Biochemical characterization of four less exploited edible fruits in Congo-Brazzaville: *Passiflora edulis* f. *flavicarpa*, *Aframomum alboviolaceum*, *Saba comorensis* and *Clitandra cymulosa*

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The aim of this study was to determine the biochemical characteristics (moisture, crude protein, crude lipids, ash, pH, titrable acidity, minerals and free sugars) of four popular edible fruits (*Passiflora edulis* f. *flavicarpa*, *Aframomum alboviolaceum*, *Saba comorensis* and *Clitandra cymulosa*), but less exploited. The pulp and seeds of *P. edulis* f. *flavicarpa* and *A. alboviolaceum* was also investigated in order to identify the nutritional quality of seeds which are by-products in juice and nectar production. The results showed that all the fruits had a high water content, which limited their conservation. The *P. edulis* f. *flavicarpa* contains significant protein content (9.42±1.56%), and the lipid content of *P. edulis* f. *flavicarpa* (11.65%) and *A. alboviolaceum* (10.58%) was higher than that of the other two fruits. The pulps of *Saba comorensis* and *Clitandra cymulosa* were acidic with not negligible free sugar contents. The ashes of these four fruits contained minerals such as iron, phosphorus, calcium and magnesium, with the last two being the major elements. The comparative study of the seeds and pulps of *P. edulis* f. *flavicarpa* and *A. alboviolaceum* demonstrated the seeds nutritional quality. In view of these results, the four fruits as well as the *P. edulis* f. *flavicarpa* and *A. alboviolaceum* seeds could constitute an appreciable source of nutrient intake and also be valued in the food, pharmaceutical and cosmetic industry.

Key words: *Passiflora edulis* f. *flavicarpa*, *Aframomum alboviolaceum*, *Saba comorensis*, *Clitandra cymulosa*, mineral elements, biochemical characteristic, Republic of Congo.

INTRODUCTION

In the Republic of Congo, as in most developing countries, the problem of food security remains a major...
challenge. Nutritional deficiencies are the cause of acute malnutrition affecting mostly women of childbearing age and children (OMS, 2009; Stevens et al., 2013; N’goran, 2014). One of the ways out of this impasse is the valuation of edible fruits including wild ones available but less exploited.

Fruits are considered as very good sources of minerals, vitamins, carbohydrates, phenolic compounds and antioxidants (Ahodegnon et al., 2018) and can contribute to a qualitative improvement in the health of populations (Kuhnlein, 1989).

For this reason, all scientists now agree that people who consume enough fruit are less likely to suffer from cardiovascular disease, obesity, cancer and diabetes (FAO/WHO, 2004). Fruits are an important link in the food chain both qualitatively and quantitatively. In terms of nutrition, fruits in general constitute an essential supplement of the basic diet consisting of cereals and starchy foods which are poor in mineral salts and vitamins (Kouyaté et al., 2009; Krishnamurthy and Sarala, 2012).

In the Republic of Congo, despite its usefulness in improving the nutritional status of populations, conventional fruits are still inaccessible to the middle class because of its high cost. This situation could lead to nutritional deficiencies that increase the risk of non-communicable diseases (NCDs). However, there are under-exploited pick fruits such as Passiflora edulis f. flavicarpa, Aframomum alboviolaceum, Saba comorensis and Citranda cymulosa that are highly valued by urban and rural populations, which could be important sources of nutrients and thus play an important role in food security and the improvement of nutritional status of the populations.

Grenadilla (P. edulis f. flavicarpa), known as "sour passion fruit", native to South America (Koko et al., 2018; Carr, 2013), is a climbing plant in the Passifloraceae family (Hoff and Cremers, 2005) grown for its edible pulp fruits. The Passifloraceae family has more than 500 species divided into 18 genera among which the Passiflora genus (Corrêa et al., 2016). Its fruits have a round shape with a diameter ranging from 8 to 10 cm, a yellowish green skin when mature and contain multiple seeds surrounded by a gelatinous yellow pulp with a tangy taste and intense aroma (López-Vargas et al., 2013). The fruit is marketed worldwide with Brazil, Ecuador and Colombia as the largest producers (Cardoso et al., 2012). Its leaves are shiny on their upper surfaces and dull on their lower surfaces (Zas and John, 2016) with a thickness of 7.5 to 20 cm.

