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Evolution of the organoleptic characteristics of the kola nut (*Cola nitida*) depending on the packaging used in Côte d'Ivoire

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Abstract

In Ivory Coast, the conditions of conservation and storage of kola nut promote enormous losses during its marketing. Indeed, the nut is attacked by weevils, diptera and fungi which cause between 30 and 70% of losses during storage. The objective of this study is to propose good practices for post-harvest conservation of kola nut, in order to reduce these enormous losses. 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. Organoleptic analyses were carried out on kola nuts after 0, 1, 2, 3, 6 and 10 months of storage. The organoleptic characteristics that deteriorate over time are color, brightness and texture. Of all the combinations, rattan baskets and PVC trays preserve kola nuts best for up to ten months of storage.

Keywords: Cola nitida; Kola preservation; Storage; Kola packaging

1. Introduction

The kola tree is widely cultivated in West Africa because its nuts contain two alkaloids: caffeine and theobromine. These are powerful stimulants that act on fatigue, thirst, hunger and are supposed to improve intellectual activity [**1**].

Côte d'Ivoire is the world's leading producer and exporter of kola, with approximately 100,000 tons 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**].

Cola is attacked by weevils (*Balanogastris kolae, Paremydica insperata*), diptera (*Pterandrus colae*) and fungi (*Aspergillus niger*) which can cause 30 to 70% losses during storage [**3**].

Most of the harvest is sold, generally wholesale, to exporters, in packaged form. Short-term storage is done in baskets previously lined with *Thaumatococus daniellii* leaves, or in cardboard boxes. These storage methods must be based on the use of bio-insecticides that are not very harmful to human health and are financially accessible [**4**] with a packaging system that allows products to be obtained without the use of additives or preservatives [**5**]. For this purpose, the control of hermetic storage and transport, the improvement of conditioning and packaging, particularly for perishable

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products, are necessary **[6]**. The objective of this study is to propose good practices for post-harvest conservation of kola nut, in order to reduce these enormous losses.

2. Material and methods

2.1. Biological material

The study material consists of mature cola nuts (4 months after flowering) of the species *Cola nitida* (Figure 1). 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)

2.2. Technical material

The technical material consists of cellulose and plastic packaging. These are, as shown in figure 2 below, the rattan basket, the food cardboard, the cardboard trays and the PVC trays.

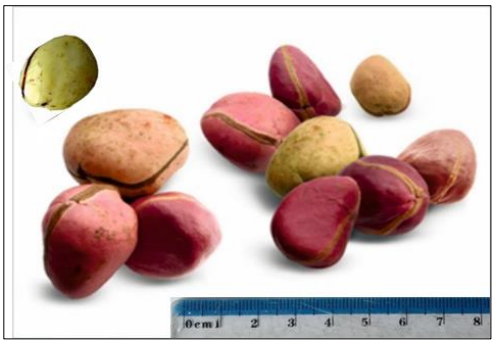


Figure 1 Photograph of kola nuts

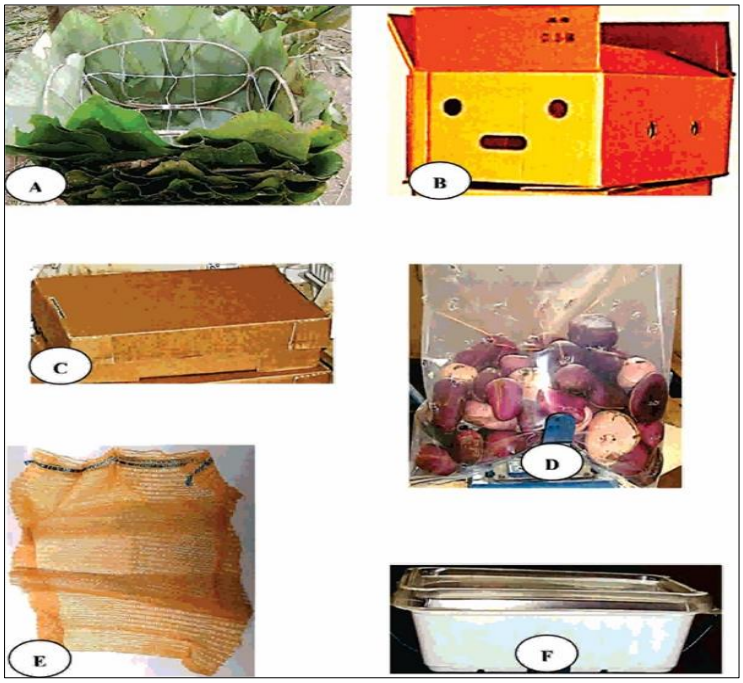


Figure 2 Different types of packaging used during the study: Cellulosic materials

