SENSORY STABILITY OF MAIZE GRAINS PRESERVED BY A TRIPLE PACKING SYSTEM AND BIOPESTICIDES (LEAVES OF *LIPPIA MULTIFLORA* MOLDENKE AND *HYPTIS SUAVEOLENS* POIT)

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ABSTRACT

The aim of this study was to evaluate the sensory stability of maize grains preserved in a triple bagging system with or without plant biopesticides (leaves of Lippia multiflora and Hyptissuaveolens), using a three-factor central composite design (CCD).
The first factor of the CCP consisted of six periods. The second factor was the type of treatment. Finally, the third factor concerned the combination of the two biopesticides with the percentage of Lippia multiflora as a reference.
The samples were stored at room temperature for 18 months and periodically removed from storage for descriptive sensory analysis. All samples showed significant differences in sensory attributes initially and after storage. Intensity scores for negative sensory attributes such as musty and rancid aromas and acidic and astringent flavors increased during storage. After 18 months of storage, samples stored in a triple bagging system without biopesticides showed the highest intensity scores for rancid, moldy, acidic, and astringent flavors. These scores were 7.33±0.35; 6±1.67; 3.57±1.15; 4.38±1.57 respectively. However, samples preserved in triple bagging systems with biopesticides showed the lowest intensity scores for these negative attributes (4.5±0.8; 3.2±0.6; 2.18±1.73 and 1.96±0.67, respectively). In addition, the intensity scores for color, sweetness, and corn aroma decreased for all samples. Samples stored in triple bagging systems showed the smallest decrease at the end of storage for these positive attributes (5.67±1.21 for color, 5.66±1.5 for sweetness, and 5.25±1.47 for corn aroma).

Keywords: Stored maize; biopesticides;descriptive sensory analysis; triple bagging.

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1. INTRODUCTION

Maize (*Zea mays* L.) is an important and widely grown cereal crop worldwide [1]**.** In addition to being a staple food crop in sub-Saharan Africa, maize is also used for industrial purposes and animal feed, Human food also [2]**.** In Côte d'Ivoire, maize is the second most important cereal crop after rice [3][4]. 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 [5]. Maize grains provide about 15% of the energy needs of the Ivorian population and therefore constitute the most energetic cereal of these populations [6]**.**
Maize growing in Côte d'Ivoire is mainly done in the Poro, Hambol, Folon, Worodougou and Bagoué regions where the temperature is relatively high; this favours insect infestation [7]. In addition, the largest proportion of maize is produced by resource-poor farmers in remote villages. They store maize using systems that facilitate high post-harvest losses [8].
Insects are the main cause of loss of stored maize grains and represent a major obstacle to maintaining food security [9]. The work of Ezoua[10] reported 64.78±0.02% damaged kernels and 58.85±0.03% weight loss due to insect pests in maize stored in polypropylene

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bags during six months. Niamketchi[11] found 86.96±8.50% and 91.1±3.5% insect damage to cobs and grains, respectively, in maize stored in farmers' traditional granaries for 6-8 months in the Poro region. Hendrik and De Boer[12] reported 37% insect losses in maize in Ethiopia, based on self-reported post-harvest losses.

Faced with the threat posed by these insects, some farmers sell their maize early at a very low price to avoid the losses mentioned above. Others treat their crops with non-organic pesticides of unproven efficacy [13] whose widespread use causes severe environmental pollution, affects human health and results in the death of non-target organisms [14][15]**.** Therefore, the promotion of non-toxic substances to prevent these non-organic molecules from being used on stored products is required.

In recent years, various attempts have been made in Côte d'Ivoire to offer maize producers appropriate methods of controlling these pests. Promising results have been obtained that are safer for the environment and human health. The work of Niamketchi [16] showed significant changes in the market and health qualities of maize after 6 months of storage in granaries in the presence of *Lippia multiflora* and *Hyptis suaveolens* leaves. Ezoua[17] studied the evolution of market and sanitary qualities of maize grain stored in polypropylene bags in the presence of the same leaves for 8 months and obtained that its qualities (market and sanitary) remain in conformity with international standards during the first 6 months of storage, contrary to the control without these leaves which resists only for 3 months.

Furthermore, the effectiveness of triple bagging systems associated or not with *Lippia multiflora* and *Hyptis suaveolens* leaves on market and sanitary quality has been highlighted by recent studies of maize grain storage in Côte d'Ivoire [18]. It should be noted that *Lippia multiflora* and *Hyptis 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 life cycle of insect pests of maize could make them biopesticides.

These numerous research studies have confirmed the preservation of the marketability and hygienic qualities of maize using biopesticides. They have not addressed the impact of this preservation on the organoleptic quality of the treated food. It is to fill this scientific gap that the present study was conducted to assess the sensory stability of maize grains stored in the presence of *L. multiflora and H. suaveolens* leaves, as conducted by Yao[19]

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2. MATERIAL AND METHODS

2.1Maize used in the study

Dry maize grains of the improved variety GMRP-18 of yellow morphotype were collected at different periods of the triple bagging conservation process associated with the biopesticides *Lippiamultiflora and Hyptis suaveolens*) as operated by Yao[20]. As a reminder, this maize grain conservation methodology was implemented using a central composite design (CCD). It is based on mixing a proportion of crushed dried leaves with a defined amount of maize grains. It is an alternating layering of maize grains and leaves of *Lippia multiflora* and *Hyptis suaveolens* so that the leaves on the bottom and surface of the bags cover the grains. A total of nine (9) experimental batches and one control batch were formed as follows: WB control treated without biopesticides in the polypropylene bag, TS0 triple bagged with 0% biopesticides, TS1 triple bagged with 2.5% biopesticides (0.625 kg of *L. multiflora* and 0.625

kg of *H. suaveolens*), TS2 triple bagged with 3.99% biopesticides (0.40 kg *of L. multiflora* and 1.60 kg of *H. suaveolens*), TS3 triple bagged with 3.99% biopesticides (1.60 kg of *L. multiflora* and 0.40 kg of *H. suaveolens*), TS4 triple bagged with 1.01% biopesticides (0.10 kg of *L. multiflora* and 0.40 kg of *H. suaveolens*), TS5 triple bagged with 1.01% biopesticides (0.40 kg of *L. multiflora* and 0.10 kg *of H. suaveolens*), TS6 triple bagged with 5% biopesticides (1.25 kg of *L. multiflora* and 1.25 kg of *H. suaveolens*), TS7 triple bagged with 2.5% biopesticides (1.25 kg of *L. multiflora*), and TS8 triple bagged with 2.5% biopesticides (1.25 kg of *H. suaveolens*) The experiment lasted 18 months.

