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Comparative Study of the Nutritional Value of Unripe and Ripe Arils of *Blighia sapida* (K. D. KOENIG)

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Abstract *B. sapida* arils are of great socio-economic importance in West Africa due to their food uses. Several studies have focused on mature arils but few studies have focused on immature ones. The objective of this work was to assess the nutritional potential of mature and immature arils of these species. The arils were collected in Kara (Northern-Togo) and in Lomé (Southern-Togo). The organic substances contained in the arils were determined according to the methods of AOAC while the minerals were determined by flame atomic absorption spectrophotometry for sodium, potassium, calcium and magnesium and by molecular absorption spectrophotometry for phosphorus. The main results showed that the mature and immature arils of *B. sapida* contain alkaloids, tannins, reducing compounds and carbohydrates and are a good source of proteins, fats, carbohydrates and minerals. Furthermore, immature arils showed a better dietary fiber content compared to mature arils. The metabolisable energy of the two types of arils were 526.78 ± 39.87 and 615.95 ± 33.90 Kcal/100 g of dry matter, respectively for the unripe arils and the ripe ones. All these results show that these arils have an appreciable nutritional value and can contribute to food safety. This justifies their food uses.

Keywords: *Blighia sapida, Unripe and ripe arils, Biochemical composition, Nutritional value*

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1. Introduction

Plants are a vital resource for sustainable human development. They are full of food nutrients and active ingredients for care. According to the FAO [1], more than 60 million indigenous peoples depend almost entirely on forests. Indeed, many varieties of plants, known as food plants, are cultivated for their medicinal use and food. Much more often these are domesticated plants such as *Blighia Sapida*, a tropical plant very bountiful in West Africa [2]. The leaves, the bark and the roots of this plant are used in traditional medicine. Fruits are made up of three parts, namely: valves, seeds and arils. The valves and seeds have foaming properties and therefore, are used in some households for laundry. Arils have a very great socio-economic importance due to their food uses. These are cup-shaped apples, cream to yellow in color, housed at the bottom of the valves. Depending on the maturity of the fruits, we can distinguish immature or unripe arils and mature or ripe ones. The arils of mature fruits that are at the stage of natural fruit dehiscence are not toxic [3]. Indeed, the ripe arils of *B. sapida* are eaten raw or cooked [4]. Previous studies have reported that these arils are a good source of macronutrients such as protein, carbohydrate, dietary fiber and fat [3,4,5]. In addition, analysis of mature arils has shown that they contain interesting levels of minerals such as K, Na, Mg, Fe and Ca [6,7,8]. This shows that the arils of *B. sapida* constitute an important food source which could contribute to food safety. Previous studies were thus more interested in ripe arils and particularly their fats. However, despite the presence in unripe arils of "hypoglycin A" which is toxic and can lead to childhood encephalopathies [3], people include these arils in their diet. While the mature arils are eaten raw, the unripe ones are eaten after drying through their use as a source of proteins and lipids in the sauce in Togo. It is therefore necessary to know the nutritional values for both unripe and mature arils in order to contribute to the fight against malnutrition, of which the lack of quality control of the food consumed remains one of the causes. Thus, the objective of this work is to assess the influence of the degree of maturity of the arils of *B. sapida* on their nutritional value.

2. Materials and Methods

2.1. Vegetable Material

B. sapida fruits were harvested during their season of abundance (May to August 2019) in Togo. The fruits were sampled at two stages of maturity: the first sample consisted of the immature arils, that is to say the arils of the fruits which did not reach their natural dehiscence stage (Figure 1A) and the second sample was formed from the arils of mature fruits (Figure 1B). The arils were separated from their seeds, washed with distilled water, dried at room temperature (25-28 °C) during 15 days and then crushed. The ground materials obtained were stored in polyethylene bags in the freezer at -20 °C until their use for analyzes.

