HEDONIC SENSORY QUALITY OF MAIZE GRAINS CONSERVED BY A TRIPLE BAGGING AND BIOPESTICIDES SYSTEM (LEAVES OF *Lippia multiflora* Moldenke AND *Hyptis suaveolens* Poit)

.

ABSTRACT

In Côte d'Ivoire, inefficient storage methods that are sometimes harmful to the health of consumers and the environment hinder the large-scale availability of cereals, particularly maize. Thus, a triple bagging system associated or not with biopesticides of plant origin (leaves of *Lippia multiflora* and *Hyptis suaveolens*) was proposed in this study in order to evaluate its effectiveness on the conservation of the hedonic sensory qualities of the grains during a period of 18 months following a 3-factor composite central plan (PCC). The first PCC factor consisted of 6 observation periods: 0; 1; 4.5; 9.5; 14.5 and 18 months. The second factor was the type of treatment which included one control lot with a polypropylene bag (TB0SP) and 9 experimental batches including one batch in triple bagging without biopesticides (TB0P) and the eight (8) other batches containing variable proportions and/or combinations of biopesticides (TB1 to TB8). And finally, the third factor concerned the combination of the two biopesticides with the percentage (%) of *Lippia multiflora* as a reference. Treated and stored maize kernels were periodically removed and processed into porridge for sensory analysis using a 9-point hedonic scale. The sensory parameters studied were color, taste, aroma, smell, mouthfeel and overall acceptability. The results showed that storage of maize grains in a triple bagging and biopesticide system for up to 18 months did not affect the hedonic sensory attributes studied. The porridges made from these grains were therefore judged pleasant by the panelists throughout the storage period. On the other hand, the porridges produced from grains stored in a polypropylene bag (TB0SP) were considered unpalatable by the panelists after only 4.5 months of storage with respect to these sensory parameters evaluated.
The results of multivariate analysis (PCA and CAH) indicate that the addition of at least 1.01% biopesticides (*Lippia multiflora* and *Hyptis suaveolens* leaves) in triple bagging systems makes preservation more effective and preserves the organoleptic quality of the maize kernels over the entire 18-month period.

Keywords: Stored maize; biopesticides; hedonic sensory; triple bagging.

1. INTRODUCTION

Maize (*Zea mays*) is one of the most important cereal crops in the world, accounting for 41% of global cereal production, slightly ahead of rice and wheat [1]. It enjoys global distribution due to its exceptional geographic adaptability and relatively low cost [2].

In Côte d'Ivoire, maize ranks second in cereal production after rice [3]. Its annual national production increased from 760,000 tons in 2016 to 1,006,000 tons in 2018, for a total sown area of 386,633 ha [4]. Maize grains provide about 15% of the population's energy needs and therefore constitute the primary source of cereal-based energy [5]. Grains are consumed in various forms and used in the preparation of several human and animal food recipes [6].

In most developing countries, particularly in Côte d'Ivoire, maize grains constitute an enormous reserve of food in the dry seeds form.

However, large amounts of stored grains are lost each year due to mold contamination and insect attacks [7]. According to Olakojo and Akinlosotu [8], insect and pest infestations are the main factors responsible for reducing the quantity, quality and germination potential of maize seed during storage. To cope with these stock destroyers, producers often resort to synthetic pesticides whose bad practices (abusive use, lack of precaution in their handling and failure to respect deficiency periods) can lead to pest resistance, environmental and health problems [9], [10]. In addition, the majority of farmers in Africa are resource-poor and lack the means and skills to procure and handle pesticides appropriately [11].

Consequently, the search for alternatives to synthetic pesticides has become a major challenge for the scientific world and for consumer and environmental protection organizations [12]. Several areas of research have been explored in Côte d'Ivoire in particular, hermetic storage, and the use of plant extracts. Research on sealed storage has led to the development of triple bagging technology such as the PICS bag [13]. This technology is currently widely used as an alternative to synthetic insecticides. The study of the effects of insecticidal or repellent plants for maize storage in Côte d'Ivoire has received much attention and has been an important research topic for the conservation of maize in the farming environment. Niamketchi [14] showed very significant changes in the marketability and sanitary qualities of maize after 6 months of storage in granaries in the presence of *Lippia multiflora* and *Hyptis suaveolens* leaves. Ezoua [15] studied the marketable and sanitary qualities of grain maize stored in polypropylene bags in the presence of biopesticides (*L. multiflora* and *H. suaveolens*) for 8 months and reported that these qualities (marketable and sanitary) remain in accordance with international standards during the first 6 months of storage. Moreover, the effectiveness of triple bagging systems associated or not with *L. multiflora* and *H. suaveolens* leaves on market and sanitary quality has been demonstrated by recent studies of maize grain storage in Côte d'Ivoire [16]. It should be noted that *L. multiflora* and *H. suaveolens* are food plants present in the immediate environment of consumers with no adverse effect on their health and living environment. Their proven specific effectiveness on the evolutionary cycle of insect pests of corn could make them biopesticides.

These many results have shown that the conservation of maize grains in granaries, polypropylene bags or triple bagging systems in the presence of *L. multiflora* and *H. suaveolens* leaves is effective against the development of pests responsible for the deterioration of the marketable and hygienic quality of maize grains. However, the sensory aspect has not yet been specifically taken into account, despite the strong belief that the constituents of these plants could have effects on the organoleptic quality of foods derived from processed grains. It is to remedy this deficiency that the present study was initiated. Its objective is to evaluate the effects of triple bagging systems associated or not with the leaves of *L. multiflora* and *H. suaveolens* on the hedonic organoleptic properties of foods derived from maize during storage.

2. MATERIAL AND METHODS

2.1 Maize used in the study

Dried maize grains of the improved GMRP-18 yellow morphotype variety were collected at different periods of the triple bagging preservation process associated with the biopesticides *L. multiflora* and *H. suaveolens*) as operated by Yao [17]. As a reminder, this maize grain conservation methodology was implemented using a central composite plan (PCC). It is based on the mixture of a proportion of crushed dried leaves with a defined quantity of maize grains. It is an alternating stratification of maize kernels and leaves of *L. multiflora* and *H. suaveolens* so as to obtain the leaves at the bottom and on the surface of the bags covering the grains. A total of nine (9) experimental batches and one control batch were made up as follows: TB0SP control treated without biopesticides in the polypropylene bag, TB0P triple bagged with 0% biopesticides, TB1 triple bagged with 2.5% biopesticides (0.625 kg *L*. *multiflora* and 0.625 kg *H*. *suaveolens*), TB2 triple bagged with 3.99% biopesticides (0.40 kg of *L. multiflora* and 1.60 kg of *H. suaveolens*), TB3 triple bagged with 3.99% biopesticides (1.60 kg of *L. multiflora* and 0.40 kg of *H. suaveolens*), TB4 triple bagging with 1.01% biopesticides (0.10 kg of *L. multiflora* and 0.40 kg of *H. suaveolens*), TB5 triple bagging with 1.01% biopesticides (i.e. 0.40 kg of *L. multiflora* and 0.10 kg of *H. suaveolens*), TB6 triple bagging with 5% biopesticides (1.25 kg of *L. multiflora* and 1.25 kg of H. suaveolens), TB7 triple bagging with 2.5% biopesticides (1.25 kg of *L. multiflora*), and TB8 triple bagging with 2.5% biopesticides (1.25 kg of *H. suaveolens*). The experiment lasted for 18 months. Thus, at different periods of storage, the maize grains collected were subjected to technological transformations resulting in a flour and a dish submitted to the panelists for evaluation. For this purpose, and taking into account the culinary habits of the populations, the flours from the grains were transformed into porridge.