Thus, at different periods of storage, the maize grains collected underwent technological transformations leading to a flour and a meal submitted to the appreciation of the panelists. To this end, and taking into account the culinary habits of the populations, the grains were transformed into porridges.

2.2 Collecting Samples

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Maize grains and leaves of L. multiflora and H. suaveolenswere 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.

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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.

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2 2.1 Maize meal 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 wooden mortar and pestle. The crushed beans were winnowed to remove the husks. The pulped grains were washed and soaked for ten (10) hours. Finally, the grains were drained, ground with a Moulinex and sieved with a 200 micron diameter sieve. The different flours obtained were used to make the different porridges.

2.2.2 Preparation of the porridges

Preliminary tests with tasters led to the decision to cook 10 g of flour in 100 mL of tap water. This quantity took into account the fluidity of the porridge. The cooking time was eight minutes on low heat and sugar was not added at the end of the cooking time. The porridges were cooled at room temperature in the preparation room to 50 °C before being served.

2.3 Descriptive sensory analysis

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The detailed sensory evaluation of the maize porridge samples was carried out by implementing quantitative descriptive analysis (QDA) according to a procedure described by Stone [21]. This method has been chosen as a widely used method for the evaluation of different food products providing information on the whole product profile, which can be easily analysed as well as presented statistically and graphically [22] [23].

❖ **Selection of panelists**

Twenty (20) healthy volunteers with experience in sensory analysis were recruited from among the students of the Biochemistry and Food Science Laboratory by means of flyers and email. Potential panelists were selected according to the following criteria:
a) People with natural dentition;
b) People without food allergies,
c) Non-smokers,
d) People who consume maize and/or maize products at least once a month
e) People who are available for all sessions.
A written consent form explaining all detailed information about the study was presented and signed by all participants. Members were free to withdraw from the study at any time. Monetary incentives were offered to all participants to compensate for their time.

The selection process was based on the methodology described by Stone[24]. Panelists completed the basic taste recognition test. Chemically pure solutions of basic tastes were used for this phase: sweet (2% sucrose), sour (0.07% citric acid), salty (0.2% sodium chloride) and bitter (0.07% caffeine). Panelists received 25 ml of each solution in disposable plastic cups coded with random three-digit numbers. Eighteen (18) subjects who responded correctly to at least 70% of the test sets were selected as panelists for the descriptive analysis. Two panelists were eliminated from the study during the screening period due to poor performance and lack of availability

❖ **Training session.**

All selected panelists were introduced to quantitative descriptive analysis (QDA) in order to familiarize them with the methodology. The selected panelists were trained in 20 sessions (one session per day), which took place four (4) days a week for five (5) weeks. The average duration of a session per day was one hour. During these training sessions the panelists carried out the development of descriptors, during which they evaluated samples of maize cooked in slurry form. The sessions took place in the laboratory of biochemistry and food science of the University Félix HOUPHOUËT-BOIGNY of Cocody (Côte d'Ivoire) in an air-conditioned environment under artificial lighting. Panelists were spaced at least 2 m apart to avoid any interaction. During the training sessions, the panelists defined the lexicon of nine (09) sensory descriptors as well as specific and unambiguous definitions. A continuous unstructured scale of 10 cm length with the left end corresponding to the lowest intensity (value 0) and the right end to the highest intensity (value 10). The definitions of all descriptors and their reference standards that were determined by consensus among the panel members are listed in **Table I**.(**APPENDIX)**

❖ **Calibration and performance of panelists**

Before doing the main test, the people on the panel watched how well they did by looking at their test results. Additional training was provided to panelists whose performance differed from that of the entire group. Training continued until panelists showed reliable and consistent performance. To control for panelist performance, an analysis of variance was conducted for each panelist and each attribute. Finally, fifteen people were chosen to take part in the final session. They were selected because they were good at figuring out what was different and could do it again and again using the information they learned during the training session. Sample preparation and presentation. The oatmeal was cooked by adding 10 g of flour to 100 mL of tap water. The cooking time was eight minutes on low heat. The oatmeal was cooled to about 50 °C before serving. Individual samples of each type of maize oatmeal (weighing about 15 g) were placed in odorless, transparent plastic cans (125 mL) with lids to evenly contain the flavors in the sample headspace. The samples were evaluated at the laboratory of biochemistry and food science of the University Félix HOUPHOUËT-BOIGNY (Côte d'Ivoire). Each panelist received 10 g of samples in disposable plastic cups coded with random three-digit numbers, paper towels and mineral water for palate cleansing between tastings were provided.

2.4 Statistical Analysis

Statistical analyses of the data were carried out using SPSS (version 22.0) and STATISTICA (version 7.1) software. All tests for the sensory analyses 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 carried out on all results during the first nine and a half (9.5) months of storage. It was then completed by a one-factor analysis of variance (the type of treatment) for the rest of the storage period (14.5 and 18 months). Significant differences were highlighted by the Tukey test at the 5% level. Finally, multiple variance statistical analyses (MVA) including Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were performed to classify samples with similar behavior on all sensory characteristics during storage.

3. RESULTS AND DISCUSSION

3.1 Results

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The sensory characteristics of all the maize samples studied are presented in Tables II, III, IV and V. It should be noted that the sensory parameters of the maize grains from the different batches showed significant variation (~~P~~p=.05) over time and according to the preservation method used.

Regarding color, the score 7.97±0.15 given by the panel at the beginning of the storage period dropped significantly (p~~P~~ =.05) to 5.10 ± 0.61 in the control lot in polypropylene bags after 4.5 months of storage (Tables II and V), and then to 7.56 ±0.35 in 9.5 months in the triple bagged system without biopesticides. However, in the triple bagging systems with the addition of biopesticides, the color score of the Porridges produced does not vary in 15 months of storage.

Corn flavor is the sensory characteristic of this product. Significant changes (~~P~~p=.05) in the intensity indices for aroma were observed for different storage periods and for each treatment. A strong decrease in the score of this sensory attribute was observed during the storage period in the polypropylene control batch (p~~P~~ =.05) in contrast to the triple bagging systems without biopesticides and the triple bagging systems with different proportions of biopesticides. For the polypropylene control, the sensory scores recorded at the first month of storage 8.6± 0.67 decreased rapidly to 5.74 ± 0.57 after 4.5 months while in the triple bagged system without biopesticide, the score for this sensory attribute remained constant until 9.5 months of storage.

