Original Research Article

Evaluation of loss rate and organoleptic characterization of kola nuts (Cola nitida) during conservation

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Aims: The conservation of fresh kola nuts produced in Côte d'Ivoire and intended for the export, poses a veritable problem for the farmers. The aim of this study was to evaluate the ability of biopesticide TopBio and three types of packaging to preserve kola nut.
Study design: harvest kola nuts, cleaning, setting up conservation methods, sensory evaluation and loss rate.
Place and Duration of Study: University of Nangui Abrogoua, Abidjan, Côte d'Ivoire, from September 2018 to March 2018.
Methodology: Good Hygiene Practices (GHP), a biopesticide (TopBio) and three containers, namely the rattan basket lined with *Thaumatococcus daniellii.,* leaves, the polystyrene trays and the triple bagging bag have been used for the treatment and preservation of kola nuts. The rate of loss and organoleptic characteristics were assessed during conservation.
Results: After one month of storage, the BPH-CBS, BPH-CRS, Bio-CBP, Bio-CBS and Bio-CRS methods favoured 100% of loss rate. Moreover, after 6 months of storage, the BPH-CBB, BPH-CRB, Bio-CBB and Bio-CRB methods allowed to have a loss rate of less than 10%. While the highest loss rates were observed at the BPH-CBP and BPH-CRP methods with respectively 42.47% and 81.57% loss.
Conclusion: The preservation method with Good Hygiene Practices and PS trays has made it possible to conserve the water content and organoleptic characteristics of kola nuts, unlike technologies with the biopesticide, the rattan basket and the bag triple bagging.

Keywords: Cola nitida, packaging, bio-pesticide, sensory analysis

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

The kola tree *Cola nitida* (family of *Sterculiaceae*) is a plant found in central and sub-Saharan Africa where it forms a large natural stand in the forest area [1]. Côte d'Ivoire is the world's leading producer and exporter, producing 260,747 ton of fresh nuts in 2016 [2]. Most Ivorian production is used for local consumption and for export to neighboring countries, particularly Mali, Niger, Senegal, Nigeria and Burkina Faso. Kola nut is used as a stimulant, promoting the physical and psychic endurance of manual workers [3, 4] or as ingredients in the formulation of certain pharmaceutical products and energy drinks. In addition, various research studies have highlighted the nephroprotective, anti-inflammatory and antioxidant effects of the aqueous extract of kola nuts [5, 6]. However, very little research has been done on the post-harvest component of this product, particularly the conservation and valorization of kola nuts, which represents 4.18% of literature documents identified for this

theme [7]. Kola is attacked by weevils (*Balanogastris kolae, Paremydica insperata),* Diptera (*Pterandrus colae*) and fungi (*Fusarium sp*., *Penicillium sp*., *Aspergillus flavus*, *Alternaria sp*., *Aspergillus niger* and *Mucor spinosus*), which can cause 30 to 70% losses during storage [8, 9, 10]. Faced with these huge production losses, it is only the chemical fight that is envisaged by the actors of the sector. According to [9], they use unapproved chemicals for the processing of fresh fruit consumed in the cola production chain. Chemical control is dangerous for environment and consumer. According to [11], the presence of organochlorine pesticides is observed in 135 samples of kola nuts collected in the city of Anyama (Côte d'Ivoire). Thus, faced with the numerous post-harvest losses of kola nuts and the limits of chemical pesticides, it seems important to carry out investigations on use of bio-pesticides for conservation of fresh kola nuts. So, the overall objective of this study is to contribute to improving the conservation of fresh kola nut using biopesticides and appropriate packaging materials in order to reduce the huge post-harvest losses and to preserve the consumer health.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

2.1. Material

Fresh kola nuts: mature pulped kola nuts of the species *Cola nitida* were collected during September 2017. After shelling, untreated pulped kola nuts were sent to the laboratory in polypropylene bags for their immediate treatment and conditioning.

Containers for kola nuts: Three (3) containers were used namely basket lined with leaves of *Thaumatococcus daniellii* (Benn.) Benth., (Container 1), opaque polystyrene [PS] trays, (Container 2) and triple bagging bag (Container 3)

2.2. Methods

2.2.1. Temperature and relative humidity of kola nuts storage room

The temperature and relative humidity of kola nuts storage room were recorded twice daily; at 8:00 am and 1:00 pm using a miniature thermo-hygrometer (SMART SENSOR AR807).