Maniguette (Aframomum), of African origin, is a plant that grows for example in Ivory Coast, Cameroon, Gabon, Congo, the DRC, Madagascar, and is found mostly in the undergrowth. Aframomum species are large herbaceous plants that reach 5-6 m (Ngakegni-Limbili et al., 2013). They are perennial and aromatic, and have large trumpet-shaped yellow or pink flowers, purple petals and pedicels which are covered with sterile, superimposed bracts (Fankam et al., 2011). The pericarp, of variable woodiness, contains an edible whitish flesh dotted with dark brown seeds measuring 2.3 mm in diameter while the flesh has a very aromatic and refreshing taste (Herzog et al., 1994).

S. comorensis of the Apocynaceae family (Okullo et al., 2014) is a strong forest liana, up to 20 m long on other trees. It is used for its edible fleshy fruits in the form of berries (Ouattara et al., 2016). The fruits contain many almonds coated with orange-yellow pulp and are consumed during the lean season (Atato et al., 2011).

C. cymulosa (Benth) of the Apocynaceae family is native to tropical West Africa and has fruits in the form of berry containing almonds coated with red edible pulp (Mosango and Szafranski, 1985).

Despite the importance of these fruits in the food chain, very few studies on their biochemical characterization and their evaluation have been carried out up until now, to our knowledge. It is in this context that the present study was performed and is aimed at determining the biochemical characteristics of these four popular edible fruits in order to contribute to their evaluation.

**MATERIALS AND METHODS**

**Biological materials**

The biological materials used consist of fruits of P. edulis f. flavicarpa (yellow passion fruit), A. alboviolaceum (sweet maniquette), S. comorensis (Bojer) and C. cymulosa (Benth) presented in Table 1. They were bought fresh in the different markets of the city of Brazzaville (Republic of Congo).

**Sample preparation**

The fruits are washed and then cut in half with a kitchen knife (passion fruit, S. comorensis and C. cymulosa) or split longitudinally by pressing the fruit pod with both hands (A. alboviolaceum) to expose the fruit. The pulp and seeds or the pulp and almonds are extracted with the spatula for the different analyses.

**Chemical analyses**

The four fruit samples, the pulp and seed of P. edulis f. flavicarpa and A. alboviolaceum were analyzed in triplicate for moisture, crude protein, crude lipids and ash using the standard AOAC methods (1995, 2005). Free sugars were determined from the pulp of S. comorensis and C. cymulosa by anthrone-sulfuric acid method (Yemm and Willis, 1954).

After mineralization of the different samples in the oven at 450°C, the ash was recovered, moistened with water and concentrated hydrochloric acid, and then minerals elements were determined employing standard methods. Phosphorus was assayed by the cold colorimetric method using Murphy and Riley's reagent. Calcium and magnesium were determined by atomic absorption under the following spectral conditions: calcium (I = 5 A, λ = 422.7 nm) and magnesium (I = 3 A, λ = 285.2 nm). Iron was determined by atomic absorption spectrometry (AAS). After plotting the calibration lines for each element, the concentrations read for the sample and blank
Table 1. Different samples used in this work.

| Sample                                           | Fruits                  | Seeds                   |
|--------------------------------------------------|-------------------------|-------------------------|
| 1. *Passiflora edulis* f. *flavicarpa*         | ![Image](image1.png)    | ![Image](image2.png)    |
| 2. *Aframomum alboviolaceum*                   | ![Image](image3.png)    | ![Image](image4.png)    |
| 3. *Saba comorensis* (Bojer)                   | ![Image](image5.png)    | ![Image](image6.png)    |
| 4. *Clitandra cymulosa* (Benth)                 | ![Image](image7.png)    | ![Image](image8.png)    |

The pH was determined with *S. comorensis* and *C. cymulosa* pulp according to the potentiometric method using the electrode of a pH counter (55).