Similarly, with an initial score of 8.03 ± 0.30 at the beginning of storage (month 0), the sweetness of the Porridges produced drops rapidly and significantly (p~~P~~ =.05) in the polypropylene control, showing the lowest scores (4.55±0.56) at only 4.5 months of storage. However, these sensory scores remained constant during the storage period in the triple bagging system with or without biopesticide until 9.5 months of storage. On the other hand, a significant difference was observed between the sweetness of slurries produced with corn kernels stored in the triple bagging system without biopesticides and those stored in the triple bagging systems with different proportions of biopesticides. Within the triple bagged system with biopesticide, significant differences were observed between the slurries of grains preserved with 1.01% biopesticide and those of grains preserved with 2.5%; 3.99% and 5% biopesticide.

Concerning the rancid smell, we observed an increase in the scores attributed to this sensory descriptor during the storage period. Significant differences were detected between samples stored for different periods and/or different treatments. Samples stored in a triple bagging system with or without biopesticide were significantly different from control samples. The control lots showed the highest rancidity scores after only 4.5 months of storage (3.98±0.13). In the triple bagging system without biopesticide the rancid odor was only detected by the panelists after 9.5 months. In the triple bagging system with different proportions of biopesticides, this unpleasant odor was only perceptible from 14.5 months with a low score (1.30 ± 0.2). There was a significant difference between the scores of the porridges produced with maize grains stored in the triple bagging system without biopesticides and that of the grains stored in the triple bagging systems with different proportions of biopesticides. In the triple bagging system with biopesticide, there was a significant difference between the porridge scores of grains preserved with 1.01% biopesticide and those of grains preserved with 2.5%, 3.99% and 5% biopesticide.

As for the acidic taste, from a total absence at the beginning of storage, the highest scores were recorded after 4.5 months in the polypropylene control batch (3.10 ±0.62). The scores for this sensory degradation indicator remained very low (value) after 9.5 months of storage in the triple bagging systems without biopesticide. Significant differences ($P < 0.05$) were observed between the slurries from grains stored in the triple bagging system without biopesticides and those from grains stored in the triple bagging systems with biopesticides. Also, within the triple biopesticide bagging system, differences were observed between the slurries of grains preserved with 1.01% biopesticide 3.12±1.2 and those of grains treated with 2.5%, 3.99% and 5% biopesticides 1.67±0. 78.

The sensations of astringency and aftertaste increased significantly (P =.05) in the porridges obtained from the grains stored in the polypropylene bag (WB control) after 4.5 months of storage (from 00±0 to 5.60±0.81). In the triple bagged system without biopesticides (TB0P), these sensations remained almost stable during the first nine and a half (9.5) months of storage (00±00 to 0.32±0.05) and from 00±00 to 0.26±0.045 for aftertaste and acidic taste respectively. After 9.5 months, the panelists' scores escalated rapidly to 4.38±1.57 and 3.36±1.5 for astringency and aftertaste, respectively, by the eighteenth month of storage. In contrast, storage of maize grains in a triple bagging system with different proportions of biopesticides for 18 months did not develop any astringent taste or aftertaste (P =.05). For the porridges produced with the grains stored in the triple bagging systems with added biopesticides, these attributes were similar throughout the storage period to those of the initial sample (E0), i.e. at the initial time (T0). For these two sensory descriptors, no significant difference is observed (P=.05) in the triple bagging system with biopesticides (Table V).

As for the herbaceous aroma, mainly associated with the aroma of the lippia plant, no significant difference (pP=.05) was observed between the samples without biopesticides and those treated with biopesticides up to 14.5 months of storage. After 14.5 months of storage, a significant difference (pP =.05) was found between the herbaceous aroma contents of the slurry from the grains stored in the triple bagging system without biopesticides and those stored in the triple bagging systems combined with biopesticides. Similarly, in the triple bagging system, the slurry from grains preserved with 1.01% biopesticide differed from those from grains treated with 2.5%, 3.99% and 5% biopesticides.

Table II: Intensity scores for sensory attributes evaluated in porridges prepared from maize grains stored for 9.5 months by a panel of trained judges.