A. Rattan basket lined with leaves of *Thaumatococcus daniellii* B. Cardboard C. Cardboard tray Plastic materials D. Transparent food bag E. Potato packaging net F. PVC tray

2.3. 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 [**7**] 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 the results shown in figure 3 below:

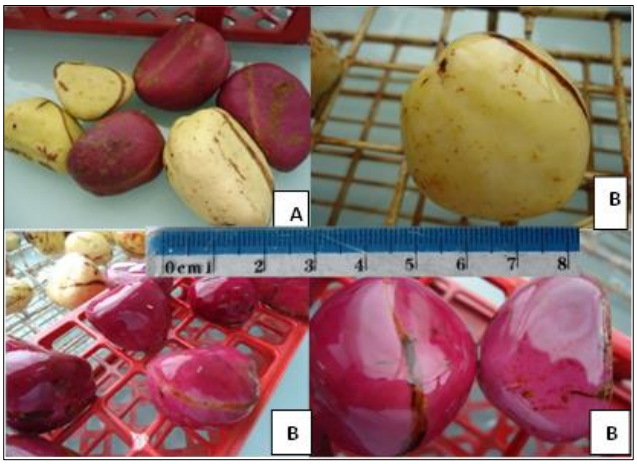


Figure 3 Appearance of cola nuts before coating (A) and after coating (B)

2.4. Method of packaging cola nuts

The choice was based on 4 types of packaging, namely the rattan basket, food cardboard, cardboard and PVC trays (Figure 4).

For the first packaging, 50 kg of washed and treated kola nuts were placed in 2 rattan baskets lined with *Thaumatococcus daniellii* leaves, or 25 kg of cola each. The first basket was stored in a warehouse at room temperature of 29°C ± 1°C and 67% ± 5% relative humidity and the second basket in the laboratory at 26°C and 74% ± 3% relative humidity (Figure 4a).

For the second packaging, 50 kg of washed and treated kola nuts were placed in two groups of clean and perforated food cartons. The 1st and 2nd groups each consisted of 25 kg of kola nuts packed respectively in potato packaging nets (Polyethylene) (Figure 4b1) and in perforated food bags (Figure 4b2). Each group was divided into two batches. The 1st batch was stored in a warehouse at room temperature of 29°C ± 1°C and 67% ± 5% relative humidity and the 2nd batch in the laboratory at 26°C and 74% ± 3% relative humidity.

For the third conditioning, 100 kg of kola nuts were washed, processed, sorted and grouped according to white and red color. Two batches of 50 kg of nuts of the same color were placed in clean and perforated cardboard trays. Each batch was divided into two groups of 25 kg of nuts to be coated or not. Thus, 25 kg of coated white cola, 25 kg of uncoated white cola, 25 kg of coated red cola and 25 kg of uncoated red cola were obtained. Each group was subdivided into two, one stored in a warehouse at room temperature of 29°C ± 1°C and 67% ± 5% relative humidity and the other in the laboratory at 26°C and 74% ± 3% relative humidity (Figure 4c).

Finally, for the fourth packaging, 100 kg of cola nuts were washed, processed, sorted and grouped according to white and red color. Two batches of 50 kg of nuts of the same color were placed in polyvinyl chloride (PVC) trays. Each batch was divided into two groups of 25 kg of nuts to be coated or not. Thus, 25 kg of coated white cola, 25 kg of uncoated white cola, 25 kg of coated red cola and 25 kg of uncoated red cola were obtained. Each group was subdivided into two, one stored in a warehouse at room temperature of 29°C ± 1°C and 67% ± 5% relative humidity and the other in the laboratory at 26°C and 74% ± 3% relative humidity (Figure 4d).

A 50 kg witness was made according to the traditional method of processing nuts and stored in traditional conditions by the traders.

Thus, the samples obtained were coded as follows:

- 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.

