Journal of Food Technology Research
2025 Vol. 12, No. 4, pp. 363-379
ISSN(e): 2312-3796
ISSN(p): 2312-6426
DOI: 10.18488/jftr.v12i4.4630

Analysis of the nutritional composition of the flesh of the fruit of Annona senegalensis harvested in the peri-urban savannas of Brazzaville: A republic of Congo

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Article History
Received: 12 August 2025
Revised: 21 October 2025
Accepted: 11 December 2025
Published: 29 December 2025

Keywords
Annona senegalensis
Brazzaville
Flesh
Nutritional composition.

ABSTRACT

Annona senegalensis, a spontaneous shrub native to tropical Africa, remains underexploited regarding its food potential, despite being part of a natural resource class whose significance is well established. The limited studies available in the literature on the nutritional value of its fruit present contradictory results. The present study aims to evaluate the nutritional composition of the flesh of fruits harvested in the peri-urban savannas of Brazzaville, revealing variability between sites: fruits from the Mabenga site exhibit higher concentrations of macronutrients than those from Lifoula, particularly in lipids (7.18% vs 4.03%) and proteins (4.28% vs 0.70%), due to a lower water content. Carbohydrate contents (26.29% vs 16.55%) are consistent with bibliographic data, while ash content remains relatively low (1.11% vs 0.61%). In terms of energy, Mabenga fruits reach 148.33 kcal/100g compared to 92.33 kcal/100g at Lifoula, positioning this species above many cultivated or foraged fruits of tropical Africa. However, these values are still lower than those of fruits rich in fats or dry, such as safou, avocado, baobab, or néré. The mineral composition is homogeneous between the two sites and generally higher than the values reported in the literature for Annona senegalensis. These findings underscore the underutilized nutritional potential of the fruit within the context of local resource valorization.

Contribution/Originality: This study demonstrates the nutritional interest of this underutilized peri-urban fruit and contributes to the enrichment of knowledge about its variability. It offers new perspectives for the enhancement of local natural resources, thus participating in the improvement of the daily food and socioeconomic needs of the people.

1. INTRODUCTION

Wild plants are of significant socioeconomic (Babalola, 2012; Mounkaila et al., 2017; Ouédraogo, Lamien, Parkouda, Kini, & Coulibaly, 2003), nutritional (Lockett & Calvert, 2000; Murray, Schoeninger, Bunn, Pickering, & Marlett, 2001; Osman, 2004; Parkouda, Diawara, Ganou, & Lamioen, 2007) and dietary (Bergeret, 1988; Kouamé,

Gnahoua, Kouassi, & Traore, 2008) importance in tropical countries. In many traditional African societies, their importance as a source of food is widely recognized by rural populations. Historically, during difficult periods such as food shortages, wars, droughts, or locust invasions, these natural resources contributed significantly to the survival of local populations. Since then, they have played a crucial role in ensuring food security for many communities (Bergeret & Ribot, 1990; Campbell, 1986; Kouamé et al., 2015).

The wild plants produce several edible organs (leaves, roots, barks, tubers, seeds, and fruits). Among these organs, fruits are the most widely consumed by rural populations because of their appetizing flavor and interesting nutritional contribution (Kouamé et al., 2008; Okhale, Akpan, Fatokun, Esievo, & Kunle, 2016).

In Brazzaville, a number of wild fruit species growing on the outskirts of the city, including *Annona senegalensis* (Ololo or Moulolo), *Seba senegalensis* (Malombo), *Anisophyllea quangensis* (Mbila esobe), *Aframomum alboviolaceum* (Tondolo, Toundou), contribute to the immediate food and socio-economic needs of the surrounding populations. A study carried out in Congo-Brazzaville on non-timber forest product data between 1998 and 2000 by Nkeoua and Boundzanga (1999) (Project GCP/INT/679/EC) showed that, in the field of plants for various uses, out of 176 wild fruit species listed, divided into 57 families, the Annonaceae were the most represented, with 17 species. *Annona senegalensis*, one of the species in this family, is widely consumed in the sub-region (Diallo et al., 2022; Donhouedé et al., 2022; Okhale et al., 2016; Zoure, Ouattara, & Ouédraogo, 2021).

Annona senegalensis is a savannah species whose range extends throughout the semi-arid to sub-humid zones between Senegal and Sudan, and as far south as the Guinean savannah. In some areas, it forms natural orchards. It can be found almost everywhere in the Congo. In Mayombe, 20 genera have been recorded, divided into 37 families (Mampouya & Moutsamboté, 2021). The edible nature of its fruit has been demonstrated by several authors (Busson, 1965; Chevalier, 1948; Dale & Greenway, 1961; Diallo et al., 2022; Okhale et al., 2016; Szolnoki, 1985; Von Meydell, 1983; Watt & Breyer-Brandwijk, 1962; William, 1983). Consumption of the leaves as a vegetable and the seeds and flowers as spices has also been reported in the literature (Donhouedé et al., 2022; Lamien, Bamba, Poda, & Lankouande, 2008; Okhale et al., 2016). Unfortunately, only two recent studies have looked at the nutritional value of leaves (Bello et al., 2023) and flowers (Mubarak, Keta, Tilli, & Musa, 2022) for their contribution to livestock and human nutrition.

As with leaves and flowers, studies on fruit composition are rare, but old. The few that have been found are those on samples from Zaire (Malaisse & Parent, 1985), Côte d'Ivoire (Herzog, Farah, & Amado, 1994), and Burkina Faso (Parkouda et al., 2007), which reveal contradictory results. Malaisse and Parent (1985) according to Herzog et al. (1994) reported protein and lipid levels of 12% and 20.2% of dry matter, while those in this study reported protein levels of 5.5% and 3.6% and lipid levels of 7.1% and 2.3%, respectively, and Parkouda et al. (2007) reported lower levels of 1.3% and 0.8% of dry matter. Herzog et al. (1994) attribute the results of Malaisse and Parent (1985) to samples of whole fruit ground with the seeds, whose protein and lipid content, probably higher than in the flesh, would increase the overall content of these fruit components. A recent study focusing on the relative role of soil, climate, and genotype on the nutritional value of the fruits and leaves of *Annona senegalensis* collected in four sites, including two in Benin and two in Mozambique, (Donhouedé, Salako, Assogbadjo, Ribeiro Barros, & Ribeiro, 2023), reveals a strong variation in the nutritional composition of the latter related to genotype, then to soil.