PARAMETERS	Storage period	WB	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8
COLOR	0	7.97±0.15^{Aa}	7.97±0.15^{Aa}	7.97±0.15^{Aa}	7.97±0.15^{Aa}	7.97±015^{Aa}	7.97±015^{Aa}	7.97±015^{Aa}	7.97±015^{Aa}	7.97±015^{Aa}	7.97±0,15^{Aa}
	1	7.53±0.12^{Aa}	7.63±0.22^{Aa}	7.84±0.36^{Aa}	7.80±0.37 ^{Aa}	7.66±0.3 ^{Aa}	7.83±0.62 ^{Aa}	7.59±0.58 ^{Aa}	7.98±0.37 ^{Aa}	7.84±0.77 ^{Aa}	7.85±0.47 ^{Aa}
	4.5	5.10±0.61^{Bb}	7.50±0.35 ^{Aa}	7.77±0.75 ^{Aa}	7.74±0.45 ^{Aa}	7.66±0.92 ^{Aa}	7.36±0.61 ^{Aa}	7.52±0.63 ^{Aa}	7.80±0.47 ^{Aa}	7.74±0.70 ^{Aa}	7.80±0.54 ^{Aa}
	9.5	4,6±0.46^{Bb}	7.56±0.35^{Bb}	7.65±0.70 ^{Aa}	7.62±0.51 ^{Aa}	7.56±0.55 ^{Aa}	7.50±0.35 ^{Aa}	7.62±0.55 ^{Aa}	7.75±0.63 ^{Aa}	7.58±0.48 ^{Aa}	7.55±0.67 ^{Aa}
MAIZE FLAVOR	0	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}	8.72±0.58^{Aa}
	1	8.23±0.43^{Aa}	8.23±0.43 ^{Aa}	8.20±0.36 ^{Aa}	8.50±0.37 ^{Aa}	8.26±0.35 ^{Aa}	8.33±0.61 ^{Aa}	8.29±0.58 ^{Aa}	8.68±0.37 ^{Aa}	8.54±0.77 ^{Aa}	8.55±0.47 ^{Aa}
	4.5	5.74±0.57^{Bb}	8.14±0.65^{Ba}	8.21±0.74 ^{Aa}	8.38±0.43 ^{Aa}	8.10±0.91^{Ba}	8.02±0.45^{Ba}	8.16±0.61^{Ba}	8.44±0.48^{Ba}	8.38±0.70^{Aa}	8.44±0.54^{Aa}
	9.5	5.24±0.47^{Cb}	5.56±0.24^{Cc}	6.70±0.75^{Cb}	7.96±0.51^{Ba}	6.64±0.53^{Cb}	6.95±0.37^{Cb}	7.06±0.55^{Bb}	7.96±0.62^{Ba}	7.06±0.48^{Bb}	6.88±0.66^{Bb}
SWEETNESS	0	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}	8.03±0.57^{Aa}
	1	7.54±0.42^{Aa}	7.65±0.45^{Aa}	7.56±0.35 ^{Aa}	7.60±0.51 ^{Aa}	7.60±0.33 ^{Aa}	7.69±0.60 ^{Aa}	7.60±0.55 ^{Aa}	8.01±0.35 ^{Aa}	7.89±0.76 ^{Aa}	7.87±0.45 ^{Aa}
	4.5	5.05±0,56^{Bb}	7.60±0.51^{Aa}	7.58±0.72 ^{Aa}	7.71±0.42 ^{Aa}	7.45±0.92 ^{Aa}	7.69±0.60 ^{Aa}	7.60±0.55 ^{Aa}	8.01±0.35 ^{Aa}	7.89±0.76 ^{Aa}	7.87±0.45 ^{Aa}
	9.5	4.55±0.50^{Bb}	7.30±0.39 ^{Bb}	7.54±0.52 ^{Aa}	7.69±0.52 ^{Aa}	7.59±0.56 ^{Aa}	7.60±0.51 ^{Aa}	7.51±0.52 ^{Aa}	7.70±0.63 ^{Aa}	7.73±0.48 ^{Aa}	7.71±0.65 ^{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. WB: treated control without biopesticides in the polypropylene bag, TS0: triple bagging with 0% biopesticides, TS1: triple bagging with 2.5% biopesticides (0.625 kg of L. multiflora and 0.625 kg of H. suaveolens), TS2: triple bagging with 3.99% biopesticides (0.40 kg of L. multiflora and 1.60 kg of H. suaveolens), TS3: triple bagging with 3.99% biopesticides (1.60 kg of L. multiflora and 0.40 kg of H. suaveolens), TS4: triple bagging with 1.01% biopesticides (0.10 kg of L. multiflora and 0.40 kg of H. suaveolens), TS5: triple bagging with 1.01% biopesticides (0.40 kg of L. multiflora and 0.10 kg of H. suaveolens), TB6: triple bagged with 5% biopesticides (1.25 kg of L. multiflora and 1.25 kg of H. suaveolens) TS7: triple bagged with 2.5% biopesticides (1.25 kg of L. multiflora) and TS8: triple bagged with 2.5% biopesticides (1.25 kg of H. suaveolens).

Table III: Intensity scores for sensory attributes evaluated in porridges prepared from maize grains stored for 9.5 months by a panel of trained judges.

PARAMETERS	Storage duration	WB	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8
MUSTYFLAVOR	**0**	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}
	1	0.50±0.14^{Ba}	0.11±0.19^{Aa}	0.11±0.19^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}
	4.5	1.68±0.30^{Db}	1.30±0.39^{Ca}	0.11±0.19^{Aa}	1.00±0.0b^{Aa}	1.00±0.53^{Ba}	1.10±0,46^{Bb}	1.13±0.47^{Bb}	0.57±0.24^{Aa}	1.07±0.56^{Bb}	1.10±0.50^{Bb}
	9.5	4.07±0.56^{Cc}	2.90±0.36^{Cc}	0.83±0.64^{ABa}	1.72±0.23^{Ac}	1.65±0.22^{Ac}	1.68±0.25^{Bc}	1.71±0.45^{Bc}	0.66±0.23^{Bc}	1.76±0.40^{Bc}	1.76±0.24^{Bc}
ASTRINGENT	**0**	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}	00 ±00 ^{Aa}
	1	0.06±0.25^{Aa}	0.13±0.35^{Aa}	0.06±0.25^{Aa}	0.06±0.25^{Aa}	0.06±0.25^{Aa}	0.13±0.35^{Aa}	0.06±0.25^{Aa}	0.13±0.35^{Aa}	0.13±0.51^{Aa}	0.13±0.35^{Aa}
	4.5	1.89±0.89^{Bb}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}	0.00±0.00^{Aa}
	9.5	5.60±0.81^{Cc}	0.32±0.50^{Bb}	0.19±0.36^{Ab}	0.14±0.32^{Ab}	0.18±0.33^{Ab}	0.21±0.44^{Ab}	0.20±0.42^{Ab}	0.16±0.35^{Ab}	0.18±0.33^{Ab}	0.19±0.31^{Ab}
RANCE	**0**	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}
	1	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}	0.00 ±0.00^{Aa}
	4.5	3.98±0.13^{Bb}	0.66±0.13^{Aa}	0.34±0.13 ^{Aa}	0.34±0.13 ^{Aa}	0.40±0.13 ^{Aa}	0.55±0.13^{Bb}	0.60±0.13^{Bb}	0.38±0.13^{Bb}	0,55±0.13^{Bb}	0.55±0.13^{Bb}
	9.5	5.03±0.16^{Cc}	3.80±0.16^{Cc}	1.00±0.16^{Bb}	1,10±0.16^{Bb}	0.90±0.16^{Bb}	1.13±0.16^{Bb}	1.60±0.16^{Bb}	0.86±0.16^{Bb}	1.90±0.16^{Bb}	1.90±0.16^{Bb}

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. WB: treated control without biopesticides in the polypropylene bag, TS0: triple bagging with 0% biopesticides, TS1: triple bagging with 2.5% biopesticides (0.625 kg of L. multiflora and 0.625 kg of H. suaveolens), TS2: triple bagging with 3.99% biopesticides (0.40 kg of L. multiflora and 1.60 kg of H. suaveolens), TS3: triple bagging with 3.99% biopesticides (1.60 kg of L. multiflora and 0.40 kg of H. suaveolens), TS4: triple bagging with 1.01% biopesticides (0.10 kg of L. multiflora and 0.40 kg of H. suaveolens), TS5: triple bagging with 1.01% biopesticides (0.40 kg of L. multiflora and 0.10 kg of H. suaveolens), TB6: triple bagged with 5% biopesticides (1.25 kg of L. multiflora and 1.25 kg of H. suaveolens) TS7: triple bagged with 2.5% biopesticides (1.25 kg of L. multiflora) and TS8: triple bagged with 2.5% biopesticides (1.25 kg of H. suaveolens).