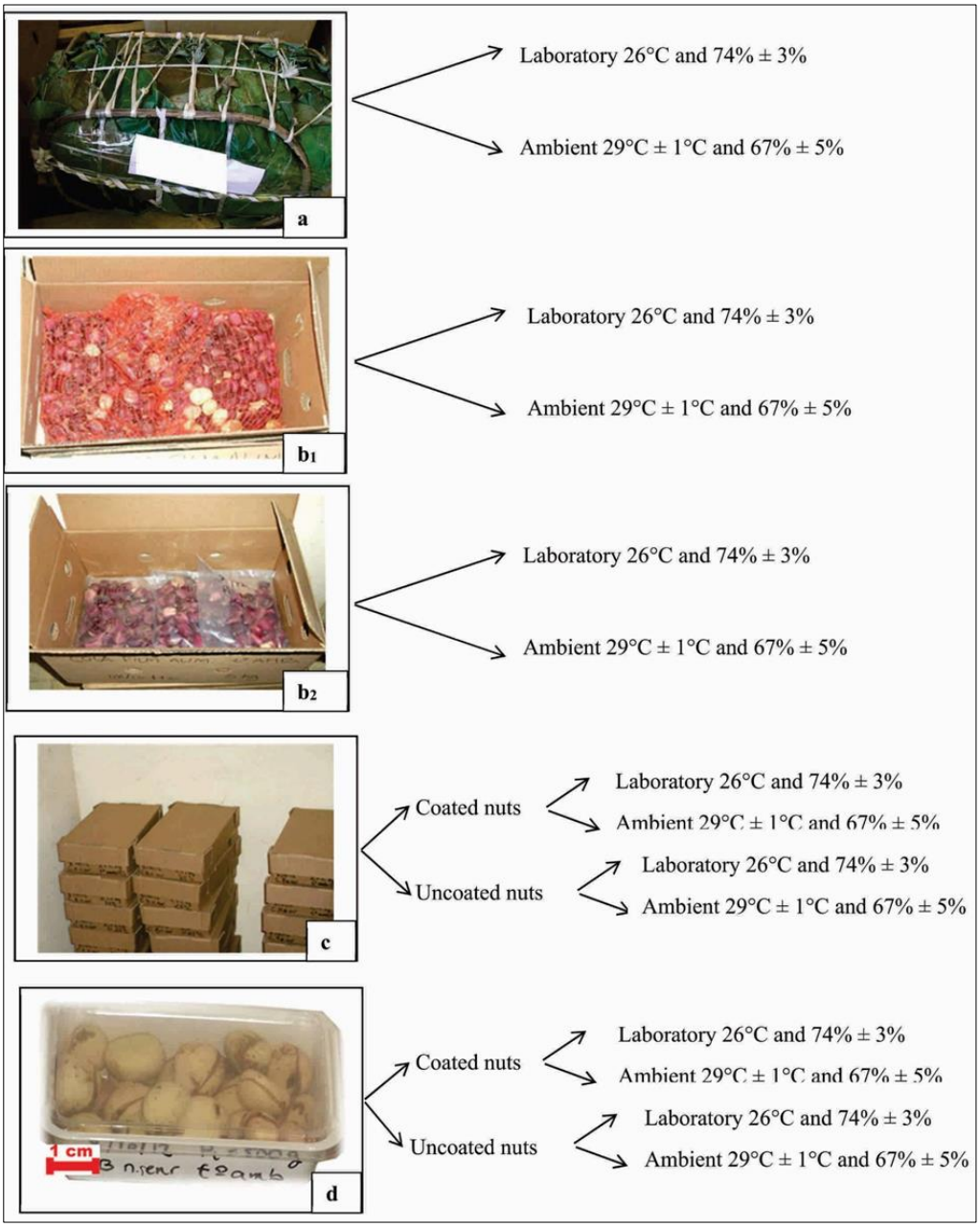


Figure 4 Packaging methods for kola nut

- a. Rattan basket lined with *Thaumatococcus daniellii* leaves
- b1. Cardboard with potato packaging net
- b2. Cardboard with perforated food bag
- c. Cardboard tray
- d. PVC tray

2.5. Sensory analysis

The sensory analysis used is the descriptive test and was carried out with 10 panelists, fully available and motivated throughout the study period [**8**]. These people, who are regular consumers of cola, received training for one month, in accordance with the standards in force [**9, 10**]. At the end of this training, these people were able to recognize, evaluate and memorize the stimuli specific to the cola nut, to creativity and the capacity for appropriate verbal expression and to use a rating scale. The repeatability of the subjects was verified. The practical training consisted of generating and reducing the list of cola descriptors to a minimum, namely taste, color, brightness, browning, aging and texture. Then, each descriptor was associated with a reference product that will allow the panelist to evaluate the cola on a 9-point scale.

