

## **Nutritional Potential of Two Maturity Stages of Eggplant *Solanum aethiopicum* "Striped Toga" Variety Harvested in Côte d'Ivoire**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors DCG and FJB designed the study and the statistical analysis, Author DCG wrote the protocol and wrote the first draft of the manuscript. Authors DCG and FJB managed the analyses of the study. Author FM managed the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

African eggplant *Solanum aethiopicum* var. striped toga is a vegetable-fruit widely consumed in Côte d'Ivoire. However, observations have shown that the cortex was removed from the pulp during culinary preparations for various reasons. The objective of this study is to contribute to the valorization of this eggplant by showing the nutritional interest of the cortex and the pulp. The samples used in this study were collected in a market garden located south of Abidjan. After separating the cortex from the pulp, they were ground into powder and used for physicochemical analysis. The results concerning physicochemical parameters showed that the ripe pulp (Pm) compared to the ripe cortex (Cm) contained more total sugars ( $165 \pm 0.7$  versus  $107 \pm 0.70$  mg/100 g DM). Whereas, the unripe pulp Pnm contained significant amounts of polyphenols and tannins compared to the unripe cortex ( $636 \pm 0.25$  versus  $328 \pm 0.04$  mg/100g DM for total polyphenols;  $577 \pm 0.09$  versus  $171 \pm 0.21$  mg/100 g DM for tannins). Oxalate contents decreased in ripe parts of

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the fruit (Pnm:  $332 \pm 2.52$  and Cnm:  $131 \pm 1.00$  mg/100g DM in unripe eggplant versus Pm:  $157.75 \pm 1.52$  and Cm:  $55 \pm 0.00$  mg/100g DM in ripe eggplant). Also, *Solanum aethiopicum* var. striped toga could play an important role in human nutrition because of their nutrients content, thus contributing to better health.

**Keywords:** Eggplant (*Solanum aethiopicum* striped toga); physicochemical; powder; cortex; pulp.

## 1. INTRODUCTION

According to [1], in Côte d'Ivoire, eggplants are the basis of many dishes and are among the essential crops for the food security of the populations. The species of African origin *S. aethiopicum* and *S. macrocarpon* possess morphological diversity in Côte d'Ivoire and neighboring countries [2]. The Solanaceae family includes 98 genera and about 2700 species. About half of the Solanaceae species belong to the genus *Solanum* [3]. The species *Solanum aethiopicum* and *Solanum macrocarpon* are of African origin and the purple long eggplant *Solanum melogena* is native to India [4]. In addition, this *Solanum aethiopicum* species is particularly prized in restaurants and in many Ivorian households. The marketed proportion of eggplant is reportedly increasing to satisfy urban supply and export to Europe, among others, from Uganda, Côte d'Ivoire and Senegal [5]. It ranks third in consumption volume after tomatoes, onions and okra [6]. Generally, production is carried out by small producers living in rural and urban areas [5]. In 2018, the annual national production was 100146 tonnes according to FAOSTAT. Various compounds in eggplant juice have been reported to have antimutagenic properties compared to other vegetables [7]. The leaves are used as a poultice to treat abscesses, burns, scabs and hemorrhoids. In the East,

eggplant powder mixed with sea salt is used to whiten teeth [8]. Eggplant has antiseptic, diuretic and hemostatic properties. It dissipates toxic heat from the body, improves blood circulation and is used to relieve colitis, pain, hypertension and stomach ulcers [9]. This vegetable-fruit facilitates digestion and helps prevent the risk of degenerative diseases, cardiovascular diseases [10]. Eggplant produces natural neurotoxins called solanins. From a health point of view, the consumption of raw eggplant may cause intoxication, so their consumption in cooked form is strongly recommended. The general objective of this study is to contribute to the valorization of eggplant *S. aethiopicum* var. "striped toga" by showing the nutritional importance of its pulp and cortex.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The plant material consisted of eggplant, *S. aethiopicum* 'striped Toga' harvested at physiological maturity in the commune of Port-Bouët (Côte d'Ivoire). They were transported to the Laboratories of Biocatalysis and Bioprocesses of the University Nangui Abrogoua. After the cortex is removed from the pulp for further operations (Fig. 1).



