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Studies of the Functional Properties of the Cortex and Pulp of Ripe and Unripe Berries of Solanum Aethiopicum Variety Striped Toga

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The African eggplant Solanum aethiopicum var. striped toga is a widely consumed vegetable-fruit in Côte d'Ivoire. Although produced in abundance in the rainy season, they are subject to post-harvest losses and these commodities are expensive in the dry season. Also during culinary preparations, the cortex is often removed for various reasons (difficulty to be crushed, aesthetics, presence in the stool...). This study was carried out by determining the functional properties of powders obtained from the cortex and pulp of blackberry and non blackberry berries. The apparent density was between 0.25 and 0.35g/mL with higher values in the cortex than in the pulp. The cortex powders had higher water absorption capacities than the pulp in both ripening levels (Cortex unripe (Cnm): 657.51% versus Pulp unripe (Pnm): 622.12% and Cortex ripe (Cm): 600.33% versus Pm: 486.26%). The oil absorption capacity of pulp was lower than that of cortex in unrefined and refined oil. After analysis, it appears that the powders obtained from the cortex have the same

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physico-chemical properties as those obtained from the pulp but at different proportions. Indeed, at the biochemical level, the eggplant (S. aethiopicum striped toga) cortexes contain the same compounds as the pulp but in small quantities.

Keywords: Eggplant (Solanum aethiopicum striped toga); physicochemical; functional.

1. INTRODUCTION

Eggplant, a fruit-vegetable of economic importance in Mediterranean countries, is a vegetable plant of the Solanaceae family. It is mentioned for the first time in a Chinese treaty dated 500 years before our era. Several species are of African origin among which we note the presence of S. macrocarpon, Solanum melogena and S. aethiopicum [1] [2]. The species S. aethiopicum commonly known as 'garden-egg' originates from tropical Africa according to Hebert [3] Consumption of eggplant leaves and fruits provides the body with carotenes, various vitamins, folic acid, mineral salts, and protein [4]. Eggplant is eaten raw or prepared as an ingredient in stews, soups and vegetable sauces. It is recommended as an excellent remedy for those who suffer from liver problems [5]. In the East, eggplant powder mixed with sea salt is used to whiten teeth [6].

According to FAO [7], in Côte d'Ivoire, eggplants are the basis of many dishes and are among the crops essential for the food security of the population. The species Solanum aethiopicum is particularly popular 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 [8]. Well adapted to tropical climates, eggplant can be grown anywhere in Côte d'Ivoire but prefers light, organic-rich and well-drained soils. Eggplant cultivation is possible all year round with the provision of water during drought periods [9]. Generally, production is carried out by small producers living in rural and urban areas [8]. Many local or introduced varieties of different species (Solanum aethiopicum Gilo, Solanum aethiopicum Klogbo, Solanum aethiopicum Kumba) are grown in small market gardens, usually in urban and peri-urban areas, but the crop is grown throughout the country [10].

Although this species is widely consumed by the population, observations revealed a problem with its use in the preparation of dishes. Indeed, in some restaurants and households, the cortex was often removed during culinary preparations for various reasons (difficulty to be crushed, aesthetics, presence in the stool after consumption...). Also, it should be noted that this commodity is only available in large quantities during the rainy season, making it an expensive vegetable-fruit in the dry season. Primary processing could improve conservation and make it available throughout the year. This study contributes to the valorization of eggplant S. aethiopicum var. striped toga. More specifically, it aims to determine the functional properties of the cortex and pulp powders of unripe and ripe S. aethiopicum var. striped toga.

3. METHODS

3.1 Biological Material

The plant material consisted of eggplants, Solanum aethiopicum 'striped Toga' harvested at physiological maturity and ripened on the same day in a market garden located in the commune of Port-Bouët, south of Abidjan (Ivory Coast).