For the cola samples, this descriptive test consisted of measuring the intensity of the sensation perceived for each of the chosen descriptors, and establishing, using all of the quantified descriptors, the sensory profile of the cola. Similarly, graphs representing the "taste" evolution of the cola were produced as a function of the storage temperature and the packaging method.

2.6. Statistical processing of data

The results of the sensory analyses were subjected to an analysis of variance (ANOVA) at a significance level of 0.05 with the STATISTICA software [**11**]. In case of significant difference of the samples (or homogeneous groups), the Scheffé post hoc comparison test is used to determine the samples that differ from each other.

3. Results

It should be noted that regardless of the packaging and temperature used, the organoleptic characteristics of the nut deteriorate during storage. The temperature of 29°C ± 1°C preserves slightly better than that of 26°C. There is therefore a first group of packaging that promotes a rapid degradation of the descriptors of the nuts in the first three months. These are the Potato net cardboard and the cardboard trays.

As for the second group, there is a progressive degradation of the nuts that stabilizes around an average assessment, up to 10 months of storage. These are the PVC trays and the basket (Figures 5, 6 and 7). In the first month of storage, the kola nuts all have the same sensory profile regardless of the storage temperature and the type of packaging used. The nuts are very fresh and show little browning in figure 7. The bitter taste, color and shine are very pronounced on the one hand and on the other hand the texture, apart from the Potato net cardboard at 26°C, is very crunchy for all the packages (Figure 6).

In the 2nd month of storage, very distinct groups are formed with a deterioration of almost all the sensory descriptors of the nut. The general assessment of a group of packages becomes very poor, whatever the packaging temperature (Figure 5). These are the Coated white cola cardboard trays, coated red cola cardboard trays, uncoated red cola cardboard trays and Potato net cardboards which at this stage experience very advanced aging and browning, which already allows them to be excluded for the rest of the analyses of the 3rd, 6th and 10th months of storage. In the 3rd month of storage, the coated red cola PVC trays at 26°C show the lowest assessment due in part to the marked aging of the nuts. Whereas at 29°C ± 1°C, it is rather on the one hand the SA cardboard which experiences more significant aging and browning (Figure 7) and on the other hand the uncoated red cola PVC trays whose color deteriorates considerably (Figure 6).

At the 6th month of storage, the food bag carton clearly stands out from the other packages because it presents kola nuts with the worst organoleptic characteristics, especially in terms of aging and browning (Figures 5 and 6). In addition, the kola nuts in this package, regardless of the temperature, are dry and hard, have a bland taste, and a less pronounced color and shine. The food bag carton is therefore excluded for the analyses of the 10th month of storage. At the 10th month of storage, the kola nuts in the PVC trays and the basket still have good organoleptic characteristics according to figure 6. Indeed, browning and average aging of the kola nuts are observed (Figure 7). These are more

significant at 26°C than at 29°C ± 1°C, with the best results for the control and the basket. Next come the white coated and red uncoated PVC trays.