2.2 Collecting samples

Maize grains and leaves of *L. multiflora* and *H. suaveolens* were collected from producers of Gbêkê region (7º50 North and 5º18West in center of Côte d'Ivoire). Prior to the storage, maize were sun-dried for 2-3 days before being used for the experiment. While, the *L. multiflora* and *H. suaveolens* leaves were drying at an average temperature of 30ºC for 6-7 days, and kept away from direct sun exposure. The dried leaves were chopped into fine particles before being used for the experiment. [18]

The samples for the different analyses were taken at the following storage periods: In month T0, just after purchase and before storage; then in months T1, T4.5, T9.5, T14.5 and T18. These samples were taken in triplicate. These different times were determined from the composite central plane (PCC). Thus, samples of 5 Kg of maize were collected in each bag at different strata.

2.2.1 Maize flour production

The flours were produced using the traditional milling technique. The maize grains were first sorted and then washed with tap water. Then they were crushed manually using a mortar and a wooden pestle. The crushed grains were winnowed to remove the skins. The pulped grains were washed and then soaked for ten (10) hours. Finally, the grains were drained, ground in the Moulinex and sieved with a sieve of about 200 microns in diameter. The different flours obtained were used to make the different porridges.

2.2.2 Preparation of porridges

Preliminary trials with tasters have shown that 10 g of flour can be baked in 100 mL of tap water. This quantity took into account the fluidity of the porridge. Cooking lasted eight minutes over low heat and table sugar was added (at a mass rate of 5%) at the end of cooking. The porridges were cooled to room temperature in the preparation room to 50 °C before being served. [19]

2.3 Sensory analysis

Sensory analysis consists of analyzing and interpreting the organoleptic characteristics of a product as perceived by the sense organs [20]. As part of this study, hedonic analysis was performed to evaluate the effect of biopesticides on the color, taste, aroma, odor, mouthfeel and overall acceptability of the derived product. The panel was made up of 60 untrained people (young girls and boys, adult women and men), recruited on the basis of their availability. The coded (three-digit) porridge samples were presented monadically (one after the other) to each panelist in random order. The pleasure perceived by each panelist was marked on a nine-point hedonic scale. Scores ranging from nine (extremely pleasant) to one (extremely unpleasant) were assigned to the different modalities of the scale [21]. The attributes of: color, taste, aroma, smell, mouthfeel and overall acceptability were the sensory parameters measured.

2.4 Statistical Analysis

Statistical analyses of the data were performed using SPSS (version 22.0) and STATISTICA (version 7.1) software. All tests for sensory analysis were performed in triplicate and the results are expressed as mean ± standard deviation. An analysis of variance (repeated measures ANOVA) with two classification criteria (type of treatment and shelf life) was first performed on all results during the first nine and a half (9.5) months of storage. It was then supplemented by a one-factor analysis of variance (the type of treatment) for the remainder of the storage period (14.5 and 18 months). Significant differences were revealed by Tukey's test at the 5% level. Finally, Multiple Variance Statistical Analysis (MSA) including Principal Component Analysis (PCA) and Classification Ascending Hierarchy (CAH) Analysis were performed to classify samples with similar behavior on all sensory characteristics during storage.

3. RESULTS AND DISCUSSION

3.1 Results

The results of the hedonic organoleptic analysis of porridges prepared with maize stored for 0; 1; 4.5; 9.5; 14.5 and 18 months are presented in Tables 1, 2 and 3. The sensory parameters of the porridges evaluated were, color, taste, aroma, smell; mouthfeel and overall acceptability. Statistical analysis revealed significant variations (*P*=.001) in these sensory parameters as a function of storage time and conditions. Moreover, the interaction between the two variables has a significant effect (Tables 4 and 5).

3.1-1 Effect of storage on the color of the produced porridges

The average color scores of the different prepared porridges are shown in Tables 1 and 3. The results show that these scores decreased significantly during storage depending on the type of treatment. The color score of the maize porridges recorded at the beginning of storage was 8.08±0.77 (Very pleasant), decreased significantly (*P*=.05) after only 4.5 months of storage to 5.20±0.93 (Neither pleasant nor unpalatable) in the polypropylene control lot. This decrease was slight during the first nine and a half months (9.5) of storage in the triple bagging system without biopesticides. After 9.5 months of storage, the decrease was significant (*P*=.001) and reached an average value of 3.30± 0.89 (unpalatable) at month 18.

On the other hand, the color scores of the porridges obtained from maize grains stored in the triple bagging systems associated with the biopesticides remained statistically identical (*P*=.05) during the 15 months of storage (6.76±0.35). After the 15th month, the color deteriorated to the average score of 6.35±1.03. However, the average score was within the acceptable range for a good quality attribute (6)

3.1.2-Effect of storage on the taste and aroma of porridges produced

Taste and aroma scores dropped significantly (*P*=.05) in the porridges obtained from grains stored in the polypropylene bag (TB0SP control) after 4.5 months of storage, from 7.67 ± 0.92 to 4.48 ± 0.68 and 7.62±0.90 to 5.10 ± 0.77, respectively. In the triple bagging system without biopesticides (TB0P), these scores of 7.67 ± 0.92 and 7.62 ± 0.90 remained virtually stable during the first nine and a half (9.5) months of storage. After 9.5 months, the panelists' scores dropped rapidly to 3.41 ± 0.94 and 3.38 ± 0.88 (unpalatable) for taste and aroma, respectively, after 18 months of storage.

On the other hand, storing maize grains in a triple bagging system with different proportions of biopesticides for 18 months did not significantly affect (*P*=.05) the aroma and taste of the prepared porridges. These sensory attributes were similar throughout the retention period to those of the initial sample (E0) at the initial time (T0) which were 7.67 ± 0.92 and 7.62 ± 0.90, respectively. In triple bagging systems with biopesticides added generally, no significant difference was observed (*P*=.05) for these sensory parameters (Table 1).

