

Nutritional and Antioxidant Values of the Black Plum (*Vitex doniana*)

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Abstract

This study was conducted to first determine the nutritional potential and the antioxidant activity of black plum fruit pulp and peel. For these characterizations, classic methods were used. The results indicated high fibre and ash contents of black plum from all localities studied, ranging, respectively, from 34.79 ± 0.07 – $39.83 \pm 1.85\%$ and 4.91 ± 0.45 – $5.91 \pm 0.41\%$ for pulp, and 46.38 ± 0.09 – $50.21 \pm 1.07\%$ and 4.16 ± 0.81 – $4.28 \pm 0.20\%$ for peel. The mineral analysis revealed that Black plum pulp and peel are high in potassium (1863.00 ± 1.4 – 2584.55 ± 3.54 mg/100 g dry weight [DW]) and calcium (355.30 ± 2.52 – 389.52 ± 3.54 mg/100 g DW). Both the peel and pulp are characterised by a good essential amino acids profile of the protein. The total polyphenol, flavonoid and anthocyanin contents of pulp and peel ranged from 202.51 ± 4.19 to 463.45 ± 6.85 mg gallic acid equivalent (GAE)/100 g of Dry Weight (DW), 75.71 ± 1.03 to 145.55 ± 1.03 mg quercetin equivalent (QE)/100 g DW, and from 1.91 ± 0.08 to 8.28 ± 0.83 mg cyanidin 3-O- β -D-glucoside equivalent (C3GE)/100 g DW respectively. Thus, these fruits constitute a good source of important nutrients for health.

Keywords: Nutritional values, antioxidant, black plum, valorization

1. Introduction

Fruits and vegetables have always been considered as essential sources of micro-nutrients and dietary fibre for the body to function properly. Moreover, regular fruit consumption is recommended for disease prevention and health benefits due to the nutrient composition of fruits, which includes vitamins, minerals, fibre and bioactive compounds [1]. In Côte d'Ivoire, these nutrients are generally delivered by some cultivated tropical fruit, including mangoes, papaya, citrus fruit, as well as imported temperate climate fruit, such as apple, pear and grape [2]. These tropical fruits are often not readily accessible to the populations beyond production time, especially in the developing countries due to their high cost or scarcity in the local market [3, 4]. However, these shortages correspond to the production stage of some wild fruit-bearing species, underutilised because of the limited knowledge

regarding their nutritional values. Assessing the quantitative and qualitative value of this fruit (including peel, pulp and seed) could reveal novel food sources with potential health-protective properties.

Among these wild plant resources, black plum (*Vitex doniana*) is an abundant and widespread species in tropical countries, such as Côte d'Ivoire [5–8]. In Côte d'Ivoire, it is found, for example, in Pakobo, Ahiérou and Zougoussi, located in the centre of the country [9], Seguela in the west–north, Korhogo and Tingrela in the north [10], and Bondoukou in the east–north region [11]. Various parts of the plant, including the leaves and bark, have been used for many decades by some rural populations to treat diabetes, ulcer, diarrhoea, dysentery, asthma, insomnia and various other illnesses. The fruit of this species is an ellipsoid drupe of about 2.5–3.0 cm in height and 2.0–2.5 cm in diameter, and rich in sugar [12, 13]. The unripe fruit is green but turn brown–black when ripe, and are eaten raw [9, 14]. Nutritional analyses indicate that black plum is a good source of vitamins, such as calcium, iron, magnesium, phosphorus and vitamin C [15–18]. In addition, the pulp provides useful quantities of flavonoids with strong antioxidant properties [19].

Interestingly, no comparative study between the nutritional composition of black plum pulp and peel has yet been carried out. This study sought to show the nutritional potential and antioxidant properties of black plum peel and pulp, by analysing the physicochemical and nutritional properties in order to contribute to the valorization of this fruit, produced in large quantities, even in some remote areas of Côte d'Ivoire, particularly in the regions of Ferke, Tiebissou and Yamoussoukro.

2. Materials and methods he entirety

2.1 Sample preparation

The ripe black plum were harvested in three Côte d'Ivoire localities: Ferkéssédougou (Ferke), Tiébissou and Yamoussoukro. The fresh fruit was washed with tap and distilled water, sequentially. After drying the fruit with a paper towel, the pulp and peel were separated by hand using a stainless-steel knife, dried in an oven (Memmert U30-Gemini BV, GmbH, Germany) at 50°C for 24 h, then milled using a miller (ZBK220077–88 LW74d(B) A, China). Milled pulp and peel were packaged in polyethylene bag using a vacuum packager (NG 10121 MULTIVAC, Belgium) and frozen at –19°C until analysis. All tests were realised in triplicate.

2.2 Chemical and biochemical analyses

2.2.1 Ash, protein, fat, carbohydrate and dietary fibre contents

Ash, crude protein, fat and total carbohydrate were determined by standard methods AOAC [20]. Dietary fibre was analysed by AOAC 991.43. [21], and total carbohydrates by the protocol reported by Bertrand and Thomas [22]. The energy value (kcal/100 g) was calculated by multiplying the protein, fat and carbohydrate contents (g) by factors of 4, 9 and 4 kcal/g, respectively.