3.2 Dispersibility

The method described by Mora-Escobedo et al. [11] was used for the determination of the dispersibility (D) of eggplant powder. To 1 g of powder contained in a graduated cylinder, 50 mL of distilled water was added. The mixture was carefully shaken by hand for 2 min. The dispersibility of the powder is defined as the difference between the total volume (V0) of the particles just after manual shaking and the volume (Vt) of the deposited particles recorded at time t (min).

$$Dispersibility\ (\%) = \frac{(V_0 - V_t) \times 100}{V_0}$$

3.3 Bulk Density and Porosity

He bulk density (BD) of eggplant powder was determined by the method of Narayana and Narasinga [12]. In a 100 mL graduated cylinder, 50 g of powder (Me) was deposited. After a good clearing with a spatula, the volume (V0) of this sample was noted. Then, the test tube was tapped gently on the bench until a constant volume (Vt) was obtained.

$$BD\ (g/ml) = \frac{\mathrm{ME}}{V_0}$$

$$Porosity\ (\%) = \frac{(V_0 - V_t) \times 100}{V_0}$$

3.4 Water Absorption Capacity

Measurement of the water capacity (WAC) of the powder was performed according to the method of Elkhalifa and Bernhardt [13]. 2 g of powder (M0) was dissolved in 20 ml of distilled water contained in a centrifuge tube. The mixture was homogenized by mechanical stirring and heated in a water bath at 37°C for 30 min. The mixture was then centrifuged at 5000 rpm for 30 min in a centrifuge. The wet pellet (M2) obtained after centrifugation is weighed, then dried at 105°C in the oven for about 8 h until a constant mass (M1) is obtained.

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$$WAC\ (\%) = \frac{(M_2 - M_1) \times 100}{M_1}$$

3.6 Water Solubility Index

The water solubility index (WSI) was determined as described by Anderson et al. [14]. 2.5 g of powder was poured into 30 mL of distilled water in a previously tared 60 mL centrifuge tube. The mixture was homogenized by hand shaking for 1 min and centrifuged at 3000 rpm for 10 min. The supernatant and pellet were then carefully transferred to a porcelain crucible and an aluminum crucible, respectively, both previously tared. These crucibles are placed in an oven at 110°C overnight for evaporation. P1: weight of dissolved solid in the supernatant ; P2 : weight of dried solid.

$$WSI\ (\%) = \frac{(M_2 - M_1) \times 100}{M_1}$$

3.7 Oil Absorption Capacity

The oil absorption capacity of eggplant powder was determined according to the method of Sosulski [15]. 1 g of powder was dissolved in 10 mL of refined (Dinor) and unrefined (red oil) oil, shaken for 30 min at room temperature (28°C) with a mechanical shaker and centrifuged at 4500 rpm for 10 min. M0 : Mass of powder, M1 : Mass of pellet OAH : Oil absorption capacity.

$$OAC(\%) = \frac{(M_1 - M_0)}{M_0} \times 100$$

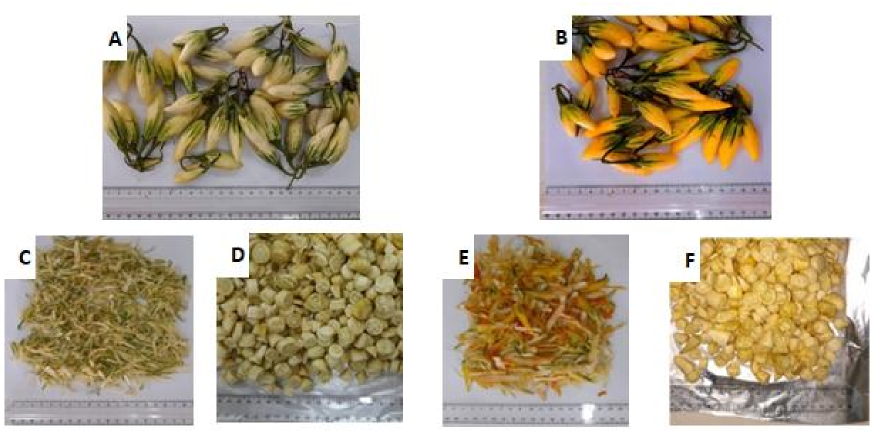

Fig. 1. African eggplant (S. aethiopicum striped toga)

