes analyzed all show statistically significant variations ($p < 0.05$) and ranged from 2.097 to 5.518 g; from 1.380 to 2.020 cm; from 1.360 to 2.030 cm ; from 0.388 to 0.860 g; from 0.319 to 0.876 g; from 7.800 to 11.200 and from 1.390 to 3.766 g respectively for whole fruit mass, thickness, length, skin mass, seed mass, total number of seeds, and pulp mass. Our results differ from those found by [20] [30] and Karishma Sebastian *et al.* [15].

The mass percentage of the three structural parts was also presented (**Table 2**). The percentage of pulp ranged from 58.806% to 70.530%; from 57.649 to 71.392%; and from 64.909 to 73.831% for small, medium, and large fruits, respectively. These results lead us to conclude that fruit size is not an obstacle in this case to the manufacture of value-added products such as preserves, jams, purées, and beverages. The average pulp percentage ranged from 65.020% (medium size) to 68.226% (large size). However, in terms of fruit mass percentage, our results differ from those found by [15], where they are lower.

Table 2. Mass percentage of the different structural parts of the fruit of *Flacourtia jangomas* (Lour) Raeusch.

Fruit shape	Physical parameters	%Mpu	%Mpé	%Mpe
F. jangomas small caliber	Minimum	58.806	12.952	15.033
	Maximum	70.530	20.452	21.539
	Average	**66.168B**	**15.268C**	**18.584B**
	Ecartype	3.677	2.371	2.167
F. jangomas medium-caliber	Minimum	57.649	11.927	13.071
	Maximum	71.392	20.682	25.615
	Average	**65.020C**	**16.369A**	**18.611A**
	Ecartype	3.794	2.751	3.583
F. jangomas large caliber	Minimum	64.909	13.297	10.905
	Maximum	73.831	18.548	20.738
	Average	**68.226A**	**15.810B**	**15.773C**
	Ecartype	2.902	1.914	3.009

Mpe: skin mass; Mpé: seed mass; Mpu: pulp mass.Means with different upper cases in a column (comparison between *F. jangomas* fruit) are statistically significant at 5% probability level.

The percentage of skin varies from 15.033% to 21.539%; 13.071% to 25.615%; 10.905% to 20.738% for small, medium, and large fruits, respectively. The average percentage of pulp ranged from 15.773% (large size) to 18.584% (small size). Our results are higher than those obtained by the same authors [15]. Finally, the percentage of seeds ranged from 12.952% to 20.452%; from 11.927% to 20.682%; and from 13.297% to 18.548% for small, medium, and large visual caliber fruits, respectively. The average mass percentages of seeds are 15.268% (small caliber), 16.369% (medium size), and 15.810% (large size). These mass percentages correspond to the number of seeds in our fruits ranging from 7 to 15, which is within the range of 4 to 16 seeds per fruit proposed by the FAO [31] and reported by Md. Aktar Hossain, *et al.* [16] [30] [32] in a study conducted in the Indian state of eastern Uttar Pradesh. However, [33] mentioned a number of eight to ten in *Flacourtia jangomas* fruits.

3.2. Physicochemical Properties of *F. jangomas* (Lour) Raeusch Fruit

[34] reported that the fruit of *F. jangomas* was 100% edible, as they considered the seeds to be an edible part. Although local consumers of this fruit prefer to discard the seeds when eating them, in this study, the seeds will be included in the biochemical composition assessment.

Table 3. Physicochemical composition of the pulp and seeds of *Flacourtia jangomas* (Lour.) Raeusch.

parameters	Average content (%)	
	F. jangomas pulp	Seeds of *F. jangomas*
Moisture content (%)*	69.03 ± 1.19 b	7.98 ± 0.67 a
Ash content (%)**	1.00 ± 0.33 a	2.86 ± 0.78 b
Dry matter (%)**	30.97 ± 0.00 a	92.02 ± 0.00 b
Lipids content (%)**	2.97 ± 0.21 a	9.47 ± 0.09 b
Proteins Content (%)**	3.25 ± 0.37 a	5.06 ± 0.11 b
Soluble sugar content (mg/mL)**	0.99 ± 0.02 b	0.04 ± 0.01 a
Total Carbohydrate Content (%)**	23.75 ± 1.06 a	74.63 ± 0.13 b
pH**	3.38 ± 0.70 a	5.36 ± 0.04 b
Energy Intake (Kcal)**	134.73 ± 1.03 a	403.99 ± 1.86 b

*: Fresh weight basis; **: Dry weight basis; ±: Means and total deviation. Means with different upper cases in a line (comparison between *F. jangomas* fruit) are statistically significant at 5% probability level.

The composition of chemical constituents depends on several factors such as maturity, growing locations, and extraction solvents [35]**.** The results of the analysis are presented in **Table 3**.