2.2. Qualitative Phytochemical Screening

The preliminary phytochemical tests consisted of the search for chemical constituents such as alkaloids, flavonoids, tannins, reducing compounds, saponins and carbohydrates using standard procedures [9].

2.3. Biochemical Analyzes

2.3.1. Determination of Water Content

The water content of the arils of *B. sapida* was determined after drying in an oven at 45 °C of a sample mass gain until stabilization.

2.3.2. Determination of Proteins

The total proteins were determined by the Kjeldahl method adapted to foods [10].

2.3.3. Determination of the Rate of Dietary Fiber

The dietary fiber content was determined using the insoluble cellulose matter method according to AFNOR standard NF V 03-040 [10].

2.3.4. Determination of the Total Ash Content

The ash content was determined from a test portion of 5 g. The test portion was placed in a porcelain crucible previously heated to 550 °C then cooled in a desiccator and tared. The whole was brought to 550 °C in an oven for slow charring without ignition. The temperature was thus maintained at 550 °C for 6 hours and white ash was obtained [10].

2.3.5. Fat Content

The fat content was determined according to AFNOR standard NF V03 ISO 900 [11], based on the extraction of the fat contained in a product with an organic solvent (hexane) which is then evaporated by vacuum distillation.

2.3.6. Carbohydrate Content

The total carbohydrate and digestible carbohydrate contents were deduced by differential calculations:

$$Total\ Carbohydrates : TC = DM - (P + F + A)$$

$$Digestible\ Carbohydrates : DC = DM - (P + F + A + TF)$$

$$DM = Dry\ Matter$$

P = mass of total Protein
F = mass of Fat
A = mass of total Ash
TF = mass of Total Fibers

2.3.7. Energy Value

The energy (kcal) value was calculated using the specific coefficients of Atwater and Benedict which are 4 kcal/g for proteins and carbohydrates and 9 kcal/g for lipids.

$$E(kcal) = \left[\left((P + TC) \times 4\right) + (F \times 9)\right].$$

2.4. Determination of Minerals

The determination of minerals was performed according to AOAC methods. After mineralization by wet destruction of organic matter using the combined action of nitric and sulfuric acids, the mineral contents were determined by flame atomic absorption spectrophotometry. As for the phosphorus assay, it was carried out by colorimetry. Total phosphorus was first transformed into a yellow phosphomolybdate complex measured at 430 nm.

2.5. Statistical Analyzes

The data collected in this study was entered using Excel 2016 spreadsheet and processed using GraphPad Prism software, version 8.4.3. The differences were considered significant at the 5% ($p < 0.05$). Results were presented as the mean ± standard error of the mean (SEM).

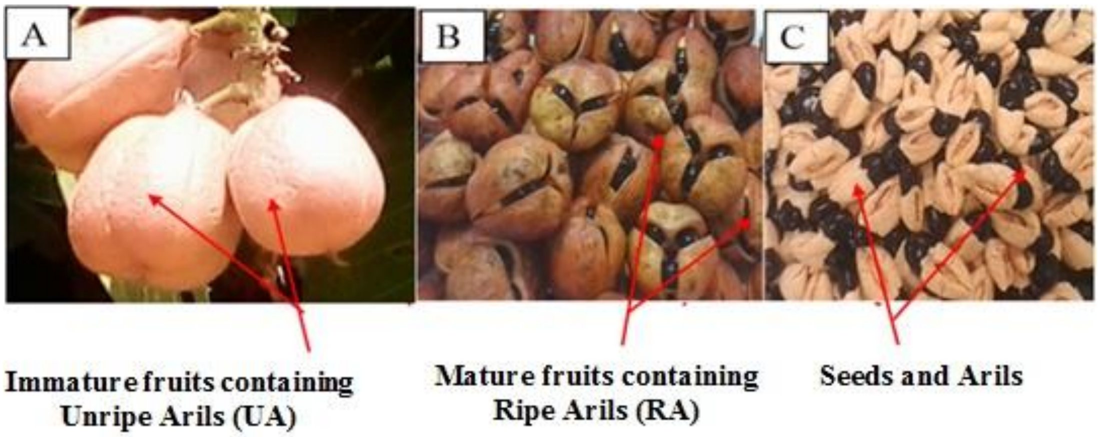

Figure 1. Immature fruits (A), mature fruits (B), seeds and arils of *B. sapida* (C)