Table IV: Intensity scores for sensory attributes evaluated in porridges prepared from maize grains stored for 9.5 months by a panel of trained judges.

PARAMETERS	Storage duration	WB	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8
AFTERTASTE	**0**	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	1	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{A}a	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	4,5	3.2±0.24^{Bb}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	9.5	5.30±^{Dc}	2.92±0.13^{Cb}	0.24±0.39 ^{Aa}	0.13±0.11 ^{Aa}	0.28±0.40 ^{Aa}	1.12±0.2 ^{Aa}	1.30±0.42 ^{Aa}	0.16±0.35 ^{Aa}	0.25±0.43 ^{Aa}	0.27±0.15 ^{Aa}
ACID FLAVOUR	**0**	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{A}a	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	1	0,1±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	4.5	3.10±0.62^{Bb}	0.26±0.45 ^{Aa}	0.18±0.33 ^{Aa}	0.24±0.39 ^{Aa}	0.13±0.35 ^{Aa}	0.31±0.57 ^{Aa}	0.30±0.53 ^{Aa}	0.15±0.33 ^{Aa}	0.31±057 ^{Aa}	0.32±0.61 ^{Aa}
	9.5	5.00±0.73^{Bb}	0.24±0.57 ^{Aa}	0.16±0.36 ^{Aa}	0.2±0.44 ^{Aa}	0.20±0.56 ^{Aa}	0.27±0.59 ^{Aa}	0.44±0.66 ^{Aa}	0.18±0.44 ^{Aa}	0.23±0.49 ^{Aa}	0.25±0.57 ^{Aa}
LIPPIA AROME	**0**	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	1	0.1±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}	00±00 ^{Aa}
	4.5	3.10±0.62^{Bb}	0.26±0.45 ^{Aa}	0.18±0.33 ^{Aa}	0.24±0.39 ^{Aa}	0.13±0.35 ^{Aa}	0.31±0.57 ^{Aa}	0.30±0.53 ^{Aa}	0.15±0.33 ^{Aa}	0.31±0.57 ^{Aa}	0.32±0.61 ^{Aa}
	9.5	5.00±0.73^{Bb}	0.24±0.57 ^{Aa}	0.16±0.36 ^{Aa}	0.2±0.44 ^{Aa}	0.20±0.56 ^{Aa}	0.27±0.59 ^{Aa}	0.44±0.66 ^{Aa}	0.18±0.44 ^{Aa}	0.23±0.49 ^{Aa}	0.25±0.57 ^{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. WB: treated control without biopesticides in the polypropylene bag, TS0: triple bagging with 0% biopesticides, TS1: triple bagging with 2.5% biopesticides (0.625 kg of L. multiflora and 0.625 kg of H. suaveolens), TS2: triple bagging with 3.99% biopesticides (0.40 kg of L. multiflora and 1.60 kg of H. suaveolens), TS3: triple bagging with 3.99% biopesticides (1.60 kg of L. multiflora and 0.40 kg of H. suaveolens), TS4: triple bagging with 1.01% biopesticides (0.10 kg of L. multiflora and 0.40 kg of H. suaveolens), TS5: triple bagging with 1.01% biopesticides (0.40 kg of L. multiflora and 0.10 kg of H. suaveolens), TB6: triple bagged with 5% biopesticides (1.25 kg of L. multiflora and 1.25 kg of H. suaveolens) TS7: triple bagged with 2.5% biopesticides (1.25 kg of L. multiflora) and TS8: triple bagged with 2.5% biopesticides (1.25 kg of H. suaveolens).

Table V: Intensity scores for sensory attributes evaluated in porridges prepared from maize grains stored for 15 and 18 months by a panel of trained judges.