3.2.1. Moisture Content (MC) and Dry Matter (DM)

The moisture content of fruit depends on variations in soil moisture conditions, plant growth conditions, and fruit maturity stage, and ultimately affects proximate compositions [34]; cited by Utpal Barua *et al.*, [30].

The data in **Table 3** show that the water content is higher in the pulp with skin (69.03 ± 19%) than in the seeds (7.98 ± 0.67%). Referring only to the average value for the pulp, we find that our results are close to the average values found in the whole fruit by R. I. Barbhuiya *et al.* (2020), who found 69.00 ± 1.84%. However, some authors, such as [36], found a lower moisture content (65.27%), and [30] found a higher moisture content (75.54 ± 0.277%). Taking into account the two values obtained (those for pulp with skin and seeds), the total water content would be approximately 77.01%, which is much higher than the values mentioned by the authors cited above. However, the latter is close (78.28%) to that found by Dubey and Pandey [14] and is much lower (87.23 g/100g) than that found by Srivastava *et al.* [32].

The dry matter content is estimated at 30.97 ± 0.00% in the pulp with skin and 92.02 ± 0.00% in the seeds. There is a clear difference between these two values, with the value obtained for the seeds being three times higher. On the other hand, the average value for the pulp with skin is relatively lower and close (33 and 36.40% for an average of 34.84 ± 1.24) to those mentioned by R. I. Barbhuiya *et al.* [11].

3.2.2. Ash Content (AC)

Ash content is an indicator of product purity and represents the total amount of mineral salts present in the product.

Ash analysis of processed fruit pulp-skin and seed powders (see **Table 3**) revealed levels of 1.00 ± 0.33% and 2.86 ± 0.78%, respectively. Based on these results, it could be argued that the seeds contain a higher concentration of minerals. However, the distribution of mineral elements depends on the origin of the fruit and factors related to the growing site. Results in this regard have been reported in the literature [23].

The ash content in the pulp in our study is similar to that found in the whole fruit by certain authors such as [36] (1.20%); [11] (values between 0.98% and 1.09% for an average of 1.01 ± 0.04%). The results for the seeds are closer to those found by Tulika Mishra *et al.* [5] [14] and [30] reported 2% and 2.51 ± 0.033% ash in whole *Flacourtia jangomas* fruits, respectively.

3.2.3. Lipid Content (LC)

The parts of the fruit studied have an average lipid content of 2.97 ± 0.21% for the pulp-skin and 9.47 ± 0.09% for the seeds (see **Table 3**). Our results are relatively higher in each structural part of the fruit than those found by some authors for the whole fruit. Authors such as [5] [14] found the same fat content of 0.80% in the fruit. In contrast [30] and **Srivastava *et al.*** [32] reported lower values for fat (0.60 ± 0.010% and 0.21 g/100 g, respectively). However, [36], cited by Utpal Barua *et al.* [31], reported a very high crude fat content (4.09%) in a study of fruit samples collected from the local market in Meghalaya. Nevertheless, this result remains low when the percentages of the two structural parts are combined.

3.2.4. Protein Content (PC)

Previous studies have mentioned that ripe *Flacourtia jangomas* fruit has a good protein content. Our work (see **Table 3**) shows that the seeds (5.06 ± 0.11%) contain more protein than the pulp and skin (3.25 ± 0.37%), with the latter value being more or less in line with those reported by [7] [11] (3.9% and 3.18 ± 0.22% respectively).

However, [36], in a study of fruit samples collected from the local market in Meghalaya, reported a very high crude protein content (7.39%). This is also the case for Dubey [14] (6.16%); [5] (6.16%); [30] (6.04 ± 0.042%).

[32], on the other hand, reported lower protein values (0.65 g/100 g), as did Karishma *et al.* [15], who reported protein values for sweet lovi-lovi accessions ranging from 0.80 to 2.33 g/100 g.

3.2.5. Soluble Sugar Content (SSC)

The taste quality of the product, which determines the value of the fruit for consumers, depends on the content of sugars, organic acids, etc. (Sonu and Rao, 2013 cited by Karishma *et al.* [15].

In unripe fruit, the amount of sugars is very low, but as the fruit ripens, it gradually increases [32].

In addition, soluble sugars are metabolic substrates that play a fundamental role in controlling several processes during various stages of plant development. They are therefore essential for proper metabolic functioning. The values obtained after analyses focused on glucose levels gave the following very low averages: 0.99 ± 0.02 mg/mL for pulp and 0.04 ± 0.01 mg/mL for seeds (see **Table 3**). Many authors have instead evaluated the total amount of soluble sugars in the whole fruit in greater depth. [30] evaluated total soluble sugars, reducing sugars, and non-reducing sugars at 13.77 ± 0.031%, 9.82 ± 0.036%, and 3.95 ± 0.049%, respectively. Similarly, [15] reported in their work that reducing sugar, non-reducing sugar, and total sugar showed significant variation among different accessions of sweet lovi-lovi, ranging from 6.68 to 12.13 percent, 0.67 to 1.33 percent, and 7.36 to 12.81 percent, respectively.