2.2.2. Treatment of cola nuts

Freshly picked pulp kola nuts were used for testing. After hulling, sorting and washing (Fig.1 and 2), 240 kg of hulled kola nuts (120 kg of red nuts and 120 white nuts) were used for the implementation of preservation techniques. 120 kg of kola nuts of each color were separated into 2 batches (60 kg/batch). 60 kg of each color of sorted and washed nuts were treated with biopesticide by dipping at a rate of 10 ml/l of water and per kilogram of kola nut for 1 hour. After treatment, kola nuts were left drained for 30 minutes before being packaged in the different packages.

2.2.3. Conditioning and preservation of cola nuts

Six (6) preservation methods were used for each nut color. Indeed, three (3) techniques have been developed according to the Good Hygiene Practice (BPH) and the other three (3) by coupling the

BPH and biopesticide TopBio. After dripping, 60 kg of each color of walnuts treated with bio pesticide were separated into three batches of 20 kg.

Each batch of 20 kg was packaged in a specific packaging: rattan basket lined with *Thaumatococcus daniellii* leaves, polystyrene trays (PS), food cartons and the triple bagging bag (Fig. 3, 4 and 5). All packaged nuts were kept for 6 months (Fig. 6). Thus, twelve types of conditioning have been formed.

- Bio-CBB: white kola nuts treated according to BPH with biopesticide and then stored in polystyrene trays,

- Bio-CBP: white kola nuts treated according to BPH with biopesticide and then stored in rattan basket lined with leaves of *Thaumatococcus daniellii*,

- Bio-CBS: white kola nuts treated according to BPH with biopesticide and then kept in a triple bagging bag,

- BPH-CBB: white kola nuts treated according to BPH and stored in polystyrene trays,

- BPH-CBP: white kola nuts treated according to BPH and stored in rattan basket lined with leaves of *Thaumatococcus daniellii*,

- BPH-CBS: white kola nuts treated according to BPH and stored in a triple bagging bag,

- Bio-CRB: red kola nuts treated according to BPH with biopesticide and stored in polystyrene trays,

- Bio-CRP: red kola nuts treated according to BPH with biopesticide and preserved in the rattan basket lined with leaves of *Thaumatococcus daniellii*,

- Bio-CRS: red kola nuts treated according to BPH with biopesticide and kept in a triple bagging bag,

- BPH-CRB: red kola nuts treated according to BPH and stored in polystyrene trays,

- BPH-CRP: red cola nuts treated according to BPH and kept in the rattan basket lined with leaves of *Thaumatococcus daniellii*,

- BPH-CRS: red kola nuts treated according to BPH and stored in the triple bagging bag.

After 3 months of storage, all packaged lots were unpacked sorted before being reconditioned.

Fig. 1: Sorting of kola nuts

Fig. 2: Washing of kola nuts

Fig. 3: Packaging of kola nuts in polystyrene trays (PS) and carton

Fig. 4: Packaging of kola nuts in the triple bagging bag

Figure 5: Packaging of kola nuts in a rattan basket lined with leaves of *T. daniellii*

Fig. 6: Storage of cola nuts

2.2.4. Loss rate of kola nuts during conservation

Rate of loss is ratio of the mass of nuts carrying at least one infestation on the total mass of nuts. Thus, the loss ratio (LR), expressed as a percentage, is given by the following formula:

$$LR\ (\%) = \frac{MIN}{TNM} \times 100$$

MIN = Mass of Infested Nuts; TNM = Total Nuts Mass

2.2.5. Appearance and color of nuts during conservation

The appearance and color of kola nuts were followed by taking pictures with a SAMSUNG WB35F digital camera (16 Megapixels) during conservation.

2.2.6. Sensory analysis of nuts during conservation.

Evaluation of organoleptic characteristics was done by a panel of 15 habitual consumers trained to evaluate attribute scores. Thus, the quality criteria for kola nut are: color, shine, browning, aging, texture, juiciness and bitter taste were assessed on a 9 point scale (from 0 to 8).