PARAMETERS	Storage duration	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8
COLOR	**14,5**	4.54±0.94^{d}	5.7±0.5^{ab}	6.96±0.97^{ab}	5.82±1.04^{c}	4.5±0.97^{d}	5.94±1.05^{d}	7.2±0.75^{a}	5.23±1.06^{bc}	5.34±1.11^{bc}
	18	3.1±1.11^{d}	5.67±1.21^{c}	6.7±0.68^{c}	6.5±1^{c}	5.7±0.90^{d}	6.5±0.75^{d}	7.78±0.79^{a}	5.98±1.2^{c}	6±1.01b^{c}
MAIZE FLAVOR	**14,5**	4,66±0.7^{d}	7.46±0.44^{a}	7.53±2.46^{ab}	7.46±0.74^{abc}	5.85±0.87^{d}	5.82±1.05^{d}	7.18±0.46^{b}	6.32±0.68^{c}	6.46±0.36^{bcd}
	18	4,17±0.98^{c}	7.05±0.42^{a}	7.1±1.10^{a}	6.8±0.65^{a}	4.62±2.2^{b}	4.76±2.08^{b}	4.45±0.72^{b}	6.04±0.62^{b}	6.56±0.37^{b}
SUGAR FLAVOUR	**14,5**	3.05±0.48^{b}	6.32±1.49^{a}	4.8±2.8^{ab}	5.8±1.25^{ab}	4.26±2.13^{b}	5.2±2.13^{b}	6.32±1.38^{a}	6.09±2.09^{a}	6.32±2.10^{a}
	18	3,66±0.37^{b}	6.97±0.66^{a}	4.45ab±0.88	4.54±0.71^{ab}	4.73±0.69^{b}	5.2±1.80^{b}	5.3±2.01^{a}	4.92±1.98^{ab}	5.1±1.67^{ab}
LIPPIA FLAVOR	**14,5**	0±00^{a}	1.26±1.86^{ab}	1.31±2.27^{ab}	1.49±1.71^{ab}	0.93±1,64^{ab}	1.02±1.79^{ab}	0.74±1.16^{ab}	0.93±1.01^{ab}	1.21±1.28^{ab}
	18	0±00^{a}	1.30±1.96^{ab}	1.86±1.73b^{ab}	1.58±1.9^{ab}	1.12±1.69^{ab}	1.21±2.17^{ab}	1.4±2.04^{ab}	1.21±1.16^{ab}	1.49±1.53^{ab}
AFTERTASTE	**14,5**	3.27±1.14^{b}	1.4±2.04^{a}	1.68±2,19^{a}	0.37±0.64^{a}	1.4±1.58^{b}	1.35±2.12^{b}	0.56±1.15^{a}	1.33±1.63^{b}	0.56±0,70^{b}
	18	3.36±1.15^{a}	1.86±2.73^{b}	2.42±2.36^{ab}	0.56±0.70^{ab}	2.92±1.02^{ab}	1.58±1.74^{ab}	1.3±1.79^{ab}	1.69±1.09^{ab}	1.12±1.69^{ab}
RANCE	**14,5**	7.13±0.35^{d}	2.96±0.64^{b}	2.7±0.56^{b}	1.18±0.75^{a}	3.8±0.75^{c}	3.9±0.84^{c}	3.82±0.78^{c}	2.97±0.71^{b}	2.77±0.67^{b}
	18	7.33±0.35^{c}	4.5±0.80^{ab}	4.68±0.83^{ab}	3.97±0.92^{ab}	5.23±1.20^{b}	5.5±1.28^{c}	4.28±0.87^{c}	4.18±1.1^{b}	4.35±0.89^{b}
ASTRINGENCE	**14,5**	3.37±1.7^{b}	1.96±0.69^{a}	1.66±1.15^{a}	0.56±1.15^{a}	2.42±1.5^{a}	1.96±1.83^{a}	1.96±1.74^{a}	1.77±1.29^{a}	1.58±1.29^{a}
	18	4.38±1.57^{b}	1.95±0.69^{ab}	1.76±0.77^{ab}	2.15±0.87^{ab}	1.92±0.79^{ab}	2.12±0.55^{ab}	2.04±0.70^{a}	2.11±0.57^{b}	2.1±2.10±^{ab}
ACID	**14,5**	3.56±1.17^{b}	1.7±1.6^{a}	1.98±1.19^{a}	0.67±0.64^{a}	1.7±1.58^{a}	1.7±1.42^{a}	0.86±115^{a}	1.63±1.63^{ab}	0.86±0.70^{a}
	18	3.57±1.15^{b}	2.06±2.73^{ab}	2.72±1.36^{ab}	0.86±0.70^{ab}	3.12±1.02^{b}	1.88±1.74^{b}	1.5±1.79^{ab}	1.99±1.09^{ab}	1.42±1.68^{ab}
MOULDY	**14,5**	497±2.08^{d}	1.63±1.68^{ab}	2.13±1.24^{ab}	2±0.81^{ab}	3.33±1.33^{c}	3.25±1.45^{bc}	1.21±^{ab}	1.02±1.23^{a}	2.9±2.41^{ab}
	18	6±1.67^{d}	3.3±0.69^{abc}	3.64±2.58^{bc}	1.3±1.34^{ab}	4.83±2.8^{cd}	3.38±1.86^{bc}	2.9±1,70^{a}	3.04±1.22^{ab}	3.54±0.89^{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.

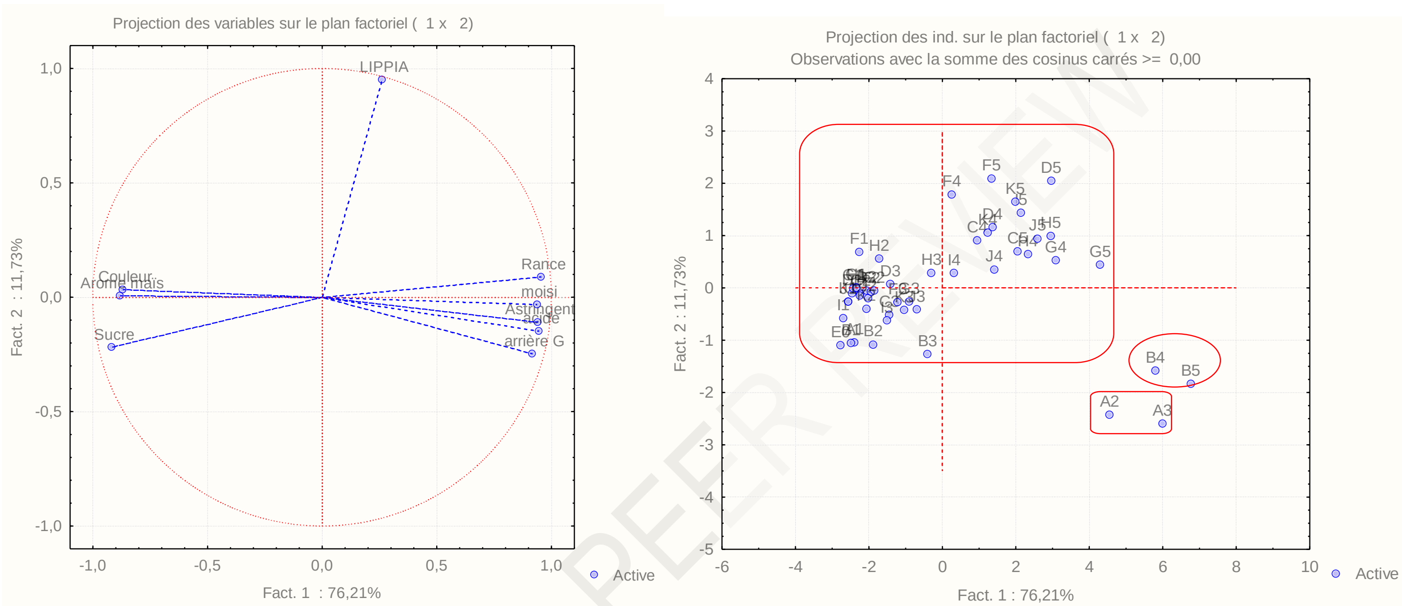
3.2 Correlations between sensory parameters (PCA)

3.2.1 Principal Component Analysis (PCA)

A principal component analysis was used to characterize the retained maize samples because of their sensory properties (Figure 1). The F1 and F2 axes characterized the different treatments evaluated during storage. These axes contributed 87.94% of the observed variation. The descriptors uniform color, corn aroma, and sweetness were strongly and negatively correlated with the F1 axis (Figure 1a). This axis allowed us to divide the individuals into three (3) groups (Figure 1b). Group 1 is made up of individuals A2 and A3, the polypropylene control batch, respectively, after 4.5 months of storage (A2) and 9.5 months of storage (A3). These individuals are characterized by low values for sensory parameters such as color uniformity, corn aroma, and sweetness and high scores for sensory degradation descriptors such as rancid odor, moldy aroma, astringent taste, and aftertaste. This result of the principal component analysis (PCA) indicates that slurries prepared with maize grains stored in a polypropylene bag develop a higher degree of sensory quality deterioration. The samples of slurry from maize grains from the triple bagging system without biopesticides at 14.5 and 18 months of storage (B4 and B5) form the second group. The values of their sensory characteristics studied are higher than those of the sensory characteristics of individuals A3, but lower than the values of the parameters of the other individuals. The third group contains all samples from the triple bagging system with biopesticides during the entire storage period, the triple bagging system without biopesticides from 1 to 9.5 months (B1, B2, and B3), and the polypropylene control lot at 1 and 2 months of storage (A1 and A2). The samples were placed separately in different groups because of their different performance during storage. The protective effect of the triple bagging system alone was less effective than the triple bagging system combined with biopesticides.