A



B



**Fig. 1. African eggplant (*S. aethiopicum striped toga*); A: African eggplant matures (unripe); B: African eggplant (ripe); C: Cortex (unripe et ripe); D: pulp (unripe et ripe)**

## 2.2 Methodology

### 2.2.1 Proximate analysis

Moisture and dry matter were determined according to [11]. The pH of the sample was determined according to [12] with a digital pH meter (PHS-3D pH Meter). The total titratable acidity was deduced according to the method of [13]. One (1) g of the sample was dissolved, after shaking well, in 50 mL of distilled water contained in an Erlenmeyer flask. To 5 mL of the sample taken were added 2 drops of phenolphthalein. The resulting mixture was titrated with sodium hydroxide solution (0, 1 N). The turning point was reached when a change in coloration was observed. The calculation of the percentage of total titratable acidity was carried out by the following mathematical expression:

$$ATT (\%) = \frac{N \times V_1}{V_2} \times 100$$

With:

V1: Volume of titrant (mL)

V2: Volume of the sample (mL)

N: Normality of the titrant solution (0,1N)

Total sugars were determined by the method of [14] using phenol and sulfuric acid. The ethanol-soluble extract (150  $\mu$ L) was taken and put in a test tube. To this volume, 1 mL of phenol (5%, w/v) and 1 mL of concentrated sulfuric acid (97%) were added. The reaction medium was homogenized and allowed to cool for 5 min. The optical density reading was taken at 490 nm with a spectrophotometer (UV/VIS SPECTROPHOTOMETER) against a control containing all products except the ethano-soluble extract. The optical density was converted into the quantity of total sugars thanks to a standard

curve obtained from a glucose solution (1g/L). The reducing sugars were determined according to the method of [15] using 3,5 dinitrosalicylic acid (DNS). The ash was the residue obtained after the destruction of the organic substance by calcination.

### 2.2.2 Phytochemical contents

The method described by [16] was used for the determination of total phenols. A volume of 0.5 mL of methanolic extract was added to 0.5 mL of Folin-ciocalteu reagent in a test tube. The mixture was thoroughly homogenized by manual shaking. After 3 min, a volume of 0.5 mL of an aqueous sodium carbonate solution (20%, w/v) was added and the volume was adjusted to 3.5 mL with distilled water. Then the tube was placed in the dark for 30 min. The absorbance reading was taken with a spectrophotometer (UV/VIS SPECTROPHOTOMETER) at 725 nm against the blank. Finally, a calibration curve was performed using a range of gallic acid concentration from 0 to 1 mg / mL. The results were expressed as mg gallic acid equivalent (GAE)/100 g Dry Matter (DM).

The determination of total flavonoids was performed according to the method described by [17]. To a volume of 0.5 mL of methanolic extract was successively added 0.5 mL of distilled water, 0.5 mL of aluminum chloride (10% w/v), 0.5 mL of sodium acetate (1 M) and 2 mL of distilled water. Then, the tube was allowed to stand for 20 min in the dark and the absorbance reading was taken with a spectrophotometer (UV/VIS SPECTROPHOTOMETER) at 415 nm against a blank. Finally, a calibration curve was performed using a range of quercetin concentration from 0 to 0.1 mg/mL. The results were expressed as mg quercetin equivalent (QE)/100 g Dry Matter (DM).

Tannin determination was performed as described by [18]. A volume of 1 mL of methanolic extract was taken and to this volume was added 5 mL of vanillin reagent (50 g vanillin + 4 mL hydrochloric acid in 100 mL distilled water). Then the tube was allowed to stand for 20 min in the dark and the absorbance reading with a spectrophotometer (UV/VIS SPECTROPHOTOMETER) was taken at 500 nm against the blank. Finally, a calibration curve was performed using a tannic acid range of concentration from 0 to 2 mg/mL. The results were expressed as mg tannic acid equivalent (TEA)/100g dry matter (DM).

### 2.2.3 Anti-nutritional compounds

Oxalates were determined according to the method described by [19]. Two (2) g of eggplant (*S. aethiopicum* striped toga) powder was homogenized in 75 mL H<sub>2</sub>SO<sub>4</sub> (3M). The resulting mixture was put under magnetic stirring for 1 h at room temperature (28 °C). The whole mixture was filtered through Whatman N°4 filter paper. Twenty-five (25) mL of filtrate was hot titrated with 0.05 M potassium permanganate (KMnO<sub>4</sub>) solution until the persistent pink color change. The oxalate content was obtained by the equation:

$$\text{Oxalates (mg/100g)} = \frac{2,2 \times V_{\text{eq}} \times 100}{m_e}$$

With:

V<sub>eq</sub>: volume (mL) of KMnO<sub>4</sub> poured at the equivalence.

