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Hedonic Sensory Quality of Maize Grains Conserved by A Triple Bagging and Biopesticides System (Leaves of *Lippia multiflora* Moldenke and *Hyptis suaveolens* Poit)

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Authors' contributions

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

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ABSTRACT

In Côte d'Ivoire, inefficient storage Practices which can be dangerous to consumers' safety and to the environment are hampering the widespread availability of cereals, especially maize. Thus, a triple bagged system with or without plant biopesticides (Lippia multiflora and Hyptis suaveolens leaves) was used in this study to determine its effectiveness in preserving the hedonic sensory qualities of the grains for a period of 18 months under a 3-factor central composite design (CCD).

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The first CCD 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 a control lot with a polypropylene bag (NT) and 9 experimental lots, one of which was triple bagged without biopesticides (MGT1 and the other eight (8) lots containing varying proportions and/or combinations of biopesticides (MGT2 to MGT9). Finally, the third factor concerned the combination of the two biopesticides with the percentage (%) of *Lippia multiflora* as 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 (NT) were considered unpalatable by the panelists after only 4.5 months of storage with respect to these sensory parameters evaluated. The results of the PCA and CAH analysis showed that the incorporation of at a minimum of 1.01% biopesticides (*Lippia multiflora* and *Hyptis suaveolens* leaves) in the triple bagging systems made the conservation better and maintained the organoleptic properties of the maize grains throughout the 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]. It occupies a place of choice in agricultural activities, in the diet of the Ivorian population, constituting the staple food of many Ivorian populations and represents 68% of the total national cereal production [5]. Grains are used in many forms and in the manufacture of many 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 control these stock pests, farmers often have to use synthetic pesticides that, when misused, can lead to pest resistance and 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] reported considerable differences in the market and health properties of corn stored in granaries for 6 months with *Lippia multiflora* and *Hyptis suaveolens* leaves. Ezoua [15] examined the commercial and health properties of maize kernels kept in polypropylene bags whith biopesticides (*L. multiflora* and *H. suaveolens*) for 8 months and reported these maize kernels remained within international standards during the first 6 months of storage.

Moreover, the effectiveness of triple packaging equipment, whether or not it is associated 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. MATERIALS AND METHODS

2.1 Maize Used in the Study

Dried maize kernels of the improved variety GMRP-18 yellow morphotype were collected at different periods of the triple bag preservation process associated with the biopesticides *L. multiflora* and *H. suaveolens)* as operated by Yao [17]. As a reminder, this method of maize grain preserving was carried out with a CCD (central composite design). It was developed by a mixture of a ratio of ground leaf litter with a defined amount of maize grain. This is an alternating superposition of maize kernels and sheets of L. multiflora and H. suaveolens so as to obtain the sheets below and on the face of the bags covering the kernels. In all nine (9) test plots and one control plot were set up as described below: NT control processed free of biopesticides in the polypropylene pack, MGT1 tri-bagged with 0% biopesticides, MGT2 tri-bagged with 2.5% biopesticides (0.625 kg of L. multiflora and 0.625 kg of H. suaveolens), MGT3 tri-bagged with 3. 99% biopesticides (0.40 kg of L. multiflora and 1.60 kg of H. suaveolens), MGT4 in three bags with 3.99% biopesticides (1.60 kg of L. multiflora and 0.40 kg of H. suaveolens), MGT5 in three bags with 1. 01% biopesticides (0.10 kg of L. multiflora and 0.40 kg of H. suaveolens), MGT6 tri-bagged with 1.01% biopesticides (i.e. 0.40 kg of L. multiflora and 0.10 kg of H. suaveolens), MGT7 tri-bagged with 5% biopesticides (1. 25 kg of L. multiflora and 1.25 kg of H. suaveolens), MGT8 triple bagged with 2.5% biopesticide (1.25 kg of L. multiflora), and MGT8 triple bagged with 2.5% biopesticide (1.25 kg of H. suaveolens). The study was conducted over 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 farmers in the Gbêkê region (7º50 North and 5º18 West in central Côte d'Ivoire). Before storage, the maize was sun-dried for 2-3 days and then used for the study. The leaves of *L. multiflora* and *H. suaveolens* were left to dry at an approximate room temperature of 30ºC for 6-7 days, away from direct sunlight. The selected dried leaves were minced into fine fragments for use in the study [18].