3.1.3 Effect of storage on the odour of the porridges produced.

Storage of maize grains also revealed a significant decrease in odor scores of prepared porridges depending on the type of treatment and over time. With a mean odor score of 7.8 ± 1.17 (pleasant) initially, this score droped significantly to 4.60±1.10 in the polypropylene control lot (TB0SP) after only 4.5 months of storage. In the triple bagging system without biopesticides, this sensory parameter did not decrease significantly (*P*=.05) until 9.5 months. After 9.5 months of storage, the odour score dropped significantly to a value of 4.13 ± 0.85 after 18 months. From 0 to 18 months shelf life, in the batches in triple bagging systems with added biopesticides, the odor of the porridges did not show any significant decrease (*P*=.05) over time. The panelists found the odour of the porridges to be pleasant throughout the shelf life.

3.1.4 Effect of storage on the general acceptability of the porridges produced

Sensory data on the general acceptability of maize porridges are presented in Tables 2 and 3. These results show a gradual reduction in the overall acceptability of the porridges as the storage period increased. The general acceptability scores of 7.65±0.5 recorded at the beginning of storage in the porridges decreased significantly (*P*=.05) during the 4.5 months of storage in the polypropylene control lot. The decrease was slight during the first 9.5 months of storage in the triple bagging system without biopesticide. After 9.5 months of storage, the decrease was very significant (*P*=.001) and reached an average value of 3.35±0.89 (unpalatable) at 18 months.

On the other hand, the overall acceptability score recorded in the porridges prepared from maize grains stored in the triple bagging systems associated with the biopesticide remained statistically identical (*P*=.05) during the 18 months of storage (Table 3).

Table 1: Average sensory scores for the organoleptic characteristics of maize porridges prepared with grains preserved according to the different treatments for 0, 1, 4.5 and 9.5 months.

Parameters	Storage time	TB0SP	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
Color	**0**	8.08±0.61 ^{Aa}	8.08±0.61 ^{Aa}	8.08±0.61^{Aa}	8.08±0.61^{Aa}	8.08±0.61 ^{Aa}	8.08±0.61 ^{Aa}	8.08±0.61 ^{Aa}	8.08±0.61 ^{Aa}	8.08±0.61 ^{Aa}	8.08±0.61 ^{Aa}
	1	7.53±1.57^{ABa}	7.80±0.75 ^{Aa}	8.10±0.87 ^{Aa}	7.93±1.06 ^{Aa}	8.23±0.62 ^{Aa}	8.20±0.67 ^{Aa}	8.17±0.87 ^{Aa}	8.10±0.79 ^{Aa}	8.03±1.34 ^{Aa}	7.80±1.17 ^{Aa}
	4.5	5.20±0.93^{Cb}	7.82±0.80 ^{Aa}	7.84±1.12 ^{Aa}	7.87±1.20	8.07±0.82 ^{Aa}	7.97±0.95 ^{Aa}	8.15±0.86 ^{Aa}	7.93±0.77 ^{Aa}	7.93±0.78 ^{Aa}	7.83±0.97 ^{Aa}
	9.5	5.05±0.80^{Cb}	7.90±1.30 ^{Aa}	7.90±1.08 ^{Aa}	7.80±1.15 ^{Aa}	8.02±0.81 ^{Aa}	7.93±0.95 ^{Aa}	8.10±1.08 ^{Aa}	7.73±1.19 ^{Aa}	7.95±0.87 ^{Aa}	7.70±1.97 ^{Aa}
Taste	**0**	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}	7.67±0.9 ^{Aa} 2	7.67±0.92 ^{Aa}	7.67±0.92 ^{Aa}
	1	7.33±0.93 ^{Aa}	7.37±0.92 ^{Aa}	7.77±0.85 ^{Aa}	7.63±1.37 ^{Aa}	7.87±0.99 ^{Aa}	7.77±1.01 ^{Aa}	7.68±0.99 ^{Aa}	7.63±1.23 ^{Aa}	7.53±1.12 ^{Aa}	7.55±1,57 ^{Aa}
	4.5	4.48±0.68^{Bb}	7.34±0.91 ^{Aa}	7.60±0.99 ^{Aa}	7.40±1.08 ^{Aa}	7.78±0.95 ^{Aa}	7.47±0.99 ^{Aa}	7.53±1.30 ^{Aa}	7.37±1.17 ^{Aa}	7.58±1.51 ^{Aa}	7.50±1.17 ^{Aa}
	9.5	4.45±0.62^{Bc}	7.12±0.88^{Bb}	7.70±0.75 ^{Aa}	7.33±1.08 ^{Aa}	7.43±1.06 ^{Aa}	7.37±1.36 ^{Aa}	7.27±1.44	7.30±1.25 ^{Aa}	7.53±0,89 ^{Aa}	7.47±1.24 ^{Aa}
Flavor	**0**	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0.90 ^{Aa}	7.62±0,90 ^{Aa}	7.62±0.90 ^{Aa}
	1	7.50±1.03 ^{Aa}	7.53±1.12 ^{Aa}	7.73±1.12 ^{Aa}	7.60±1.02 ^{Aa}	7.77±1.03 ^{Aa}	7.40±080 ^{Aa}	780±1.05 ^{Aa}	7.50±1.01 ^{Aa}	7.60±1.18 ^{Aa}	7.72±1.10 ^{Aa}
	4.5	5.10±0.77^{Bb}	7.15±0.98 ^{Aa}	7.80±0.80 ^{Aa}	7.52±1.18 ^{Aa}	7.60±1.29 ^{Aa}	7.30±1.28 ^{Aa}	7.37±0.80 ^{Aa}	7.37±1.08 ^{Aa}	7.47±1.32 ^{Aa}	7.67±0.95 ^{Aa}
	9.5	4.75±0.95^{Bc}	7.17±0.98 ^{Bb}	7.78±0.88 ^{Aa}	7.50±1.12 ^{Aa}	7.60±1.29 ^{Aa}	7.30±1.28 ^{Aa}	7.37±0.88 ^{Aa}	7.37±1.08 ^{Aa}	7.47±1.32 ^{Aa}	7.67±0.95 ^{Aa}

The means (± standard deviation) with different lowercase / upper case letters on the same row/in the same column are different in the 5% probability test.TB0SP: control treated without biopesticides in the polypropylene bag, TB0P: triple bagging with 0% biopesticides, TB1: triple bagging with 2.5% biopesticides (0.625 kg *L. multiflora* and 0.625 kg *H. suaveolens*), TB2: triple bagging with 3.99% biopesticides (0.40 kg *L. multiflora* and 1.60 kg *H. suaveolens*), TB3: triple bagging with 3.99% biopesticides (1.60 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB4: triple bagging with 1.01% biopesticides (0.10 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB5: triple bagging with 1.01% biopesticides (0.40 kg *L. multiflora* and 0.10 kg *H. suaveolens*), TB6: triple bagging with 5% biopesticides (1.25 kg *L. multiflora* and 1.25 kg *H. suaveolens*) TB7: triple bagging with 2.5% biopesticides (1.25 kg *L. multiflora*) and TB8: triple bagging with 2.5% biopesticides (1.25 kg *H. suaveolens*)

Table 2: Average sensory scores for the organoleptic characteristics of maize porridges prepared with grains preserved according to the different treatments for 0, 1, 4.5 and 9.5 months.