Titratable acidity was determined according to the normalized method FP7n°245025 (AFTER, 2011) with some modifications. The acidity has been obtained according to the following formula:

\[
\text{Acidity (mEq/100 g MF)} = N \times V \times \frac{50}{V_0} \times \frac{100}{m}
\]

where \( N \) is the normality of the soda used; \( V \) is the volume (ml) of the sodium hydroxide solution; \( m \) is the mass (g) of the sampled product; 50 is the final volume of the solution in the volumetric flask; and \( V_0 \) is the volume (ml) of the aliquot test sample of the solution.

The titratable acidity can also be expressed in grams of acids per 100 g of product, multiplied by a factor equivalent to the chosen acid. In our case, we used citric acid so this formula was multiplied by 0.07 (AFTER, 2011).

**RESULTS AND DISCUSSION**

Table 2 shows that, like most fleshy fruits, the four fruits analyzed (*P. edulis* f. *flavicarpa*, *A. alboviolaceum*, *S. comorensis*, and *C. cymulosa*)...
Table 2. Chemical composition of four fruit (%).

| Fruit                              | Moisture      | Crude protein | Crude lipid | Ash          |
|------------------------------------|---------------|---------------|-------------|--------------|
| Passiflora edulis f. flavicarpa     | 68.77 ± 0.05  | 9.42 ± 1.56   | 11.65       | 3.77 ± 0.33  |
| Aframomum albiovaleceum            | 66.86 ± 1.66  | 5.78 ± 0.83   | 10.58       | 3.84 ± 0.07  |
| Saba comorensis Bojer              | 64.82 ± 1.09  | 3.76 ± 0.06   | 0.72 ± 0.02 | 3.60 ± 0.02  |
| Clitandra cymulosa (Benth)         | 60.49 ± 1.28  | 5.23 ± 0.13   | 0.79 ± 0.069| 1.35 ± 0.49  |

Comorensis Bojer and C. Cymulosa (Benth) contained high water content.

These moisture contents were higher than the value found by Boamponsem et al. (2013) with Saba senegalensis fruits, similar to those obtained by Diop et al. (2010) in the pulps from Detarium senegalense J.F. Gmel fruits harvested in five localities of Senegal, and by Kone et al. (2018) in the fruit pulp of black plum (Vitex doniana) from Ivory Coast. However, our values were lower than those obtained by Corrèa et al. (2016) in the pulp of five species of Passiflora (72.93 - 95.6%).

Moisture content is important for the stability and quality of food. Fruits that contain a large amount of water are subject to rapid deterioration due to mold growth and insect damage (Boamponsem et al., 2013).

The P. edulis f. flavicarpa had the highest protein content while the S. comorensis had the lowest protein content. These protein levels were lower than those found by Ayessou et al. (2011) in five Senegalese forest fruits. However, these values were higher than those reported in the literature (Favier, 1993) on some pick fruits such as passion fruit (2.6%), cinnamon apple (1.8%), medlar (0.4%), desert date (1.8%), and Aframomum (1.1%) and by Corrèa et al. (2016) in five Passiflora species.

They were also close to the values obtained in the pulp of Hippophae rhamnoides fruit (Dhyani et al., 2007). These values could make these fruits a significant source of protein necessary for human nutrition compared to other fruits already valued or exploited.

From analysis of Table 2, the four fruits had a lipid content that varied between 0.72 ± 0.02% and 11.65%. S. comorensis and C. cymulosa had very low lipid content. However, the lipid contents of P. edulis f. flavicarpa and A. albiovaleceum were high and similar, and these values were close to those found in the pulp of H. rhamnoides fruit (Dhyani et al., 2007) making these two fruits a significant source of lipid.

Table 2 showed ash content between 1.35 ± 0.49% and 3.84 ± 0.07%. The ash content found in the pulp of C. cymulosa is lower compared to that obtained in S. comorensis, P. edulis f. flavicarpa and A. albiovaleceum. These values were similar to those obtained by Ayessou et al. (2011) in two Senegalese fruits (F. gnaphalocarpa and S. latifolius). In comparison with the work of Boamponsem et al. (2013) on the pulp of S. senegalensis, we noted that the pulp of S. comorensis had higher ash content.