A: Mature eggplant (unripe) B: Mature eggplant (ripe) C: Cortex (unripe) D: Pulp (unripe) E: Cortex (unripe) F: Pulp (ripe)

3.8 Foaming Capacity and Foam Stability

The foaming capacity (FC) and foam stability (FS) of eggplant powder were determined according to the method of Coffman and Garcia [16]. 3 g of powder was transferred to a 50 mL graduated cylinder previously dried in an oven at 50°C. The powder was leveled. Then, 30 mL of distilled water was added to the sample to facilitate dispersion in the test tube and the volume was noted (volume before homogenization); then the test tube was vigorously shaken by hand, the level and volume were read off the test tube (volume after homogenization). The volume of the foam was calculated as the difference between the volume after homogenization and the volume before homogenization. The test tube was left on the bench until the foam collapsed and at each time interval (every 10min), the foaming capacity and stability of the foam were determined from the following formulas:

$$FS(\%) = \frac{(V_t \times 100)}{V_0} \quad \mathrm{FC}(\%) = \frac{(V_2 - V_1)}{V_2} \times 100$$

V0: Initial volume;
V1: Volume before homogenization; V2 :
Volume after homogenization;
Vt: Volume of the foam; FC : Foaming capacity;
FS : Stability of the foam.

3.9 Hydrophilic/Lipophilic Ratio

The hydrophilic-lipophilic index (HLI) or hydrophilic-lipophilic ratio as defined by Njintang et al, [17] was obtained by making the ratio of the water absorption capacity (WAC) to the oil absorption capacity (OAC). This ratio allows to evaluate the affinity of the sample for water and for oil.

$$HLI(\%) = \frac{\mathrm{WAC}}{\mathrm{OAC}}$$

3.10 Statistical Analyses

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 means (homogeneous groups) was performed with Duncan's test. The significance level (α) was 0.05.

4. RESULTS AND DISCUSSION

La porosité d'une poudre est une mesure de la masse de la poudre [18]. Elle détermine la convenance d'une poudre à être facilement empaquetée, ce qui faciliterait le transport d'une grande quantité de nourriture [19]. La forte porosité d'un produit alimentaire favorise sa digestibilité [20]. Les analyses ont montré une augmentation significative de la porosité au seuil de 5% dans les differentes parties lors du murissement. Les poudres de pulpe (Pnm (40,29%) ; Pm (43%)) présentent une plus grande porosité que celles obtenues avec les cortex (Cnm (19,82%) ; Cm (26,79%)). L'augmentation de la porosité au cours du mûrissement serait due à la fragilisation des parois cellulaires et à la forte perméabilité de membranes cellulaires [21]. En effet, les parois cellulaires deviennent perméables à l'eau, aux ions et aux molécules organiques au cours du mûrissement [22].

As for bulk density (BD), it is an important functional property in many food applications according to Adebowale et al., [23]. The analyses showed that the evaluated powders generally have low bulk densities. The cortex-based powders have a higher bulk density than the pulp-based powders, with a maximum value for the Cm powder. The low AD of ripe pulp powder compared to unripe pulp could be explained by the decrease in dry matter during ripening. Indeed, unripe eggplants contain less water and are richer in dry matter than ripe eggplants. Ripe eggplants have less dry matter because of the large movement of water during the biochemical, physiological and organoleptic changes that occur during ripening [22]. The relatively low bulk density value of ripe pulp powder (Pm: 0.25g/mL) would be a good thing. Indeed, according to Nelson-Quartey et al. [20] a low AD is desirable as it helps to reduce pulp thickness which is an important factor in convalescent feeding.