m<sub>e</sub> : mass (g) of the sample

Phytates were determined according to the method of [20] using Wade's reagent. One gram of eggplant (*S. aethiopicum* striped toga) powder was homogenized in 20 mL of 0.65 N HCl. The resulting mixture was stirred for 12 h at room temperature (28°C). The whole mixture was

centrifuged at 3000 rpm for 40 min. To 0.5 mL of supernatant was added 3 mL of Wade's reagent. Then the tube was left to stand for 20 min in the dark and the absorbance reading was taken with a spectrophotometer at 490 nm against a blank. Finally, a calibration curve was performed using a phytic acid range of concentration from 0 to 10 mg/mL. The results were expressed as mg phytic acid equivalent (PAE)/100g of dry matter (DM).

### 2.2.4 Statistical analysis

Statistical analyses were performed using Statistica 7.1 Software. The analysis of variance (ANOVA) was performed to study the degree of difference between the variables. In case of significant difference between the studied parameters, the classification of the means (homogeneous groups) was done with the Duncan test at p < 0.05.

## 3. RESULTS

### 3.1 Physicochemical Properties of Eggplant *S. aethiopicum* Striped Toga

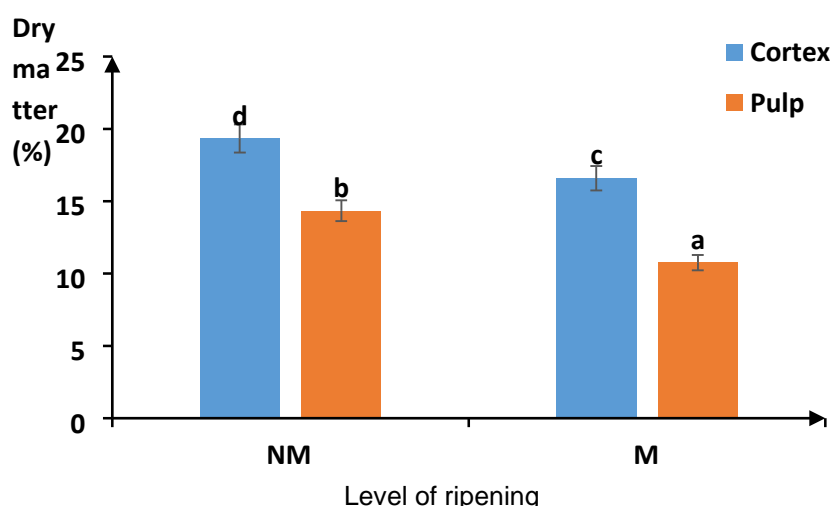
The pH values obtained show a significant difference at the 5% threshold depending on the nature of the powder evaluated, these values are between 5.62 and 5.73 (Table 1). Regarding the percentages of total titratable acidity, there are no significant differences between the values obtained in the pulp and that obtained in the mature cortex.

Fig. 2 showed the different dry matter contents of the *S. aethiopicum* striped toga eggplant powders that were evaluated. The dry matter contents decrease significantly at the 5% threshold from unripe to ripe eggplant in the different parts, these values are between 10.75 and 19.33%.

**Table 1. pH et % total titratable acidity of powder of *S. aethiopicum* var. striped toga**

Samples	pH	% Total titratable acidity
Cnm	5.73 ± 0.01 <sup>c</sup>	1 ± 0 <sup>a</sup>
Cm	5.64 ± 0.01 <sup>b</sup>	1.5 ± 0 <sup>b</sup>
Pnm	5.62 ± 0.01 <sup>a</sup>	1.33 ± 0 <sup>b</sup>
Pm	5.63 ± 0.01 <sup>ab</sup>	1.5 ± 0 <sup>b</sup>

Means in the same column with different superscripts are significantly different at the 5% level according to Duncan's test. Cnm: Unripe Cortex; Cm: Ripe Cortex; Pnm: Unripe Pulp; Pm: Ripe Pulp



**Fig. 2. Dry matter of eggplant powders *S. aethiopicum* var. striped toga**

On the histograms, the means with different letters are significantly different from each other at the 5% level according to Duncan's test. NM: Non Ripe; M: Ripe

Table 2 indicated the contents of total sugars and reducing sugars present in eggplant *S. aethiopicum* striped toga powders (Cnm, Cm, Pnm, Pm).

The total sugar content is higher in the ripe parts of the eggplant compared to the unripe parts. However, we observe that the contents are higher in the pulp than in the cortex of the eggplant (165 mg/100g DM in the ripe pulp against 107mg/100g DM in the ripe cortex).