2.2.2 Minerals analysis

Dried pulp and peel (0.5 g in each case) of Black plum were transferred to digestion flasks containing 5 mL of HCl/HNO₃ (1:3). After 2 h of slowly boiling, the mixture was cooled at room temperature, then 50 mL of distilled water was added

and followed by filtration. The cooled solution was placed in flasks and transferred to the atomic absorption spectrophotometer (Analyst 200, Perkin Elmer, Waltham, MA, USA) for mineral determination. The phosphorous was measured spectrophotometrically. Standard calibration curves constructed for each element were used for direct quantification.

2.2.3 Amino acid analysis

The black plum pulp and peel amino acids composition was determined based on a previous method [23]. Duplicate samples were hydrolysed by transferring around 50 mg of sample weighed accurately in a 15 mL flask in which 5 mL of HCl (6.0 N) was added. The flask was closed under vacuum, nitrogen-purged and digested at 110°C for 24 h. Sulphur-containing amino acids were determined by using performic acid. The amino acids were analysed using a Biochrom 20+ amino acid analyser, Cambridge, United Kingdom).

2.2.4 Phenols extraction

Phenols were extracted by the method of Soro et al. [19]. Dried *V. doniana* pulp and peel samples (1 g) were homogenised in 10 mL solution of 80% methanol and 2% formic acid, using an Ultra TurraxT25 basic homogeniser (Heldoph Instruments D-91126, Schabach, Germany) at room temperature. The homogenate was sonicated for 30 min in a Bandelin electronic RK 541 H sonicator (Heinrichstrasse 3–4 D-12207, Germany) and then centrifuged at 9400 × g for 25 min in a DBS centrifuger (PCB 1500, Italy). The supernatant was collected and the precipitate extracted again with 10 mL of 80% methanol, under the conditions previously described. The two supernatants were mixed and filtered using Whatman filter paper No.1. The final methanolic extract was stored at 25°C to be used in determination of total phenols, flavonoids and anthocyanin contents.

2.2.4.1 Determination of total phenols

Total phenolic compounds (TPC) determination was performed as described by Gao et al. [24] Phenolic extract (100 µL) was mixed with 0.2 mL Folin–Ciocalteu reagent (Sigma), 2 mL of H₂O and 1 mL of 15% Na₂CO₃ and the absorbance measured at 765 nm in a spectrophotometer (Thermo Scientific™ 75003631, ThermoFisher Scientific SAS, Strasbourg, France) after 2 h incubation at room temperature. Gallic acid was used for the calibration curve with a concentration range from 0 to 200 mg/L. Total phenols were expressed as mg gallic acid equivalent (GAE)/100 g DW.

2.2.4.2 Determination of total flavonoids

Total flavonoid (TF) contents were determined according method used by Meda et al. [25], but slightly modified. A volume of 0.5 mL of sample methanolic extract was diluted in 0.5 mL of distilled water. Then, 0.5 mL of aluminium chloride 10% (w/v) and the same volume of 1 M sodium acetate was added. Finally, 2 mL of distilled water was added and absorption reading at 415 nm was taken after 30 min against a blank sample consisting of a 4 mL methanolic extract without aluminium chloride. Quercetin was used for the calibration curve with a concentration range from 0 to 3.125 mg/mL. Results were expressed as mg quercetin equivalent (QE)/100 g DW.

2.3 Statistical analysis

All data were analysed using ANOVA based on Tukey's HSD multiple comparison test at $p < 0.05$. Software RStudio version 1.2.1335 2009–2019 was used, and triple analyses were performed. The results were presented as mean $\pm$ standard deviation.

3. Results and discussion

The nutritional composition of black plum pulp and peel harvested in three localities of Côte d'Ivoire (Ferre, Tiébissou and Yamoussoukro) are given in **Figures 1–3**. Values are compared on a dry weight (DW) basis, except for moisture content.

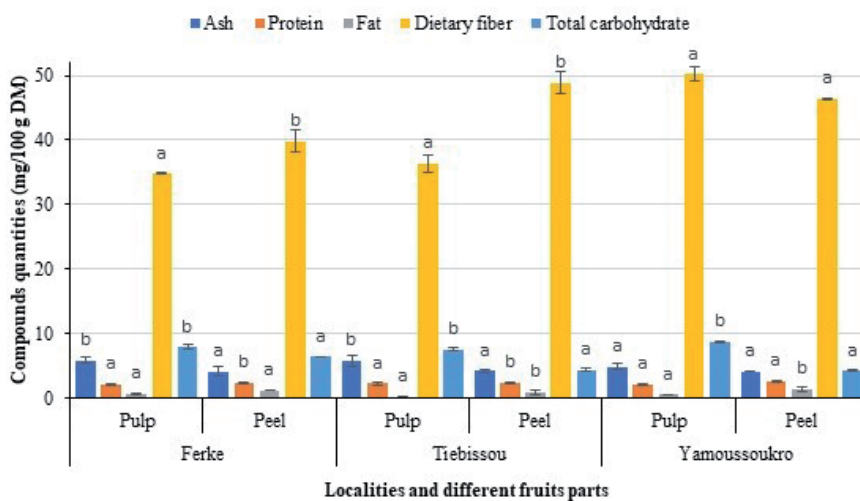


Figure 1. Comparison between the nutritional composition of pulp and peel of *Vitex doniana* fruit harvested in Ferre, Tiébissou and Yamoussoukro.