3. Results and Discussion

3.1. Major Phytochemical Groups of *B. sapida* Arils

Qualitative tests on the ethanolic (96% ethanol) and hydroethanolic (50 - 50% v/v) extracts of the arils of *Blighia sapida* revealed the presence of certain major chemical groups presented in Table 1.

Table 1. Phytochemical composition of arils of *B. sapida*

Group of Phytochemicals tested	Hydroethanolic Extract		Ethanolic Extract	
	RA	UA	RA	UA
Alkaloids	+	+	+	+
Saponins	+	-	+	-
Tannins	+	+	+	+
Flavonoids	-	-	-	-
Reducing compounds	+	+	+	+
Carbohydrate	+	+	+	+

Legend: + = presence of the group of tested components;
- = absence of the group of tested components;
RA = Ripe arils; UA = Unripe arils

The ripe and unripe arils of *Blighia sapida* contain almost identical phytochemical groups such as alkaloids; reducing compounds; tannins and carbohydrates. However, only ripe arils revealed the presence of saponins. In contrast, flavonoids were absent in both ripe and unripe arils. Previous studies [13] have also shown the absence of flavonoids in the stem barks of *B. sapida*. However, these flavonoids have been found in the root barks of this species [14]. This can be explained by the difference in polarity of the solvents but also, by the ecological and intrinsic parameters of the plant. Indeed soil composition can influence the phytochemical makeup of plant organs [15].

3.2. Biochemical Composition of the Arils of *B. sapida*

Table 2 shows the biochemical composition and the energy values of the ripe and unripe arils of *B. sapida*.

Analysis of Table 2 shows that the two types of arils have a similar composition of protein, carbohydrate, fat and ash. In contrast, immature arils exhibited a higher dietary fiber content compared to mature arils ($p < 0.05$).

The moisture content (58.14 ± 6.31%) of the mature arils of *B. sapida* analyzed (Table 2) was relatively high compared to that of cereals (10 - 20%) but, approaching that of fish and animal meats (60 - 75%) [16] and certain fruits such as sweet bananas (73.8 ± 0.50%) [12]. The unripe arils exhibited a higher water content compared to that of the ripe ones. This is linked to the water requirement for the maturation of unripe arils. The increment in water content in unripe arils is however not significant ($p > 0.05$) compared to that of the ripe ones. The maturation of the arils therefore does not significantly influence their water content.

The crude protein content was 20.83 ± 2.33% for the mature arils (Table 2). This value is close to 24.3% and 21.5%, respectively reported in previous studies in Jamaica and Nigeria [5,17] for mature arils but above 11.99%, reported in Côte d'Ivoire [6]. The mature arils of *B. sapida* can be assimilated to foods rich in protein, such as cowpea whose protein content reported by [18] was 24.20%. The immature arils were less rich in protein (13.38 ± 1.27%) compared to the mature arils (Table 2), but this difference was not significant ($p > 0.05$). The results show that these arils could contribute to the fight against protein-energy malnutrition.

The crude lipid content of mature arils was 52.47 ± 4.53% (Table 2). This content is greater than 45.32%, 46.44% and 45.50% respectively reported in Benin, in Côte d'Ivoire and in Nigeria [4,6,17]. However, it is well above the 18.78% reported by [8] in Nigeria. This difference could depend on the intrinsic and ecological conditions of the plants or the extraction methods and solvents used. The arils of *B. sapida* can therefore be compared to oil seeds such as rapeseed or flax seeds which contain between 47.9% and 51.1% crude lipids [19]. This lipid content was lower (43.18 ± 4.76%) for the immature arils (Table 2).