Parameters	Storage time	TB0SP	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
Smell	**0**	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17 ^{Aa}	7.80±1.17 ^{Aa}
	1	7.77±1.03^{ABa}	7.77±1.24^{Aa}	7.97±1.18^{Aa}	7.80±1.11^{Aa}	8.18±0.77 ^{Aa}	8.07±0.73 ^{Aa}	8.03±0.73 ^{Aa}	7.93±0,82 ^{Aa}	7.87±0.85 ^{Aa}	7.87±1.10 ^{Aa}
	4.5	4.60±1.10^{Bc}	7.72±1.23 ^{Aa}	8.03±1.20 ^{Aa}	8.07±0.97 ^{Aa}	8.07±0.86 ^{Aa}	8.05±0.74 ^{Aa}	7.98±0.79 ^{Aa}	7.63±1.17 ^{Aa}	7.83±1.04 ^{Aa}	7.83±1.25 ^{Aa}
	9.5	4.38±0.68^{Bc}	7.65±1.10 ^{Aa}	7.73±0.77 ^{Aa}	7.70±1.47 ^{Aa}	7.97±1.05 ^{Aa}	8.07±0.82 ^{Aa}	7.97±1.10^{Aa}	7.87±1.08 ^{Aa}	7.87±1.06 ^{Aa}	7.77±0.89 ^{Aa}
Mouthfeel	**0**	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}	7.78±0.66 ^{Aa}
	1	7.57±0.98 ^{Aa}	7.58±1.29 ^{Aa}	7.83±1.19 ^{Aa}	7.77±1.15 ^{Aa}	7.83±1.01 ^{Aa}	7.80±1.01 ^{Aa}	7.75±0.89 ^{Aa}	7.70±1.04 ^{Aa}	7.57±1.44 ^{Aa}	7.78±1.20 ^{Aa}
	4.5	4.58±0.78^{Bb}	7.42±1.21 ^{Aa}	8.15±0.77 ^{Aa}	7.55±1.14 ^{Aa}	7.77±1.15 ^{Aa}	7.80±1.22 ^{Aa}	7.75±0.93 ^{Aa}	7.53±0.92 ^{Aa}	7.70±1.01 ^{Aa}	7.72±1.28 ^{Aa}
	9.5	4.43±0.72^{Bb}	7.37±1.48	7.72±0.99 ^{Aa}	7.50±1.21 ^{Aa}	7.70±1.30 ^{Aa}	7.33±1.28 ^{Aa}	7.63±1.17 ^{Aa}	7.47±1.38 ^{Aa}	7.53±1.12 ^{Aa}	7.68±1.17 ^{Aa}
Overall evaluation	**0**	7.65±0.5 ^{Aa}	7.65±05 ^{Aa}	7.65±0.5 ^{Aa}	7,65±0.5 ^{Aa}	7.65±0.5 ^{Aa}	7.65±0.5 ^{Aa}	7.65±0.5 ^{Aa}	7.65±0.5 ^{Aa}	7.65±0.5 ^{Aa}	7.65±0.5 ^{Aa}
	1	7.50±0.65 ^{Aa}	7.42±1.34 ^{Aa}	7.85±0.89 ^{Aa}	7.70±1.01 ^{Aa}	7.93±0.97 ^{Aa}	7.73±1.04 ^{Aa}	7.83±0.90 ^{Aa}	7.60±1.09 ^{Aa}	8.00±0.78 ^{Aa}	7.80±0.98 ^{Aa}
	4.5	4.40±0.64^{Bb}	7.37±1.43 ^{Aa}	7.57±1.06 ^{Aa}	7.77±1.03 ^{Aa}	7.90±0.95 ^{Aa}	7.80±0.70 ^{Aa}	7.82±0.81 ^{Aa}	7.50±1.10 ^{Aa}	7.77±1.24 ^{Aa}	7.76±0.99 ^{Aa}
	9.5	4.20±0.63^{Bb}	7.35±1.46 ^{Aa}	7.53±1.12 ^{Aa}	7.57±1.15 ^{Aa}	7.87±1.03 ^{Aa}	7.63±1.05 ^{Aa}	7.65±1.08 ^{Aa}	7.36±0.84 ^{Aa}	7.73±0.87 ^{Aa}	7.67±1.14 ^{Aa}

The means (± standard deviation) with different lowercase / upper case letters on the same row/in the same column are different in the 5% probability test.TB0SP: control treated without biopesticides in the polypropylene bag, TB0P: triple bagging with 0% biopesticides, TB1: triple bagging with 2.5% biopesticides (0.625 kg *L. multiflora* and 0.625 kg *H. suaveolens*), TB2: triple bagging with 3.99% biopesticides (0.40 kg *L. multiflora* and 1.60 kg *H. suaveolens*), TB3: triple bagging with 3.99% biopesticides (1.60 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB4: triple bagging with 1.01% biopesticides (0.10 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB5: triple bagging with 1.01% biopesticides (0.40 kg *L. multiflora* and 0.10 kg *H. suaveolens*), TB6: triple bagging with 5% biopesticides (1.25 kg *L. multiflora* and 1.25 kg *H. suaveolens*) TB7: triple bagging with 2.5% biopesticides (1.25 kg *L. multiflora*) and TB8: triple bagging with 2.5% biopesticides (1.25 kg *H. suaveolens*)

Table 3: Average sensory scores for the organoleptic characteristics of maize porridges prepared with grains stored for 14.5 and 18 months according to the different treatments.