In Congo-Brazzaville, to our knowledge, no study has been conducted on the nutritional potential of *A. senegalensis*. Knowing that new information on the nutritional composition of this species from other ecological areas could significantly contribute to its understanding, we focused, in this present study, on the evaluation of the morphological and physico-chemical characteristics of the fruit and the composition of macronutrients and mineral elements of the flesh of the fruit of this species found in the peri-urban savannas of Brazzaville.

2. MATERIAL AND METHODS

2.1. Plant Material

The plant material used for this study consisted of ripe fruit harvested from two natural gardens in the villages of Lifoula (suburban savannah north of Brazzaville) (GLB) and Mabenga (suburban savannah south of Brazzaville) (GMB). Figure 1 illustrates a plant with ripe fruits found in the natural garden of the village Lifoula. The choice of tree was based on the presence of ripe fruit. Harvesting stopped as soon as the quantity required for the study was reached.

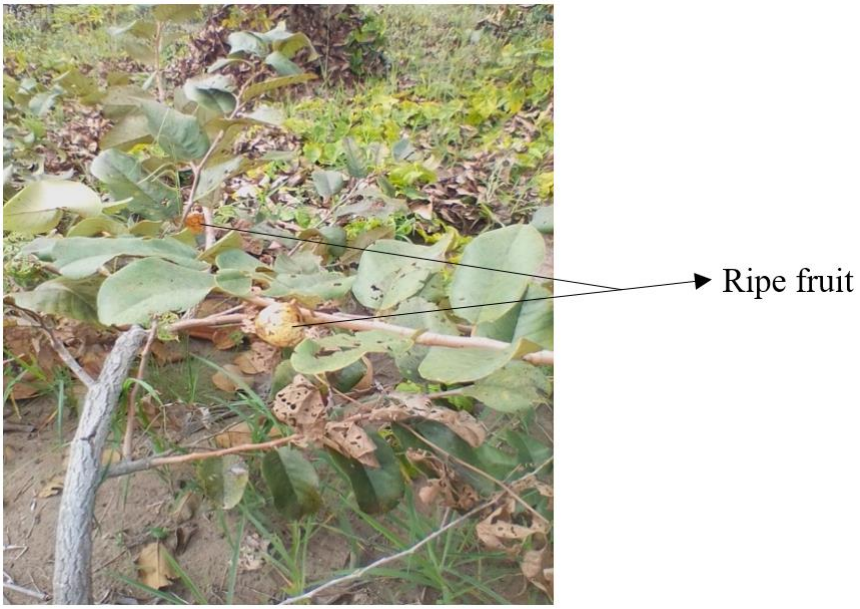


Figure 1. *A. senegalensis* in the natural garden of the village of Lifoula.

2.2. Methods

2.2.1. Sample Processing

After harvesting at each site, the fruits were transported to the laboratory and cleaned with distilled water. Ten fruits were selected at random to determine morphological and physicochemical characteristics; some were used to determine soluble sugar levels (°Brix), and the rest were oven-dried at 105°C for 24 hours. Then, the flesh (edible part) was separated from the seeds and ground using a mortar. The powders obtained were packaged in glass vials for various analyses.

2.2.2. Determination of the Morphological and Physicochemical Characteristics of the Fruit

The morphological and physicochemical parameters considered were: length, width (diameter), mass, and water content.

2.2.2.1. Determination of Morphological Parameters

The length and width of the fruit were measured in the usual way when determining the morphological size of the fruit; the length corresponds to the distance between the point of attachment of the fruit to the peduncle and its base (vertical axis), and the width corresponds to the horizontal axis. These two dimensions were determined using a caliper. As the fruit does not have a regular shape around the circumference of its width, the value taken into account was that of the largest diameter when the caliper was swept around the circumference.

2.2.2.2. Determination of Physicochemical Quantities

The mass of the fruit was determined using a PN-Model precision balance: 14192-005R, with a maximum capacity of 620 g and a readability of 0.01 g. The water content was measured by drying the sample in a Memmert oven, model UN55-53L, at 105°C for 24 hours. Seeds were removed from the fruit and weighed separately. After drying, the seeds were weighed again, and the water content was calculated using the appropriate formula.

$$\%_{water} = \frac{m_0 - m_1}{m_0} \times 100 \qquad (1)$$

With:

- m_0: Flesh mass.
- m_1: Dry mass.
- %water: Water content.

2.2.3. Determination of the Proximate Composition in Macronutrients of the Flesh

2.2.3.1. The Soluble Sugar Content (°Brix) of the Juice

The soluble sugar content of the juice was determined using a Brix refractometer model RHW-25.

2.2.3.2. Fat Content

Fat content was determined by Soxhlet extraction (3 trials) for 3 hours with 350 mL hexane (Mampouya & Moutsamboté, 2021). The mass m_0 of the flesh powder used to perform each extraction was 50 g. After extraction, the extract was dried with sodium sulfate, the solvent evaporated under vacuum, and traces of solvent removed by drying the oil in an oven at 105°C for 6 hours. The fat obtained was weighed (m_2) and the lipid content determined by the formula:

$$\%_{fat} = \frac{m_1 - m_2}{m_1} \times 100 \qquad (2)$$

2.2.3.3. Ash Content

The method used is that of standard NF76-110, Sept.1981.

The powdered flesh of *A. senegalensis* ($m_1 = 2$ g) is placed in crucibles (of mass M_0) which are placed in an oven set at 550°C for 8 hours; the powders are incinerated until a light grey or whitish colour is obtained. After cooling, the crucibles are weighed (m_3) and the percentage of crude ash is expressed by the formula.

$$\%_{ash}(\mathrm{MS}) = \frac{m_3 - M_0}{m_1} \mathrm{x}100 \qquad (3)$$

2.2.3.4. Protein Levels

Protein content was determined by the KJEDAHL method.