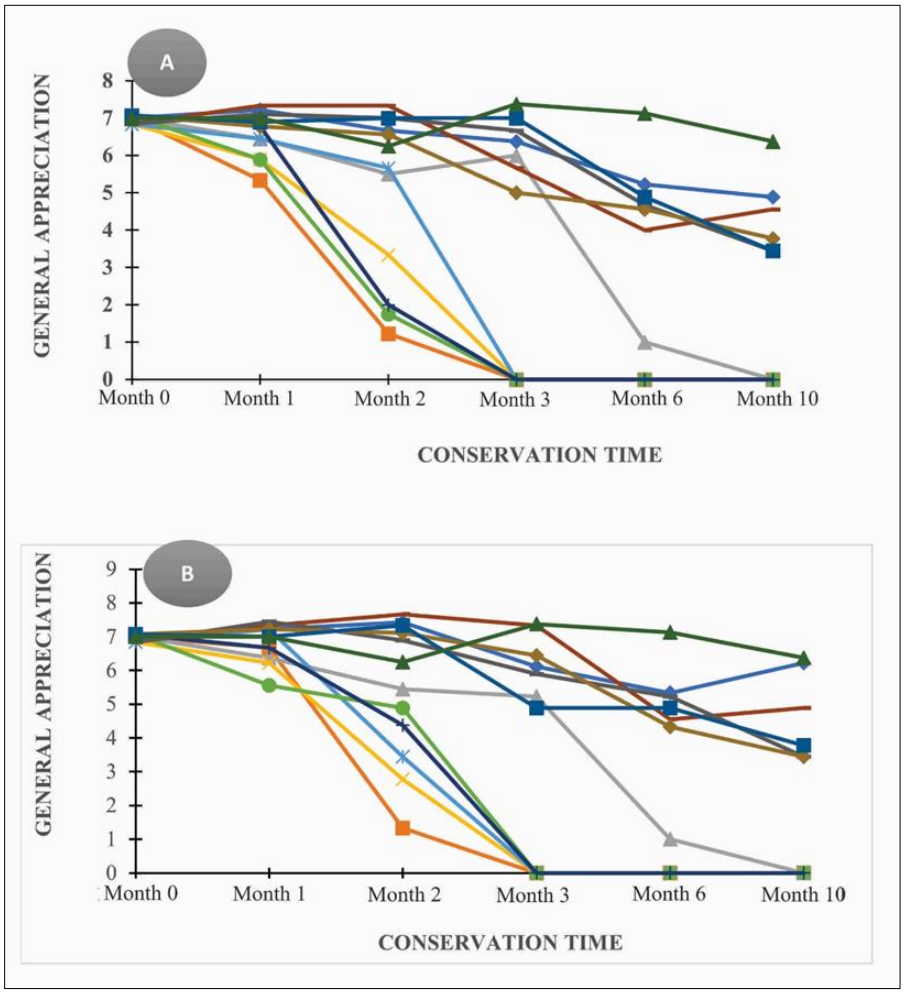
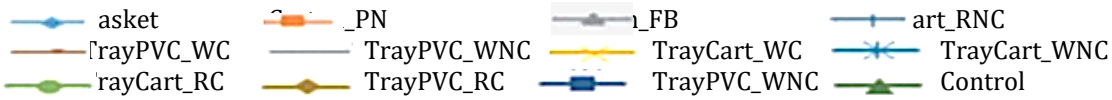


Figure 5 Variation of sensory properties over storage time according to the type of packaging at: (A) 26°C and 74% ± 5%. and (B) 29°C ± 1°C and 67% ± 5%



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.