Total carbohydrates were estimated to be 27.53 ± 07.18% in the immature arils and 19.82 ± 5.17% in the mature ones. Likewise, the dietary fiber content was 6.37 ± 0.26% for the immature arils and 4.72 ± 0.18% for the mature ones. This higher fiber content observed in immature arils could be explained by the greater water requirement of unripe arils. In fact fibers have the power to retain water, their presence allows the unripe arils to be better hydrated. As a result, the mature arils and unripe ones of *B. sapida* are of interest in carbohydrate, protein, dietary fiber and crude fat. This richness in organic matter of the arils justifies their values in metabolizable energy. The energy value have been evaluated in fact at 526.78 ± 39.87 Kcal/100g of immature arils and at 615.95 ± 33.90 Kcal/100g of mature ones. This explains the nutritional interest aroused by these fruits among consumers and shows the need to promote the use of this local resource.

The total ash content was 6.88 ± 1.35% for the mature dry arils (Table 2). This value is close to 8.01 ± 1.13% reported by [4] in Benin and 5.6% reported by [17] in Nigeria for mature arils. The immature arils exhibited a higher ash content (15.91 ± 1.05%) compared to that of the mature arils. This could be due to the greater mineral requirement in unripe arils. Indeed, certain macro-elements such as potassium and phosphorus are essential for the growth of plants, the rigidity of their tissues and their fruiting. The ash content of the arils of *B. sapida* analyzed is therefore comparable to that reported by [12] for plantains (16.30%), showing that they are rich in minerals. This was confirmed by the analysis of some elements (Na, K, Ca, Mg and P) whose contents were relatively high (Table 3).

The potassium content was 941.47 ± 47.32 mg/100g of dry mature arils. This value is lower than those reported by [5] in Jamaica and [6] in Côte d'Ivoire, i.e. 1605 ± 169 mg/100g and 1503.3 ± 1.89 mg/100g of dry mature arils, respectively, but greater than 46.44 mg/100g of dry matter reported by [4] in Benin. In addition, the immature arils of *B. sapida* contain less potassium compared to the immature ones.

Table 2. Biochemical composition of the arils of *Blighia sapida*

Elements analyzed	Unripe Arils (UA)	Ripe Arils (RA)	*p* value (UA vs RA)
Moisture (% of DM)	64.36 ±11.52a	58.14 ±6.31a	0.295
Fat (% of DM)	43.18 ±4.76a	52.47 ±4.53a	0.293
Protein (% of DM)	13.38 ±1.27a	20.83 ±2.33a	0.107
Total Fiber (% of DM)	6.37 ±0.26a	4.72 ±0.18b*	0,035 ($p < 0.05$)
Total Carbohydrate (% of DM)	27.53 ±7.18a	19.82 ±5.17a	0,389
Digestible Carbohydrates (% of DM)	21.16 ±5.16a	15.10 ±2.07a	0.474
Total Ash (% of DM)	15.91 ±1.00a	6.88 ±1.35a	0,341
Energy (Kcal/100g of DM)	526.78 ±39.87a	615.95 ±33.90a	0.176

DM = Dry Matter, FM = Fresh Matter. On the same line, the values that have different letters are significantly different and those that have the same letters are not significantly different; *: $p < 0.05$.

Table 3. Mineral composition of the arils of *B. sapida*

Mineral compounds	Contents (mg/100g of DM)		
	Unripe Arils (UA)	Ripe Arils (RA)	*p* value (UA vs RA)
Sodium	242,50 ±83,06a	218,10 ±25,48a	0,756
Potassium	670,74 ±39,72a	941,47 ±47,32b*	0,048 ($p < 0.05$)
Calcium	102,50 ±21,59a	164,40 ±18,39a	0,157
Magnesium	303,19 ±37,25a	287,70 ±22,34a	0,755
Phosphorus	84,50 ±09,92a	82,66 ±16,81a	0,933

DM = Dry Matter. On the same line, the values that have different letters are significantly different and those that have the same letters are not significantly different; *: $p < 0.05$.

