NUTRITIVE PARAMETERS EVOLUTION OF MAIZE SEEDS CONSERVED BY TRIPLE BAGGING SYSTEM AND BIOPESTICIDES (*Lippia multiflora* AND *Hyptis suaveolens* LEAVES) IN COTE D'IVOIRE

ABSTRACT

This study, initiated in Côte d'Ivoire, aimed to evaluate the effectiveness of the triple bagging system associated or not with biopesticides on the conservation of biochemical parameters, in particular its nutritional potential according to a central composite design (CCD). It was carried in Côte d'Ivoire at Laboratory of Biochemistry and Food Science from March 2016 to September 2017. Shelf life, biopesticides rate and interactions between shelf life and biopesticides had a significant influence on the biochemical characteristics of maize. The polypropylene bag (control) had the highest values after eighteen (18) months of moisture storage (9.02% to 16.99%) and showed very high fibre losses (P<0.001) (5.78% to 4.28%), total sugars (2.62% to 1.30%), reducing sugars (0.47% to 0.27%), starch (75.20% to 46.10%), fat (5.51% to 3.33%), protein (8.60% to 6.87%), total carbohydrate (75.20% to 71.51%), ash (1.68% to 1.30%) and energy value (384.78% to 343.48%). Concerning the triple bagging system without biopesticides, the variation is similar to the treatments that received the biopesticides up to 9.5 months of storage before presenting values almost similar to the control bag after the 18 months of storage. While triple bagging systems with the presence of biopesticides after 18 months of storage show slight variations in moisture (9.02% to 12.47%), fibre (5.78% to 5.56%), total sugars (2.62% to 1,88%), reducing sugars (0.47% to 0.37%), starch (75.20% to 60.03%), fat (5.51% to 5.00%), protein (8.60% to 7.84%), total carbohydrates (75.20% to 72.69%), ash (1.68% to 1.50%) and energy value (384.78% to 368.93%). The results of these tests show that maize grains stored in the presence of biopesticides best retain their biochemical characteristics. Also, the results indicate that the rate of 1.01% biopesticides could be recommended for maintaining all biochemical parameters up to 18 months of storage.

Keywords: Maize, conserved, triple bagging, biopesticides, biochemical characteristics, Côte d'Ivoire

1.INTRODUCTION

Maize is the world's largest cereal crop, ahead of rice and wheat. It is cultivated for its nutritional assets (starch richness, presence of protein and minerals) and is the staple food of many populations. In Côte d'Ivoire, maize is the seventh most important agricultural crop and the second most important cereal crop after rice [1]. With a national production estimated at nearly 760,000 tons in 2016, maize grains provide about 15% of the Ivorian population's energy needs and therefore constitute the most energy-rich cereal among these populations [3]. Despite its various uses, this cereal remains a seasonal crop in many production areas. Also, its availability during the off-season is systematically linked to the conditions of its conservation. These constraints are mainly related to post-harvest mistreatment [5]. In response to this situation, the use of chemical pesticides as effective means of control has long been advocated by producers. However, international institutions such as the FAO (2011) [6], prevented the misuse and uncontrolled use of synthetic pesticides for the protection and cultivation of foodstuffs. Indeed, these synthetic insecticides have a harmful effect on human health and pollute the environment. In order to improve this situation, several researchers have turned to the control of these stock pests. They have developed new storage and/or conservation technologies such as: the development of improved granaries for improving the quality of grain and corn on the farm [7] and the conservation of maize grains in polypropylene bags with added biopesticides developed by the work of Ezoua and colleagues (2017a) [8]. in fact, these biopesticides secrete bioactive compounds that affect the way insects feed and prevent their growth. Also, Konan and his collaborators (2016) [9] have developed the triple bagging method similar to the "PICS" bag (Purdue Improved Cowpea Storage). The triple bagging system is a set of three combined bags, including two inner bags made of high-density polyethylene with low air permeability and one outer bag made of polypropylene. For the two inner bags, one is mounted in the other. These two bags are enclosed in the polypropylene woven bag. This triple bagging system combined with biopesticides has shown satisfactory results in extending the shelf life and/or storage of cowpea seeds. Thus, the objective of this study initiated in Côte d'Ivoire is to evaluate the effects of triple bagging systems associated or not with *Lippia multiflora* and *Hyptis suaveolens* leaves on the evolution of maize nutrient parameters during storage.