Parametres	Storage time	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
Color	**14.5**	3.53±0,89^{C}	6.78±1.07^{A}	6.70±1.02^{A}	6.95±1.63^{A}	6.35±1.03^{AB}	6.72±0.94^{AB}	6.78±1,30^{A}	7.05±1.34^{A}	6.76±1.19^{A}
	18	3.32±0.89^{C}	6.80±0.98^{AB}	6.60±0.96^{AB}	7.03±1.02^{AB}	6.30±1.13^{B}	6.23±1.33^{B}	6.40±1.02^{AB}	6.43±1.55^{AB}	6.46±1.21^{AB}
Taste	**14.5**	3.41±0.94^{C}	6.85±0.95^{A}	6.20±1.08^{A}	6.43±1.37^{A}	6.16±1.42^{B}	6,10±1.41^{B}	6.21±1.15^{A}	6.43±1.09^{A}	6.53±1.57^{A}
	18	3.36±0.86^{C}	6.80±0,87^{A}	6.23±1.09^{B}	6.27±1.21^{B}	6.05±1.39^{B}	5.73±1.21^{B}	6.13±0.81^{B}	6.20±1.17^{B}	6.37±1.41^{B}
Flavor	**14.5**	3.38±0.88^{B}	6.06±1.37^{A}	6.17±1.58^{A}	6.60±0.99^{B}	6.23±1.39^{A}	6.30±1.13^{A}	6.20±1.08^{A}	6.50±1^{A}	6.43±1.24^{A}
	18	3.38±0.84^{B}	6.03±1.30^{A}	6.06±1.51^{A}	6.40±1.26^{A}	5.93±1.24^{A}	6.23±1.29^{A}	6.20±1.02^{A}	6.30±0.90^{A}	6.20±1.17^{A}
Smell	**14.5**	3.42±0.94^{B}	6.47±1.18^{A}	6.60±1.48^{A}	7.00±1.01^{A}	6.80±1.08^{A}	6.57±1.24^{A}	6.63±1.34^{A}	6.63±1.05^{A}	6.53±1.39^{A}
	18	3.30±0.90^{B}	6.40±1.12^{A}	6.36±0.88^{A}	6.43±0.89^{A}	6.76±1.12^{A}	6.46±1.24^{A}	6.40±1.50^{A}	6.57±1.15^{A}	6.50±1.21^{A}
Mouthfeel	**14.5**	3.42±0.94^{B}	6.18±1.25^{A}	6.43±1.18^{A}	6.43±1.15^{A}	6.23±1.44^{A}	6.08±1.60^{A}	6.50±0.89^{A}	6.60±1.23^{A}	6.40±1.34^{A}
	18	330±0.90^{B}	6.30±1.16^{A}	6.27±1.49^{A}	6.30±1.33^{A}	6.10±1.43^{A}	6.10±1.02^{A}	6.07±1.17^{A}	6.36±1.02^{A}	6.13±1.42^{A}
Overall evaluation	**14.5**	3.82±0.77^{C}	6.67±1.23^{A}	6.43±1.37^{A}	6.83±0.96^{A}	6.50±0.89^{AB}	6.03±1.48^{B}	6.53±1.16^{A}	6.70±1.01^{A}	6.33±1.17^{A}
	18	3.63±0.90^{C}	6.47±1.24^{A}	6.33±1.17^{A}	6.63±0.84^{A}	5.97±1.43^{B}	6.10±1.05^{B}	6.37±0.84^{A}	6.60±0.88^{A}	6.30±1.33^{AB}

The means (± standard deviation) with different lowercase / upper case letters on the same row/in the same column are different in the 5% probability test.TB0SP: control treated without biopesticides in the polypropylene bag, TB0P: triple bagging with 0% biopesticides, TB1: triple bagging with 2.5% biopesticides (0.625 kg *L. multiflora* and 0.625 kg *H. suaveolens*), TB2: triple bagging with 3.99% biopesticides (0.40 kg *L. multiflora* and 1.60 kg *H. suaveolens*), TB3: triple bagging with 3.99% biopesticides (1.60 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB4: triple bagging with 1.01% biopesticides (0.10 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB5: triple bagging with 1.01% biopesticides (0.40 kg *L. multiflora* and 0.10 kg *H. suaveolens*), TB6: triple bagging with 5% biopesticides (1.25 kg *L. multiflora* and 1.25 kg *H. suaveolens*) TB7: triple bagging with 2.5% biopesticides (1.25 kg *L. multiflora*) and TB8: triple bagging with 2.5% biopesticides (1.25 kg *H. suaveolens*)

Table 4 : Statistical data of sensory parameters as a function of treatments during the storage period.

SOV	St Pa	PARAMETERS					
		Color	**Taste**	**Flavor**	**Smell**	**Mouthfeel**	**Overall evaluation**
Time	**Df**	2.87	2.78	2.89	2.74	2.74	2.89
	SS	103.53	145.91	82.45	76.57	122.41	87.38
	F	48.73	56.22	27.87	25.72	43.23	42.77
	P	*P=.001*					
Error x time	**Df**	1653.12	1645.41	1708.85	1619.63	1620.99	1705.06
	SS	1695.59	1531.04	1745.15	1756.40	1670.75	1205.40
Methods	**Df**	9					
	SS	516.84	571.64	400.75	667.49	572.59	682.69
	F	58.93	49.73	32.65	51.34	41.40	56.21
	P	*P=.001*					
Error methods	**Df**	590					
	SS	574.93	753.505	804.60	852.30	572.59	796.16
Time x Methods	**Ddl**	25.86	25.10	26.06	24.70	24.72	26
	SS	362.70	471.29	362.89	589.02	516.82	578.21
	F	18.97	20.18	13.63	22.32	20.27	31.44
	P	*P=.001*					

SOV, *source of variation**; Stat Para,** statistical parameters**; Df,** degree of freedom**; SS**, sum of squares**; F**. value of the statistical test**; P**. probability value of the statistical test.*

Note: All commas (,) in the table to be replaced by points (.)

Table 5: Statistical data (ANOVA I) of sensory parameters during conservation treatments

SOV	PA ST			PARAMETERS			
		COLOR	TASTE	FLAVOR	SMELL	MOUTHFEEL	OVERALL EVALUATION
METHODS	DF				8		
	SS	581.97	510	424.07	548.93	456.28	516
	F	55.80	49.15	37.31	53.47	36.29	53.35
	P				*P=.OO1*		
ERROR	DF				531		
	SS	692	688.85	754	681	833	643
TOTAL	DF				539		
	SS	1274.29	1199.98	1178.58	1230	1290.88	1159.97

SOV, source of variation; Stat Para, statistical parameters; Df, degree of freedom; SS, sum of squares; F. value of the statistical test; P. probability value of the statistical test.

3.2 Principal Component Analysis (PCA)

The Principal Component Analysis of the different maize samples was related to the six (6) sensory parameters which allowed to show two (2) axes that best explain the dispersion and distribution of the samples. These 2 axes expressed 98.48% of the total variability observed.