0.5 g (m_4) of de-oiled and ground plant sample, previously dried in an oven at 70°C, is placed in a matron. Add a tip of a spatula of mineralization catalyst and 10 mL of concentrated H_2SO_4. Add a few glass beads, place the flask on a digestion ramp, and leave to digest cold for 30 minutes; then switch on the heating (thermostat 7) and leave to digest for 2 hours. The supernatant solution should be clear and the residue white. Leave to cool, add 20 mL of water and approximately 30 mL of sodium hydroxide at 400 g/L until the solution turns brown. By collecting the distillate in a 150 mL Erlenmeyer flask containing 20 mL boric acid and a few drops of coloured indicator, steam distillation is carried out to a volume of 125 mL (4 min distillation). Dose the solution with N/20 sulphuric acid until the indicator turns from green to pink (pH = 5.1).

The nitrogen content is determined by the formula:

$$\%_N = \frac{V_{H_2SO_4} x 0{,}07}{m_4} \quad (4)$$

and the protein content by the formula.

$$\%_{protein}(\text{DDM}) = \%_N x 5{,}70 \quad (5)$$

2.2.3.5. Carbohydrate Levels

2.2.3.5.1. Fibre Content

1 g (m_4) of deoiled sample is introduced into a 500 mL flask and 100 mL of 0.255 N sulfuric acid is added. The mixture was heated under reflux for 30 min. Filter through a muslin cloth under vacuum. The residue obtained was returned to the flask and treated with 100 mL of 0.313 N NaOH. The mixture was brought back to the boil and heated under reflux for 30 min. The residue obtained was then transferred to a pre-weighed dish (or crucible) (W_1), which was then placed in an oven at 130°C for 2 hours to dry. The dried residue-cup assembly is cooled in a desiccator and then weighed (W_2). The residue was then calcined for 30 minutes at 600°C in a muffle furnace. It is cooled to the same level in a desiccator and the whole batch (including the cup) is weighed again (W_3).

The percentage of fiber is determined by the formula.

$$\%_{fiber}(\text{DDM}) = \frac{(W_2 - W_1) - (W_3 - W_1)}{m_4} \times 100 \quad (6)$$

2.2.3.5.2. Available Carbohydrate Content

The level of available carbohydrates is determined by the method described by Antia, Akpan, Okon, and Umoren (2006) based on the following mathematical expression in relation to dry matter (*DM*).

$$\%_{\textbf{Available Carbohydrates}}(\text{DM}) = 100 - \%(proteins + ashes + lipids + fibers)(\text{DM}) \quad (7)$$

In this case, the protein and fiber contents (noted$\%_i$), determined in relation to the deoiled dry matter (*DDM*), need to be compared with the non-deoiled dry matter (*DM*). To do this, we used the formula below.

$$\%_i(DM) = \frac{\%_i(DDM)(100 - \%_{lipid})}{100} \quad (8)$$

2.2.3.5.3. Energy Value

The energy value has been determined by applying the correction coefficients established by the "Guideline on Nutritional Labeling (CAG/GL 2-1985)" of the Codex Guideline on Nutrition. This allows for the establishment of the relationship below, for 100 g of sample.

$$Energy\ value\ (kcal/100g) = (\%_{proteins} \times 4) + (\%_{lipids} \times 9) + (\%_{carbohydrates} \times 4) \quad (9)$$

In this expression, the contribution of carbohydrates only concerns digestible carbohydrates (Available), that is to say, excluding fibers.

2.2.4. Determination of the Proximate Composition in Mineral Elements of the Flesh

2.2.4.1. Mineralisation of Samples

Homogenize the finely ground plant powder and dry for 16 hours at 70-80°C. Cool for 30 minutes in a desiccator, then weigh 2 g of sample into a porcelain capsule. Place the capsule in the cold oven, along with an empty capsule to serve as a blank. Set the temperature at 450°C and hold for 2 hours. Remove the capsule and allow it to cool (the ash obtained is generally clear). Moisten the ash with 2 to 3 mL of water and 1 mL of concentrated hydrochloric acid. Heat on the hot plate until the first vapors appear, then add a few mL of water. Filter through an ash-free filter into a 100 mL volumetric flask, rinsing 3 or 4 times with lukewarm water. Incinerate the filter paper and its contents in a porcelain capsule for half an hour at a maximum of 550°C, then transfer the ash to a Teflon capsule. Take up with 5

mL of HF. Dry on a hot plate or water bath without exceeding 100°C. Remove with 1 mL of concentrated HCl. Wash with warm water. Filter. Make up to 100 mL. Make up to the mark after cooling.

2.2.4.2. Iron Dosage

Take a volume of 5 mL of the mineralized solution, place it in a plastic pillbox, and successively add 5 mL of 1% hydroxylamine chloride, 2 mL of 3% sodium citrate, 2 mL of sodium acetate pH 3.5, and 2 mL of 0.2% ortho-phenantroline (at the same time, make an iron range).

Allow staining to develop for 30 min. Measure at 490 nm with a spectrophotometer.

2.2.4.3. Phosphorus Measurement

The solution obtained from the mineralized sample is taken and placed in a pillbox into which Murphy and Riley's reagent (a mixture of several products) is added. A blue coloration develops which is read on the spectrophotometer at 660 nm, and the result of the sample is obtained by calculation taking into account a phosphorus range curve (phosphorus range at several points of different concentrations in order to obtain a curve linking the concentrations and the optical densities read on the colorimeter).

2.2.4.4. Calcium Measurement

Take a given volume (depending on the concentration of the sample) of the mineralized solution, place it in a 150 mL Erlenmeyer flask, and make up to 50 mL with water. Add 1 mL KCN and 5 mL N-triethanolamine hydrochloride, and adjust the pH with a 2.5 N NaOH solution to pH 12.5. Add a pinch of calcein and dose with N/50 EDTA solution.

2.2.4.5. Magnesium Dosage

This assay concerns the calcium-magnesium combination, then the magnesium is calculated by difference with the calcium obtained previously.