Some authors preferred to evaluate only total soluble sugars. This is the case, for example, of R. I. Barbhuiya *et al.* [11], who found an average of 6.18 ± 0.23%, with variability between 5.91 and 6.48%; [14], who found an average of 9.85%; and finally Srivastava *et al.* [32], who found 9.92 g in the fruit.

3.2.6. Carbohydrate Content (CC)

In *Flacourtia jangomas*, the part most consumed by humans is its fruit. The fruit contains a good amount of carbohydrates, which we estimated in the pulp and seeds at 23.75 ± 1.06% and 74.63 ± 0.13% respectively (see **Table 3**). The data obtained in previous studies on the fruit as a whole indicate that our values are relatively very high compared to those obtained by Dubey [14] (11.78%) cited by Tulika Mishra [5]; and those of Srivastava *et al.* [32] (11.42 g).

Authors such as Dibyojyoti Baruah [7] and R. I. Barbhuiya *et al.* [11] found an average carbohydrate content close to that of our pulp: 21% and 23.44 ± 0.57, respectively. However, Utpal Barua *et al.* [30], found a very high average amount of approximately 89.73 ± 0.057%.

3.2.7. pH Value

pH is a key parameter in food preservation and/or processing. It varies in fruits and is mostly in the acidic range (below 7).

pH is one of the main obstacles that microbial flora must overcome in order to proliferate. A pH of around 3 to 6 is very favorable for the development of yeasts and molds. Bacteria, on the other hand, prefer neutral environments, *i.e.*, 7 and 7.5, and/or some tolerate variations between 6 and 9 [37].

It is known that pH facilitates the assimilation of vitamin C. According to Dubey and Pandey (2013), the fruit of *Flacourtia jangomas* contains high levels of vitamin C, which is an antioxidant, and that the pH values found by some authors in previous studies averaged 5.56 ± 0.01 [11] and 3.20 ± 0.078 [30].

The results for the parts of *F. jangomas* fruit revealed values of 3.38 ± 0.70 and 5.36 ± 0.04 for the pulp and seeds, respectively. The skin and pulp of *F. jangomas* fruit are very acidic, while the seeds are less so. It can therefore also be argued that the pH of the skin and pulp of *Flacourtia jangomas* would be detrimental to bacteria but suitable for the development of fungal flora [38]. On the other hand, it can be argued that the seeds could be preserved better than other highly acidic fruits.

3.2.8. Energy (E)

The lipid, protein, and carbohydrate contents contribute to the energy value of the foodstuff. These have been shown to vary significantly between the different structural parts (skin, pulp, and seeds) of *Flacourtia jangomas* fruit, with these three parameters being found in greater quantities in the seeds than in the pulp with skin.

The energy level in the pulp and skin is lower (134.73 ± 1.03 Kcal) than that of the seeds (403.99 ± 1.86 Kcal). Combining the values, we find a high value of 538.72 ± 2.89 Kcal, compared to those mentioned in the works of [32] (46.0 K cal/100g) and Utpal Barua *et al.* [30] (388.43 ± 0.130 kcal). This fruit can also be considered a good source of energy.

4. Conclusions

Flacourtia jangomas is one of the fruit plants of the spontaneous flora whose fruit is most commonly consumed by people living in tropical and subtropical regions of Africa and Asia. Juicy and pleasant, this study revealed that each structural part of the fruit (seeds, pulp, and skin) of *Flacourtia jangomas* has specific chemical characteristics, with protein content (3.25 ± 0.37 a and 5.06 ± 0.11 b) for the pulp/skin and seeds, respectively, carbohydrates (23.75 ± 1.06 a for pulp/skin and 74.63 ± 0.13 b for seeds), energy (134.73 ± 1.03 a for pulp/skin versus 403.99 ± 1.86b for seeds), lipids and ash (2.97 ± 0.21 a and 9.47 ± 0.09 b respectively for pulp/skin and seeds) and 1.00 ± 0.33 a for pulp/skin versus 2.86 ± 0.78 b for seeds) make it a fruit that is not only suitable for human consumption, but also a major asset for the processing industry (in the case of pulp), particularly in confectionery, beverage production, and the use of fat extracted from *F. jangomas* seeds to meet the needs of people of all income levels as a source of functional macro- and microelements.

The variability in morphological characteristics observed in the percentages of pulp, skin, and seeds provides indications about the possibility of using all sizes (small, medium, and large) of the fruit in the formulation of value-added products.

For these many reasons, in terms of nutrition, morphology, and processing, *Flacourtia jangomas* plants should be domesticated in many areas or households, particularly in Congo, in order to reap their benefits both as food and in pharmacopoeia.

Use of AI

No use of artificial intelligence.

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Conflicts of Interest

No conflicts for this article.

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