



**INFLUENCE OF PACKAGING ON THE NUTRITIONAL QUALITY OF KOLA NUT
(COLA NITIDA) IN CÔTE D'IVOIRE**

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ABSTRACT

For tropical fruits, post-harvest losses can vary widely, from 10 to 80%, in both developed and developing countries. There is therefore a technical need for all stages of post-harvest systems, including hermetic storage and transport, improved packaging and wrapping, especially for perishable products. Containers made of rattan basket lined with *Thaumacoccus daniellii* leaves, cardboard with food bag and potato net and PVC (polyvinyl chloride) were used and stored at different temperatures of 26°C and 29°C±1°C. Biochemical analyses (proteins, total sugars, total polyphenols, caffeine) were carried out on kola nuts after 0, 1, 2, 3, 6 and 10 months of storage. Regarding proteins, the best contents are obtained at 29°C for the basket and the PVC trays. All containers have contents higher than that of the control (8.40%). The highest contents were obtained with the PVC trays at 29°C (from 12.3% to 12.8%) while the basket (10% at 29°C and 8.82% at 26°C) decreases compared to the 6th month of storage. Compared to sugar levels, the basket at 29°C and the PVC RC at 26°C have the best sugar levels with 5.40 mg/g and 5.60 mg/g respectively. The total polyphenol contents at the 10th month are down compared to the 6th month of storage. Indeed, the highest level is 12.31 mg/g with the PVC trays at 29°C.

KEYWORDS: *Cola nitida*, Cola packaging, Biochemical properties.

INTRODUCTION

The kola tree *Cola nitida* (Vent) Schott and Endlicher, is a perennial, allogamous and monoecious plant. It belongs to the Sterculiaceae family and is present in central and sub-Saharan Africa, where it forms a vast natural stand in the forest zone.^[1] Côte d'Ivoire is the world's leading producer and exporter of kola, with approximately 100,000 tonnes of fresh nuts per year.^[2] Ivorian production is mainly used for local consumption and export to neighboring countries, particularly Mali, Niger, Senegal and Burkina Faso. The kola nut therefore remains the leading agricultural product exported by Côte d'Ivoire to other African countries.^[2]

Many studies have shown the economic and social importance of kola nut. However, conservation and storage represent the main limiting factors in the marketing of kola nut. Many studies have shown that kola is attacked by weevils (*Balanogastriis kolae*,

Paremydica insperata), diptera (*Pterandrus colae*) and fungi (*Aspergillus niger*) which can cause 30 to 70% losses during storage.^[3] In addition, studies on the impacts of different processes and containers on the nutritional quality of cola are still few and even non-existent in Côte d'Ivoire. Since the majority of research focuses on economic and agronomic aspects and the identification of contamination pests, no study has looked at reducing production losses during handling and storage.

For tropical fruits, post-harvest losses can vary widely, from 10 to 80%, in both developed and developing countries. There is therefore a technical need for all stages of post-harvest systems, including hermetic storage and transport, improved packaging and wrapping, especially for perishable products.^[4] Packaging, according to^[5], allows to obtain around the products lowered oxygen contents and slightly increased

carbon dioxide contents compared to those of the ambient air. These “modified” gaseous atmospheres make it possible to slow down respiratory activity, the overall metabolism and therefore the degradation reactions of the products without using additives or other preservatives.

The objective of this study is therefore to evaluate the impact of cola nut storage containers over a long period to reduce production losses during handling, packaging and storage.

1. MATERIAL

1.1. Biological material

The study material consists of mature cola nuts (4 months after flowering) of the species *Cola nitida*. The freshly picked (less than a week) and peeled nuts were provided by the National Federation of Cola Producers and Traders of Côte d’Ivoire (FENAPROCO-CI).

1.2. Technical material

The technical material consists of cellulose and plastic packaging. These are the rattan basket, the food cardboard, the cardboard trays and the PVC trays.

2. METHODS

2.1. Preparation of starch-based biofilm

Coating is a preservation technique used to guarantee fruits and a longer shelf life. This is done by controlling the respiration process of the fruit, thus slowing down aging. The availability, ease of preparation and interesting preliminary results obtained by^[6] guided the choice of starch for coating. For this purpose, a mass of 0.2 g of potassium benzoate E211 (FOODCHEM International) and 4 g of cassava starch were mixed to obtain a 4% starch solution. The mixture is heated to 90 °C on a hot plate for 30 minutes, with constant stirring, in order to obtain complete gelatinization of the starch. The kola nuts are immersed in this starch gel to obtain coated kola nuts.