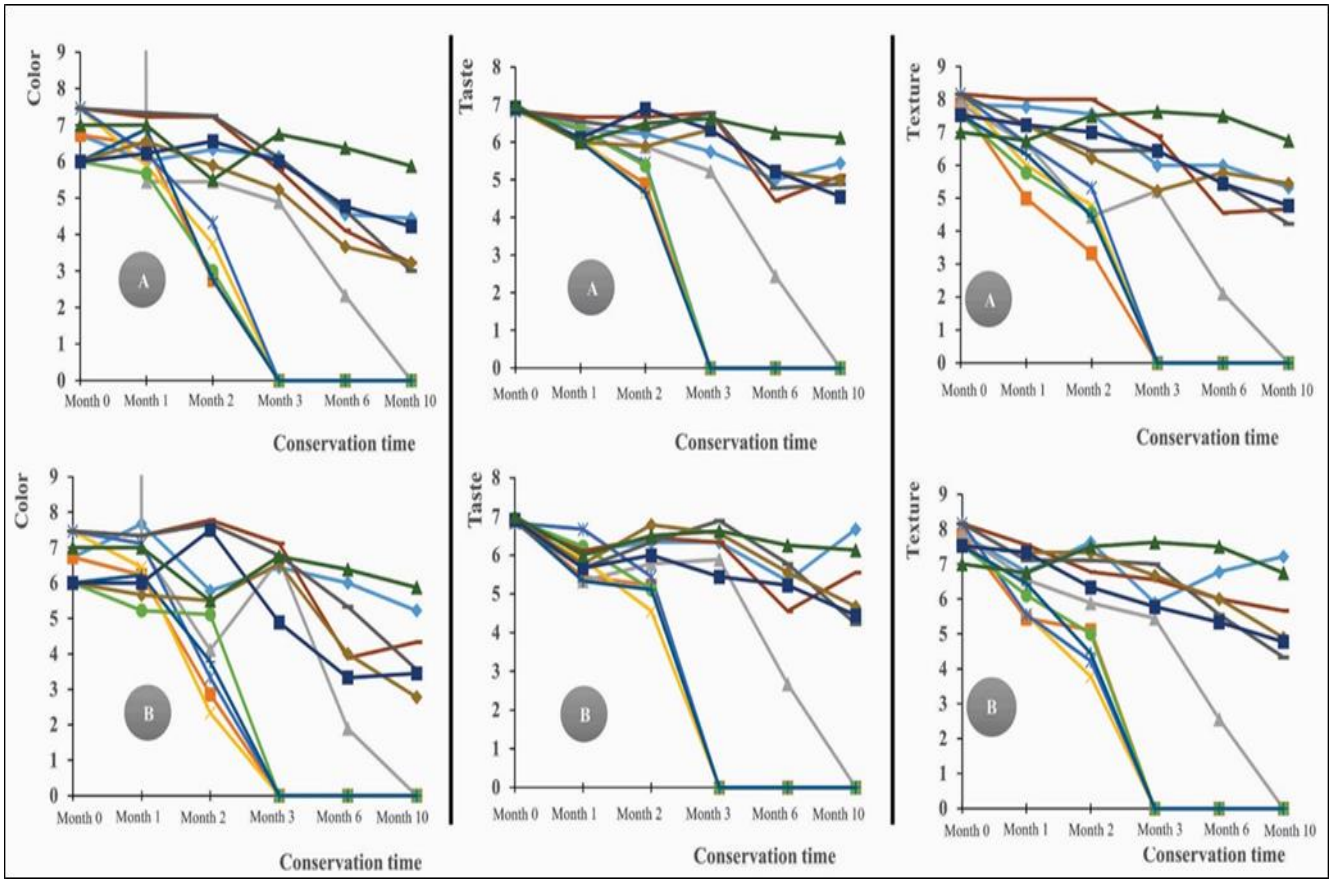


Figure 6 Variation of sensory properties over storage time according to the type of packaging at 26°C and 74% ± 5% (A) and at 29°C ± 1°C and 67% ± 5% (B)

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.