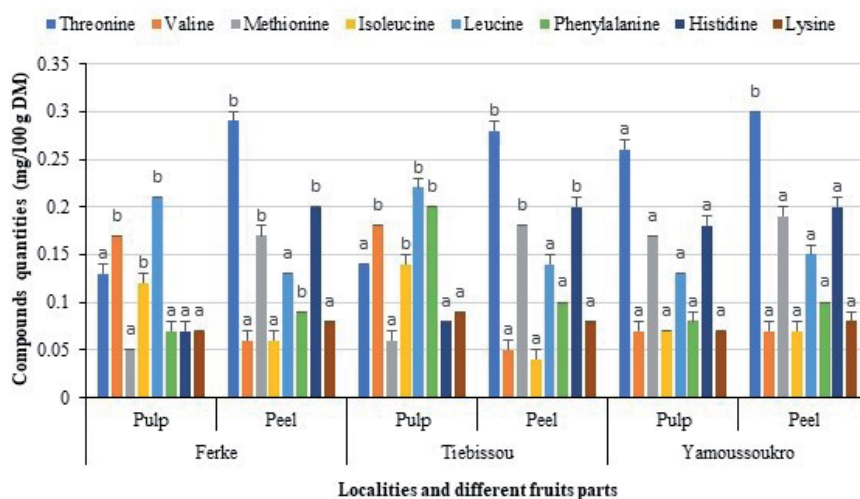


Figure 2. Comparison between pulp and peel amino acid contents of black plum harvested in Ferre, Tiébissou and Yamoussoukro.

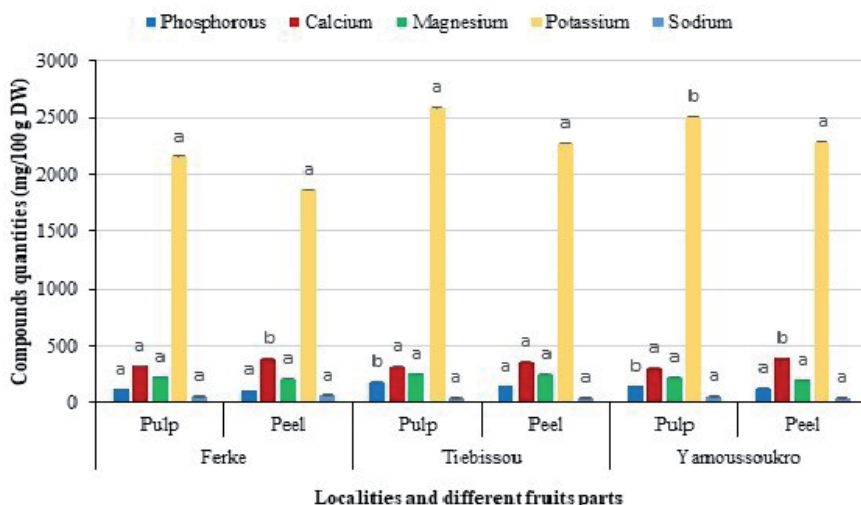


Figure 3.
Comparison between pulp and peel micromineral contents of *Vitex doniana* fruit harvested in Ferke, Tiebissou and Yamoussoukro.

3.1 Ash content

There was no significant difference between pulp and peel of fruit among the localities, but the ash contents of Ferke and Tiebissou fruit pulps were significantly higher ($p < 0.05$) than those of Yamoussoukro (**Figure 1**).

These results contrast sharply with those of previous authors, notably, Soro et al. [19], who obtained average ash contents of 1.4% and 3.53%, respectively, for the fruit pulp of *V. doniana* harvested in V-Baoulé and Nord of Côte d'Ivoire. Comparatively higher ash contents of 11.50% were reported by Vunchi et al. [18], whereas Agbede and Ibitoye [16] stated levels (5.1%) similar to the current work. In addition, compared with the pulp from fruit of the same genus, the ash content found here is higher than that of baobab ($4.5 \pm 0.2\%$; Magdi, 2004) and avocado ($2.1 \pm 0.6\%$; [26]).

This ash content variation within the same fruit and between the same species may be due to the water content and soil properties [27]. The ash content of food reflects its total mineral content, and so Black plum would be a valuable source of minerals.

3.2 Protein content

Pulp and peel protein contents of Black plum ranged from 2.11 ± 0.15 to $2.28 \pm 0.16\%$ (**Figure 1**). A markedly higher protein content ($2.61 \pm 0.07\%$) occurred in the peel of fruit from Yamoussoukro than Ferke and Tiebissou, respectively, of 2.35 ± 0.10 and $2.40 \pm 0.13\%$, which had more protein in their pulps than peels (**Figure 1**). In comparison to these data, higher protein values (3.04%) have been recorded for Black plum in Uganda by Acipa et al. [15], and in the work by Jacob et al. [28] for *Strychnos spinosa* ($8.72 \pm 0.02\%$), *Diospyros mespiliformis* ($6.99 \pm 0.02\%$) and *Dialium guineense* ($5.23 \pm 0.01\%$). The fruit pulps studied have a low protein content, as per most fruits [26]. Protein contents are known to be influenced by the soil composition, including nitrogen content [29].