2.2. Method of packaging cola nuts

For packaging 1, 50 kg of washed and treated kola nuts were placed in rattan baskets lined with *Thaumatococcus daniellii* leaves (*Basket*). These baskets were divided into 2 batches of 25 kg each. The 1st batch was stored at warehouse temperature (29°C) and the 2nd batch at 26°C.

Packaging 2 consisted of 50 kg of washed and treated kola nuts placed in two groups of clean and perforated food cartons. The 1st group (25 kg) is composed of kola nuts packed in perforated food bags (*Carton FB*). The 2nd group (25 kg) is composed of kola nuts packed in potato nets (*Carton PN*). Each group was divided into two batches. The 1st batch was stored at warehouse temperature (29°C) and the 2nd batch at 26°C.

Packaging 3 consisted of 50 kg of washed and treated kola nuts placed in two groups of clean and perforated

cardboard trays. The 1st group (25 kg) consisted of coated kola nuts (*TrayCart WC* and *TrayCart RC*) and the 2nd group (25 kg) of uncoated kola nuts (*TrayCart WNC* and *TrayCart RNC*). Each group was divided into two batches. The 1st batch was stored at warehouse temperature (29°C) and the 2nd batch at 26°C.

Finally, for packaging 4, 50 kg of kola nuts divided into two groups were placed in 100 PVC (Polyvinyl chloride) food trays. The 1st group (25 kg) consisted of coated kola nuts (*TrayPVC WC* and *TrayPVC RC*) and the 2nd group (25 kg) of uncoated kola nuts (*TrayPVC WNC* and *TrayPVC RNC*). Each group was divided into two batches. The 1st batch was stored at warehouse temperature (29°C) and the 2nd batch at 26°C.

2.3. Biochemical analysis of kola nuts

Proteins were determined from the total nitrogen assay by the Kjeldhal method.^[7] Total sugars were measured by the phenol test.^[8] For the determination of total polyphenols, the method based on the Folin-Ciocalteu reagent was used^[9] with 1 ml of the cola extract obtained with 55 g of cola in 90% methanol. The caffeine extraction was done in 4 steps ranging from extraction to the elimination of the solvent, namely dichloromethane. It includes two extractions (liquid-solid and liquid-liquid) and a drying and solvent elimination phase.

2.4. Statistical analyses

After investigating, the collected data have been treated with statistical software SPSS 22.0. Data have been submitted to an analysis of variance (ANOVA) and Tukey post hoc test at a significance level of 5 %.

3. RESULTS

3.1. Evolution of caffeine during storage

The interaction effect being significant at the 1st, 6th and 10th of storage, the differences in caffeine levels are significant at 95%, regardless of the type of container and storage temperature used (**Fig. 1**).

In the 1st month, the best caffeine levels are obtained at room temperature (29°C). In addition, the highest caffeine levels are observed with the basket, cardboard (PN, FB and WC and WNC tray) containers. The peak is observed with the food bag cardboard at 29°C (4.97%). Then come the basket, cardboard (PN and FB) and the WC and WNC cardboard trays at 26°C and on the other hand at 29°C with the WC and WNC cardboard trays (3%). It is at the level of this group that the control is located (**Fig. 1**).

There is a general decrease in caffeine content during the 6 months of storage of the kola nut. The basket (29°C) and the control have the best contents, respectively with 3.49% and 3.20%. The basket (26°C) and the PVC trays have intermediate values varying between 2.73% and 1.72. For the PVC trays, the temperature of 26°C remains the best after a 3-month storage. The FB cartons

lose practically all their caffeine content which is 1.26% at 26°C and 0.83% at 26°C (Fig. 1).

After 10 months of storage, there is a decrease in caffeine content, especially in containers stored at 29°C. A slight increase (around 2%) at a temperature of 26°C.

The basket, for its part, still retains, at 29°C, the same content as at the 6th month of storage. The basket (26°C) and the PVC trays at 29°C, which have values varying between 1.29% and 1.47%. The PVC trays at 26°C, which have values varying between 2.03% and 2.06% (Fig. 1).