2. MATERIAL AND METHODS

2.1 Experimental Site

The experiments were carried out in the storage room of the Laboratory of Biochemistry and Food Sciences in Félix Houphouët-Boigny University, where the average temperature and relative humidity were respectively (27.27ºC±1.41 and 81.58±3.02%). Wooden pallets were placed on the floor as a support for storing the bags.

2.2 Vegetable material

2.2.1 Maize used in the study

The dry maize grains were obtained from producers in the Hambol region of north-central of Côte d'Ivoire in the department of Katiola, between 8°10' North and 5°40' West just after the harvest. It is an improved GMRP-18 variety of yellow morphotype and is characterized by a short production cycle of 90-95 days.

2.2.2 Selected plants

The leaves of *Lippia multiflora* and *Hyptis suaveolens*, harvested in the Gbêkê region (70°50' North and 50°18' West). They were dried in the shade for a week and then chopped into fine particles.

2.2.3 Storage equipment

Polypropylene and polyethylene bags with a capacity of 120 kg were purchased at the Adjamé market (municipality of Abidjan) to form the triple bagging system. It is a set of bags made of synthetic fabric (polypropylene), lined on the inside with two bags made of (polyethylene). This makes it possible to make a triple bottom bag.

2.3 Methods

2.3.1 Bagging

The maize grain conservation methodology was implemented using a central composite design (CCD). It was 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 *Lippia multiflora* and *Hyptis suaveolens* leaves so as to obtain leaves on the bottom and surface of the bags, thus covering the kernels. A total of nine [9] experimental batches and one control batch were established as follows: 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*), TB8 triple bagging with 2.5% biopesticides (1.25 kg of H. *suaveolens*). The experiment lasted 18 months.

2.3.2 Samples collection

Samples for the various analyses were taken at different storage periods: At month T0, just after purchase and before storage; then in month T1; T4.5; T9.5; T14.5 and T18. These samples were taken in triplicate. These differents times were determined from the central composite design (CCD). Thus, 5 Kg samples of maize were collected in each bag at differents strata. The maize samples collected were ground (using a MOULINEX mixer, France) in the laboratory to obtain a fine grind (flour) for the determination of nutrient parameters.

2.3.3 Biochemical analysis

Analyses were performed using the standard AOAC methods (no. 960.52. 2000) [10]. Thus, the moisture content of the maize was deducted after drying 10 g of the samples in an oven (MEMMERT, Germany) at 105°C until constant weight. The ash content results from the incineration of 5 g of the dry sample of maize at 550°C in a muffle furnace (PYROLABO, France) for 12 h. The determination of the fibre content was carried out according to Wolf's (1968) method [11]. taking of 2 g sample of maize meal (P0) was taken and placed in a flask to which 50 mL of sulphuric acid (0.25N) was added. The resulting mixture was homogenized and boiled for 30 minutes in reflux condenser. After 30 min, 50 mL NaOH (0.31N) was added to the contents and brought back to a boil in reflux condenser for 30 min. The extract obtained was filtered on Whatman N°4 filter paper and the residue was washed several times in hot water until the alkalis were completely removed. The residue was dried in the oven at 105°C for 8 hours. After cooling in the desiccator, the residue was weighed (P1) and then incinerated in the furnace at 550°C for 3 hours. After cooling the ashes obtained were weighed (P2). The crude fibre content was obtained in g per 100 g of MS according to the formula:

$$\text{Raw fibre} = \frac{(P_1 - P_2)}{P_0} \times 100$$

The lipids contents resulted from a solvent (hexane) extraction using a Soxhlet device. The protein content was determined using the Kjeldhal method. As for the values of total sugars, the determination was carried out using phenol and sulphuric acid using the method of Dubois and colleagues [12]. The reducing sugars were determined according to the Bernfeld and collaborators method [13] with the DNS reagent (3,5-dinitrosalicylic acid). Total carbohydrates and energy value were estimated using formulas indicated by FAO 2002 [14] as follows:

Total carbohydrates (%) = 100 - (% moisture + % protein + % fat + % ash).