3.2.2 Hierarchical Ascending Classification (HAC)

A hierarchical, ascending classification of the maize samples was performed. The results are presented in Figure 2. The dendrogram analysis revealed that there are indeed three (3) classes of stored maize samples at a Euclidean distance of 66. Indeed, the first class consists of individuals A2 and A3, namely the polypropylene control lot at 4.5 months of storage (A2) and 9.5 months of storage (A3), respectively, with lower sensory scores for positive sensory attributes. The second class contains individuals from the triple bagging system without biopesticides at the fourth and fifth months of storage (B4) and (B5). The samples in this class have sensory properties similar to those of the first class. The third group includes all the samples from the triple bagging systems with different amounts of biopesticides, and those from the triple bagging systems without biopesticides for 1 to 9.5 months. The first sample is called E0, and the second sample is called A1. These are distinguished by high sensory scores for positive sensory descriptors and very low values for descriptors indicating sensory degradation..



a- Projection of variables **b- Projection of individuals**

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

E0: initial sample, A1: polypropylene bag at 1 month, B1: triple bagging without biopesticide at 1 month, C1, D1, E1, F1, G1H1I1J1: triple bagging with 2.5%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticide at 1 month of storage A2: polypropylene bag at 4.5 months, B2: triple bagging without biopesticide at 4.5 months, C2, D2, E2, F2, G2, H2, I2, J2: triple bagging with 2.5%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticide at 4.5 months shelf life. A3: polypropylene bag at 9.5 months, B3: triple bagging without biopesticide at 9.5 monthsC3, D3, E3, F3, G3, H3, I3, J3: triple bagging with 2.5%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticide at 9.5 months. B4: triple bagging without biopesticide at 7 months, C4, D4, E4, F4, G4, H4, I4, J4: triple bagging with 2.5%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticide at 14.5 months. B5: triple bagging without biopesticide at 18 months, C5, D5, E5, F5, G5, H5, I5, J5: triple bagging with 2.5%, 3.99%, 3.99%, 1.01%, 1.01%, 5%, 2.5% and 2.5% biopesticide at 18 months.

Comment [u6]: Adjust tested variable names for the English language

3.3 Discussion

Sensory properties are the most direct assessment of the quality of food products during prolonged storage in the environment to which the products would be exposed in their final application [25]. Thus, after eighteen months of storage under a 3-factor central composite design (CCD), maize kernels were subjected to technological transformations to assess the sensory stability of the grains during a storage period. The results of this study show that the technology using Lippia multiflora and Hyptis suaveolens leaves is effective in preserving the organoleptic quality of maize grains during storage. Indeed, for all the undesirable sensory parameters, the lowest scores were recorded in the triple bagging systems with the addition of Lippia multiflora and H. suaveolens leaves compared to the triple bagging system without biopesticide and the control bag (polypropylene) which recorded the highest sensory scores at the end of storage.

During storage, the decrease in color scores observed in the control batch would be due to hydrolysis and oxidation of the lipids. Indeed, according to Zamora [26], during storage, free radicals from lipid oxidation could react with proteins to modify the color of the porridge during cooking. Similarly, after 9.5 months of storage in a triple bagging system, discolorations of the slurry produced were observed. This color change in this storage system is believed to be due to the enhanced Millard reactions. Indeed, the intense metabolic activity of stock pests following the perforation of polythene bags promotes heat production and oxygen penetration into the grains [27] [28]. Thus, high temperatures activate enzymes present in the grains, promoting reactions between oxygen and phenolic substrates such as aromatic amino acids. These reactions lead to the formation of brown compounds such as melanins, melanoidins modifying the color of the slurry produced [29]. However, the preservation technology using triple bagging systems associated with Lippia multiflora and H. suaveolens shows higher color scores than batches in triple bagging systems without biopesticide and polypropylene bag. This suggests that the addition of biopesticide (Lippia multiflora and H. suaveolens leaves) helps to maintain the natural color of the slurries produced over a long storage period.

The maize aroma is the characteristic sensory attribute of this product. Significant changes ($p<0.05$) in the intensity indices for this sensory descriptor were observed for different storage periods and for each treatment. A strong decrease in the score of this sensory attribute was observed during the storage period in the polypropylene control batch ($P < 0.05$) in contrast to the triple bagging system without biopesticide and the triple bagging systems with different proportions of biopesticides. Indeed, the sensory quality of maize can be affected during post-harvest storage by changes in the profile of volatile organic compounds. These volatile organic compounds play an important role in the sensory perception of food, having a major impact on the appreciation and acceptance of food by consumers [30]. It is evident that the addition of biopesticide to the triple bagging system helped to preserve this sensory attribute throughout storage.

Sweetness is a basic sensory attribute in a food product. Our study shows that the intensity indices of this parameter decreased during storage. This decrease was lower in the samples of slurry made from grains stored in a triple bagging system than in the control and triple bagging batches without biopesticide. Sweetness is directly related to the sugar content of a food product. Die [31] reported that storage of maize grains in polypropylene bags and the triple bagging system resulted in a significant (pP<0.05) decrease in total sugar content. These authors mentioned that the sugar content drops from a value of 2.62±0.07% to 1.30±0.01% and 1.77±0.01% respectively for TB0SP and TB0P which are the batches not treated with biopesticide. This decrease in sweetness in the triple single bagging system would be due to the Maillard reaction. Indeed, Maillard reactions, involving food proteins and reducing sugars, are one of the dominant chemical reactions occurring during heat treatment or prolonged storage of foods.