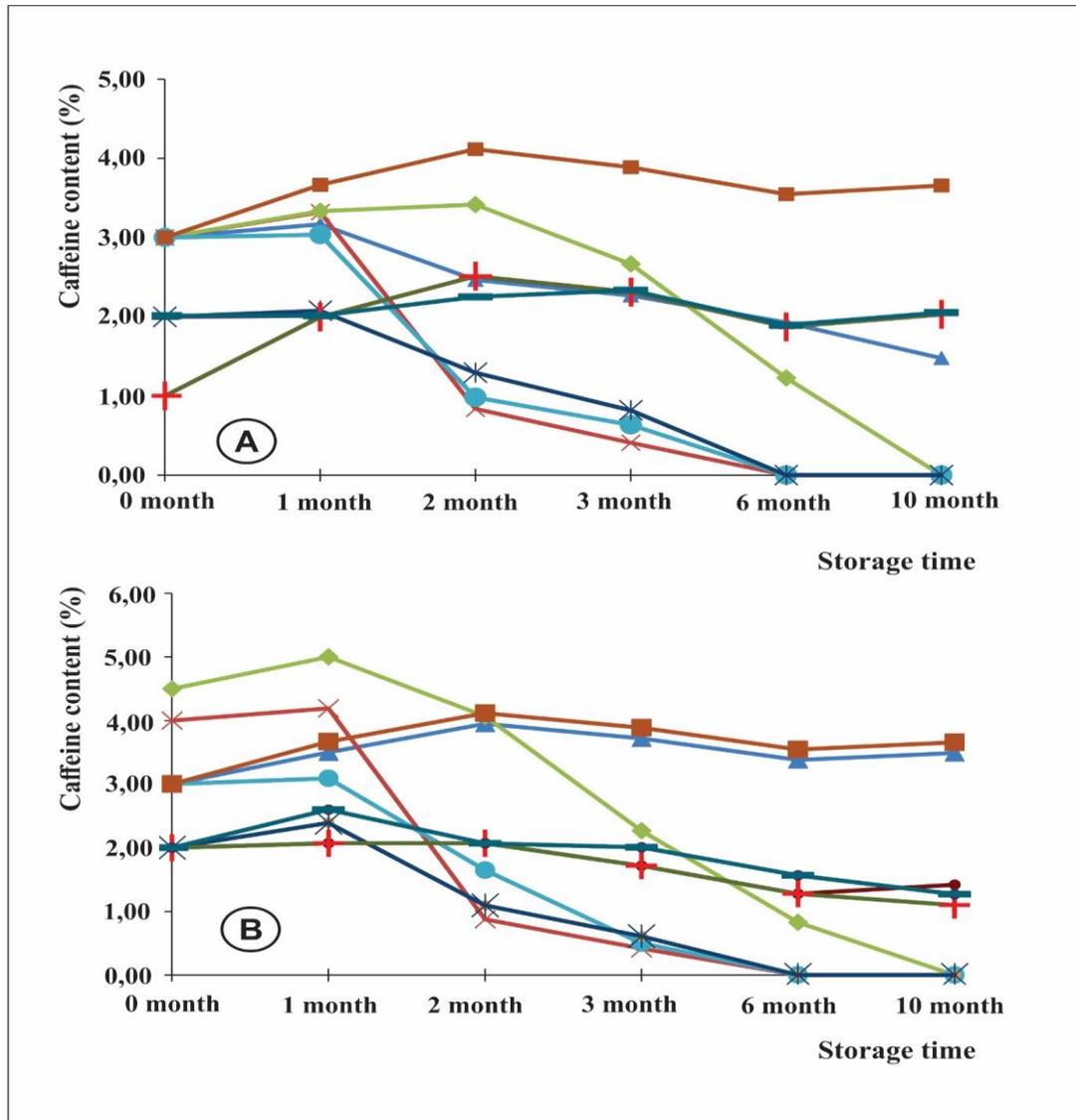


Figure 1: Evolution of the caffeine content during the storage time according to the type of packaging at 26°C and 74% ± 5% humidity (A) and at 29°C ± 1°C and 67% ± 5% moisture (B)

- Basket
- Carton_PN
- ▲— Carton_FB
- ▲— TrayCart_RNC
- TrayPVC_WC
- TrayPVC_WNC
- ▲— TrayCart_WC
- ▲— TrayCart_WNC
- ▲— TrayCart_RC
- TrayPVC_RC
- TrayPVC_WNC
- ▲— Control

Basket: Rattan basket lined with *Thaumatococcus* leaf, **Carton_PN:** Potato net cardboard, **Carton_FB:** Food bag cardboard, **TrayCart_WC:** Coated white cola cardboard tray, **TrayCart_WNC:** Uncoated white cola cardboard tray, **TrayCart_RC:** Coated red cola cardboard tray, **TrayCart_RNC:** Uncoated red cola cardboard tray, **TrayPVC_WC:** Coated white cola PVC tray, **TrayPVC_WNC:** Uncoated white cola PVC tray, **TrayPVC_RC:** Coated red cola PVC tray, **TrayPVC_RNC:** Uncoated red cola PVC tray

3.2. Evolution of the protein during storage

The interaction effect being significant at the 1st, 6th and 10th of storage, the differences in caffeine levels are significant at 95% (Fig. 2).