In addition, the starch content was determined by calculation taking into account the carbohydrate and total sugar contents by the following calculation method**:**

Starch (%) = 0.9 [Carbohydrates (%) - 0.001 x Total Sugars (mg/100 g)].

And finally, the energy value was determined as follows.

Energy Value (%) = [(% protein X 4) + (% carbohydrates X 4) + (% fat X 9)]. The results of moisture, carbohydrate compounds, macronutrients and energy values were expressed on a dry weight basis.

2.4 Statistical analysis.

All analyses were performed in triplicate and all data were statistically processed using the SPSS software (version 22.0). It consisted of an analysis of variance according to two factors: the storage duration and storage method, the different treatments carried out during storage. Significant parameters were compared using the Tukey test with a level of significance less than or equal to 5%. Multivariate analysis, including Principal Component Analysis (PCA) and Hierarchical Ascendant Classification (HAC), were then performed using STATISTICA software (version 7.1).

3.RESULTS AND DISCUSSION

3.1 Results

3.1.1 Evolution of nutrient parameters

Table I presents the data from the statistical tests used to assess macronutrients, carbohydrate compounds, moisture content and energy value. The tests carried out reveal very significant variations (P<0.001) in biochemical element contents as a function of duration and storage method. In addition, the interaction between the 2 variables has a significant effect.

3.1.2 Moisture and carbohydrate compound content.

The moisture content increases very significantly (P<0.001) during storage (Table II). With an initial value of 9.02±0.00%, the highest values were recorded in the polypropylene bag (16.99±0.20%) and the triple bagging system without biopesticides (12.76±0.10%) after 18 months. The moisture content of the maize grains recorded in the bags that have received the various treatments is increasing to a maximum of 12.47±0.06% in the TB4 batch containing 1.01% biopesticides (0.10 kg of *L. multiflora* and 0.40 kg of *H. suaveolens*). For fibres, the value recorded at the beginning of storage was 5.78±0.02% and this value gradually decreased after 4.5 months of storage to reach the values of 4.28±0.04% and 5.23±0.06% after 18 months of storage respectively for the control system and the triple bagging without biopesticides. On the other hand, in triple bagging systems with biopesticides added in general, no significant difference is observed (P=.05) for fibre contents (Table II). The storage of maize grains in polypropylene bags and the triple bagging system also revealed a significant decrease (P =.05) in total sugar levels. For an initial value of 2.62±0.07%, the total sugar content drops to values of 1.30±0.01% and 1.77±0.01% for batches not treated with the leaves respectively (TB0SP and TB0P). In experimental batches with different proportions of biopesticides, the average value is about 1.97±0.06%. In addition, the reducing sugar contents of the stored maize grains showed significant differences (P=.05) during storage. These levels decrease from the eighth month of storage, to reach values of 0.26±0.00% (TB0SP) and 0.30±0.00% (TB0P) for untreated batches after 18 months of storage (Table II). For batches treated with biopesticides (*L. multiflora* and *H. suaveolens*), the average values recorded are in the order of (0.39±0.02%) (Table II). The starch contained in maize at the beginning of storage 75.20±0.63 g/100 g MS drops to 46.10±0.78 and 58.27±0.61 g/100 g MS respectively in the control batch and the treatment that did not receive biopesticides after 18 months. While the values obtained for biopesticides systems range from 60.14±0.02 to 62.03±0.16g/100 g of MS (Table II). While the values obtained for biopesticides systems range from 60.14±0.02 to 62.03±0.16g/100 g of MS (Table II).