2.2.7. Statistical analyzes

The analysis data has been processed with SPSS software version 22.0. An analysis of variance (ANOVA) was performed to evaluate the effect of the biopesticide (TopBio) and the three containers: rattan basket topped with leaves of *Thaumatococcus daniellii* , polystyrene trays and triple bagging bag, on the rate of loss of the kola nut conserved. Scheffé test at the 5% threshold was then used to rank averages.

3. RESULTS

3.1. Temperature and relative humidity of kola nuts storage room

During 6 months of storage at 8 H, temperature varied between 26.1 °C and 29.7 °C and at 13 H between 26.7 °C and 32.1 ° C (Fig. 7).

Relative humidity ranged from 71.0% to 97.0% at 8 H and 53.0% to 94.0% at 13 H (Fig. 8).

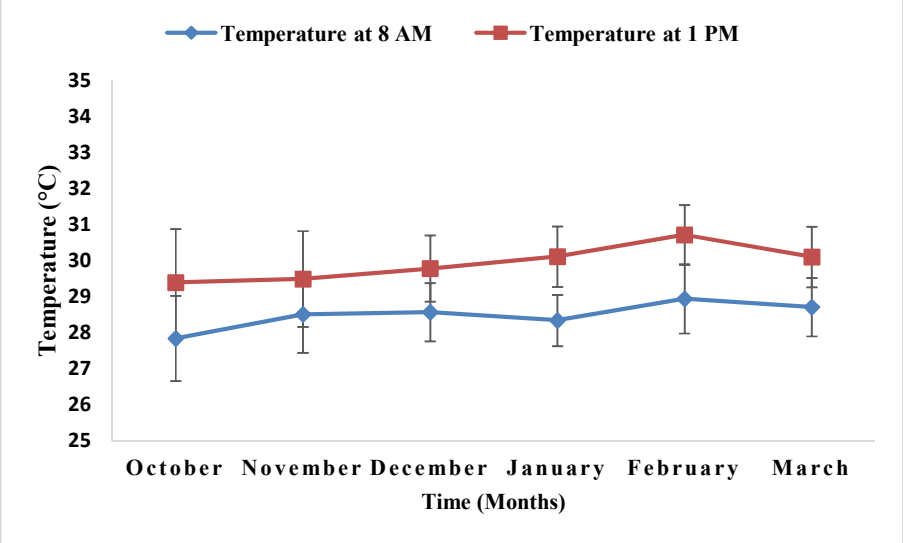

Fig. 7: Temperature of kola nuts storage room

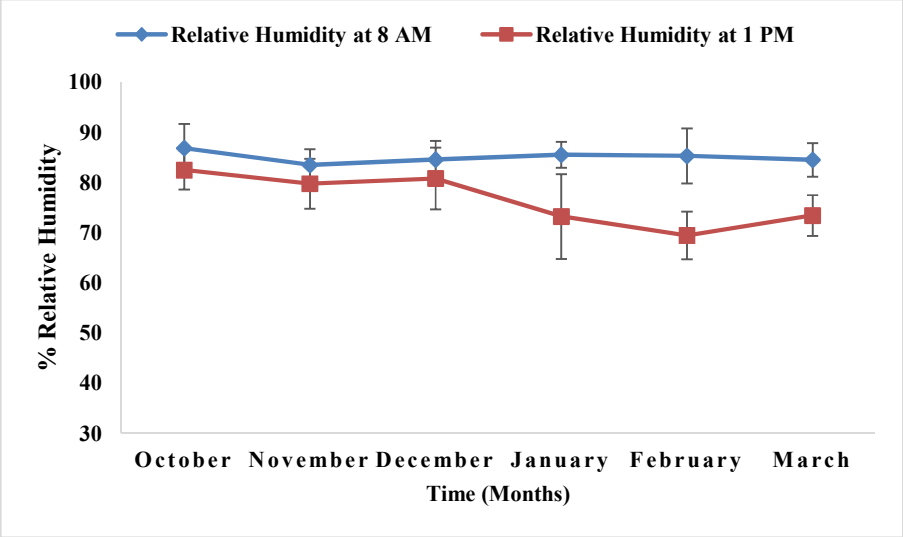

Fig.8: Relative Humidity of kola nuts storage room

3.2. Loss rate of kola nuts during conservation

ANOVA statistical analysis performed on the data from the first month of storage showed a significant difference ($P < 0.000$) between kola nut loss rates as a function of conditioning methods (Table 1).