Take a given volume (depending on the concentration of the sample) of the mineralised solution, place in a 150 mL Erlenmeyer flask and make up to 50 mL with water. Bring the solution to pH 10 with a buffer solution (A mixture of ammonium chloride and ammonia). Add a pinch of black-erochrome T (NET) and dose with EDTA solution N/50. Differentiate from the calcium obtained previously.

2.2.4.6. Sodium and Potassium Measurement

A volume of the mineralized sample is taken and placed in a 25 mL flask, into which a solution of lanthanum is added up to the mark. The flask is then stirred well to make the mixture homogeneous. The sample thus treated is determined using a Sherwood flame spectrophotometer, while fixing the element to be determined (sodium or potassium), at the same time as a range solution in several concentrations so that a calibration curve can be drawn from which the concentration of the sample can be deduced. The lanthanum solution is used as a diluent for the samples and also for the range points.

The same operation is repeated for the determination of the other element by attaching it to the machine during the analysis of the sample treated with lanthanum solution, using the Sherwood flame spectrophotometer.

3. RESULTS AND DISCUSSION

3.1. Morphological and Physicochemical Characteristics of the Fruit Studied

The fruits of *A. senegalensis* collected in GLB and GMB respectively have lengths varying from 2.32 to 3.39 cm and from 2.61 to 3.73 cm, widths varying from 2.39 to 3.35 cm and from 2.67 to 3.29 cm, masses varying from 7.70 to 22.75 g and 9.49 to 18.41 g, water contents ranging from 63.37% to 72.74% and 42.20% to 58.11%, and fruit flesh water contents ranging from 69.76% to 84.36% for GLB and 48.34% to 73.42% for GMB (Table 1).

Table 1. Morphological and physicochemical properties of 10 fruits studied.

Features	Length (cm)		Width (cm)		Mass (g)		Water content			
							Fruit		*Flesh*	
Samples	GLB	GMB	GLB	GMB	GLB	GMB	GLB	GMB	GLB	GMB
1	3.39	3.16	3.27	3.04	22.26	13.76	66.17	48.40	79.97	57.75
2	3.21	3.21	2.34	2.77	10.65	13.15	67.51	46.77	78.48	55.56
3	2.91	3.73	2.98	2.80	16.12	18.41	63.09	56.49	76.25	71.07
4	3.06	3.18	3.06	2.91	20.02	13.81	64.54	47.14	77.65	58.67
5	2.94	2.74	3.35	2.74	19.70	10.82	68.07	48.24	81.74	55.98
6	2.97	3.06	2.63	2.71	13.44	11.93	66.22	60.39	77.76	70.47
7	2.52	3.21	2.60	3.29	13.73	21.06	68.32	48.24	79.54	66.53
8	2.32	3.32	2.39	3.02	7.70	17.43	62.60	58.12	69.76	73.42
9	3.39	2.61	3.23	2.74	22.75	9.49	63.08	45.21	75.68	53.43
10	2.81	2.63	2.62	2.67	12.95	10.34	72.35	41.64	84.36	48.34
Average	2.93	2.82	3.11	2.89	15.93	14.02	66.20	51.66	78.12	61.12
Deviation	0.36	0.25	0.41	0.21	5.09	3.80	3.03	7.40	3.91	8.59

3.1.1. Morphological Parameters

As far as morphological dimensions are concerned, the sphericity index (Width/Length) of the fruits is close to unity, giving them a more or less spherical shape with widths almost similar to lengths, with the exception of a few individuals such as sample 2 from GLB and sample 3 from GMB, where the differences between length and width reach 1 cm (Figure 2).

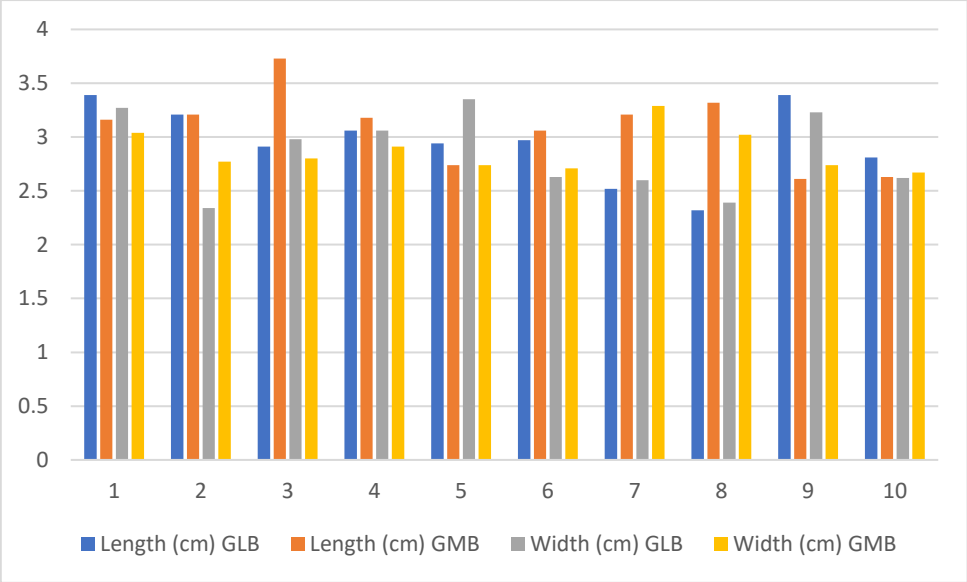


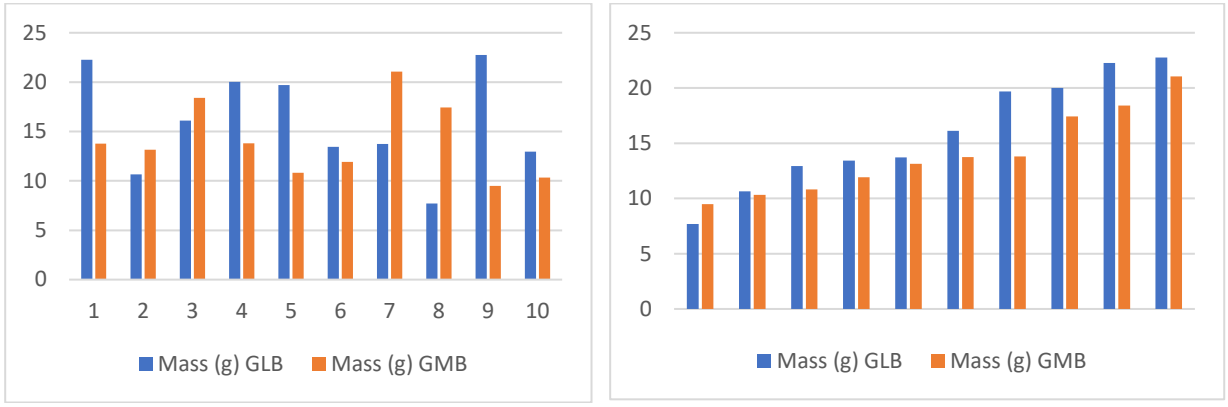
Figure 2. Lengths and widths of fruit studied.