3.1.3 Macronutrient and energy content

Statistical analysis indicates that the lipid content of maize grains recorded at the beginning of storage (5.51±0.04%) decreases significantly (P=.05) both at the control level (TB0SP) and in the triple bagging system without biopesticides (TB0P) with values of 3.33±0.10% and 4.04±0.06% respectively. For triple bagging systems with different proportions of biopesticides, the values decrease with the proportions of biopesticides provided. However, for treatments that received 3.99 and 5% biopesticides respectively, the values remain constant (P=.05) (Table III). However, for treatments that received 3.99 and 5% biopesticides respectively, the values remain constant (P=.05) (Table III). Concerning the protein content, the values drop significantly to values fluctuating between 8.60±0.10% and 6.87±0.00% and then between 8.60±0.10% and 7.52±0.00% of MS respectively for maize grains stored in the polypropylene bag and the triple bag without biopesticides after 18 months of storage. In batches treated with *L. multiflora* and *H. suaveolens* leaves, the values vary between 8.60±0.10 and 7.84±0.02% in the treatment treated with 1.01% biopesticides (0.10 kg *L. multiflora* and 0.40 kg *H. suaveolens* noted TB4) With regard to the proportions of 3.99 and 5% of biopesticides, the variation is small and remains in the order of 8.60±0.10 to 8.08±0.01% (Table III). In terms of total carbohydrate content, the initial values recorded for maize grains (75.20±0.20) decrease significantly during storage to reach average values of 71.51±0.10, respectively for the control (TB0SP) and untreated (TB0P) batches. For the batches processed the average value is 72.69±0.04%. The ash value is 1.68±0.00% at the beginning of storage and drops significantly (P=.05) to 1.30±0.01% after 18 months of storage in the simple bagging system (polypropylene bag). However, these values gradually increase after 4.5 months of storage in the triple bagging system without biopesticides to reach 1.50±0.00% after 18 months of storage. On the other hand, these values remain constant over time in triple bagging systems with different proportions of biopesticides, where the variation in ash value is not very pronounced. All stored batches also show a decrease in the energy value, these values are estimated at 384.95±0.78 kcal at the beginning of storage, gradually decrease to 343.48±0.43 and 366.49±0.53 kcal for untreated batches and to average values ranging from 368.93±0.22 to 369.54±0.78 kcal for treated batches.

3.2 Correlations between nutrient parameters

3.2.1 Principal Component Analysis (PCA)

The main component analysis of the different maize samples is correlated to the 10 biochemical parameters. Under the Kaïser rule, factors with an eigenvalue greater than or equal to 1 are taken into account when interpreting PCA data (Figure 1). Only the first factor F1 which has an eigenvalue greater than 1 was considered for the interpretation of the PCA data. It expresses 90.56% of the total variability. The second factor F2 having an eigenvalue of 0.60 with a total variability of 6.02% is coupled to the first factor and both will be used to represent the PCA. The factor F1 with an eigenvalue of 9.06 establishes negative correlations with the 9 biochemical parameters that are: the contents of ash, fibre, protein, fat, total and reducing sugars, total carbohydrates, starch, and energy value and a positive correlation with moisture content. As for character projection, 4 groups were formed. Group 1 consists only of the TB0SP control at 9.5; 14.5 and 18 months of storage noted respectively A3; A4 and A5. These individuals have the highest moisture values and the lowest values for all other parameters. The second group shows individuals rated A2 and B5, which are respectively the control samples (TB0SP) at 4.5 and triple single bagging (TB0P) at 18 months storage. Its samples are similar to those of individuals A3, A4 and A5 in terms of changes in biochemical parameters. Group 3 consists of samples from the control lot (TB0SP) after one month of storage, triple bagging without biopesticides (TB0P) up to 14.5 months of storage and triple bagging with different proportions of biopesticides at different storage times (T0, T1, T2, T2, T3, T4, T5). These are characterized by high values for biochemical parameters and low moisture values. The last group contains all experimental batches with or without biopesticides (except the control batch) after one month of storage. They have essentially the same variations in the parameters studied in group 3.