At one month of storage, regardless of the container used, the highest and lowest protein levels are obtained at room temperature (29°C). In addition, the effect of packaging is much more noticeable at 29°C (Fig. 2).

There is a general decrease in the protein content of the containers at different temperatures, at the 6th month of storage. In general, the best contents, although down by about 3%, were obtained at the temperature of 29°C, except for the RC and RNC trays. The highest contents, higher than the control (11.47%), were obtained with the

basket at 29°C (13%), the PVC WC and WNC trays at 29°C (12.3%) and the PVC RC and RNC trays at 26°C (12%). While the white PVC trays at 26°C and red at 29°C have 10.5% and 10% protein content respectively (Fig. 2).

At the 10th month of storage, the best contents are obtained at 29°C for the basket and the PVC WC and WNC trays. All containers have contents higher than that of the control (8.40%). The highest contents were obtained with the PVC WC and WNC trays at 29°C which undergo a slight increase from 12.3% to 12.8% and a decrease at 26°C from 10.5% to 9%. The contents at the basket level, 10% at 29°C and 8.82% at 26°C, decrease compared to the 6th of storage (Fig. 2).

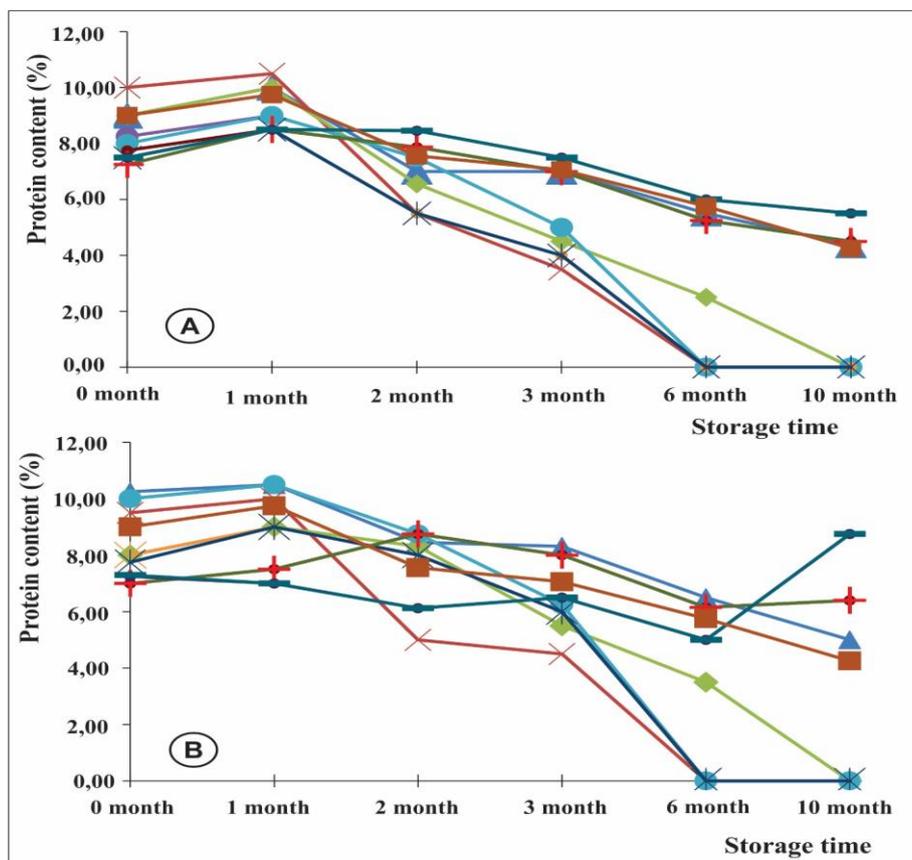


Figure 2: Evolution of protein content over storage time according to the type of packaging at 26°C and 74% ± 5% (A) and at 29°C ± 1°C and 67% ± 5% (B) humidity.