The calcium content was 164.40 ± 18.39 mg/100 g of dry mature arils. This value is close to the content reported by [6] in Côte d'Ivoire and much higher than the values reported by [17] in Nigeria and [5] in Jamaica, respectively 32.6 mg/100g and 65.2 ±8.2 mg/100g of dry matter. Furthermore the magnesium and sodium contents of the mature arils were respectively 287.70 ± 22.34 mg/100g and 218.10 ±25.48g of dry matter.

The mature and immature arils of *B. sapida* contain 82.66 ±16.81 and 84.50 ±09.92 mg/100g of phosphorus, respectively. As a result, the mature and immature arils of *B. sapida* can provide the organism with several macro-elements namely: Ca, K, Na, P and Mg.

Phosphorus is essential for metabolism and the functioning of the nervous system [20]. Sodium and potassium are regulators of the body's water content and help maintain the acid-base balance. They are also important for the activation of certain enzyme systems and are involved in the storage of glycogen [21]. Both magnesium and potassium are necessary for muscle contraction [22]. Magnesium is also essential for the proper functioning of several enzymes [23]. Calcium, on the other hand, is a major dietary element, essential for ossification and dentition and therefore necessary for the nutrition of growing children [24]. This is because calcium intake through food is very important in compensating for the body's daily losses through stool, sweat and urine. The content of unripe arils and ripe ones in various minerals in appreciable quantities constitutes, without doubt, a nutritional advantage. Their food use could therefore have beneficial effects on osteoporosis, prevention of aging and strengthening of the immune system.

They therefore play a major role in the constitution of the skeleton. However, excess sodium can cause edema and high blood pressure. Indeed, the Na/K, Ca/P and Ca/Mg ratios are illustrated in Figure 2.

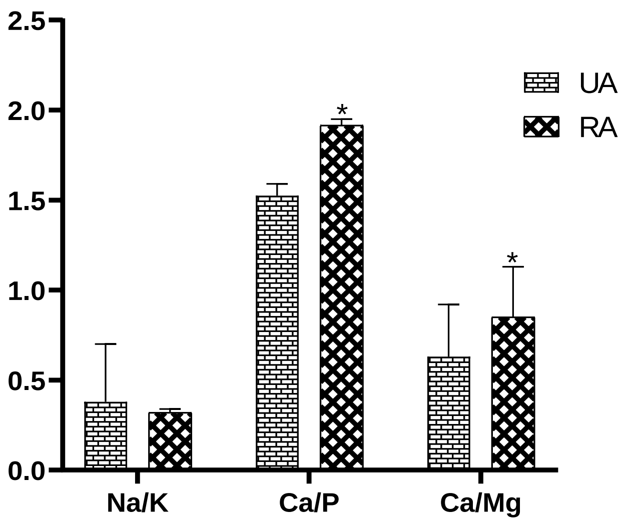

Figure 2. The Na/K, Ca/P and Ca/Mg ratios of ripe and unripe arils of *B. sapida* (Values were expressed as a mean ±SEM. Significantly different (UA vs RA), *: $p < 0.05$)

The Na/P ratios were higher for unripe arils compared to mature arils while those of Ca/P and Ca/Mg were greater for mature arils (Figure 2).

The Na/K ratios were less than unity for both immature and mature arils indicating that dietary use of these arils may be benefit to the cardiovascular system [25]. According to [26], high potassium intakes are protective against the damage induced by sodium on arterial pressure, particularly in hypertensive subjects. The Ca/P ratios were greater than unity for both mature and immature arils indicating that the arils of *B. sapida* are an important source of calcium, essential for the proper functioning of joints and muscles as well as blood clotting and the process of ossification [27,28]. The Ca/P ratio is necessary for the quality of the vertebrate skeleton because hyperphosphatemia can lead to demineralization of the bones while excess calcium causes the blockage of copper and zinc. On the other hand, the Ca/Mg ratios were less than unity and therefore the arils of *B. sapida* contain more magnesium than calcium. The Magnesium is involved in nerve transmission and muscle relaxation after contraction, which is vital for cardiac activity. It is also recognized to play an essential role in maintaining a regular heart rate, in metabolism through the functioning of many enzymes in the body, as well as in the regulation of blood sugar levels and blood pressure [22,23].