Morphologically, these individuals resemble each other, with lengths and widths of around 3 cm, similar to the Côte d'Ivoire fruits (diameter ranging from 2 to 4 cm) studied by Herzog et al. (1994), but appear smaller than fruits from other ecological zones. Okhale et al. (2016), working on a review of the ethnomedical uses, biological activities, and phytocompounds of *A. senegalensis* in Nigeria, report their dimensions ranging from 2.5 to 5 cm by 2.5 to 4 cm. Mustapha, Owuna, and Uthman (2013) attribute their diameter to 4.5 cm, characterizing the ovoid shape of the fruits.

3.1.2. Physical Quantities

Masses are highly variable in relation to morphological size (Figure 3), with large standard deviation values, 5.09 for GLB samples and 3.80 for GMB samples (Table 1), with respective means of 15.93 and 14.02 g. In proportion to

morphological size and in general, *A. senegalensis* fruits from the GLB have a higher mass than those from the GMB; but on an individual basis, we found fruits from the GLB to be lighter than those from the GMB.



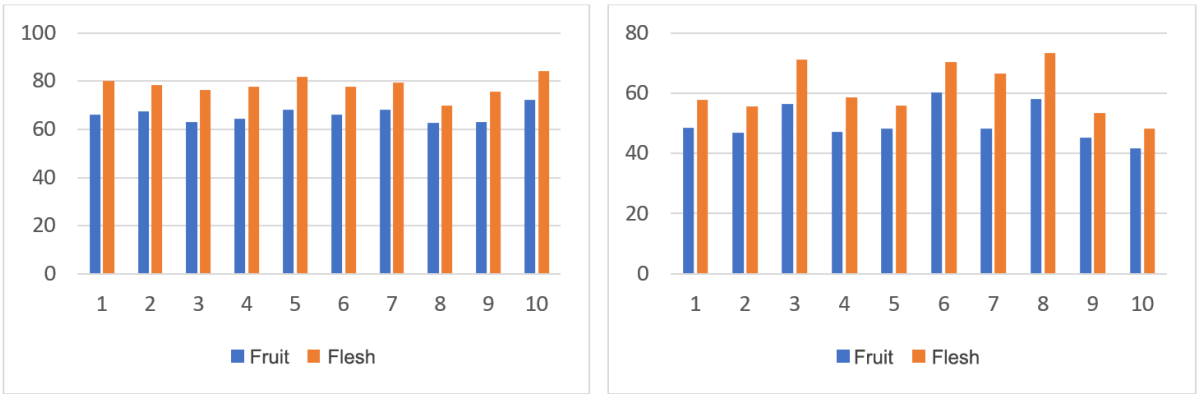
a) Mass of fruit classified by individual at each site b) Fruit weight in ascending order

Figure 3. Mass of fruit studied.

From previous work, we have found no data on the fruit masses of *A. senegalensis*.

3.1.3. Chemical Quantities

Proportionally to morphological and physical dimensions, GLB fruits are more hydrated than GMB fruits (Figure 4), with respective mean water contents of 66.20 (±3.0)% and 51.66 (±7.40)% for the fruits and 78.12 (±3.91)% and 61.12 (±8.59)% for the flesh (Table 1), with greater variability between individuals at the GMB site. This large difference in water content between individuals from the two sites studied in the same climatic environment is due to their different geographical locations (Donhouedé et al., 2023). The GLB site, where the harvest took place, is located in a valley, almost 1 km from the Congo River; therefore, although sandy, it is still humid, whereas the GMB site is on a hill, although clayey-sandy, but less humid due to the elevation. These water contents are similar to those of the fruits studied by Donhouedé et al. (2023) in the four sites in Benin and Mozambique.



a) GLB b) GMB

Figure 4. Moisture content of fruit and flesh studied.

Moreover, the water content of the flesh obtained by Parkouda et al. (2007) on samples from Burkina Faso, ranging from 76.19 to 79.59%, and by Herzog et al. (1994) on two samples from Côte d'Ivoire, worth 76.2 and 77.8%, are similar to those from the GLB site and higher than those from the GMB site. In addition, the water content of *A. senegalensis* fruit flesh appears to be slightly lower than that of common cultivated and gathered fruits in sub-Saharan Africa, except for Baobab (*Adansonia digitata L.*) and Néré *(Parkia spp.)* fruits, which have very low water contents of 16 and 13% respectively (Table 2).

Table 2. Average water content (%) of some common cultivated and harvested fruits in Africa (g/100 g fresh matter) (Exotics Fruits REGAL, version 1993).