The dispersibility of a powder is an indicator of the reconstitution power in water, a useful functional parameter in formulations of various food products [11]. It is also the ability that a powder has to wet without forming lumps, with simultaneous disintegration of agglomerates [24]. The evaluated dispersibility values are as much higher in unripe eggplant powders as in ripe eggplant. The unripe cortex powder has the highest dispersibility. A high dispersibility

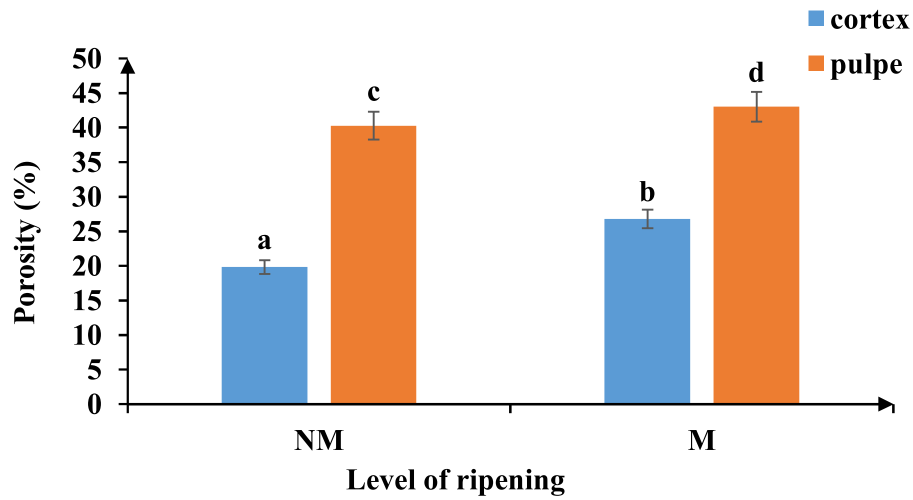

Fig. 2. Porosity of eggplant powders *S. aethiopicum* var. striped toga

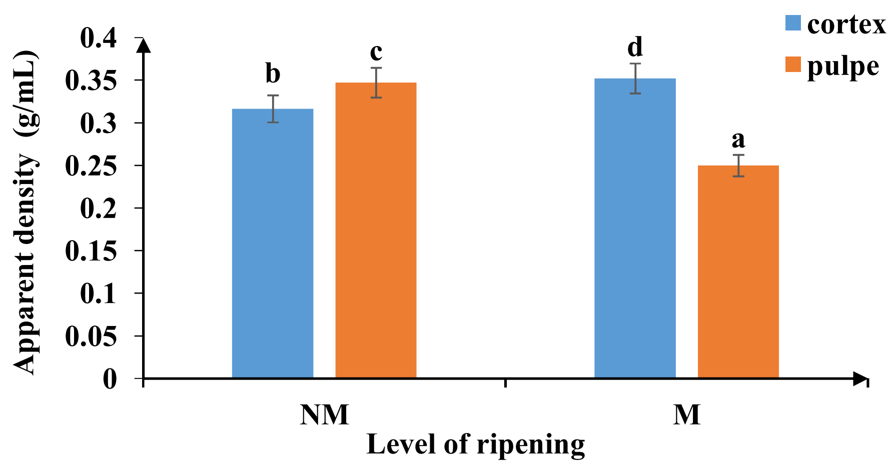

Fig. 3. Bulk density of eggplant S. aethiopicum var. striped toga powders