Rancid aroma is an undesirable sensory characteristic that can affect consumer opinion and reduce the acceptability score of a foodstuff [32]. In our study, we observed an increase in the scores for this parameter during the storage period for all treatments. Significant differences were detected between samples stored for different periods. Slurry samples produced with grains stored in a triple bagging system with different proportions of biopesticides were significantly different from control samples and samples stored in a triple bagging system without biopesticide at the storage time of 4.5 and 9.5 months respectively. The control samples had the highest oxidized value (3.98±0.13) at 4.5 months of storage, followed by the samples kept in a triple bagging system without biopesticide (3.80±0.16), while the samples in the triple bagging system had the lowest score (1.3±0.62). These results suggest that the leaves may prevent lipid oxidation and rancid aroma formation. Indeed, the more pronounced rancid aroma in the control samples could be attributed to hydrolytic reactions of triglycerides and oxidation reactions of unsaturated fatty acids. In the presence of lipoxygenase and oxygen, unsaturated fatty acids form peroxides [33]. Through the action of hydroperoxidelyase, these lead to the formation of hexanal and low molecular weight acid isomers responsible for rancidity [34]. During storage, analysis of the results showed no significant difference (pP=.05) for acidic Flavour scores in the triple bagged systems with added biopesticides compared to the triple bagged batch without biopesticide and the polypropylene control batch. This undesirable sensory attribute is noticeable in the control and triple bagged lot without biopesticide at 4.5 months and 10 months of storage respectively. This increase in the acidic Flavour score of the slurries produced could be attributed to an increasing concentration of pythic acids and phosphate thus resulting in increased deterioration of the grains by microorganisms and associated metabolisms during storage [35] [36]. In addition, enhanced Maillard reactions are other possible causes of increased grain acidity during storage [37] [38]. The inhibitory effect of acid flavour development in triple bagging systems without biopesticides is thought to be due to the low oxygen levels in these systems. Indeed, during maize storage, the low oxygen levels in triple bagging systems prevent the proliferation of insect pests in the grains, leading to a cessation of their feeding activities and therefore contribute to reduce their damage, thus slowing down the development of acidity in the grains by ricocheting in the slurry produced [39] [40] [41].

Astringency and aftertaste intensities increased over longer storage periods. In triple bagging systems without biopesticides, slurries produced with grains stored for up to 9.5 months showed no aftertaste or astringency. This preservation is thought to be due to the low oxygen levels in these systems. On the other hand, the significant increase in the levels of these two undesirable descriptors after 9.5 months in the triple bagging system without biopesticide and in the control after 4.5 months of storage could be explained by the increased metabolic activities of insect populations. Indeed, the bitter taste and astringency observed would be linked to the conversion of isoflavones glucosides into aglycones [42]. These authors, in their work on the conservation of soybeans, reported the conversion of approximately 97% of the glycosides into their aglycone forms after 9 months of storage. Okubo [43] established a relationship between the presence of aglycones and the development of bitterness and astringency.

During storage, the gradual increase in the moldy aroma of maize grains depends on the type of treatment and the length of storage. This undesirable sensory attribute is more pronounced in the control and triple bagging system without biopesticide compared to the triple bagging system with biopesticide. This observation could be explained by the fact that the polypropylene bag is less airtight and therefore conducive to greater infestation by stock pests. Furthermore, the good conservation of maize grains is also a function of their moisture content, insofar as a high moisture content causes a significant degradation of the grains [44] [45]. The work of Die [46] on maize grain storage indicates a progressive increase in the moisture content of maize grains stored in polypropylene bags and triple bagging systems, thus favoring the activity of insects and microorganisms responsible for the moldy aroma of the grains.

4 CONCLUSION

The aim of the work carried out in this study was to evaluate the sensory stability of maize grains after their preservation in a triple bagging system with *L. multiflora* and *H. suaveolens* leaves. To achieve this, maize grains were subjected to technological transformations to assess the effect of preservation with biopesticides on sensory characteristics.
The results obtained indicated that preserved maize grains develop differently depending on the treatment method. The storage time and the treatment significantly ($p = 0.05$) influence its sensory quality during storage.
Indeed, triple bagging systems maintained sensory qualities by maintaining higher intensity of sweetness, cooked maize aroma and color uniformity of the porridges produced during storage while lowering the intensity values of rancid, moldy, astringent and aftertaste aromas during the first nine months of storage. However, from the ninth and a half month of storage onwards, only the triple bagging systems containing *L. multiflora* and *H. suaveolens* leaves retained the sensory characteristics of the grains better over an 18 month storage period. Therefore, the triple bagging system using *Lippia multiflora* and *H. suaveolens* leaves as a biopesticide can be used alternatively by the food industry to prolong the sensory stability of grains. This simple and less expensive technology offers products a biodegradable protection that reduces the costs of synthetic preservatives, making it a safer and natural preservative for human health.

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APPENDIX

Table I: Attributes, definitions and references used for the descriptive quantitative analysis of slurries from maize grains stored under different conditions

Descriptors	Definitions	References
Appearance -Uniform colour	Intensity of yellow colour of maize	**high level** : Yellow colour of cooked maize **low-level** : Brown colour
Aroma/Smell Characteristic(of maize)	verall intensity of aroma of cooked maize grains	**high level :** Newly cooked maize grains **low-level :** Maize grains stored for 6 months and cooked
-Herbaceous aroma	The intensity of the aroma was associated with Lippia multiflora	**high level:** Lippia green tea. **low-level**: Distilled water
(moldy)	Characteristic smell of damp wood or something mouldy.	**high level:** Moldy maize grain **low-level :** Newly cooked maize grain
-Rance	he intensity of the smell is associated with old frying oil	**high level**: two drops of maize oil diluted in 50mL of distilled water and heated in the microwave for 15min **low-level:** distilled water
Flavour Sweet (Mild)	Typical taste sensation of sugar solution (Mild after cooking)	**high level:** 0.3% sucrose solution **low-level**: Distilled water
Acid	Typical taste sensation of organic acids (citric acid)	**high level:** 0.3% citric acid solution **low-level**: Distilled water
Astringent	Sensation that lingers, dries and numbs the mouth, palate and tongue when eating corn porridge.	**high level**: 0.1% tannic acid solution **low-level**: distilled water
After taste	Sensation of feeling a taste after swallowing the food.	**high level**: 3% (w/w) unripe banana solution **low-level**: Distilled water