3.3 Fat content

Black plum pulp has a markedly lower fat content (0.20 ± 0.03 – $0.66 \pm 0.16\%$) than the pulp of strawberry ($2.1 \pm 0.16\%$; [30]), as well as mango ($5.9 \pm 0.05\%$), passion fruit ($0.8 \pm 0.4\%$) and pineapple ($1.8 \pm 0.03\%$) studied by Martinez et al. [31]. Although black plum peel (0.97 ± 0.37 – $1.46 \pm 0.33\%$) had a higher fat content relative to the pulp, it is still low in fat (**Figure 1**), particularly when considering the fat content of tomato peel ($6.01 \pm 0.13\%$; [32]). From these results, Black plum is not a useful source of lipids.

3.4 Total carbohydrates content

Both the pulp and peel studied in this work, are low in carbohydrate. Yamoussoukro pulp samples were the highest in carbohydrate compared with the other samples (**Figure 1**), while fruit from Ferke showed intermediate carbohydrate contents ($7.94 \pm 0.36\%$). Nonetheless, both values were lower than those found in the pulp of Black plum from Burkina Faso (19.68 – 20.25% ; [33]) and Nigeria ($28.40 \pm 1.06\%$; [16]), as well as the pulp of some other fruits, including mango ($11.9 \pm 0.41\%$ DW) but close to the fruit of *Adansonia digitata* (8.25 ± 0.03 – $9.25 \pm 0.21\%$; [33]). The age of the tree, and environmental factors, such as climate and soil, could be the basis of the observed differences because Ferke is located in a dry savanna zone, with a very hot and dry climate (Sudanese climate) and ferrallitic soils [34, 35], while Yamoussoukro and Tiebissou, located in mesophilous and savanna wooded areas, respectively, have a Baoulean climate, both with moderately desaturated ferrallitic soils [36].

Among the localities, Ferke ($6.49 \pm 0.00\%$) corresponded to fruit peel with the highest total carbohydrate content, while an average of 4.36% carbohydrate occurred in the peel of fruit harvested in Tiebissou and Yamoussoukro. Comparatively richer sources of carbohydrate are the peels of mango Raspuri ($28.20 \pm 0.60\%$ DW), mango Badami ($20.80 \pm 0.20\%$ DW; [37]) and tomato ($32.16 \pm 1.11\%$ DW; [38]). However, fruit pulp contained the most carbohydrates whatever the locality (**Figure 1**). The high carbohydrate content of Ferke fruit peel would be linked to the climate, as this region is located in the northern part of Côte d'Ivoire where a generally high temperature occurs. Given the Black plum are low in carbohydrate, it can be concluded that regular consumption of this fruit would be beneficial for people with obesity, who are most often subject to a diet restricted in carbohydrates.

3.5 Dietary fibre

This study showed that dietary fibre is a main component in the pulp (34.79 ± 0.07 – $39.83 \pm 1.85\%$) and peel (46.38 ± 0.09 – $50.21 \pm 1.07\%$) of Black plum harvested in the three localities of Côte d'Ivoire. The dietary fibre levels in the pulp of Black plum are high when considering the amounts present in the pulp of white guava ($3.50 \pm 0.01\%$; [39]) and Deglet-Nour and Allig date varieties ($14.4 \pm 1.12\%$ and $18, 0.45\%$; [40]). Moreover, the values obtained in this work approximate those recorded by Grigelmo-Miguel and Martín-Belloso [41] for the three orange varieties, Navel ($35.4 \pm 1.4\%$), Salustiana ($35.9 \pm 0.5\%$) and Valencia Late ($36.9 \pm 0.3\%$), which are well-recognised as sources of dietary fibre.

In addition, black plum peel displayed a much higher level of dietary fibre than some other fruit peels too, especially avocado ($43.9 \pm 2.7\%$), pineapple ($16.3 \pm 2.5\%$) and papaya ($16.6 \pm 2.2\%$) [42]. Interestingly, the peel fibre contents were significantly higher for the fruit harvested in Yamoussoukro (46.38 ± 0.09 – $50.21 \pm 1.07\%$)

than Ferke and Tiebissou (**Figure 1**). This trend could be explained as a fruit defence against heat stress. Ferke and Tiebissou fruit pulp results agree well with results found by Lamghari et al. [43], Gorinstein et al. [44] and Morais et al. [26]. Similar to the present study, these authors also obtained significantly higher ($p < 0.05$) dietary fibre values in the studied peels than pulps. It is well known that diets high in dietary fibre are associated with the prevention and treatment of various diseases, such as diverticular and coronary heart disease, colon cancer and diabetes, besides contributing to weight loss in individuals with obesity [45, 46].

Based on the results observed, black plum is a potentially good dietary fibre source and could contribute towards the prevention and treatment of several degenerative diseases. Therefore, these fruits could be included in some food formulations for possible fibre enrichment.