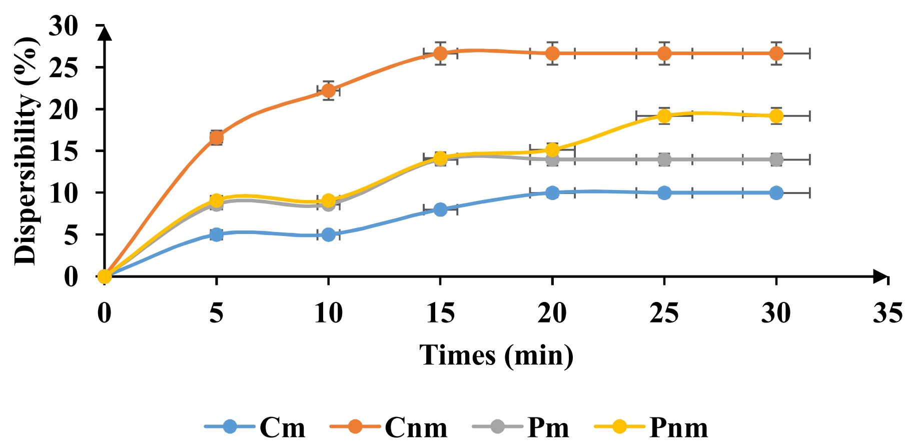

Fig. 4. Dispersibility of eggplant powders S. aethiopicum var. striped toga

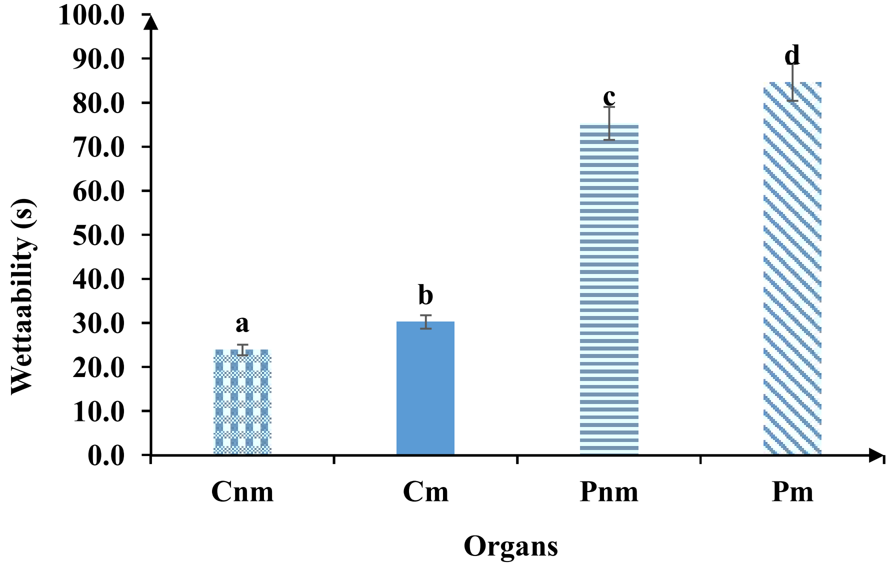

Fig. 5. Wettability of eggplant powders S. aethiopicum var. striped toga

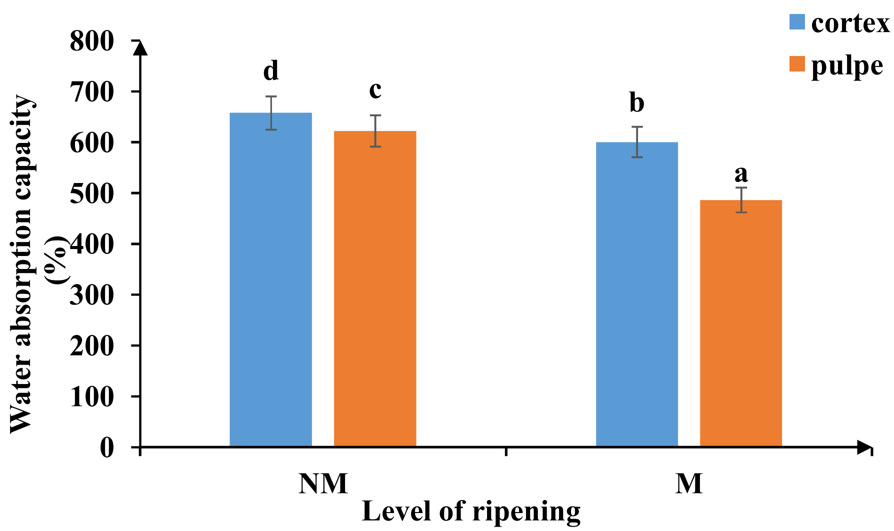

Fig. 6. Water absorption capacity of eggplant powders S. aethiopicum var. striped toga

percentage is an indicator of good water absorption capacity [25] and induces the high ability of the powder to reconstitute in water giving a fine and coherent paste. Cnm powder could be used in the formulation of instant powders. Furthermore, according to Westergaard. [26] This property could be influenced by the wettability of the powder.