The samples for were taken at the time periods during which they were stored: In month T0, immediately after procurement and before storage; then in months T1, T4.5, T9.5, T14.5 and T18. These samples were collected in triplicate. The different times were based on the central composite design (CCD). Consequently, 5 kg maize was collected from every sack in different levels.

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. Analysis of Variance (repeated measures ANOVA) with two categorical criteria (processing type and duration of storage) was first conducted 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. Lastly, a multiple variance statistical analysis (MSA) consisting of a principal component analysis (PCA) and a bottom-up classification hierarchy analysis (CAH) was conducted to rank the samples with like performance 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.

3.1.1 Effect of storage on the color of the produced porridges

The average colour scores of the different Porridges prepared are presented in Tables 1 and 3. The results show that these scores decreased significantly during storage as a function of the treatment method. 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.

In contrast, the color scores of Porridges obtained from corn kernels stored in the triple bagging systems combined with biopesticides were statistically similar *(P*=.05) during the 15 months of storage (6.76±0.35). After the 15th month, the color deteriorated to a mean score of 6.35±1.03. However, the mean score was within the acceptable level for a good quality indicator (6).

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

Taste and aroma scores dropped significantly *(P*=.05) in Porridges obtained from grains packed in the polypropylene bag (NT control) at 4.5 months after storage, from 7.67 ± 0.92 to 4.48 ± 0.68 and from 7.62 ± 0.90 to 5.10 ± 0.77 respectively. In the Triple Bagged Biopesticide Free system, these scores stayed almost stable during the first nine and a half (9.5) months of storage at 7.67 ± 0.92 and 7.62 ± 0.90. After 9.5

months, panelists' scores dropped quickly to 3.41 ± 0.94 and 3.38 ± 0.88 (unpalatable) for taste and aroma, after 18 months of storage only.

Moreover, 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 bagged 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 odor of the porridges produced

Storage of the maize grains showed a significant reduction in the odor scores of the prepared Porridges according to process type and over time. Initially, the average odor score was 7.8 ± 1.17 (pleasant), but after only 4.5 months of treatment, this score dropped significantly to 4.60±1.10 in the polypropylene control (NT). In the triple bagged system without biopesticides, this sensory parameter did not decrease significantly (*P*=.05) until 9.5 months. After 9.5 months of storage, the odor score decreased significantly to a value of 4.13 ± 0.85 after 18 months. From 0 to 18 months of storage, in the batches in the triple bag system with the addition of biopesticides, odor of Porridges did not show a significant decrease (*P*=.05) over time. The panelists found the smell of the porridges 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.

In contrast, the overall acceptability score recorded in Porridges prepared from maize grain placed in triple bagging operations with the biopesticide remained significantly unchanged (*P*=.05) over the 18 months of storage. (Table 3).

3.2 Principal Component Analysis (PCA)

The principal analysis of the various maize samples was related to the six sensory parameters, which revealed two axes that best explain the dispersion and distribution of the samples. These two axes represented 98.48% of the total variability observed.