Fruit	Water content (%)
Pineapple (*Ananas comosus (L.) (Merr.)*))	86.5
Avocado (*Persea americana Mill.*)	76.4
Sweet banana (*Musa spp.*)	74.0
Barbadine (*Passiflora quadrangularis L.*)	80.0
Spiny soursop (*Annona Muricata L.*)	82.7
Fig (*Ficus carica L.*)	79.5
Guava (*Psidium guayava L.*)	83.0
Mango (*Mangifera indica L.*)	83.0
Orange (*Citrus sinensis (L.) (Osb.)*)	86.6
Papaya (*Carica papaya L.*)	89.4
Watermelon (*Citrullus lanatus (Thumb.) Matsum. & Nakai*)	92.0
Cinnamon apple (*Annona squamosa L.*)	73.4
Aframomum (*Aframomum spp.*)	80.6
Fruits of the Baobab (*Adansonia digitata L.*)	16.0
Senegal cherry (*Aphania senegalensis (Juss. ex Poir.)*)	71.4
Gabon mango (*Irvingia gabonensis*)	85.2
Yellow huckleberry (*Spondia mombin L.*)	83.7
Fruit of the Cowpea (*Parkia spp.*)	13.2
Safou (*Dacryodes edulis (G. Don.) H. J. Lam.*)	59.0

3.2. Proximate Composition in Macronutrients of the Flesh of the Fruits Studied

The flesh of *A. senegalensis* fruits from the two samples collected from the northern and southern peri-urban savannas of Brazzaville have almost similar macronutrient contents, except for protein and diatery fiber contents, which show very different values, with higher levels in the samples from GMB (Table 3).

Table 3. Proximate composition in macronutrients of the flesh of the fruits studied.

Features	Website	Trial 1	Trial 2	Average
Brix level (° Brix)	GLB	-	-	18.8
	GMB	-	-	18.3
Total lipids (g/100g dry matter)	GLB	17.41	19.44	18.43
	GMB	18.30	18.66	18.48
Ash (g/100g dry matter)	GLB	2.88	2.70	2.79
	GMB	3.06	2.65	2.86
Proteins (g/100g of delipidated dry matter)	GLB	3.93	3.87	3.90
	GMB	13.56	13.43	13.50
Dietary fiber (g/100g of delipidated dry matter)	GLB	18.06	18.00	18.03
	GMB	30.20	30.00	30.10

3.2.1. Brix Level

The Brix levels of *A. senegalensis* fruit juices from the Lifoula and Mabenga samples, at 18.8 and 18.3% respectively, are silicic. These values, higher than those of many common fruits, are almost identical to those of figs (*Ficus carica L.*) and lower than those of cherries (*Prunus avium L.*) (Table 4).

Table 4. Brix levels of some common fruits (CODEX STAN 247-2005).

Fruit	°Brix
Soursop (*Annona muricata L.*)	14.5
Cinnamon apple (*Annona squamosa L.*)	14.5
Fig (*Ficus carica L.*)	**18.0**
Watermelon (*Citrullus lanatus (Thumb.)*)	8.0
Orange (*Citrus sinensis L.*)	11.2
Cherry (*Prunus avium L.*)	**20.0**

3.2.2. Lipid Content

The flesh of the studied fruits is moderately rich in lipids. The lipid contents obtained, 18.43% and 18.48% in relation to dry matter, respectively for GLB and GMB, are close to those of the fruits studied by Malaisse and Parent (1985) in Zaire in the Zambezian woodland zone (Malaisse & Parent, 1985), which were 20.2%.

Some results found in the literature have been reported in relation to fresh matter (*FM*). For reasons of comparison, we are obliged to relate our results also to fresh matter using Equation 10 below:

$$\%_i(FM) = m_i(100\ g\ de\ FM) = \frac{\%_i(FM)[100-\%_{water}(chair)]}{100} \qquad (10)$$

The lipid levels in the present study, expressed as a percentage of fresh matter, are higher than those of the samples from Burkina studied by Parkouda et al. (2007) and Côte d'Ivoire studied by Herzog et al. (1994) (Table 8); they are also higher than those of the samples of whole fruits ground with the seeds from the three sites Ben_MEP, Moz_MEC and Moz_MAV recently studied by Donhouedé et al. (2023) but similar to the samples from the Ben_BGN site. These results call into question the conclusion drawn by Herzog et al. (1994) that the analyses carried out by Malaisse and Parent (1985) were carried out on whole fruits, ground with the seeds. As the Republic of Congo and the Democratic Republic of Congo (formerly Zaire) are two neighboring countries, it is not surprising to find similarities between individuals growing in similar ecological zones, compared with Côte d'Ivoire, which is further away.

These contents are also high compared with those of several common fruits grown or picked in sub-Saharan African countries, but lower than those of avocado and safou (Tables 7 and 8), which give average values in relation to dry matter of 60.17% and 53.90%, respectively.

3.2.3. Ash Content

The ash contents, similar between the two sites, are 2.79% and 2.86% of dry matter for GLB and GMB, respectively, based on 100 g of fresh matter (Equation 10). These values are worth 0.61% and 1.11%, respectively, and are lower than those of the fruit studied by Parkouda et al. (2007), which ranged from 3.12% to 4.47%. However, they are similar to the fruits studied by Herzog et al. (1994), at 1.2% and 1.0% (Table 6). This difference in ash content compared to the fresh material obtained during this study is likely due to the variation in water content of individuals between the two sites. Such differences were also observed by Donhouedé et al. (2023) on whole fruits from Benin and Mozambique.

3.2.4. Protein Content

Protein content varied between the two sites, with individuals from the JMB being richer in protein, with an average content of 13.50%, close to the content of samples from the Zambezi woodland obtained by Malaisse and Parent (1985), indicating a value of 12%, compared with that of fruit flesh from the JLB, which was 3.90%. These values, obtained from the delipidated dry matter in relation to the dry matter (Equation 8), give respective values of 11.00 and 3.18% (Table 5).

Table 5. Protein and carbohydrate composition of the dried flesh of the fruits studied (g/100g of dry matter).

Features	Website	Trial 1	Trial 2	Average
Protein	GLB	3.25	3.11	3.18
	GMB	11.07	10.92	11.00
Dietary fiber	GLB	14.91	14.50	14.71
	GMB	24.68	24.41	24.55
Available carbohydrates	GLB	61.57	60.25	60.91
	GMB	42.82	43.36	43.09

These contents, in relation to fresh matter, giving a value of 4.28% for GMB and 0.70% for JLB, are higher than those of the fruits of the same species from Côte d'Ivoire studied by Herzog et al. (1994) (Table 6). Moreover, similar contents to JLB have been obtained in samples from Burkina Faso (Parkouda et al., 2007) and whole fruits from Mozambique (Donhouedé et al., 2023). This nutritional variability observed during the present study confirms the conclusions drawn by Donhouedé et al. (2023), which links it primarily to the soil and then to the genotype. The protein content of JMB is very high compared with that of common cultivated and picked fruits from tropical Africa (Tables 7 and 8), whereas that of JLB is close to that of fig (*Ficus carica L.*), mango (*Mangifera indica L.* and *Irvingia gabonensis*), yellow mombin (*Spondia mombin L.*), papaya (*Carica papaya L.*) and watermelon (*Citrullus lanatus (Thumb.) Matsum. & Nakai*).