The content of reducing sugars ranges from 3.46 to 12 mg/100g DM. The quantities of reducing sugars present in the pulp are higher than those present in the cortex. There is a significant difference at the 5% threshold between the results of the different samples except between the Pnm and Cm powder in terms of total sugar content and the Pm and Pnm powder in terms of reducing sugar content.

The ash content increases significantly at the 5% threshold in eggplant cortexes with ripening (Fig. 3), this content is opposite to that of pulp powders which decreases with ripening. Observation of the averages of the different powders shows that the ash content is higher in the cortex powders than in the pulp powders. These rates are 6.83% and 20.42% for unripe and ripe cortex powders respectively and 11.51% and 7.7% for unripe and ripe pulp powders respectively.

On the histograms, the means with different letters are significantly different from each other at the 5% level according to Duncan's test. NM: Non Ripe; M: Ripe.

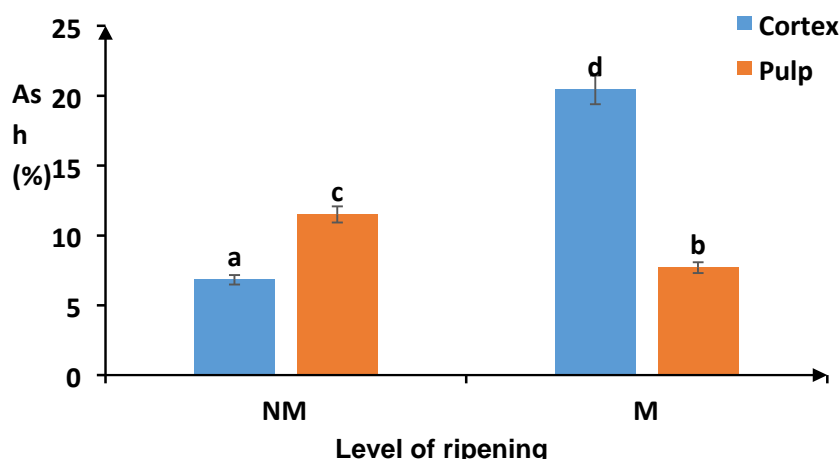
### 3.2 Phytochemical Compounds

Table 3 revealed the contents of total polyphenols, tannins and flavonoids in eggplant *S. aethiopicum* striped toga cortex and pulp powders. The polyphenol content ranged from 289 to 636 mg/100g DM. The highest values are obtained in the pulp while the lowest levels are found in the cortex. The polyphenol levels are significantly different for the different treated

**Table 2. Composition of total and reducing sugars in eggplant powders *S. aethiopicum* var. striped toga**

Powders	Reducing sugars (mg/100g DM)	Total sugars (mg/100g DM)
Cnm	3.46 ± 0.64 <sup>a</sup>	42 ± 0 <sup>a</sup>
Cm	6.2 ± 0.72 <sup>b</sup>	107.0 ± 0.70 <sup>b</sup>
Pnm	10.8 ± 1.90 <sup>c</sup>	104.0 ± 0.53 <sup>b</sup>
Pm	12.0 ± 0.60 <sup>c</sup>	165.0 ± 0.7 <sup>c</sup>

Means in the same column with different superscripts are significantly different at the 5% level according to Duncan's test. Cnm: Unripe Cortex; Cm: Ripe Cortex; Pnm: Unripe Pulp; Pm: Ripe Pulp



**Fig. 3. Ash content of eggplant powders *S. aethiopicum* striped toga**

powders at the 5% threshold. Tannin contents ranged from 151 to 577 mg/100g DM with maximum contents for Pnm and Pm powders ( $577 \pm 0.09$  and  $512 \pm 0.06$  mg/100g DM respectively). The contents are higher in the pulps than in the cortexes. Statistical analyses show that there are no significant differences between the tannin contents of the cortex-based powders. Flavonoid contents ranged from 56 to 531 mg/100g DM. Cm and Cnm powders have the lowest flavonoid contents with  $73 \pm 0.19$  and  $56 \pm 0.23$  mg/100g DM respectively. In addition, there is no significant difference between these levels at the 5% threshold. In general, the compounds studied previously (total polyphenols, tannins and flavonoids) are higher in the pulp-based powders. Another observation also confirms that the phenolic compounds measured

are present in high quantities in the unripe parts of the eggplant.