- Basket
- Carton_PN
- ▲— Carton_FB
- ▲— TrayCart_RNC
- TrayPVC_WC
- TrayPVC_WNC
- ▲— TrayCart_WC
- ▲— TrayCart_WNC
- ▲— TrayCart_RC
- TrayPVC_RC
- TrayPVC_WNC
- ▲— Control

Basket: Rattan basket lined with *Thaumatococcus* leaf, **Carton_PN:** Potato net cardboard, **Carton_FB:** Food bag cardboard, **TrayCart_WC:** Coated white cola cardboard tray, **TrayCart_WNC:** Uncoated white cola cardboard tray, **TrayCart_RC:** Coated red cola cardboard tray, **TrayCart_RNC:** Uncoated red cola cardboard tray, **TrayPVC_WC:** Coated white cola PVC tray, **TrayPVC_WNC:** Uncoated white cola PVC tray, **TrayPVC_RC:** Coated red cola PVC tray, **TrayPVC_RNC:** Uncoated red cola PVC tray.

3.3. Evolution of total sugars during storage

The interaction effect is significant throughout the storage period.

At one month of storage, the lowest total sugar content (0.97 mg/g) is obtained with PN cardboard at room temperature (29°C). In addition, at the level of cardboard packaging, the best results are obtained at 26°C, with RC and RNC trays (12.30 mg/g) (Fig. 3).

There is a general decrease, in the 6th month of storage, in the total sugar content of the containers at different temperatures. Indeed, at 29°C, the FB cardboard and the

PVC trays stand out, with contents of 2 mg/g and 3.57 mg/g respectively. The basket and the control have higher contents with 6.56 mg/g and 7.49 mg/g respectively (Fig. 3).

At the 10th month of storage, the basket at 29°C and the PVC RC trays at 26°C have the best sugar levels with 5.40 mg/g and 5.60 mg/g respectively. The control is also in this group. The second group contains all the other containers with levels varying from 1.74 mg/g (PVC RNC tray at 26°C) to 3.24 mg/g (PVC WC and WNC tray at 26°C) (Fig. 3).