The wettability of eggplant powders of the striated variety studied shows significant differences at the 5% threshold from one powder to another. The powders of the cortex are very wettable compared to the powders of the pulp. This difference in wettability would be due, on the one hand, to the composition of the powders and the affinity between its components and water, and on the other hand, to the accessibility of water in terms of structure (porosity and capillarity) [27] [27] and the size of the particles [28]. This analysis of the results obtained is supported by the research of Pohl et al. [29] who states that if the wettability time is less than 30 s, the powder is considered very wettable, if it is less than 60 s, the powder is considered wettable, and if the time is greater than 120 s, the powder is non-wettable. A powder that is capable of wetting would be suitable for swelling during paste handling [27]. The Cnm and Cm powders being very wettable with values lower than 30 s are then more favorable in the preparation of soups as well as those of the pulp which have a time of wettability ranging between 60 s and 120 s thus wettable.

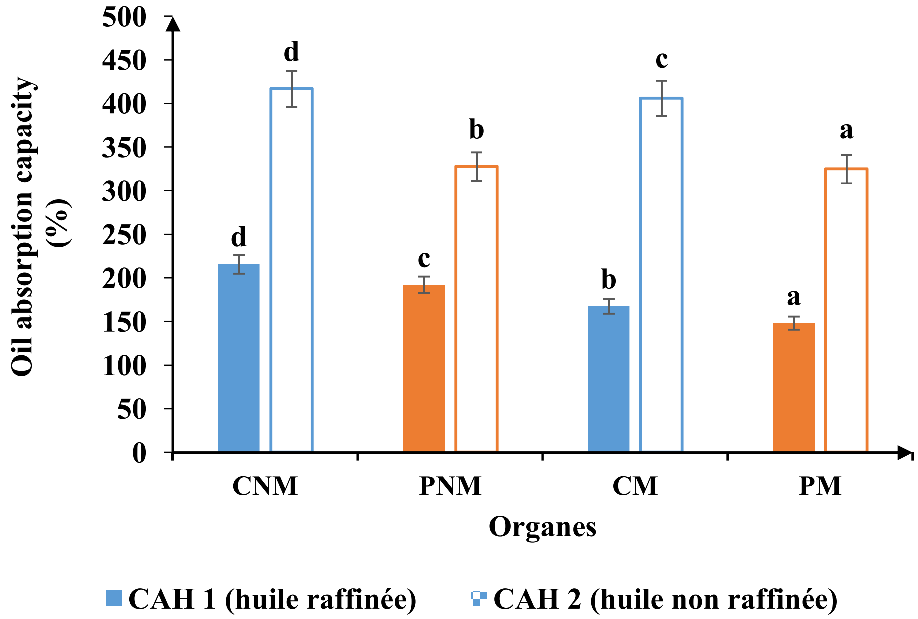

Fig. 7. Oil absorption capacity of eggplant powders S. aethiopicum var. striped toga

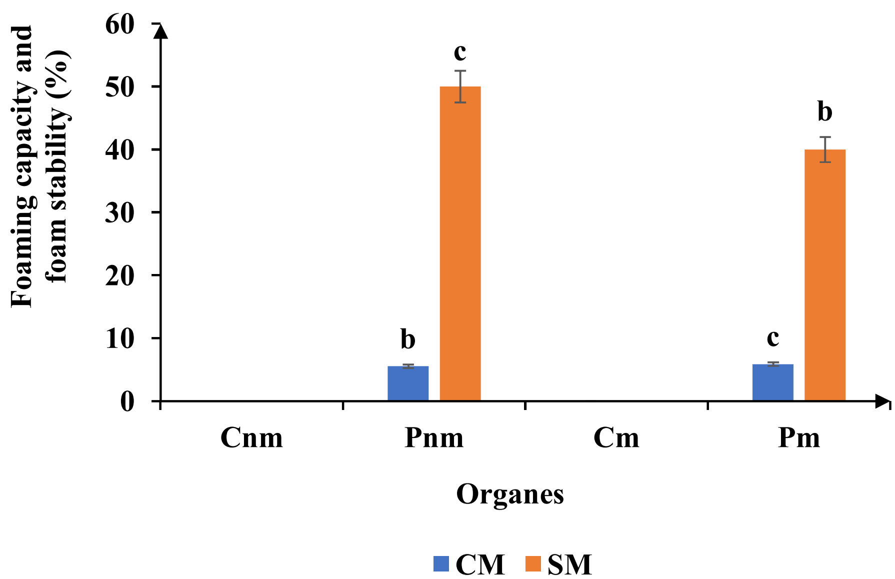

Fig. 8. Foaming capacity and foam stability of eggplant powders S. aethiopicum var. striped toga. CM: Foaming capacity; SM: foam stability