3.2.5. Carbohydrate Content

3.2.5.1. Diatery fiber

The flesh of these fruits is also a good source of fiber, with contents of 14.71% for GLB and 24.55% for GMB in relation to dry matter. These values, also variable between the two studied sites, relate to the fresh matter (Table 6) and are lower than those of the whole fruits studied by Donhouedé et al. (2023) in Benin and Mozambique, thus reflecting the contribution of the seeds in the composition of these fruits. The fiber content of the seeds of the fruits of A. senegalensis was determined by Yisa, Egila, and Darlinton (2010) on samples from Nigeria and is 17.6%. This value, equivalent to double that of the flesh obtained in the present study, could increase the fiber content of the fruit when studied in its entirety. These contents in relation to fresh matter are similar to those of many of the common fruits grown and gathered in Africa (Tables 7 and 8).

3.2.5.2. Available Carbohydrates

The available carbohydrate content is 60.91% for GLB and 43.09% for GMB in relation to dry matter. These levels, high, explain the sweet (soft) taste of these meats, even if the level of GLB appears superior to that of GMB. These contents, in relation to fresh matter, are 13.33% and 16.75%, respectively (Table 6). The available carbohydrate content of individuals from GLB is close to that of fig (*Ficus carica L.*), mango (*Mangifera indica L.*), and yellow mombin (*Spondia mombin L.*) (Tables 7 and 8).

Table 6. Proximate composition in macronutrients of the flesh of the fruits studied and of some *A. senegalensis* fruits found in the literature (g/100g fresh matter).

Constituents	Flesh of the fruit					Whole fruit			
	This study		Zaire (Malaisse & Parent, 1985)	Côte d'Ivoire (Herzog et al., 1994)	Burkina Faso (Parkouda et al., 2007)	Donhouedé et al. (2023)			
						Benin		Mozambique	
	GLB*	GMB*				Ben_BGN	Ben_MPE	Moz_MEC	Moz_MAV
Total lipids	4.03	**7.18**	20.2**	0.3	1.7 and 0.5	4.90±1.63	2.70±0.90	2.52±0.84	2.84±0.94
Proteins	0.70	**4.28**	12.0**	0.2	1.3 and 0.8	-	-	4.73±1.57	4.72±1.57
Ash	0.61	1.11	-	3.12 at 4.47	1.2 and 1.0	0.88±0.29	0.99±0.33	4.40±1.46	4.53±1.51
Diatery fiber	3.22	9.54	-	-	-	11.92±3.97	15.67±5.22	21.90±7.30	21.17±10.39
Available carbohydrates	13.33	**16.75**	-	-	-	-	-	-	-
Total carbohydrates	16.55	**26.29**	-	20.07 at 21.17	19.7 and 19.2	-	-	-	-

Note: *Values obtained using equation 10.
**Value for the dry matter.

Table 7. Average composition of some common fruits grown in tropical Africa (g/100 g fresh matter) (Exotic Fruits REGAL, version 1993).

Constituent / Fruit	Available carbohydrates	Dietary fiber	Total lipids	Proteins	Energy kJ/100 g
Pineapple (*Ananas comosus (L.) (Merr.)*)	11.6	1.4	0.2	0.4	47.0
Avocado (*Persea americana Mill.*)	0.8	3.0	14.2	1.8	139.0
Sweet banana (*Musa spp.*)	21.8	2.0	0.3	1.1	89.0
Barbadine (*Passiflora quadrangularis L.*)	10.0	4.9	1.3	2.6	60.0
Spiny soursop (*Annona Muricata L.*)	11.4	4.2	0.2	1.3	50.0
Fig (*Ficus carica L.*)	13.0	2.3	0.2	0.9	54.0
Guava (*Psidium guayava L.*)	5.5	6.0	0.4	1.0	31.0
Mango (*Mangifera indica L.*)	14.3	1.9	0.2	0.6	58.0
Orange (*Citrus sinensis (L.) (Osb.)*)	8.8	1.8	0.2	1.0	42.0
Papaya (*Carica papaya L.*)	7.8	1.9	0.1	0.5	32.0
Safflower (*Citrullus lanatus (Thumb.) Matsum. & Nakai*)	0.3	6.5	0.3	0.5	30.0
Cinnamon apple (*Annona squamosa L.*)	22.2	1.6	0.2	1.8	92.0

Table 8. Average composition of some common tropical African fruits (g/100 g fresh matter) (Exotic Fruits REGAL, version 1993).

Constituents / Fruit	Available carbohydrates	Dietary fiber	Total lipids	Proteins	Energy kJ/100 g
Aframomum (*Aframomum spp.*)	9.1	7.0	0.8	1.1	46.0
Fruits of the Baobab (*Adansonia digitata L.*)	70.0	6.8	0.8	2.2	279.0
Senegal cherry (*Aphania senegalensis (Juss. ex Poir.)*)	25.6	0.5	Tr	1.5	93.0
Gabon mango (*Irvingia gabonensis*)	0.9	7.7	0.2	0.9	34.0
Yellow huckleberry (*Spondia mombin L.*)	12.4	0.9	1.6	0.8	64.0
Fruits of the Cowpea (*Parkia spp.*)	67.5	12.5	0.4	3.4	270.0
Safou (*Dacryodes edulis (G. Don.) H. J. Lam.*)	5.0	8.7	22.1	4.0	324.0

The total carbohydrate contents obtained in this study are similar to those of samples studied in Burkina Faso by Parkouda et al. (2007) and in Côte d'Ivoire by Herzog et al. (1994) (Table 6).