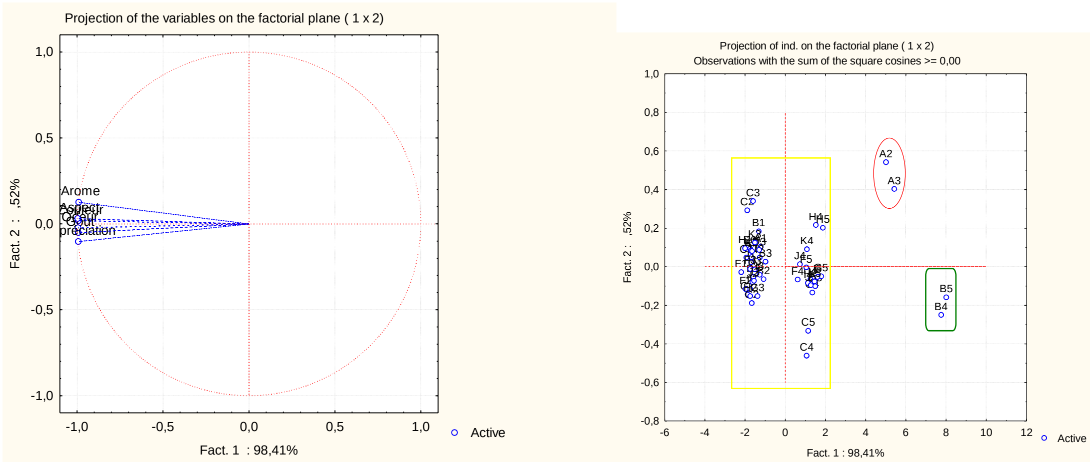
The correlation circle indicated that the organoleptic characteristics studied are strongly and negatively correlated to the F1 axis (Figure 1a). This axis is a good indicator of the sensory quality of the preserved grains. The projection of individuals in the 1-2 design allowed the samples to be divided into three (3) groups (Figure 1b). Group 1 consists of individuals from the polypropylene control lot at 4.5 months and 9.5 months of storage (A2) and (A3). It differs very clearly from other samples by very low sensory scores. The maize samples at the 15th and 18th month of storage (B4) and (B5) of the triple bagging system without biopesticides form group 2. These have low sensory scores. The third group contains all the samples kept in the triple bagging systems with biopesticides throughout the experiment, those from the triple bagging system without biopesticides from 1 to 9.5 months of storage (B1, B2 and B3), the initial sample (E0) at the initial time and those from the polypropylene bag at 1 month of storage (A1). These samples are characterized by high sensory scores.

3.3 Increasing hierarchical classification (CAH)

The hierarchical ascending classification (HAC) established by the Euclidean distance method confirms the variability observed at the PCA level (Figure 2). Indeed, the truncation of the dendrogram at a Euclidean distance of aggregation of 2 reveals three classes observed according to the different treatments (untreated, triple bagging without biopesticides and triple bagging with different proportions of biopesticides) in the shelf life.

The first class consists of samples from the control lot TB0SP at 4.5 and 9.5 months of shelf-life noted A2 and A3, respectively. These individuals are characterized by low scores for all the sensory parameters studied. The second group displays individuals graded B4 and B5 which are respectively TB0P (triple single bagged) samples at 14.5 and 18 months of storage. Individuals in this class stand out from other treatments and mark the limit by which one distinguishes the difference between the two modes of preservation, i.e. the simple triple bagging system and the triple bagging system associated with biopesticides of plant origin (leaves of *L. multiflora* and *H. suaveolens*). The third group consists of the control at 1 month of storage, triple bagging without biopesticides up to 9.5 months of storage and triple bagging with different proportions of biopesticides at different storage times

.



a- Variable projection **b- Projection of the individuals**

Figure 1: Projection of the sensory characteristics (a) and individuals (b) of maize grains in the factorial plane 1-2 of the principal component analysis.

E0: initial sample, A1: polypropylene bag at 1 month, B1: triple bagging without biopesticides at 1 month, C1, D1,E1, F1, G1,H1, I1, J1: triple bagging with 2.5%, 3.99%, 3.99%, 3.99%,1.01%, 1.01%, 1.01%, 5%, 2.5% and 2.5% of biopesticides at 1 month conservation A2 : polypropylene bag at 4.5 months, B2: triple bagging without biopesticides at 4.5 months, C2, D2, E2, E2, F2, G2, H2, I2, J2: triple bagging with 2.5%, 3.99%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticides at 4.5 months storage. B3: triple bagging without biopesticides at 9.5 monthsC3, D3, E3, F3, G3, H3, H3, I3, J3: triple bagging with 2.5%, 3.99%, 3.99%, 3.99%,1.01%,1.01%,1.01%, 5%,2.5% and 2.5% biopesticides at 9.5 months storage. B4: triple bagging without biopesticides at 7 months, C4, D4, E4, E4, F4, G4, H4, I4, J4: triple bagging with 2.5%, 3.99%, 3.99%,1.01%,1.01%,1.01%, 5%.2.5% and 2.5% biopesticides at 14.5 months storage. B5: triple bagging without biopesticides at 18 months, C5, D5, E5, E5, F5, G5, H5, I5, J5: triple bagging with 2.5%, 3.99%, 3.99%, 1.99%,1.01%,1.01%, 5%,2.5% and 2.5% biopesticides at 18 months storage