Table 4. Contribution in organic and mineral substances of 100 g of dry matter of the arils of *B. sapida* to (RDA)

Elements considered	RDA (%) for an adult (Man/Woman)	Quantity in 100g of DM of Arils of *B. Sapida*		Contribution in 100 g of dry matter of the arils of *B. sapida* to RDA	
		UA	RA	UA	RA
Carbohydrate (g)	130[a]	21,16	15,10	16,28	11,62
Fat (g)	44-97[a]	43,18	52,47	44,52-98,14	54,09-119,25
Protein (g)	56	13,38	20,83	23,89	37,20
Energy (kcal)	2500/2000[a]	526,78	615,95	21,07/26,34	24,64/30,80
Na (mg)	1500[b]	242,50	218,10	16,17	14,54
K (mg)	4700[b]	670,74	941,47	14,27	19,46
Ca (mg)	900[bc]	102,50	164,40	11,39	18,27
Mg (mg)	420[a]	303,19	287,70	72,19	68,50
P (mg)	750[bc]	84,50	82,66	11,27	11,02

[a]Dietary reference intake of minerals, energies, carbohydrates, fibers, lipids, fatty acids, cholesterols, proteins and amino acids (OMS/FAO) [29]; [b]Recommended nutritional intake for a body weight of 70 kg [30]; [c]AFSSA [31].

3.3. Contribution in Organic and Mineral Substances of 100 g of Dry Matter of the Arils of *B. sapida* to the RDA

Table 4 gives the contribution in organic and mineral substances of 100 g of dry matter of the arils of *B. sapida* to the Recommended Daily Allowances (RDA).

The metabolizable energy obtained with the arils of *B. sapida* was 526.78 ± 39.87 Kcal/100g DM for the unripe arils and 615.95 ± 33.90 Kcal/100g DM for the ripe ones. Unripe arils contribute 21.07% in males and 26.34% in females while ripe arils contribute 24.64% in males and 30.80% in females to the RDA in energy. In addition, the arils of *B. sapida* could also contribute to the Recommended Daily Intakes of minerals important for the proper functioning of the body such as K, Ca, Mg and P, ie 19.46% respectively; 18.27%; 68.50 and 11.02% for ripe arils and 14.27%; 11.39%; 72.19% and 11.27% for the unripe ones.

4. Conclusion

In view of all the organic and mineral contents, the ripe and unripe arils of *B. sapida* can be considered as fruits of significant nutritional value. These results showed that both types of arils are rich in fat, minerals and protein and relatively low in carbohydrates with an interesting energy value. Mature arils are particularly richer in potassium, while immature arils are a better source of dietary fiber. The nutritional values of the two types of arils are appreciable and without any significant difference. In addition, the arils of *B. sapida* can make a significant contribution in organic and mineral substances to the Recommended Daily Intakes. From an energetic point of view, the mature and immature arils of *B. sapida* do not show a significant difference, they can have similar contributions to the RDA in organic and mineral substances. However, the presence of “hypoglycin A” in immature arils makes them less attractive for direct consumption. Studies are needed to examine the mechanism of its elimination.

Author Contributions

Conceived and designed the experiments: MM, EN and KMN. Species identification and fruit collection: MM and EN. Performed the experiments: EN, EK, KMN, MM, KD, KK and GA. Analyzed the data: MM, EN and KMN. Contributed reagents/materials/analysis tools: KHK and KMN. Wrote the paper: MM, EN, EK and KMN.

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Conflicts of Interest

The authors declare no conflict of interest.

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