3.2.2 Increasing Hierarchical Classification (HAC)

The Hierarchical Ascendant Classification (HAC) established by the Euclidean distance method confirms the variability observed at the PCA level (Figure 2). Indeed, truncation of the dendrogram at an Euclidean aggregation distance of 44 and reveals four classes observed according to the different treatments (untreated, triple bagging without biopesticides and triple bagging with different proportions of biopesticides) in storage time. The first class consists of samples from the control lot TB0SP at 9.5; 14.5 and 18 months of storage noted respectively A3; A4 and A5. These individuals are characterized by high humidity values and low values for all other parameters. The second group shows individuals rated A2 and B5 which are respectively TB0SP samples at 4.5 and TB0P (triple single bagging) at 18 months storage. Individuals in this class are distinguished from other treatments and mark the boundary by which the difference between the two modes of preservation is distinguished. The third group consists of the control at 1 month storage, the triple bagging without biopesticides up to 14.5 months storage and the triple bagging with different proportions of biopesticides at different storage times. The samples in this group have similar values to those in the fourth and last group, allowing samples of bags with or without biopesticides to be seen after one month of storage except for the B0SP control lot. The values of these samples thus make it possible to distinguish the efficiency of the storage system used.

Table I: Statistical data of the parameters according to the treatments during the storage time.

SDV	Pa St	PARAMETERS									
		Mc	**ash**	**Fib**	***fat***	**Pro**	**ST**	**SR**	**GT**	***starch***	**V E**
Time	**ddl**	3.54	3.47	1.39	1.75	1.83	1.87	1.42	2.03	1.4	2.28
	SC	382.63	0.34	2.65	6.81	14.14	11.82	0.26	174.33	1731.81	44438.88
	F	16985.88	309.73	67.05	131.86	411.05	595.69	292.37	1686.29	468.2	23024.95
	P	*p<0.OO1*									
Erreur Time	**ddl**	70.88	69.32	27.77	35.03	0.69	37.5	28.45	40.66	27.8	45.71
	SC	0.45	0.02	0.79	1.03	7.4	0.4	0.02	2.07	73.98	38.6
Methods	**ddl**	9									
	SC	171.43	0.59	12.6	15.54	7.4	5.21	0.14	35.83	1363.78	45476.84
	F	3590.54	379.33	162.38	117.15	87.64	163.44	57.18	203.71	178.88	9354.2
	P	*p<0.OO1*									
Erreur Methods	**ddl**	20									
	SC	0.11	0	0.17	0.29	0.19	0.07	0.05	0.39	16.94	10.8
Time x Methods	**ddl**	31.9	31.19	12.5	15.77	16.5	16.87	12.8	18.3	12.51	20.57
	SC	70.78	0.17	3.32	8.46	2.65	1.32	0.05	32.82	427.25	206290.65
	F	349.12	16.72	9.35	18.2	8.56	7.4	6.82	35.27	12.83	11876.07
	P	*p<0.OO1*									

***SC:** sum of squares; **F:** value of the statistical test; **P:** probable value of the statistical test; **ddl:** degree of freedom; **Mc:** moisture content;**ash:** ash content; **Fib:** fibre content; **fat:** fat content; **Pro:** protein content; **ST:** total sugar content; **SR:** reducing sugar content; **GT:** total sugar content; starch: starch content; **VE:** energy value.*

Table II: Evolution of humidity and carbohydrate compounds during storage time according to treatment