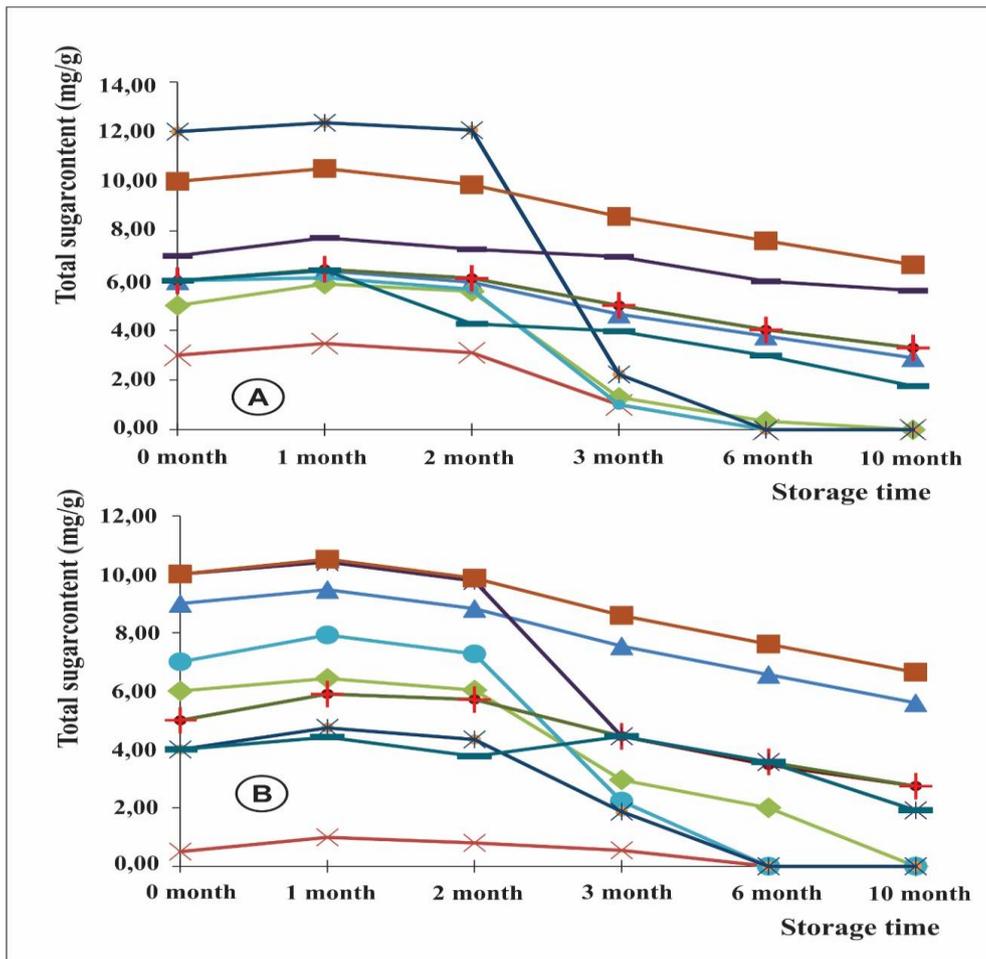


Figure 3: Evolution of the protein content during the storage time according to the type of packaging at 26°C and 74% ± 5% (A) and at 29°C ± 1°C and 67% ± 5% (B) moisture.

- Basket
- Carton_PN
- *— Carton_FB
- ▲— TrayCart_RNC
- TrayPVC_WC
- TrayPVC_WNC
- ◇— TrayCart_WC
- ◆— TrayCart_WNC
- ◇— TrayCart_RC
- ◇— TrayPVC_RC
- TrayPVC_WNC
- ▲— Control

Basket: Rattan basket lined with *Thaumatococcus* leaf, **Carton_PN:** Potato net cardboard, **Carton_FB:** Food bag cardboard, **TrayCart_WC:** Coated white cola cardboard tray, **TrayCart_WNC:** Uncoated white cola cardboard tray, **TrayCart_RC:** Coated red cola cardboard tray, **TrayCart_RNC:** Uncoated red cola cardboard tray, **TrayPVC_WC:** Coated white cola PVC tray, **TrayPVC_WNC:** Uncoated white cola PVC tray, **TrayPVC_RC:** Coated red cola PVC tray, **TrayPVC_RNC:** Uncoated red cola PVC tray.

3.4. Evolution of total polyphenols during storage

In the 1st month, the interaction effect is significant and the highest polyphenol contents are observed at 26°C. At 29°C, the low contents, from 10.68 mg/g (basket) to 19.31 mg/g (FB cardboard), are obtained with the basket, cardboards and PVC trays. The other containers, all from the cardboard tray group (WC, WNC, RC and RNC) have relatively high contents which vary from 28.64 mg/g (RNC cardboard tray) to 35.52 mg/g (WNC cardboard tray) (Fig. 4).

The total polyphenol contents at the 6th month are slightly down compared to the 3rd month of storage. The basket at 29°C and the PVC trays have lower contents varying around 15 mg/g. The contents for the basket at 26°C are 11.31 mg/g and for the FB carton are 2.34 mg/g at 29°C and 3.75 mg/g at 26°C (Fig. 4).

The total polyphenol contents at the 10th month are down compared to the 6th month of storage. In fact, the highest rate is 12.31 mg/g (PVC tray RNC 29°C) and most of the rates vary between this value and 10.35 mg/g (PVC tray RC 26°C) (Fig. 4).