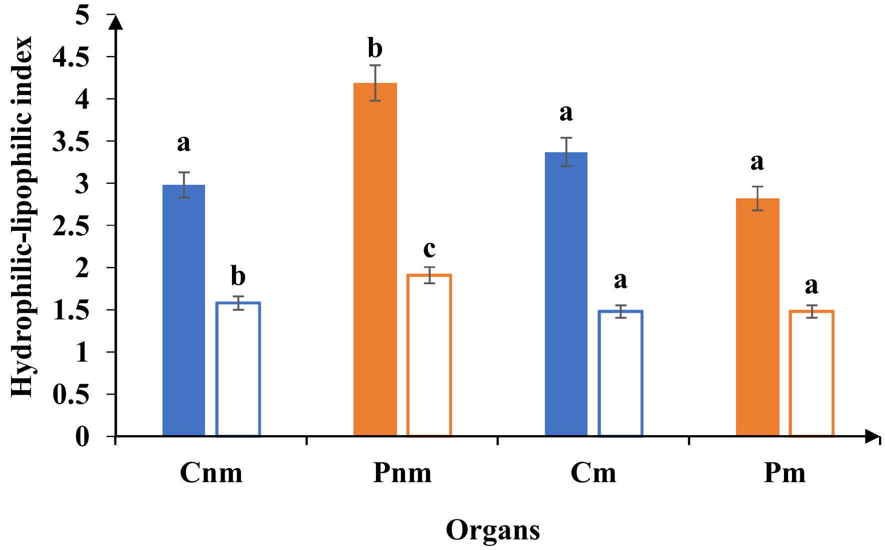

Fig. 9. Hydrophilic-lipophilic index of eggplant powders S. aethiopicum var. striped toga

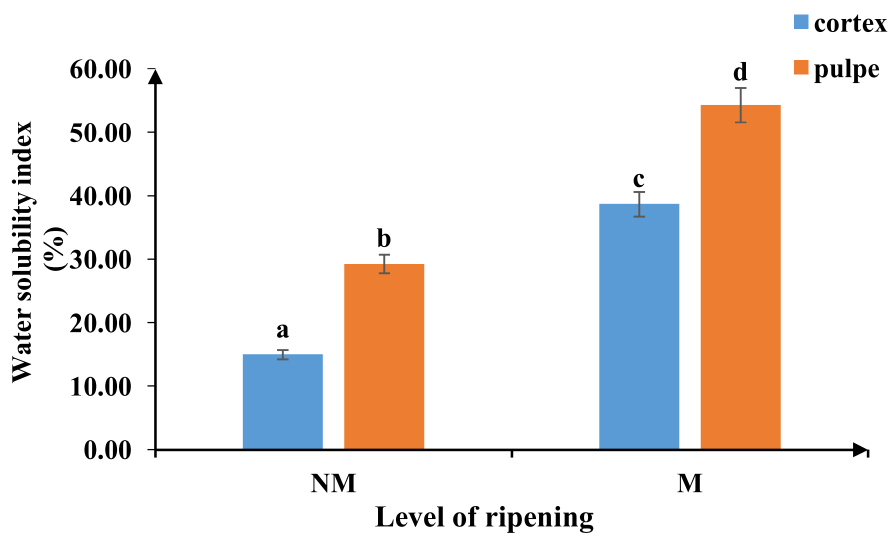

Fig. 10. Water solubility index of eggplant powders S. aethiopicum var. striped toga