Thus, at the end of first month, the rate of loss of nuts was zero at the level of six conditioning methods that are BPH-CBB; BPH-CBP; BPH-CRB; BPH-CRP; Bio-CBB and Bio-CRB. Then the Bio-CRP method recorded a loss rate of 32.37%. Finally, the loss rate was 100% in the BPH-CBS conditioning methods; BPH-CRS; Bio-CBP; Bio-CBS and Bio-CRS.

After 3 months of storage, the highest loss rate (24.39%) was recorded at the level of the batch treated according to the Bio-CRB method. With the Bio-CBB method, the loss rate was 18.76%. Moreover, BPH-CBB conditioning methods; BPH-CRB; BPH-CRP and BPH-CBP provided loss rates of between 1.32% and 4.88%.

After three months of preservation, the conditioning methods using Good Hygiene Practice (GHP) favored a better conservation of kola nuts compared to conditioning methods using the biopesticide.

After 6 months of preservation, BPH-CBB conditioning methods; BPH-CRB; Bio-CBB and Bio-CRB registered a loss rate of less than 10%. Then, loss rate was 42.47% with the BPH-CBP conditioning method. Finally, BPH-CRP conditioning method recorded a loss rate of 81.57%. Conditioning methods that recorded highest loss rates were those using the rattan basket lined with *Thaumatococcus daniellii* leaves as packaging.

Table 1: Loss rates of different packaging methods during conservation

Conditioning method	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
BPH-CBB	0[a]	0[a]	0[a]	1,32±1,14[a]	0[a]	2,68±1,23[a]	7,64±1,87[a]
BPH-CBP	0[a]	0[a]	0[a]	4,88±0,88[a]	0[a]	3,55±1,43[a]	42,47±2,91[b]
BPH-CBS	0[a]	100[c]	-	-	-	-	-
BPH-CRB	0[a]	0[a]	0[a]	1,48±1,29[a]	0[a]	2,80±1,00[a]	7,61±1,89[a]
BPH-CRP	0[a]	0[a]	0[a]	4,30±1,84[a]	0[a]	2,87±1,16[a]	81,57±3,76[c]
BPH-CRS	0[a]	100[c]	-	-	-	-	-
Bio-CBB	0[a]	0[a]	7,17±1,25[b]	18,76±0,96[b]	0[a]	3,94±2,06[a]	9,54±1,88[a]
Bio-CBP	0[a]	100[c]	-	-	-	-	-
Bio-CBS	0[a]	100[c]	-	-	-	-	-
Bio-CRB	0[a]	0[a]	8,27±0,79[b]	24,39±0,89[c]	0[a]	3,57±2,06[a]	11,46±1,85[a]
Bio-CRP	0[a]	32,37±3,63[b]	100[c]	-	-	-	-
Bio-CRS	0[a]	100[c]	-	-	-	-	-

Mean ± standard deviation, n = 3; the values of the same column being assigned the same letter are not significantly different according to the Scheffé test at the 5% threshold.,
***BPH-CBB:** White kola nuts BPH + Polystyrene trays, **BPH-CBP:** White kola nuts BPH + Rattan basket, **BPH-CBS:** White kola nuts BPH + Triple bagging bag, **Bio-CBB:** White kola nuts BPH + Biopesticide + Polystyrene trays, **Bio-CBP:** White kola nuts BPH + biopesticide + Rattan basket, **Bio-CBS:** White kola nuts BPH + biopesticide + Triple bagging bag,**BPH-CRB:** Red kola nuts BPH + Polystyrene trays, **BPH-CRP:** Red kola nuts BPH + Rattan basket, **BPH-CRS:** Red kola nuts BPH + Triple bagging bag, **Bio-CRB:** Red kola nuts BPH + Biopesticide + Polystyrene trays, **Bio-CRP:** Red kola nuts BPH + biopesticide + Rattan basket, **Bio-CRS:** Red kola nuts BPH + biopesticide + Triple bagging bag,*