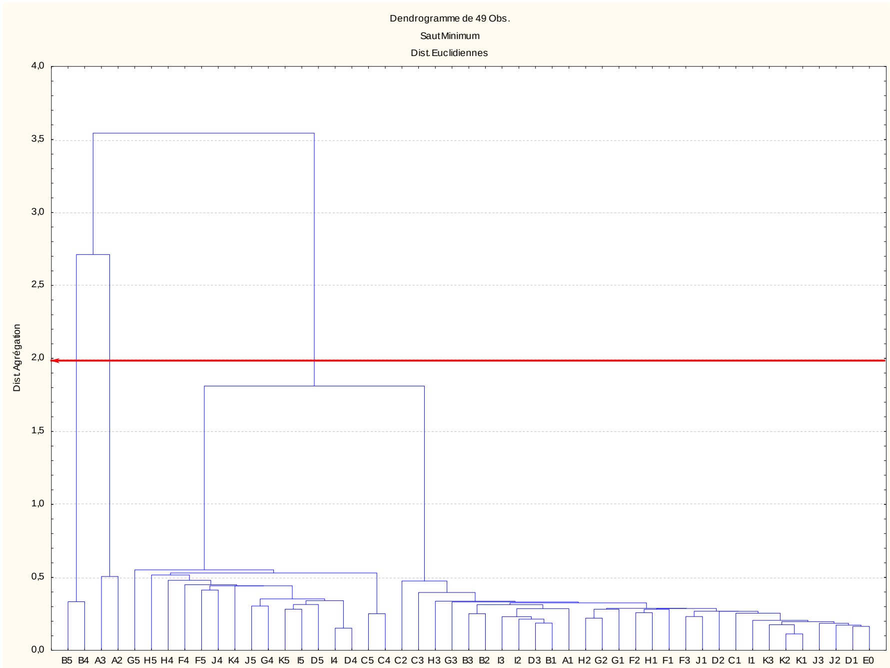


Figure 2:
E0: initial sample, A1: polypropylene bag at 1 month, B1: triple bagging without biopesticides at 1 month, C1, D1,E1, F1, G1,H1, I1, J1: triple bagging with 2.5%, 3.99%, 3.99%, 3.99%,1.01%, 1.01%, 1.01%, 5%, 2.5% and 2.5% of biopesticides at 1 month conservation A2 : polypropylene bag at 4.5 months, B2: triple bagging without biopesticides at 4.5 months, C2, D2, E2, E2, F2, G2, H2, I2, J2: triple bagging with 2.5%, 3.99%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticides at 4.5 months storage. B3: triple bagging without biopesticides at 9.5 monthsC3, D3, E3, F3, G3, H3, H3, I3, J3: triple bagging with 2.5%, 3.99%, 3.99%, 3.99%,1.01%,1.01%,1.01%, 5%,2.5% and 2.5% biopesticides at 9.5 months storage. B4: triple bagging without biopesticides at 7 months, C4, D4, E4, E4, F4, G4, H4, I4, J4: triple bagging with 2.5%, 3.99%, 3.99%,1.01%,1.01%,1.01%, 5%.2.5% and 2.5% biopesticides at 14.5 months storage. B5: triple bagging without biopesticides at 18 months, C5, D5, E5, E5, F5, G5, H5, I5, J5: triple bagging with 2.5%, 3.99%, 3.99%, 1.99%,1.01%,1.01%, 5%,2.5% and 2.5% biopesticides at 18 months storage.

3.2 Discussion

Loss of consumer acceptance is a commonly used criterion for monitoring the shelf life of foods. Often the assessment of shelf life of products stored at room temperature is based on sensory quality [22]. Thus, after 18 months of conservation according to a central composite plan (PCC) with 3 factors, the maize grains were subjected to technological transformations in order to assess the effect of conservation by means of biopesticides on its sensory characteristics. The results of this study showed that the preservation technique using the leaves of *L. multiflora* and *H. suaveolens* is effective in preserving the organoleptic quality of maize grains during storage. Indeed, for all the sensory parameters, the highest scores were recorded in the triple bagging systems added to the *L. multiflora* and *H. suaveolens* leaves compared to the triple bagging system without biopesticides and the control bag (polypropylene) which recorded the lowest sensory scores at the end of storage.

During storage, the drop in color scores observed in the control lot would be due to hydrolysis and oxidation of lipids. In fact, according to Zamora, [23] during storage, free radicals resulting from the oxidation of lipids could react with proteins modifying the color of the porridge during cooking. A protective effect of the sensory properties can be attributed to this conservation technique using leaves. The taste and aroma scores of the prepared porridges decreased significantly after 4.5 months, 9.5 months and 14.5 months for the control, biopesticide-free triple bagging system and biopesticide-treated triple bagging system (*L. multiflora* and *H. suaveolens*), respectively. In addition, all porridges prepared from maize grains preserved with biopesticides scored above 5 on the intensity scale for these sensory parameters evaluated. It is obvious that the triple bagging system associated with biopesticides has made it possible to preserve these different sensory attributes of the porridge. Our results are similar to those of Houinsou and al [24]. The results of the sensory analysis of these authors showed that the use of essential oils significantly influenced the smell and taste of preserved cowpea samples and increased consumer preference.

At the level of the different preservation methods, there are significant differences between the overall acceptability scores obtained, which would indicate that the preservation of maize using biopesticides has a positive effect on the organoleptic characteristics of our samples. However, in terms of averages, a clear variability was reported at between 9.5 and 18 months. This study would indicate that the shelf life has an influence on the various parameters evaluated. According to Niamketchi and al [25], the conservation of agricultural products over a long period of time leads to their deterioration. However, the combined methods of the triple bagging system and biopesticides seem to maintain the organoleptic characteristics of our products. In fact, regardless of the shelf life, the scores obtained for samples stored with biopesticides are significantly higher than those obtained for control samples. These results show that the sensory parameters of the samples preserved using the triple bagging technology and biopesticides were more appreciated than those of the control samples. Thus, this observation makes it possible to affirm that the biopesticides used during this experiment slowed down the various degradation mechanisms such as the oxidation of lipids and the proliferation of insects and fungi likely to cause the alteration of organoleptic characteristics. In fact, Gnandé and al [26] found a stability of lipids in maize grains stored in the triple bagging system with 1.01% biopesticides after 18 months of storage. Several other studies around the world have shown the efficacy of biopesticides [27]. Also, the biological activity (insecticide) of the essential oil of *L. multiflora* has been described by several works [28]. Essential oils of this species have insecticidal activity against insect pests of stored foodstuffs, particularly against *Callosobruchus maculatus* that alter the quality of stored products [29]. In view of these results, *L. multiflora* and *H.*

suaveolens leaves could be considered as natural protection products for maize grains, thus contributing to the improvement of food safety.

In fact, according to Glitho [30], research programs in Africa are interested in the approach of valuing plants in grain stocks to limit post-harvest losses. These plants for food and medicinal uses are therefore an alternative for the conservation of stored foodstuffs and all the more so since they have been classified and recognized as healthy" (Generally Recognized As Safe GRAS., 2002) or approved as food additives.

4 Conclusion

The objective of this study was to propose an alternative solution to the use of chemical pesticides for the conservation of organoleptic parameters to the actors of the maize sector in Côte d'Ivoire and to industrialists using maize. The results obtained confirm the use of triple bagging technology as an adequate solution. In fact, the triple bagging systems made it possible to maintain the organoleptic characteristics (color, taste, odor; mouthfeel and overall appreciation) of the maize over a period of 9.5 months. However, the addition of *L. multiflora* and *H. suaveolens* leaves at a proportion of 1.01% as biopesticides made it possible to maintain the sensory characteristics of the maize for 18 months.

It is therefore recommended that the use of this simple method of storing maize grains be promoted to rural and urban households, maize vendors and food service operators to help extend shelf life, while maintaining the attributes of acceptability, in order to save them time, money and energy on regular maize purchases. For food processors and industrialists using maize, the benefits of this method could be immense as they would be able to process large quantities of maize without incurring too many post-harvest losses, thus increasing their profit margins.

REFERENCES

1-FAOSTAT. Statistical databases on African countries “food commodities” trade, production, consumption, and utilization. *FAO*, Rome, Italy ; 2020.

2-IFDC Training on Storage and Conservation of Agricultural Products. Training manual; 2016. 289p.