The water absorption capacity (WAC) of eggplant powders S. aethiopicum striped toga ranged from 486.89 to 657.92% and varied significantly from sample to sample depending on the level of ripening and the part being evaluated. EAC is an index of the maximum amount of water that a food product would absorb and hold [30]. These variations could be due to various factors such as the particle size contained in the powder [31] and the presence of impurities such as proteins and lipids [32], thus the acidic residues of the proteins in the powder will have an affinity for the water molecules [33]. This ability is a very important property of all powders in food preparation as it influences some functional and sensory properties. The use of powders as food ingredients depends to a large extent on their interaction with water. The high CAE content observed in eggplant powders, allows the powders to absorb water without dissolving the protein, which results in thickening and increasing the viscosity of the cooked dishes. The high-water absorption capacity is believed to be due to the hydrophilic groups of the proteins

[34]. According to Prinyawiwatkul et al. [35] and Sila and Malleshi [36], powders with high water absorption are more hydrophilic. Eggplant powders of S. aethiopicum striped toga absorb more water than eggplant powders of S. anguivi Lam evaluated at different stages of ripening and at different concentration by Dan [37] who found a maximum value of 70.23% (highest concentration level).

The oil absorption capacity (OAC) varied significantly from refined oil (Dinor oil) to unrefined oil (red oil), but also from sample to sample. This study showed that evaluated eggplant powders absorbed more red (unrefined) oil than Dinor (refined) oil. The cortex-based powders absorbed more oil than the pulp-based powder. This may be due to the fact that lipid binding depends on the surface availability of hydrophobic amino acids and the presence of other non-polar side chains [23]. The high CAH 2 would be due to the fact that red oil, which is an unrefined oil, would have a denser composition and would have more binding sites for the molecules [38] This is an important property in food formulation because the oil improves the flavor and gives a soft texture to the food [38] [39]. It plays an important role in food preservation because it prevents the development of oxidative rancidity [40].

Foaming capacity (FC) and foam stability (FS) improve the texture, uniformity and appearance of the food [41]. These properties are highly valued in pastries (cakes, soufflés, meringues) [42]. The results showed an absence of CM and SM in Cm and Cnm powders. This result may be due to the collapse and bursting of the air bubbles formed. These results may also be related to the denaturation of the proteins. A protein with good foaming properties must be highly soluble, as foaming capacity requires rapid adsorption of proteins at the air/water interface upon penetration into the surface layer and reorganization of the interface [43]. Therefore, eggplant pulp-based powders possess more protein than cortex-based powders in S. aethiopicum striped toga fruit. Therefore, the bulk of the protein amount should be in the pulp.

Lipophilic Hydrophilic Index (LHI) values of eggplant powders range from 2.82% to 4.19% in refined oil and then from 1.48% to 1.91% in unrefined oil show that LHIs are strongly influenced by oil quality. The LHI values for refined oil are higher than those for unrefined oil. The higher LHI values prove a greater affinity for water compared to oil [44]. This suggests that eggplant pulp powders should be preferentially used in the formulation of products requiring high water absorption capacity especially Pnm powder.

The water solubility index (WSI) of powders is the affinity of a powder to disperse in water and give a homogeneous solution [45] The ISE of the different powders studied shows a significant increase at the 5% threshold as a function of ripening level. The pulp powders (Pnm and Pm) show a higher affinity for water compared to the cortex powders (Cnm and Cm). This may be due to the compositional variation of polysaccharides [46]. Indeed, water molecules hydrogen bond to the free hydroxyl groups of amylose and amylopectin, causing increased granule swelling and solubility [47] [48]

6. CONCLUSION

The objective of this study was to contribute to the valorization of Solanum aethiopicum berries of the striped toga variety harvested in the South of Abidjan (Ivory Coast). This study allowed us to understand the functional properties of the pulp and cortex powders. The functional properties indicate that the water absorption capacity is high in all parts of the eggplant while the oil absorption capacity is low in the refined oil. Also, the pulp powders present a higher porosity than those obtained with the cortexes. It would be more interesting to consume the eggplant S. aethiopicum var. striped toga entirely cortex and pulp.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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