3.3. Appearance and color

Appearance and color of white and red kola nuts during six months of storage are shown in Fig. 9 and 10. Nuts treated only according to Good Hygiene Practices (GHP) and packaged in polystyrene trays (PS) showed no visible physiological changes. However, nuts treated only with GHP and packaged in rattan baskets experienced severe wilting due to water loss. While, nuts treated with GHP plus biopesticide showed a brown coloring. This method of conditioning favored a rot of the nuts preserved in the triple bagging bags and in the baskets. Only the polystyrene (PS) trays allowed the nuts to be preserved for 6 months. On the other hand, the triple bagged bags could not keep the nuts for 1 month.

	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
BPH-CBB							
BPH-CBP							
BPH-CBS			---	---	---	---	---
Bio-CBB							
Bio-CBP			---	---	---	---	---
Bio-CBS			---	---	---	---	---

Fig. 9: Appearance of white nuts after 6 months of conservation

BPH-CBB: *White kola nuts BPH + Polystyrene trays,* ***BPH-CBP:*** *White kola nuts BPH + Rattan basket,* ***BPH-CBS****: White kola nuts BPH + Triple bagging bag,* ***Bio-CBB:*** *White kola nuts BPH + Biopesticide + Polystyrene trays,* ***Bio-CBP:*** *White kola nuts BPH + biopesticide + Rattan basket,* ***Bio-CBS****: White kola nuts BPH + biopesticide + Triple bagging bag,*

	Month 0	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
BPH-CRB							
BPH-CRP							
BPH-CRS			---	---	---	---	---
Bio-CRB							

Bio-CRP				---	---	---	---
Bio-CRS			---	---	---	---	---

186 **Fig. 10:** Appearance of red nuts after 6 months of conservation

187 ***BPH-CRB****: Red kola nuts BPH + Polystyrene trays,* ***BPH-CRP****: Red kola nuts BPH + Rattan basket,*
188 ***BPH-CRS****: Red kola nuts BPH + Triple bagging bag,* ***Bio-CRB****: Red kola nuts BPH + Biopesticide +*
189 *Polystyrene trays, Bio****-CRP****: Red kola nuts BPH + biopesticide + Rattan basket,* ***Bio-CRS****: Red kola*
190 *nuts BPH + biopesticide + Triple bagging bag.*

3.4. Sensory profile of preserved kola nuts

Before storage, all the nuts had a good appearance at the level of the different descriptors. However, it should be noted that the biopesticide treatment had already affected to a lesser degree the color, brightness and browning of kola nuts. White nuts are the most affected by browning. As for the other descriptors, no major difference was observed (Fig. 11).

After six (6) months of preservation, the color and brightness of the nuts preserved according to the methods (Bio-CBB and Bio-CRB) were deteriorated with a degree of browning was very extensive. In addition, the BPH-CRP method favored a very pronounced aging, followed by the BPH-CBP method. As for the other methods (BPH-CBB, BPH-CRB, Bio-CBB and Bio-CRB), no aging was observed. In general, panellists favored preserved kola nuts according to methods using GHP plus PS trays (BPH-CBB and BPH-CRB) (Fig. 12).