3.6 Amino acids

Similarly to most fruits, such as apple [47], medlar [48], strawberry [49] and tomato [50], the main amino acids present in Black plum pulp were glutamic acid and aspartic acid, which had averages of 0.27 mg/100 g DW (**Table 1**). Conversely, the peels were particularly high in threonine and proline, with mean contents of 0.29 ± 0.01 and 0.27 ± 0.01 mg/100 g DW, respectively. Furthermore, the percentages of essential amino acids in the protein of black plum pulp and peel compare well with standard protein, according to the World Health Organisation (WHO; **Table 2**). In pulp protein, only two amino acids or amino acid pairs (methionine/cysteine and lysine) had scores below 100%, of a few percentage points only or around 50% (lysine). However, only isoleucine (47.82–80.42%), lysine (41.60–51.62%) and valine (30.80–41.43%) percentages characterised the peel protein. In addition to Yamoussoukro fruit, Ferke and Tiebissou fruit pulps contained higher threonine, histidine and methionine amounts than their peels (**Figure 2**). The peels were rather rich in valine and leucine. Despite the low protein content, black plum protein has a good amino acids profile.

3.7 Mineral contents

Regarding the macrominerals, all samples contained high amounts of potassium (K), followed by calcium (Ca), magnesium (Mg), phosphorus (P) and sodium (Na). In addition, the main micro-minerals were iron (Fe), followed by manganese (Mn) and Zinc (Zn). The concentration ranges of K, Ca, Mg, P and Na in Black plum, were respectively, 1863.00 ± 1.41 – 2283 ± 1.41 , 355.30 ± 2.52 – 389.52 ± 3.54 , 221.00 ± 1.41 – 255.5 ± 2.12 , 118.00 ± 0.71 – 179.00 ± 2.83 and $38, 30 \pm 7.77$ – 53.33 ± 1.53 mg/100 g DW for the pulp, and 2155.50 ± 4.95 – 2584.55 ± 3.54 , 301.50 ± 2.12 – 325.50 ± 0.00 , 199.67 ± 1.15 – 250.00 ± 2.83 , 105.50 ± 2.12 – 142.00 ± 1.41 and 39.70 ± 5.69 – 62.31 ± 2.08 mg/100 g DW for the peel (**Table 3**).

The pulp and peel of fruit collected in Tiébissou and Yamoussoukro exhibited the highest levels of K, while the lowest K levels (2155.50 ± 4.95 and 1863.00 ± 1.41 mg/100 g DW, respectively) occurred in those from Ferke. The K content of the fruit pulp of *V. doniana* in this work is higher than that obtained by Ladeji and Okoye [51] of 127.2 mg/100 g DW, and Vunchi et al. [18] of 15.70 ± 0.26 mg/100 g DW. In addition, the observed Black plum pulp and peel K contents are higher than those in banana (382 ± 15 and 337 ± 7 mg/100 g DW; [52]) and mango (185 ± 11 and 444 ± 13 mg/100 g DW; [53]). The pulps Ca concentrations were significantly similar ($p > 0.05$) among the localities, whereas Ca concentration was highest in Yamoussoukro fruit peel (389.52 ± 3.54 mg/100 g DW), and lowest in Tiebissou fruit peel (355.30 ± 2.52 mg/100 g DW). In addition, except for Tiebissou

Amino acid	Pulp			Peel		
	Ferke	Tiebissou	Yamoussoukro	Ferke	Tiebissou	Yamoussoukro
Essential amino acids						
Threonine	0.13 ± 0.01a	0.14 ± 0.00a	0.12± 001a	0.29 ± 0.02a	0.28 ± 0.01a	0.30 ± 0.00a
Valine	0.17 ± 0.00a	0.18 ± 0.00a	0.17 ± 0.01a	0.06 ± 0.01a	0.05 ± 0.02a	0.07 ± 0.03a
Methionine	0.05 ± 0.00a	0.06 ± 0.02a	0.07 ± 0.00a	0.17 ± 0.01ab	0.18 ± 0.00a	0.19 ± 0.01b
Isoleucine	0.12 ± 0.01a	0.14 ± 0.01a	0.13 ± 0.00a	0.06 ± 0.01ab	0.04 ± 0.01a	0.07 ± 0.01b
Leucine	0.21 ± 0.00a	0.22 ± 0.01a	0.20± 0.00a	0.13 ± 0.00a	0.14 ± 0.01a	0.15 ± 0.02a
Phenylalanine	0.07 ± 0.01a	0.20 ± 0.00c	0.08 ± 0.01b	0.09 ± 0.00a	0.10 ± 0.00a	0.10 ± 0.00a
Histidine	0.07 ± 0.01a	0.08 ± 0.00a	0.18 ± 0.04b	0.20 ± 0.00a	0.20 ± 0.01a	0.20 ± 0.01a
Lysine	0.07 ± 0.00a	0.09 ± 0.00b	0.07 ± 0.00a	0.08 ± 0.00a	0.08 ± 0.00a	0.08 ± 0.01a
Non-essential amino acids						
Aspartate	0.26 ± 0.01a	0.29 ± 0.01a	0.26 ± 0.00a	0.04 ± 0.00a	0.02 ± 0.02a	0.04 ± 0.00a
Serine	0.14 ± 0.00b	0.16 ± 0.00b	0.12 ± 0.00a	0.14 ± 0.00a	0.14 ± 0.00a	0.14 ± 0.01a
Glutamate	0.26 ± 0.01a	0.30 ± 0.01b	0.26 ± 0.00a	0.17 ± 0.00a	0.17 ± 0.00a	0.17 ± 0.01a
Proline	0.15 ± 0.04a	0.14 ± 0.01a	0.15 ± 0.01a	0.28 ± 0.01a	0.29 ± 0.01a	0.29 ± 0.00a
Glycine	0.13 ± 0.00a	0.14 ± 0.00a	0.15 ± 0.01a	0.16 ± 0.00a	0.15 ± 0.03a	0.15 ± 0.02a
Alanine	0.13 ± 0.00a	0.16 ± 0.00b	0.12 ± 0.00a	0.15 ± 0.01a	0.16 ± 0.00b	0.15 ± 0.00ab
Cysteine	0.08 ± 0.01a	0.07 ± 0.02a	0.13 ± 0.00b	0.14 ± 0.00a	0.15 ± 0.00a	0.15 ± 0.00a
Tyrosine	0.10 ± 0.01a	0.10 ± 0.00a	0.20 ± 0.00b	0.22 ± 0.01a	0.23 ± 0.01a	0.24 ± 0.00a