The results of the analysis show a strong and negative correlation between the organoleptic characteristics studied and the F1 axis (Fig. 1a). This axis is a strong measure of the sensory quality of preserved grains. By projecting the individuals in plane 1-2, the samples were divided into three (3) categories (Fig. 1b). The first group is made up of individuals from the polypropylene batch control at 4.5 months and 9.5 months of conservation (NTT2) and (NTT3). It is clearly distinguished from the other samples with very low sensory scores. The maize samples at 15 and 18 months of storage (MGT1T4) and (MGT1T5) from the triple bag storage method without biopesticides form group 2. They have low sensory scores. Group 3 includes all samples stored in the three bag methods using biopesticides during the entire experiment, the samples from the three systems without biopesticides from 1 to 9.5 months of storage (MGT1T1, MGT1T2 and MGT1T3), the initial sample (E0) at the initial time and these samples from the polypropylene bag at 1 month of storage (NTT1). These samples show elevated sensory scores.

3.3 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 study showed that the technique of storage with the leaves of *L. multiflora* and *H. suaveolens* is effective in

Table 1. Average sensory notes of the organoleptic characteristics of maize Porridges produced using grains conserved in the different processes for 0, 1, 4.5 and 9.5 months

sensorial attributes	Storage time	NT	MGT1	MGT2	MGT3	MGT4	MGT5	MGT6	MGT7	MGT8	MGT9
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}

By column and row, averages with the same letters are statistically identical. Lower case letters are representative of rows and upper case letters are representative of columns. NT: processed maize grains without leaves in a polypropylene bag, MGT1: triple bag with 0% leaves, MGT2: triple bag with 2.5% leaves (0.625 kg L. multiflora and 0.625 kg H. suaveolens), MGT3: triple bag with 3.99% leaves (0.40 kg L. multiflora and 1.60 kg H. suaveolens), MGT4: triple bag with 3.99% leaves (1.60 kg L. multiflora and 0.40 kg H. suaveolens), MGT5: triple bag with 1.01% leaves (0.10 kg L. multiflora and 0.40 kg H. suaveolens), MGT6: triple bag with 1.01% leaves (0.40 kg L. multiflora and 0.10 kg H. suaveolens), MGT7: triple bag with 5% leaves (1. 25 kg L. multiflora and 1.25 kg H. suaveolens), MGT8: triple bag with 2.5% leaves (1.25 kg L. multiflora) and MGT9: triple bag with 2.5% leaves (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

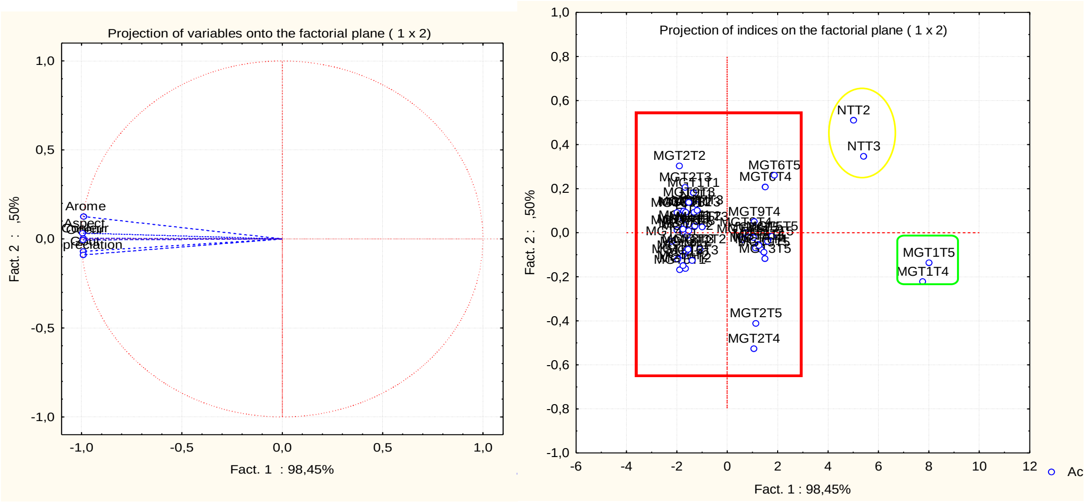
sensorial attributes	Storage time	NT	MGT1	MGT2	MGT3	MGT4	MGT5	MGT6	MGT7	MGT8	MGT9
Smell	**0**	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17^{Aa}	7.80±1.17 ^{Aa}	7.80±1.17 ^{Aa}
	1	7.77±1.03^{ABa}	7.77±1.24^{Aa}	7.97±1.18^{Aa}	7.80±1.11^{Aa}	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}