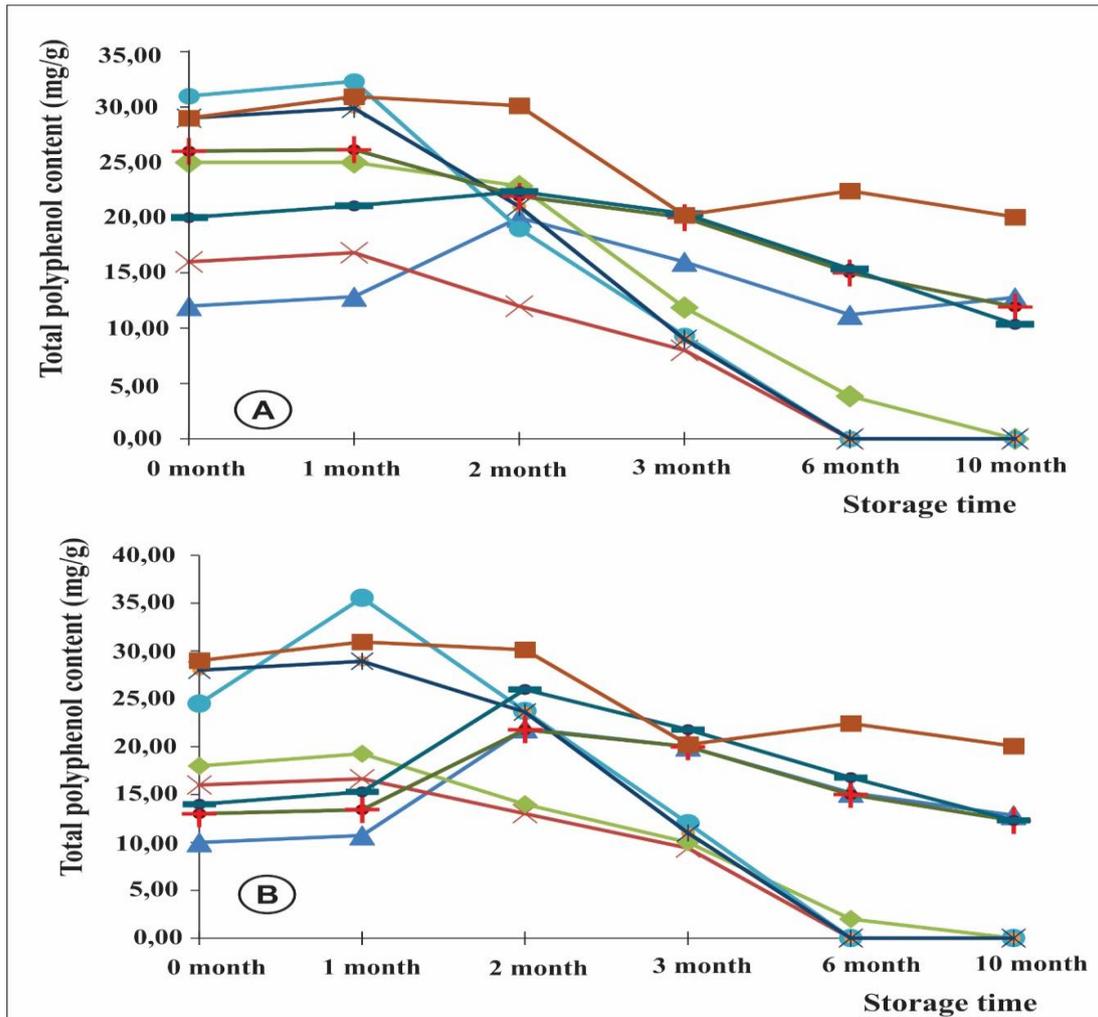


Figure 4: Evolution of the total polyphenol content over the storage time according to the type of packaging at 26°C and 74% ± 5% humidity (A) and at 29°C ± 1°C and 67% ± 5% humidity (B)

- Basket
- Carton_PN
- ▲— Carton_FB
- ▲— TrayCart_RNC
- TrayPVC_WC
- TrayPVC_WNC
- TrayCart_WC
- ▲— TrayCart_WNC
- TrayCart_RC
- TrayPVC_RC
- TrayPVC_WNC
- ▲— Control

Basket: Rattan basket lined with *Thaumatococcus* leaf, **Carton_PN:** Potato net cardboard, **Carton_FB:** Food bag cardboard, **TrayCart_WC:** Coated white cola cardboard tray, **TrayCart_WNC:** Uncoated white cola cardboard tray, **TrayCart_RC:** Coated red cola cardboard tray, **TrayCart_RNC:** Uncoated red cola cardboard tray, **TrayPVC_WC:** Coated white cola PVC tray, **TrayPVC_WNC:** Uncoated white cola PVC tray, **TrayPVC_RC:** Coated red cola PVC tray, **TrayPVC_RNC:** Uncoated red cola PVC tray

DISCUSSION

The methods of preserving kola nuts presented and retained above make it possible, at a reasonable cost, to resell the colas purchased at harvest 6 to 10 months later. Their resale price can then be optimized according to the evolution of supply and demand. Indeed, kola nuts remain fresh for more than ten months. The real problem, however, is the possible proliferation of diseases and/or insect attacks during the storage period, despite the relative insulation of the baskets. These difficulties are increased by the fact that the mode of consumption of kola (raw) makes the use of insecticides or chemical products delicate, the methods of combating these evils such as the use of cobalt 60 radiation^[10] being too sophisticated and expensive for the main players in the marketing of kola. The popularization of products that can solve these problems without harming the health of consumers would therefore be more than useful.