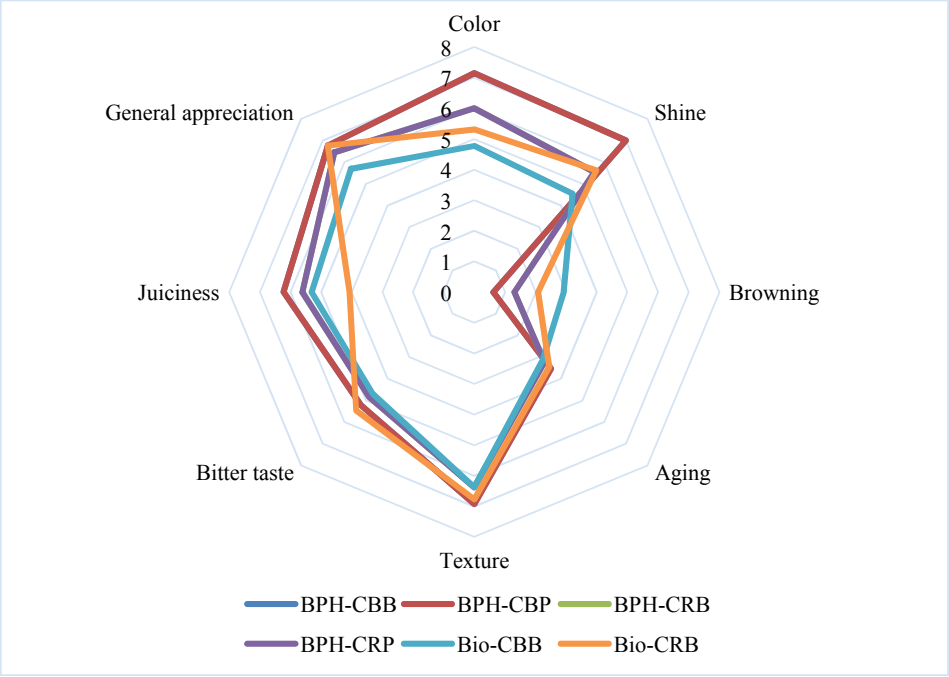

Fig. 11: Sensory profile of kola nuts before conservation (Month 0)