Amino acid	Pulp			Peel		
	Ferke	Tiebissou	Yamoussoukro	Ferke	Tiebissou	Yamoussoukro
Lysine	0.07 ± 0.00a	0.09 ± 0.00b	0.07 ± 0.00a	0.08 ± 0.00a	0.08 ± 0.00a	0.08 ± 0.01a
Arginine	0.11 ± 0.01b	0.12 ± 0.01b	0.08 ± 0.00a	0.09 ± 0.00a	0.08 ± 0.01a	0.07 ± 0.00a
ΣProtein (mg/100 g DW)	2.25	2.59	2.26	2.47	2.46	2.56

Results are expressed as mean ± standard deviation of three separate extractions and determinations. Data were analysed by ANOVA. In each column of each group, different letters indicate statistically different values according to Tukey's HSD comparison at $p < 0.05$. DW: dry weight.

Table 1.
Amino acids contents (mg/100 g DW) of pulp and peel of black plum harvested in Ferke, Tiebissou and Yamoussoukro.

Pulp			Peel															
Amino acid	Ferre			Tiebissou			Yamoussoukro			Ferre			Tiebissou			Yamoussoukro		
	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	% Total AA	(%AA) ×100% ideal	WHO Ideal Protein	
Thr	5.78	206.35	5.41	193.05	11.50	410.87	11.74	419.32	11.38	406.50	11.72	418.53	2.8					
Val	7.56	114.48	6.95	105.30	3.10	46.93	2.43	36.81	2.03	30.80	2.73	41.43	6.6					
Met+ Cys	5.78	99.62	4.63	79.88	7.96	137.32	7.69	132.63	8.13	140.17	7.81	134.70	5.8					
Phe + Thr	8.89	355.56	8.11	324.32	14.60	584.07	14.57	583.00	14.23	569.11	14.45	578.13	2.5					
Lys	3.11	49.38	3.47	55.16	3.10	49.16	3.24	51.41	3.25	51.62	3.13	49.60	6.3					
Ile	5.33	156.86	5.41	158.98	3.10	91.10	2.43	71.45	1.63	47.82	2.73	80.42	3.4					
Leu	9.33	266.67	8.49	242.69	5.75	164.35	5.26	150.38	5.69	162.60	5.86	167.41	3.5					
AA: amino acid; Thr: threonine; Val: valine; Met + Cys: methionine + cysteine; Phe + Thr: phenylalanine + threonine; Lys: lysine; Ile: isoleucine; Leu: leucine. *WHO (1985)																		

Table 2.
Pulp and peel amino acid contents of black plum harvested in Ferre, Tiebissou and Yamoussoukro compared with the “ideal” amino acid profile of the protein according to the World Health Organisation.

Mineral (mg/100 g dry weight)	Pulp			Peel		
	Ferke	Tiebissou	Yamousoukro	Ferke	Tiebissou	Yamousoukro
Phosphorous, P	118.00 ± 0.71a	179.00 ± 2.83c	146.00 ± 1.00b	105.50 ± 2.12a	142.00 ± 1.41b	127.00 ± 1.00b
Calcium, Ca	325.50 ± 0.00a	316.00 ± 3.61a	301.50 ± 2.12a	387.30 ± 3.06ab	355.30 ± 2.52a	389.52 ± 3.54b
Magnesium, Mg	228.50 ± 2.12a	255.5 ± 2.12a	221.00 ± 1.41a	207.00 ± 1.41a	250.00 ± 2.83a	199.67 ± 1.15a
Potassium, K	2155.50 ± 4.95a	2584.55 ± 3.54b	2505.00 ± 2.83b	1863.00 ± 1.41a	2270.50 ± 2.12b	2283.00 ± 1.41b
Sodium, Na	53.33 ± 1.53b	38.30 ± 7.77a	52.76 ± 0.58b	62.31 ± 2.08b	41.71 ± 1.53a	39.70 ± 5.69a
Zinc, Zn	1.11 ± 0.06a	0.97 ± 0.06a	1.00 ± 0.00a	1.07 ± 0.15a	1.00 ± 0.00a	1.03 ± 0.06a
Iron, Fe	19.00 ± 0.10b	15.30 ± 0.42a	46.75 ± 0.92c	9.20 ± 0.57a	42.77 ± 0.57c	21.33 ± 0.76b
Manganese, Mn	3.43 ± 0.07b	2.23 ± 0.25a	2.87 ± 0.35ab	3.57 ± 0.64a	2.93 ± 0.51a	3.17 ± 0.47a
Ca/P	2.7:1	18:1	1.8:1	2.0:1	3.8:1	2.5:1
K/Na	40.28:1	67.3:1	47.2:1	30.83:1	55.24:1	56.40:1