Table 4 grouped the anti-nutritional factors (oxalates and phytates) determined in the different eggplant powders. The levels of oxalates and phytates are between  $55.00 \pm 0.00$  and  $332.00 \pm 2.52$  mg/100g;  $6.44 \pm 0.77$  and  $7.12 \pm 0.69$  mg/100g respectively. According to the statistical data, the oxalate content is higher in pulp-based powders than in cortex-based powders. This rate decreases with the ripening of the eggplant. Oxalate levels are higher than phytate levels in all powders, they are significantly different at the 5% threshold in all samples. There is a similarity between the phytate contents of Pm, Pnm and Cnm powders which are higher than that of Cm powder.

**Table 3. Total polyphenols, tannins et flavonoïdes of eggplant *S. aethiopicum* striped toga**

Samples	Total polyphenols (mg EAG/100g DM)	Tannins (mg EAT/100g DM)	Flavonoïdes (mg EQ/100g DM)
Cnm	$328 \pm 0.04^b$	$171 \pm 0.21^a$	$56 \pm 0.23^a$
Cm	$289 \pm 0.07^a$	$151 \pm 0.40^a$	$73 \pm 0.19^a$
Pnm	$636 \pm 0.25^d$	$577 \pm 0.09^c$	$531 \pm 0.46^c$
Pm	$531 \pm 0.17^c$	$512 \pm 0.06^b$	$245 \pm 0.17^b$

Means in the same column with different superscripts are significantly different at the 5% level according to Duncan's test. Cnm: Unripe Cortex; Cm: Ripe Cortex; Pnm: Unripe Pulp; Pm: Ripe Pulp

**Table 4. Oxalates et en phytates of eggplant *S. aethiopicum* striped toga**

Samples	Oxalates (mg/100g DM)	Phytates (EAP/100g DM)
Cnm	$131.00 \pm 1.00^b$	$7.08 \pm 0.69^b$
Cm	$55.00 \pm 0.00^a$	$6.44 \pm 0.77^a$
Pnm	$332.00 \pm 2.52^d$	$7.12 \pm 0.69^b$
Pm	$157.75 \pm 1.52^c$	$7.02 \pm 1.03^b$

Means in the same column with different superscripts are significantly different at the 5% level according to Duncan's test. Cnm: Unripe Cortex; Cm: Ripe Cortex; Pnm: Unripe Pulp; Pm: Ripe Pulp

#### 4. DISCUSSION

pH analysis showed a significant difference at the 5% threshold. The results showed that the different eggplant powders evaluated have an acidic pH. However, the analysis of the averages of the different parts evaluated shows that the pulps are more acidic than the cortices. According to [21], an acidic pH is recommended for the preservation of food products because it would be detrimental to pathogenic bacteria. Indeed, this level of pH could significantly reduce the nature and effect of microorganisms that can grow on the product. Only acidophilic microorganisms, such as yeasts, molds, acetobacters and lactobacillus, can grow. These values are higher than those obtained by [22] who found pH values of 4.36 and 4.35 for tomato *S. lycopersicum* with epicarp and for tomato without epicarp.

Dry matter (DM) content decreased significantly at the 5% threshold in the cortex and pulp of the ripe fruit. The analyses showed that the pulp-based powders had lower dry matter contents than the cortex. The dry matter content decreased as the eggplant ripened. This decrease could be explained by the fact that the amount of water increases with ripening. These results corroborate those of [23] who observed a decrease in DM of *S. anguivi* Lam berries during ripening. However, the average dry matter content obtained in the powders of 15.25% is lower than those recorded on tomato *S. lycopersicum* and purple eggplant (*S. melongena*) whose respective values are 16 and 27.07% [24,25].

The total sugar content varies significantly at the 5% threshold, it increases from unripe to ripe stage and also depending on the organ studied. Indeed, the analyses showed that the total sugar level is higher in the ripe parts compared to those of the unripe fruit. As for the evolution of reducing sugars, a significant variation between the contents in pulp-based powders and those based on cortex was observed. The level of reducing sugars also evolves with the level of ripening of the fruit but is higher in the pulp of ripe eggplant (Cm: 12 mg/100g DM). These results are consistent because of the fact that total sugars increase during ripening due to enzymatic hydrolysis of starch to sugar [26]. The increase in reducing sugars is confirmed by [27] who showed that during ripening of dessert banana, reducing sugars contents from stage 1 to stage 9 increased from 0.2 to 33.6%.