3.2.6. Energy Value of Flesh

From equation 9 and the results given in Table 8, the energies of *A. senegalensis* fruit flesh were calculated. The GLB flesh, at 92.39 kcal/100g, which is similar to that of Senegal cherry (*Aphania senegalensis (Juss. ex Poir.)*), cinnamon apple (*Annona squamosa L.*) and sweet banana (*Musa spp.*) (Tables 9 and 10), is lower than that of fruit from the Mabenga village, at 148.74 kcal/100g, which is slightly higher than that of avocado (*Persea americana Mill.*) (Table 9). These two energy values are lower than those of safflower pulp (*Dacryodes edulis*), which is rich in fat, Baobad fruit pulp (*Adansonia digitata L.*) and Néré fruit pulp (*Parkia spp.*), which are rich in dry matter (Table 10), but higher than those of a large number of cultivated and gathered fruits from sub-Saharan Africa.

3.3. Proximate Composition in Mineral Elements of the Flesh of A. Senegalensis

Mineral elements are micronutrients that play vital roles in living organisms. Mineral elements are essential for the survival of living species. *A. senegalensis* populations of the two peri-urban savannas studied in Brazzaville have similar levels of mineral elements (Table 9). Potassium, which is the main element, has a content of 0.75 g/100 g of ash for GLB and 1 g/100 g of ash for GMB, followed by calcium, magnesium, and phosphorus with similar contents of around 0.10 g/100 g of ash. Sodium, which is a macroelement not identified in this study, could have a content of less than 100 mg/100 g of ash, since its presence was detected in fruit from Burkina Faso (Parkouda et al., 2007) and in flowers of the same species from Nigeria (Mubarak et al., 2022) (Tables 10 and 11).

Table 9. Proximate composition of mineral elements in the studied fruit flesh (g/100g of ash).

Mineral elements	Website	Trial 1	Trial 2	Average
Calcium	GLB	0.12	0.12	0.12
	GMB	0.10	0.10	0.10
Potassium	GLB	0.75	0.75	0.75
	GMB	1.00	1.00	1.00
Magnesium	GLB	0.09	0.11	0.10
	GMB	0.08	0.08	0.08
Phosphorus	GLB	0.10	0.09	0.10
	GMB	0.10	0.08	0.09
Sodium	GLB	0.00	0.00	0.00
	GMB	0.00	0.00	0.00
Iron	GLB	0.004	0.004	0.004
	GMB	0.004	0.004	0.004

These levels are higher than in the fruit from the Baoulé village of Côte d'Ivoire (Herzog et al., 1994), but are practically similar to the calcium and potassium elements in the fruit from Burkina Faso (Parkouda et al., 2007) and around half the magnesium, phosphorus, and iron elements (Table 10). These results also show that the flesh of the fruit is richer in mineral elements than the other edible parts of the plant (leaves, Bello et al. (2023)), flowers, (Mubarak et al., 2022) and seeds (Yisa et al., 2010) (Table 11).

Table 10. Mineral elements in *A. senegalensis* fruit found in the literature (mg/100 g of ash).

Element	Burkina Faso (Parkouda et al., 2007)	South of V-Baoulé, Côte d'Ivoire (Herzog et al., 1994)	
Na	97		
Ca	129	49.2	37.0
K	1000	484	419
Mg	168	43.4	35.6
Zn	1.651	-	-
P	131	-	-
Fe	11.398	1.51	2.30
Cu	0.92	-	-
NH_3	48.429	-	-
S	66.911	-	-
NO_3^-	74.182	-	-

Table 11. Mineral elements in *A. senegalensis* seeds, flowers and leaves found in the literature (mg/100 g of ash).

Element	Seeds (Yisa et al., 2010)	Leaves (Bello et al., 2023)	Flowers (Mubarak et al., 2022)
Na	-	-	36.33 ± 1.53
Ca	1.35	0.66	1.23 ± 0.12
K	0.47	4.68	38.00 ± 1.00
Mg	0.24	3.12	3.77 ± 0.15
Zn	0.48	1.88	-
P	-	22.16	0.35 ± 0.01
Fe	1.80	0.21	-
Cu	0.29	0.10	-
Mn	0.13	-	-
Pb	1.10	-	-
Cr	< 0.10	-	-
NO_3^-	-	-	1.34 ± 0.02

4. CONCLUSION

This study involved analyzing the nutritional composition of the fruit flesh of *A. senegalensis* fruits found in the peri-urban savannas of Brazzaville.

The results indicated that these fruits have nearly similar dimensions, approaching 3 cm in length and width. With an almost spherical shape, these specimens resemble fruits studied in Côte d'Ivoire over three decades ago and appear smaller than fruits from other ecological zones. Beyond morphological similarities, the mass shows greater variability within each site, correlating with water content, with mean values of 15.93 (± 5.09)% and 66.20 (± 3.03)% for Lifoula village (GLB) and 14.02 (± 3.80)% and 51.66 (± 7.40)% for Mabenga village (GMB). Fruits from the heavier Lifoula village are more hydrated than those from Mabenga and also appear more hydrated than fruits from other ecological zones, whose hydration levels are similar to those of fruits from Mabenga. The nutritional value of the fruit flesh is notably interesting. Unlike mineral element composition, which showed similar values between the two sites and exceeded those reported in the literature for the same species, the macronutrient composition relative to fresh matter was higher at the Mabenga site than at Lifoula. These elevated macronutrient levels in Mabenga individuals suggest a richness in lipids and proteins rarely documented in the literature, except for samples from Zaire studied in the Zambezi forest area, which show similar values. Additionally, the ash rates of the two sites, 0.61% for Lifoula and 1.11% for Mabenga, are lower, while carbohydrate levels, at 16.55% and 26.29% respectively, align with literature findings. Conversely, this macronutrient profile surpasses that of many cultivated and wild fruits from tropical Africa, providing energy values per 100g of fresh matter of 92.33 kcal for Lifoula and 148.79 kcal for Mabenga. These energy values are lower than those of safflower and avocado, due to their high fat content, and Baobab and Néré fruits, owing to their high dry matter content.

This study presents a double interest; it highlights the food importance of this species in the immediate needs of increasingly vulnerable populations due to its nutritional value and contributes to the knowledge of its compositional variability, which may be due to genotype or the nature of the soil, as described in the literature.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
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. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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