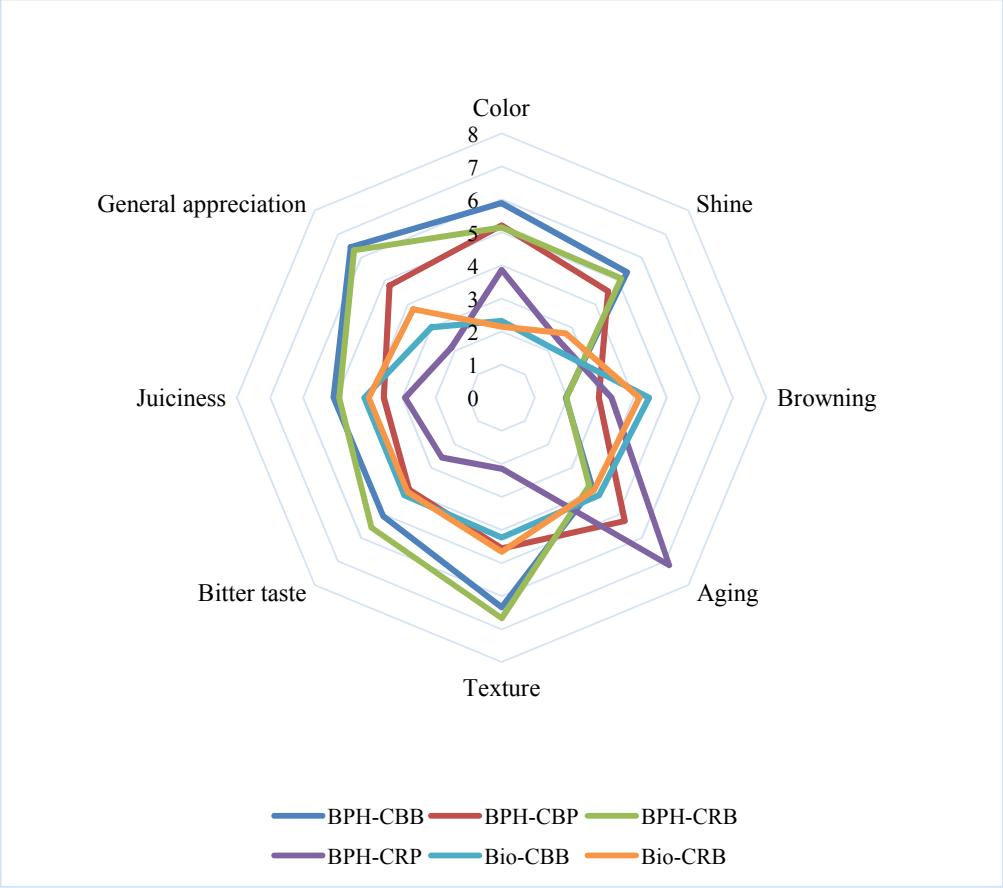

Fig. 12: Sensory profile of kola nuts after 6 months of storage

4. DISCUSSION

Of the three types of packaging used, opaque PS trays have proven very suitable for long-term storage of fresh kola nuts. While, the triple bagged bag and the rattan basket lined with leaves of *Thaumatococcus daniellii* are unsuitable for the preservation of fresh kola nuts for a long time. Indeed, the rattan basket lined with leaves of *Thaumatococcus daniellii* promotes the circulation of air after three months. Over-permeable packaging will result in rapid loss of moisture, which will be accompanied by wilting and wrinkling of the product [12]. Also, after 1 month of storage, all the nuts kept in the triple bagging bag had undergone alteration related to high transpiration. Triple bagging would be a very suitable conservation technique for the preservation of dried fruits and vegetables. The work of [13] showed that cowpea seeds were preserved by the triple bagging technique for 7 months with efficiency. As for the rattan basket lined with leaves of *Thaumatococcus daniellii*, empirically it has always been used for the conservation of kola nuts in Côte d'Ivoire. According to [9], the best packaging obtained during its work is the basket with *Thaumatococcus daniellii* leaves and PVC packaging.

However, after six months of storage, the results obtained showed that of the three types of packaging studied, only PS trays allow the kola nuts to be preserved for a long time. In fact, the lowest loss rates were observed with PS trays, whereas the highest loss rate was observed with the basket lined with leaves of *Thaumatococcus daniellii*.

Fruits and vegetables absorb moisture from the air and must be packaged in airtight and moisture-proof packaging. Some must also be protected from light in order to preserve their color. Thus, according to [14], each storage package, regardless of its shape or nature, must keep the product dry, cold and protect it against insects, molds, rodents and domestic animals. A small amount of cola infected by insects or molds or with too much moisture content is sufficient to destroy the entire stock. In addition, he says that plastic bags are generally suitable for storage in the humid and arid tropics. The product must however be well dried because the continuation of it is impossible during storage. Even if the plastic bags remain open, the product can not dry because air circulation does not occur. In general, the effectiveness of fruit conservation strongly depends on the storage conditions of these organs [15]. Overall, temperatures, high pressures, and oxygen abundance accelerate fruit degradation, while weak measurements of these three parameters lengthen the green life of organs. Extending the lifespan of nuts by some methods suggests that the different treatments applied favorably modify fruit interactions with the surrounding environment. Losses were relatively low in nuts treated with biopesticide. These results are in agreement with those of [16] who used bio-pesticides on apple fruits. The use of these bio-pesticides on other foods such as cowpeas and beans has also yielded the same results [13,17]. Bio-pesticides reduce the proliferation of insects and molds in stocks. This result was also observed by [18] who used bio-pesticides in the conservation of rice stocks.

Organoleptic characteristics of the nuts, such as the color, shine, texture and taste of the nuts, as well as the overall appreciation of the nuts, have been preserved in the nuts preserved in the PS trays. According to [9], the conservation of organoleptic characteristics is strongly linked to the types of packaging. The results of his work during storage with chemical pesticides and PVC trays gave similar results. In contrast to the nuts treated with bio-pesticide and the nuts kept in the triple bagging bag, the organoleptic qualities of the nuts were preserved during the six (6) months of storage with the PS trays. These results confirm that PS trays are the most suitable for long-term preservation of nuts. The methods of treatment and conservation favoring a rapid alteration of the organoleptic characteristics of kola nuts negatively affect the sale. This hypothesis is shared by [9] who showed that consumers choose kola nuts in relation to their colors, tastes, crisp textures, sizes and juices.

5. CONCLUSION

This study shows that the different methods of preservation have had a significant influence on the physical and organoleptic properties of kola nuts. In general, preservation methods with Good Hygiene Practices (GHP) and polystyrene (PS) trays have better preserved the organoleptic and physical properties of kola nuts, unlike the methods with the biopesticide, the rattan basket and the triple bagging bag. Kola nut losses due to insufficiently effective packaging could therefore have adverse effects on the income of the actors in the sector.

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