In this study, the least suitable packaging for the preservation of nuts were those that promoted air circulation and therefore direct contact with the nuts. These were cardboard boxes and perforated food bags. In the presence of oxygen, there may therefore be oxidation of phenolic compounds by polyphenoloxidases and peroxidases, leading to the formation of brown pigments and therefore a decrease in the concentration of polyphenols. In general, the effectiveness of fruit preservation depends strongly on the storage conditions of these organs.^[11] Overall, high temperatures, high pressures and abundant oxygen accelerate fruit degradation, while low measurements of these 3 parameters extend the green life of the organs. The extension of the nut life suggests that the different treatments applied favorably modify the interactions of the fruits with the ambient environment. Taking into account the nature and reactivity of the products tested, it can be assumed that the different actions of these products are of physical or biochemical types, as suggested by.^[11] In fact, phenolic constituents are in high quantity in kola nut compared to some fruits like grapes, pears, peaches and apples. According to Haard and Chism (1996), the content of phenolic compounds decreases during the ripening of climacteric fruits because of their structure and they are easily oxidized by enzymes. Thus, the reactions of browning of fruits and vegetables are generally considered as a direct consequence of the oxidation of phenolic compounds by the enzymes polyphenol oxidase (PPO) and peroxidase (POD) which results in the formation of quinones which subsequently polymerize to give brown compounds.^[12]

The biochemical composition after 10 months of storage varies on average, all packages included, for proteins from 3.79 to 11%, caffeine from 0.47 to 3.1%, total polyphenols from 8.90 to 36 mg/g and total sugars from 0.96 to 12.5 mg/g. These rates are relatively the same as those obtained by Purseglove, 1968^[13] with 9.5% crude proteins, 2.8% caffeine and 0.05% theobromine. Other researchers^[14,15] had already observed respectively

8.90%, 8.0% and 6.9% of proteins in fresh kola nut. These results prove, contrary to popular thinking, which rather devalues this nut, that it is a product to be recommended. Indeed, Moloney, 1887^[16] compared the nutritive constituent of kola nuts with other species used as stimulants such as cocoa (Sterculiaceae) and coffee (Rubiaceae). He stated that kola contains more caffeine than coffee, and has an appreciable amount of theobromine and considerable glucose. Kola has three times the amount of starch as cocoa, but with relatively little fat.

Most fruits are rich in polyphenolic compounds that play an important role in determining color and flavor. Chromatogram analysis of kola nuts indicated the presence of phenolic compounds in higher amounts than are typical for many fruits. Apples, for example, contain 0.1 to 2.0 g/100 g fresh weight of polyphenolic compounds^[17], compared with over 4.0 g/100 g fresh weight in kola nuts.

The variable composition reported by different researchers may mean that the nutrient composition of these kola nuts varies with season, environment and/or condition at the time of analysis. Indeed, according to Albert, 2003^[18], total phenolic compounds vary according to species, being 3 times higher in red walnuts than in white or pink walnuts. Purseglove, 1991^[19] also reported nut polyphenol values of 0.8% to 1.3% for *Garcinia cola* and 2.5% to 3.0% for *Cola nitida*. Work by Ducksworth and Coleman, 1970^[20] showed that white cultivars of most plant products such as kola nut lack carotene, a polyphenol, which is responsible for the pigmentation seen, especially in the red variety. There are also intraspecific differences in total polyphenol concentrations according to Odeunmi, 2009.^[21] For example, in *C. nitida*, the total amount of polyphenol in red walnuts was three times that of white and pink walnuts.

Furthermore, contrary to the results of the evaluation of the effect of weevil infestation on the caffeine content of red and white cultivars of *C. nitida* by Lale and Okunade, 2000^[22], which showed a significant decrease in the amount of caffeine with increasing levels of infestation, our study shows that the caffeine level tends rather to increase over time, proving the effectiveness of the treatments and conditioning applied.

CONCLUSION

At the end of these 10 months of conservation of the kola nut, it appears from the results obtained that the different packaging have a significant influence on the biochemical and organoleptic qualities of the kola nuts. The temperature, although affecting at the beginning of conservation, nevertheless remains little influential over time. The other factor, namely the packaging, and the packaging-duration interaction have a significant influence throughout the 10 months of conservation. Of all the combinations (packaging-temperature-coating)

proposed, twenty-two in total, two packaging were retained, namely the basket and the PVC trays.

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