Ash content increased significantly from unripe to ripe cortex and then decreased from unripe to ripe pulp. The high ash content in cortex powder could be explained by their mineral compositions because according to [28] the ash content of a food is indicative of its mineral content. The decrease in ash content in pulp powders observed when switching from unripe to ripe fruit is correlated by that of [29] who observed a decrease in ash content on unripe and ripe *Terminalia catappa* fruit with respective ash contents of 5.1 and 4.6%.

Total polyphenol levels decrease significantly at the 5% threshold in *S. aethiopicum* striped toga powders when switching from powders composed of unripe parts to powders composed of ripe parts. They are more concentrated in the pulp than in the cortex. This observation is consistent with the results of [30] who observed a decrease of total polyphenols in eggplant *S. anguivi* Lam during post-harvest storage and ripening. According to his authors, this would be due to polymerization and condensation reactions of these compounds for the formation of insoluble polymers. These results also corroborate with those of [31] who reported a higher presence of polyphenols in green and yellow berries of *S. anguivi* Lam. Indeed, oxidation and polymerization reactions lead to the formation of quinones that cause the browning and bitterness seen in foods [32].

The presence of flavonoids in *S. aethiopicum* striped toga eggplant powders was determined and showed significant differences between them except for the cortex powders (Cm and Cnm). Flavonoids are more concentrated in the pulp than in the cortex. Comparison of the averages obtained in the cortex powders indicates that the flavonoid content is high in the mature cortex (Cm: 73 mg/100g DM). These results corroborate with those of [31] who explained that the presence of flavonoids in orange berries of *S. anguivi* Lam could be justified by the fact that during ripening, the amount of flavonoids would be higher. Indeed, the carotenoid pigments such as alpha and beta-carotene responsible for the orange and red coloring are part of the flavonoid family. The presence of flavonoids is a good indicator. Indeed, flavonoids are effective scavengers of the most prooxidant free radicals, particularly involved in lipid peroxidation. They are used in industry as dyes (gaude and dyer's broom) and in the manufacture of a number of drugs with flavonic derivatives used in therapeutics [33].

The level of tannins varies significantly from one organ to another with a similarity in the cortex-based powders (Cm and Cnm). Based on the results of the analysis of pulp powders, a decrease in tannin content during ripening is noted. Indeed, it is at this stage that the activation of protein and lipid synthesis takes place. These biochemical reactions degrade the tannins responsible for the astringency. This would result in a less pronounced astringency in ripe berries. According to [23] the decrease of tannins during ripening would be caused by the weakening of the cell walls. These results corroborate those of [31] who observed a decrease in tannin levels in *S. anguivi* Lam berries during ripening.

The oxalate level varies significantly at the 5% threshold in all tested samples. This level is more present in the pulp than in the cortex. The analyses showed a decrease of oxalate with the ripening of the eggplant *S. aethiopicum* striped toga. Indeed, ripening is a factor that reduces the amount of total oxalates as a result of the increase in water content in the food product [34]. The oxalate levels obtained in all the samples studied are higher than those of round and oval purple eggplant with respective values of 41.72 and 23.97 mg/100g DM [25]. The observed levels are all below the lethal dose which is between 2000 and 5000 mg/100g.

Concerning phytates, the results do not show any significant difference between Cnm, Pm and Pnm powders except for Cm powder where a decrease of this rate is observed. An overall observation of the results suggests that phytates are evenly distributed between the cortex and the pulp. However, a slight decrease in phytate levels is observed when the eggplant ripens. The decrease in phytate levels is thought to be caused by the activation of phytases during the biochemical and physiological changes that occur in the plant during ripening. The results obtained are much lower than those published for purple eggplant (*S. melongena*) of round and oval varieties by [25] who noted values of 28.19 and 18.67 mg/100 g DM, respectively. The phytate levels evaluated are all below the lethal dose, which is 250 to 500 mg/100 g.

## 5. CONCLUSION

This study was carried out with the aim of valorizing the African eggplant *S. aethiopicum* var. striped toga. It allowed to understand the differences between the physico-chemical

parameters of the pulp powders and those of the cortex. After analysis, it appears that the powders obtained from the cortex (Cnm and Cm) have the same physicochemical properties as those obtained from the pulp (Pnm and Pm) but in different proportions. Indeed, biochemically, the eggplant cortex (*S. aethiopicum* striped toga) contain the same compounds as the pulp but in low quantities except for the phytate content where the values are similar.

## DISCLAIMER

The products used for this research are commonly of research and our country. There is absolutely no conflict of interest between the authors. Also, the research was funded by personal efforts of the authors.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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