The results are expressed as mean ± standard deviation of three separate extractions and determinations. Data were analysed by ANOVA. In each column of each group, different letters indicate statistically different values according to Tukey's HSD comparison at $p < 0.05$.

Table 3.
 Mineral composition of pulp and peel of *Vitex doniana* fruit harvested in Ferke, Tiebissou and Yamousoukro.

fruit pulp and peel, which showed no significant difference ($p > 0.05$), there was more Ca in the Black plum peel than pulp (**Figure 3**). Moreover, Black plum pulp and peel possess remarkably higher Ca contents than stated by Manzoor et al. [52] and Singh et al. ([53] for mango pulp and peel (105 ± 3 and 60 ± 0), banana (52 ± 2 and 55 ± 4 mg/100 g DW) and apple (19.8 ± 0.41 – 48.9 ± 0.99 and 35.6 ± 0.78 – 72.1 ± 1.47 mg/100 g DW).

Thus, the consumption of Black plum could contribute to the proper functioning of the body, the constitution of bones and teeth, and the regulation of nerve, muscle and hormonal functions through its high levels of K and Ca [54–58].

Yamoussoukro fruit pulp (46.75 ± 0.92 mg/100 g DW) and Tiebissou peel (42.77 ± 0.57 mg/100 g DW) had the highest levels of Fe. However, no significant variation was observed between fruit pulp and peel from these localities with regards to Zn and Mn contents (**Figure 4**).

Singh et al. [59] analysed important micronutrients in various plants, including mint, coriander, spinach, amaranth, cauliflower and carrot, and found, respectively, Fe, Mn and Zn concentration ranges of 7.7 ± 0.01 – 84.4 ± 0.08 , 1.8 ± 0.01 – 10.2 ± 0.05 and 2.4 ± 0.05 – 6.0 ± 0.04 mg/100 g DW. These data indicate that Yamoussoukro and Tiebissou Black plum pulps and peels are, respectively, richer in Fe than coriander, spinach, amaranth and carrot, while the pulp and peel of Black plum collected in Ferke contains less Fe than all these plants. Given the amounts of Fe in the different parts of Black plum, it is concluded that Black plums could be excellent sources of Fe. This element is an integral part of important enzymatic systems in various tissues, facilitates oxygen transport from red blood cells and to the lungs (as part of haemoglobin) and acts as a carrier for electrons within cells [60, 61]. Variations in the contents of these different minerals in fruit from region to region and from one part of the fruit to another could be explained by maturity of the fruit, fruit conditions, root system, fruiting position and the leaf area of forest cover [62].

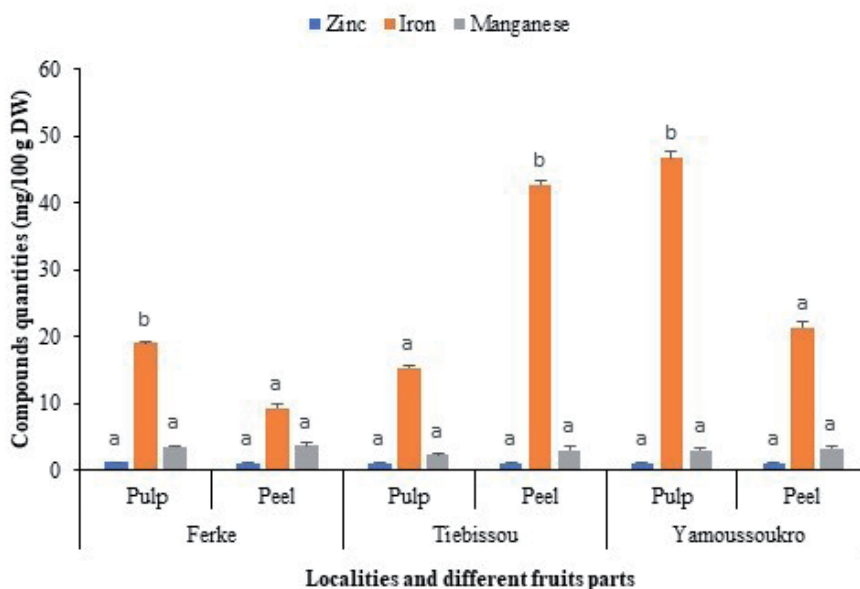


Figure 4. Comparison between pulp and peel micromineral contents of *Vitex doniana* fruit harvested in Ferke, Tiebissou and Yamoussoukro.