The composition of acidity and free sugars is given in Figure 1. From this figure, it can be observed that the pulp of two fruits contained low free sugar content. Nevertheless, the pulp of C. cymulosa (3.54%) was richer in reducing sugars than that of S. comorensis (2.52%). These values were close to those obtained by Diop et al. (2010) on the pulp of D. senegalense fruit (2.72 - 3.69%) already valued. In addition, our values were slightly lower than those obtained in wild Spondias mombin fruit available locally in Nigeria (Adepoju, 2009).

The pH of the C. cymulosa pulp (3.55) was higher than that of S. comorensis (3.2). These values were similar to those by Diop et al. (2010) who had worked on the pulp of D. senegalense (3.51) and superior to the results by Boamponsem et al. (2013) on the pulp of S. senegalensis (2.27). These results showed that the pulp of these fruits could give a juice with a favorable rate of acidity for the conservation against the degradation by the fungi.

Figure 1 showed that the pulp of C. cymulosa had titrable acidity expressed in citric acid equivalent content lower than that of S. comorensis. These results showed the concordance between the pH value and that of the acidity of the pulp of these two fruits.

Table 3 gives the results of mineral composition of P. edulis f. flavicarpa, A. albiovaleceum and S. comorensis Bojer fruits. The iron content was higher in the S. comorensis pulp compared to the two other fruits (P. edulis f. flavicarpa and A. albiovaleceum) with similar values. These values were higher than those found by Dike and Nnamdi (2012) with other fruits such as Gambeya albida, Dialium guineense and Aframomum melegueta. The S. comorensis fruit gave higher content of calcium, phosphorus and magnesium compared to the fruits of P. edulis f. flavicarpa and A. albiovaleceum.

In comparing our samples with four samples of Senegalese forest fruits and five Chinese jujube cultivars (Pareek, 2013) (Table 3) as well as three batches of jujube of Senegalese origin (Dantha et al., 2001), we could deduce that our samples constitute a source of mineral elements by their richness in magnesium, calcium and iron. Despite the low phosphorus content compared to the values of the literature (Ayessou et al., 2011), the consumption of these fruits could thus contribute to the satisfaction of the need of the human organism in terms of minerals and thus participate in a good growth, good metabolic process and prevention of...
Table 3. Comparison in mineral elements of studied fruits with other ones (mg/100 g).

| Fruits                          | Fe     | P        | Ca          | Mg         |
|--------------------------------|--------|----------|-------------|------------|
| Passiflora edulis f. flavicarpa | 6 ± 0  | 24.5 ± 3.5| 75 ± 7.07   | 65 ± 7.07  |
| Aframomum alboviolaceum        | 5.5 ± 0.7 | 17.5 ± 0.7| 70 ± 14.14  | 170 ± 28.28|
| Saba comorensis Bojer          | 25 ± 7.07 | 35 ± 7.07 | 460 ± 84.5  | 1090 ± 71  |
| Clitandra Cymulosa (Benth)     | nd     | nd       | Nd          | nd         |
| I. Senegalensis                | 8.1    | 172      | 612         | 210        |
| F. gnaphalocarpa               | 7.1    | 116      | 309         | 138        |
| C. pinnata                     | 4.1    | 137      | 46          | 79         |
| S. lutifolius                  | 5.4    | 214      | 470         | 154        |
| Jinsixiaozao                   | 4.68   | 110      | 65.2        | nd         |
| Yazao                         | 6.93   | 59.3     | 91.0        | nd         |
| Jianzao                        | 6.42   | 72.3     | 45.6        | nd         |
| Junzao                         | 7.90   | 105      | 118         | nd         |
| Sanbianhong                    | 6.01   | 79.7     | 76.9        | nd         |

Source: a This work; b Ayessou et al. (2011); c Pareek (2013).

Certain diseases (FAO/WHO, 2002). Magnesium is essential for the normal functioning of ATP (adenosine triphosphate) and glucose metabolism and therefore has extensive cellular effects. It is critical for normal ATP (adenosine triphosphate) function and glucose metabolism and therefore has widespread cellular effects. Magnesium is also important in cellular cytoskeleton contraction and at the myoneural junction (Moe, 2008).