By column and row, averages with the same letters are statistically identical. Lower case letters are representative of rows and upper case letters are representative of columns. NT: processed maize grains without leaves in a polypropylene bag, MGT1: triple bag with 0% leaves, MGT2: triple bag with 2.5% leaves (0.625 kg L. multiflora and 0.625 kg H. suaveolens), MGT3: triple bag with 3.99% leaves (0.40 kg L. multiflora and 1.60 kg H. suaveolens), MGT4: triple bag with 3.99% leaves (1.60 kg L. multiflora and 0.40 kg H. suaveolens), MGT5: triple bag with 1.01% leaves (0.10 kg L. multiflora and 0.40 kg H. suaveolens), MGT6: triple bag with 1.01% leaves (0.40 kg L. multiflora and 0.10 kg H. suaveolens), MGT7: triple bag with 5% leaves (1. 25 kg L. multiflora and 1.25 kg H. suaveolens), MGT8: triple bag with 2.5% leaves (1.25 kg L. multiflora) and MGT9: triple bag with 2.5% leaves (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

sensorial attributes	Storage time	MGT1	MGT2	MGT3	MGT4	MGT5	MGT6	MGT7	MGT8	MGT9
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}
	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}
Taste	**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	3.30±0.80^{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	**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}
evaluation	**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}

By column and row, averages with the same letters are statistically identical. Lower case letters are representative of rows and upper case letters are representative of columns. NT: processed maize grains without leaves in a polypropylene bag, MGT1: triple bag with 0% leaves, MGT2: triple bag with 2.5% leaves (0.625 kg L. multiflora and 0.625 kg H. suaveolens), MGT3: triple bag with 3.99% leaves (0.40 kg L. multiflora and 1.60 kg H. suaveolens), MGT4: triple bag with 3.99% leaves (1.60 kg L. multiflora and 0.40 kg H. suaveolens), MGT5: triple bag with 1.01% leaves (0.10 kg L. multiflora and 0.40 kg H. suaveolens), MGT6: triple bag with 1.01% leaves (0.40 kg L. multiflora and 0.10 kg H. suaveolens), MGT7: triple bag with 5% leaves (1. 25 kg L. multiflora and 1.25 kg H. suaveolens), MGT8: triple bag with 2.5% leaves (1.25 kg L. multiflora) and MGT9: triple bag with 2.5% leaves (1.25 kg H. suaveolens).



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

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

preserving the organoleptic quality of maize grains during storage. In fact, on all sensory parameters, the high scores were registered in the triple bag systems with the addition of L. multiflora and H. suaveolens leaves as opposed to the triple bag system without biopesticides and the control bag (polypropylene) that registered the highest sensory scores at the end of the 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 research was to provide an appropriate response to the use of pesticides for the storage of organoleptic parameters to the corn industry in Côte d'Ivoire and to industrialists using corn. The results indicate that triple packaging systems are an appropriate solution. The triple packaging systems were able to maintain the sensory qualities (colour, taste, smell, mouthfeel and overall appreciation) of the maize for a duration of 9.5 months. However, the addition of *L. multiflora and H. suaveolens* leaves at 1.01% as biopesticides maintained the sensory characteristics of maize for 18 months.

Therefore, the triple bagged system using *Lippia multiflora leaves and H. suaveolens* as biopesticide can be used alternatively by the food industry to prolong the sensory stability of the grains. This simple and less expensive technology offers biodegradable product protection that reduces the costs of synthetic preservatives, making it a safer and natural preservative for human health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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