Samples	TPC (mg GAE/100 g MS)		TF (mg QE/100 g MS)		TF /TPC	
	Pulp	Peel	Pulp	Peel	Pulp	Peel
Ferkessedougou	227.47 ± 3.35b	225.84 ± 5.89a	79.43 ± 1.13b	103.86 ± 0.66a	0.35	0.46
Tiébissou	202.51 ± 4.19a	383.03 ± 6.54b	75.71 ± 1.03a	145.55 ± 1.03c	0.37	0.38
Yamoussoukro	259.75 ± 2.81c	463.45 ± 6.85c	77.95 ± 0.72ab	141.48 ± 0.66b	0.30	0.30

The results are expressed as mean ± deviation of three separate extractions and determinations. The data were analysed by ANOVA and in each column of each group (pulp and skin) different letters indicate statistically different values according to Tukey's HSD test at $p < 0.05$. TPC total phenolic compounds, TF total flavonoids.

Table 4.
Content of antioxidant compounds in black plum fruit pulp and peel.

An excess of a mineral can be antagonistic for other minerals absorption and their proper utilisation. For this reason, mineral constituent ratios are important for good nutrition. Our study shows that the Ca amount contained in Black plum pulp and peel is at least twice that of P and K, and at least 40-fold greater than that of Na. The Ca:P ratios of Black plum pulp and peel ranged between 1.8:1–3.8:1 and 2:1–3.8:1, respectively, and the K:Na ratios ranged from 40.28:1–67.35:1 for the pulps and from 30.83:1–56.40:1 for the peels (**Table 3**). It is well known that a Ca:P ratio greater than or equal to 1:1 is favourable for mineralisation and bone turnover [63–65]. Previous research [63–66] reported that blood pressure reduction was strongly correlated with decreased Na:K ratio and increased K in hypertensive patients. As a result, regular consumption of Black plum could contribute to mineralisation, bone turnover, and the prevention of high blood pressure and cardiovascular disease.

3.8 Total phenolic compound and total flavonoid

The results (**Table 4**) showed that total phenolic compounds (TPC) and total flavonoids (TF) contents, extracted from Black plum pulp and peel, differed considerably ($P < 0.05$) from one locality to another. This corroborates other results that suggested that TPC content of Black plum in Côte d'Ivoire varied from region to region [19]. Thus, Black plum pulp and peel TPC contents were between 202.51 ± 4.19 and 259.75 ± 2.81 mg GAE/100 g DW and 225.84 ± 5.89 and 463.45 ± 6.85 mg GAE/100 g DW, respectively. The pulp and peel of fruit collected in Yamoussoukro exhibited the highest levels of TPC (259.75 ± 2.81 and 463.45 ± 6.85 mg GAE/100 g DW, respectively), while the lowest TPC levels occurred in those from Tiébissou and Ferke (202.51 ± 4.19) and 225.84 ± 5.89 mg GAE/100 g DW, respectively (**Table 4**). In addition, except for Ferke fruit pulp and peel, which showed no significant difference ($p > 0.05$), there were higher concentration of TPC in the Black plum peel than in pulp (**Table 4**). This result is consistent with results obtained by several authors [67–69] whose reported a higher phenolic compound content in fruit peel such as orange, grape and mango. For TF levels, significant variation was observed ($P < 0.05$) between samples (**Table 4**). The TF of Black plum pulp and peel ranged from 75.71 ± 1.03 – 145.55 ± 1.03 mg QE/100 g DW. The highest amounts of TF were also found in peel (**Table 4**). Tiébissou peel (145.55 ± 1.03 mg QE/100 g DW) and Ferke pulp (79.43 ± 1.13 mg QE/100 g DW) showed high TF content. Those results agree well with results reported by Levaj et al. [70] and Reza et al. [71]. **Table 4** shows that the TF content of Black plum pulp and peel represent 34% and 38% of TPC, respectively. In this study, the fruit pulp and peel TF/TPC ratios are higher than those of carrot (0.28), tomato (0.17) and red pepper (0.08) and similar to okra (0.32) for the pulp [72]. In addition, these ratios are also higher than those of nine varieties of grenadine (0.114–0.288) for peel [71].

4. Conclusion

Black plum pulps and peels collected in Ferke, Tiebissou and Yamoussoukro (Côte d'Ivoire) areas were characterised by high contents of dietary fibre (34.79–50.21%) and minerals, including K (2415.01 and 2138.83%), P (147.66 and 124.83%) and Ca (314.33 and 377.37%), besides displaying a good essential amino acids profile (threonine, leucine, isoleucine) of the protein, compared to kiwi, fruit reference rich in ash and polyphenols. However, the fruit peels are the parts rich in dietary fibre, Ca, total polyphenols and total flavonoids. Thus, these fruits constitute a good source of important nutrients (fibre, potassium, calcium and phosphorus)

and compounds (antioxidants) beneficial for health. It is recommended that both parts of this fruit (pulp and peel) are consumed. Therefore, we propose that these fruit parts are integrated into the human diet in order to contribute to good health. Furthermore, incorporation of the fruit parts in some foods (like flour of wheat, maize, millet, etc.,...) could be of great interest in the valorization of this species. Especially this incorporation would allow the fight against malnutrition in rural areas where food is less rich in minerals and polyphenols.

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