Figures 2 and 3 showed the chemical composition of seeds and pulps of Passiflora edulis f. flavicarpa and Aframomum alboviolaceum. In the analysis of Figure 2, except for the ash content which was higher in the two pulps (3.82 ± 0.04% for Passiflora edulis f. flavicarpa and 10.41% ± 0.02 for Aframomum alboviolaceum), the other nutrients (proteins and lipids) were present in high quantities in the seeds of two fruits. The seeds of Passiflora edulis f. flavicarpa had the highest lipid content (17.86%), and this value was lower than that obtained by Malacrïda and Jorge (2012) who worked on the same fruit, but native from Brazilia. In addition, this oil content...
Figure 2. Chemical composition of seeds and pulp of *Passiflora edulis f. flavicarpa* and *Aframomum alboviolaceum*.

Figure 3. Mineral composition of seeds and pulp of *Passiflora edulis f. flavicarpa* and *Aframomum alboviolaceum*.

was similar to that obtained by Bireche et al. (2014) in *Citrullus colocynthis* seeds and by El Hachimi et al. (2015) in the seeds of two grenadier varieties. The seeds of *P. edulis f.* also presented oil content higher than that obtained both in the seeds of the prickly pear (El Hachimi et al., 2015) and the guava (Bourgeois et al., 1998).

Figure 3 shows the mineral content in the seeds and pulps of *P. edulis, f. flavicarpa* and *A. alboviolaceum*. 
Concerning the *P. edulis f. flavicarpa* fruit, iron content (seeds: 10 ± 1.41 mg/100g and pulp: 8 ± 1.41 mg/100g), phosphorus (seeds: 27.5 ± 2.12 mg/100g and pulp: 15.5 ± 0.7 mg/100g) and magnesium (seeds: 105 ± 21.21 mg/100g and pulp: 55 ± 7.07 mg/100g) were higher in the seeds than in the pulp. However, calcium was more abundant in the pulp (130 ± 1.41 mg/100g) than in the seeds (75 ± 7.07 mg/100g). The magnesium and iron contents were similar to those found in guava seeds (Bourgeois et al., 1998) which already had values. With regard to the fruit of *A. alboviolaceum*, the analysis of Figure 3 showed, except the phosphorus which was more abundant in the seed (19.5 ± 2.12 mg/100g) than in the pulp (14 ± 1.41 mg/100g), iron (seeds: 3 mg/100g and pulp: 11 mg/100g), calcium (seeds: 80 mg/100g and pulp: 120 mg/100g) and magnesium (seeds: 80 ± 14.14 mg/100g and pulp: 185 ± 21.21 mg/100g) were present in greater quantity in the pulp than in the seeds. These results showed that the seeds of two fruits which were edible, but considered as waste during processing into juice or nectar had very interesting characteristics because of their essential nutrient composition. Thus, they could be valued in the same way as the pulp. These seeds could be used in human food by making flours utilized as a supplement in the formulation of infant flours and in cosmetology by extraction of essential oil.

**Conclusion**

This study allowed us, on the one hand, to determine the biochemical characteristics of the four (*P. edulis flavicarpa*, *A. alboviolaceum*, *S. comorensis* and *C. cymulosa*) popular edible fruits in the Republic of Congo and, on the other hand, to compare the pulp and seeds of *P. edulis f. flavicarpa* and *A. alboviolaceum*. The four fruits were characterized by a wealth of water and were a significant source of proteins, lipids, ashes and minerals. Nevertheless, *S. comorensis* and *C. cymulosa* presented very low lipid content. The pulp of *S. comorensis* and *C. cymulosa* were characterized by an important content of acidity and reducing sugar. Ashes contained iron, phosphorus, calcium and magnesium. All these mineral elements were in greater quantity in the pulp of *S. comorensis*. The comparative study of the seeds and pulps of *P. edulis f. flavicarpa* and *A. alboviolaceum* showed that the seeds contained higher levels of protein and lipids. The seeds of the passion fruit were rich in iron, calcium and magnesium. However, the values obtained in those of *A. alboviolaceum* were not negligible. These fruits including their seeds could be an important source of nutrients and are valued in the food, pharmaceutical and cosmetic industries. The encouraging results of this study deserve to be further investigated.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

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