3-N'da A, Akanvou L, Kouakou K. Local management of purple maize (Zea mays L.) varietal diversity by the Tagouana in North Central Côte d'Ivoire. International Journal of Biological and Chemical Sciences. 2013;(7): 2058-2068

4-FAOSTAT. Statistical databases on African countries “food commodities” trade, production, consumption, and utilization. *FAO*, Rome, Italy ; 2020.

5-Charcosset A, Gallais A. Emergence and development of the concept of hybrid varieties in maize. Le Sélectionneur Français. 2009; 60: 21-30

6-Deffan KP, Akanvou L, Akanvou R, Nemlin GJ, Kouamé PL. Morphological and nutritional evaluation of local and improved maize (zea mays l.) varieties produced in Côte d'Ivoire Africa science 2015;11(3) 181-196.

7-Waongo A, Yamkoulg M, Dabire-Binso C, Ba M, Sanon A. Post-harvest conservation of cereals in the southern Sudanian zone of Burkina Faso: Peasant perception and stock assessment. International Journal of Biological and Chemical Sciences. 2013; 7(3):1157-1167.

8-Olakojo SA, Akinlosotu TA. Comparative study of maize grain storage methods in south-western Nigeria . African Journal of Biotechnology. 2004;37:362-365.

9-Jayaraj R, Megha P, Sreedev P.Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment, Interdisciplinary Toxicology.2016;9(3):90-100.

10-Aktar w, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards,” Interdisciplinary Toxicology.2009;2(1):1-12.

11-Obeng-Ofori, D. Residual insecticides, inert dusts and botanicals for the protection of durable stored products against pest infestation in developing countries. Julius-Kühn Archiv. 2010; 425:774–788.

12-Mvumi B, Sthaters T. Challenges of grain protection in sub-Saharan Africa: the case of diatomaceous earths.2003Paper presented at: Proceedings of Food Africa Internet-based Forum; March 31-April 11, 2003

13-Konan KC, Coulibaly A, SIdibe D, CHatigre O, Biego GHM. Evolution of Aflatoxins Levels during Storage of Cowpeas (Vigna unguiculata L Walp) Bagged Pics Containing Lippia multiflora Moldenke Leaves and Ivorian Exposure Risk, International Journal of Science and Research.2016;5(7):1-15.

14-Niamketchi. Contribution to the improvement of the quality of maize grain (farmer's environment: quality monitoring during storage using biopesticides (Lippia multiflora suaveolens) in granaries. PhD thesis in Biochemistry and Food Science. Université Félix Houphouët- Boigny, Faculty of Biosciences.2017;276.

15-Ezoua P, Konan KC, Amane D, Coulibaly A, Konan Y, Sidibe D et al. efficacy of *lippia multiflora* (verbenaceae) and *hyptis suaveolens* (lamiaceae) leaves on sanitary quality during the storage of maize grain *(zea mays* l.) from côte d'ivoire, asian journal of biotechnology and bioresource technology 20171(2): 1-15.

16-Yao V, Konan K, Niamketchi G, Aka B, Adama C, Biego H. Evolution of Merchantability during Storage of Maize Triple Bagged Containing Biopesticides (Lippia multiflora and Hyptis suaveolens).European Journal of Nutrition & Food Safety.2019;11(4): 274-283a

17-Yao V, Konan K, Niamketchi G, Aka B, Adama C, Biego H. Evolution of Merchantability during Storage of Maize Triple Bagged Containing Biopesticides (Lippia multiflora and Hyptis suaveolens).European Journal of Nutrition & Food Safety.2019;11(4): 274-283b.

18-Yao V, Konan K, Niamketchi G, Aka B, Adama C, Biego H. Evolution of Merchantability during Storage of Maize Triple Bagged Containing Biopesticides (Lippia multiflora and Hyptis suaveolens).European Journal of Nutrition & Food Safety.2019;11(4): 274-283c.

19- Soro S, Konan G, Elleingand E, N'guessan D, Koffi E. Formulation d'aliments infantiles à base de farines d'igname enrichies au soja. 2013 ;13 (5) :8313-8339. French.

20-Daudin, D., Mathematical technique for the food industry". Collection Science et Techniques agroalimentaire. Edition Lavoisier 500p, 2002.

21-Meilgaard M, Civille GV, Carr BT. Sensory Evaluation Techniques. 3dr Edition.CRC Press, Boca Raton. p281.

22-Kilcast D, Sensory analysis for food and beverage quality control: a practical guide. Woodhead Publishing Limited, Cambridge; 2010

23-Zamora R, Hidalgo FC. Coordinate Contribution of Lipid Oxidation and Maillard Reaction to the Nonenzymatic Food Browning, Critical Reviews in Food Science and Nutrition. 2005; 45(1):49-59

24-Houinsou R, Adjou ES, Dahouenon Ahoussi E, Sohounhloué DC, Soumanou MM.. Biochemical and sensory characteristics of cowpea (Vigna unguiculata) preserved using essential oils extracted from plants of the Myrtaceae family International Journal of Innovation and Applied Studied. 2014 ; 9(1):428-437.

25-Niamketchi L., Biego G. H., Chatigre O., Didier A., Emmanuel K. & Augustin A. Optimization of Post-Harvest Maize Storage using Biopesticides in Granaries in Rural Environment of Côte d'Ivoire. International Journal of Science and Research.2016;4 (9) :1727-1736

26-Gnadé R, Kouamé O, Fofana I.Conservation of Minéral elements in maize grains by a triple bagging system and biopesticide (Lippia multiflora Modenke and Hyptis suaveolens Poit leaves).Asian journal of Agriculture and food Sciences. 2020; 8(3):1571-2321

27-Doumma A, Alfari BY, Sembène M. Toxicity and persistence of Boscia senegalensis Lam. (Ex Poir.) (Capparaceae) leaves on Callosobruchus maculatus Fab. (Coleoptera: Bruchidae). Int J Biol Chem Sci. 2011;5:1562–1570.

28-Sanon A, Ba NM, Dabiré-Binso LC, Niébié RCH, Monge,JP. Side effects of grain protectants on biological control agents: how Hyptis plant extract effect parasitism and larval development of Dinarmus basalis 2011, 39:215-222.

29-Ilboudo Z, Dabiré LCB, Niébé RCH, Dicko IO, Dugravot S, Costesero AM et al. Biological activity and persistence of four essential oils towards the main pest of stored cowpeas, Callosobruchus maculatus F. (Coleoptera: Bruchidae). Journal of Stored Products Research. 2010; 46: 124-128.

30-Glitho A. Post-harvest and biopesticides in Africa. In Regnault-Roger C, Philogene BJR, Vincent, C, edithor. Biopesticide d'origine Vegetale liter edition. Paris: Lavoisier ; 2005.