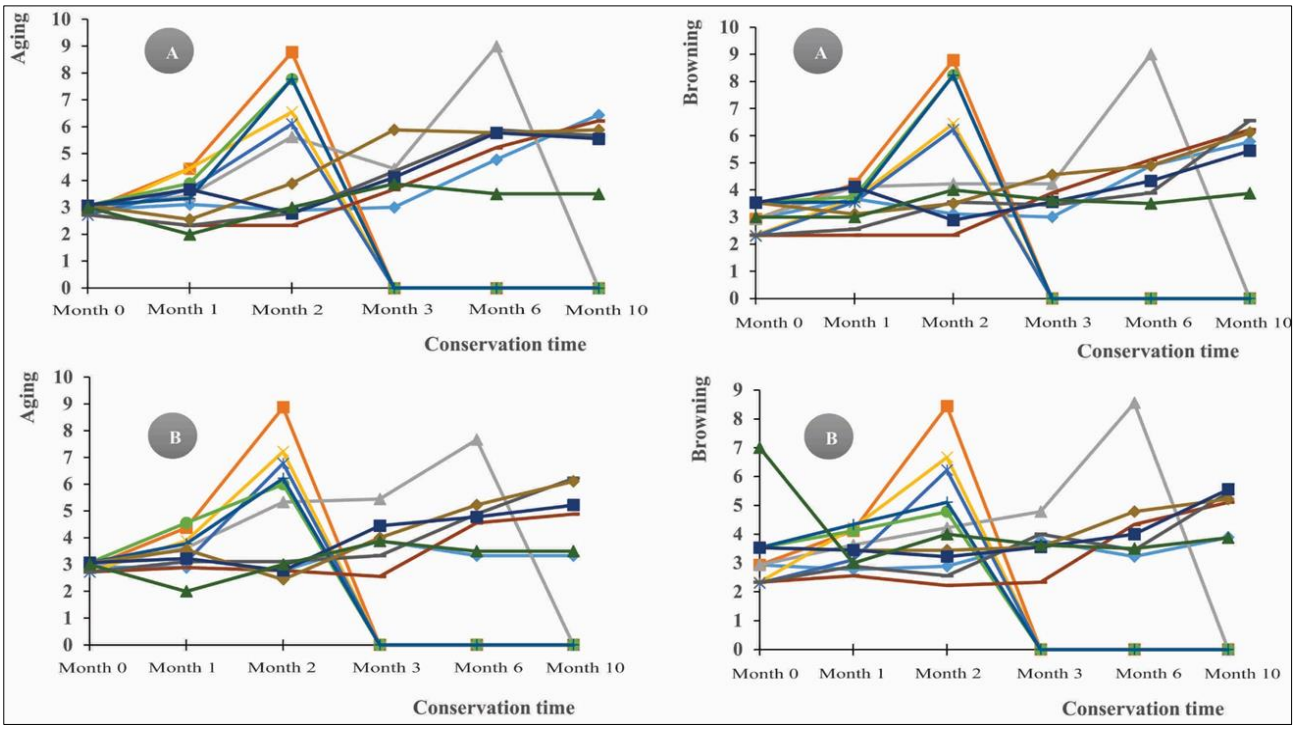


Figure 7 Variation of aging and browning of cola over storage time according to the type of packaging at 26°C and 74% ± 5% (A) and at 29°C ± 1°C and 67% ± 5% (B)

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.

4. Discussion

Packaging is often the biggest problem encountered by stakeholders in the sector. Indeed, when choosing packaging materials, it is imperative to take several criteria into account. These include the technical requirements of the product (protection against light, crushing, air, humidity, etc.), the relative cost and the availability of different types of packaging. Cardboard and plastic cola packaging were proposed in this study, due to their availability and can generally be used by all traders and producers throughout the country. Fruits and vegetables absorb moisture from the air and must therefore be packaged in airtight and moisture-resistant packaging. Some must also be protected from light in order to preserve their color. Thus, for [**12**], each storage package, regardless of its form or nature, must keep the product dry, cold and protected against insects, mould, rodents and domestic animals. A small quantity of cola infected by insects or mould or whose moisture content is too high is enough to destroy the entire stock. In addition, he states that plastic bags are generally suitable for storage, in the humid and arid tropics. However, the product must be well dried because the continuation of the latter is impossible during storage. Even if the plastic bags remain open, the product cannot dry because the circulation of air does not take place in them.

The methods of preserving kola nuts presented and retained above make it possible, at a reasonable cost, to resell the colas purchased at harvest six to ten 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

[**13**] 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 was that which 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 reduction in the concentration of polyphenols. In general, the effectiveness of fruit preservation depends strongly on the storage conditions of these organs [**14**]. Overall, high temperatures, 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 [**14**]. Indeed, phenolic constituents are in large quantities in kola nuts compared to some fruits such as grapes, pears, peaches and apples. According to Haard et Chism [**15**]**,** the content of phenolic compounds decreases during the maturation of climacteric fruits because of their structure they are easily oxidized by enzymes. Thus, the browning reactions of fruits and vegetables are generally considered to be a direct consequence of the oxidation of phenolic compounds by the enzymes polyphenol oxidases (PPO) and peroxidase (POD) which results in the formation of quinones which subsequently polymerize to give brown compounds [**16**].

5. Conclusion

During storage, the packaging used significantly influenced the organoleptic qualities of the kola nuts. The effects of temperature, although negatively influencing the sensory composition at the beginning of storage, fade over time. The second factor, namely the packaging, and the "packaging-temperature" interaction have a significant influence throughout the 10 months of storage. Of all the combinations (packaging-temperature-coating) proposed, twenty-two in total, two packagings were selected, namely the basket and the PVC trays. These made it possible, on the one hand, to store the nuts for up to ten months and, on the other hand, to obtain low loss rates. This will make it possible to offer other marketing alternatives for kola nuts, in particular sales in supermarkets. This will undoubtedly constitute added value for the players in the sector.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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