Parameters	Storage Time	TB0SP	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
***moisture* content (%)**	**0**	9.02±0.00 ^{Da}	9.02±0.00^{Fa}	9.02±0.00^{Ea}	9.02±0.00^{Da}	9.02±0.00^{Ea}	9.02±0.00^{Ea}	9.02±0.00^{Ea}	9.02±0.00^{Ea}	9.02±0.00^{Ea}	9.02±0.00^{Ea}
	1	10.20±0.10^{Ca}	9.23±0.06^{Eb}	9.10±0.02^{Ebc}	9.09±0.07^{Dbc}	9.07±0.04^{Dc}	9.17±0.06^{Ebc}	9.12±0.03^{Ebc}	9.08±0.03^{Ec}	9.12±0.03^{Ebc}	9.09±0.04^{Ebc}
	4.5	14.05±0.07^{Ba}	11.37±0.08^{Db}	11.02±0.13^{Dc}	10.96±0.06^{Cc}	10.96±0.13^{Cc}	11.08±0.07^{Dc}	10.96±0.06^{Dc}	10.92±0.06^{Dc}	10.98±0.09^{Dc}	10.92±0.07 ^{Dc}
	9.5	16.67±0.27^{Aa}	11.99±0.04^{Cb}	11.29±0.03^{Ccd}	11.11±0.02^{Ccd}	11.08±0.01^{Ccd}	11.33±0.08^{Cc}	11.29±0.05^{Ccd}	11.05±0.01 ^{Cd}	11.19±0.05^{Ccd}	11.15±0.02^{Ccd}
	14.5	16.97±0.07 ^{Aa}	12.28±0.06 ^{Bb}	11.85±0.06^{Bcd}	11.66±0.10^{Be}	11.64±0.04^{Be}	12.14±0.06^{Bb}	11.95±0.06^{Bc}	11.44±0.05^{Bf}	11.78±0.02^{Bcde}	11.71±0.05^{Bde}
	18	16.99±0.20^{Aa}	12.76±0.10^{Ab}	12.32±0.02^{Acde}	12.11±0.01^{Aef}	12.07±0.02^{Af}	12.47±0.06^{Ac}	12.45±0.18 ^{Ac}	12.07±0.06^{Af}	12.37±0.06^{Acd}	12.18±0.03^{Adef}
Fibre (%)	**0**	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}	5.78±0.02^{Aa}
	1	5.03±0.15^{Bb}	5.60±0.08^{Bb}	5.79±0.20^{Aa}	5.77±0.32^{Aa}	5.77±0.15^{Aa}	5.72±0.07^{ABa}	5.72±0.11^{ABa}	5.77±0.30^{Aa}	5.77±0.20^{Aa}	5.73±0.30^{Aa}
	4.5	4.82±0.03^{Cb}	5.52±0.02^{Ba}	5.67±0.23^{Aa}	5.70±0.01^{Aa}	5.70±0.03^{Aa}	5.65±0.02^{BCa}	5.67±0.01^{ABCa}	5.70±0.03^{Aa}	5.65±0.03^{Ba}	5.67±0.01^{Aa}
	9.5	4.55±0.04^{Df}	5.36±0.03^{Ce}	5.63±0.00^{Ad}	5.66±0.01^{Acd}	5.67±0.01^{Aab}	5.60±0.01^{Cd}	5.62±0.01^{BCcd}	5.68±0.01^{Aa}	5.64±0.04^{Babcd}	5.65±0.00^{Aabc}
	14.5	4.36±0.06^{DEc}	5.29±0.07^{Cb}	5.61±0.01^{Aa}	5.65±0.03^{Aa}	5.68±0.00^{Aa}	5.59±0.01^{Ca}	5.60±0.00^{BCa}	5.68±0.01^{Aa}	5.64±0.01^{Ba}	5.65±0.01^{Aa}
	18	4.28±0.04^{Ec}	5.23±0.06^{Cb}	5.57±0.01^{Aa}	5.61±0.01^{Aa}	5.63±0.00^{Aa}	5.56±0.02^{Ca}	5.57±0.01^{Ca}	5.62±0.01^{Aa}	5.60±0.00^{Ba}	5.60±0.01^{Aa}
***total sugar* content (%)**	**0**	2.62±0.07^{Aa}	.62±0.07^{Aa}	2.62±0.07^{Aa}	2.62±0.07 ^{Aa}	2.62±0.07^{Aa}	2.62±0.07^{Aa}	2.62±0.07^{Aa}	2.62±0.07^{Aa}	2.62±0.07^{ABa}	2.62±0.07^{Aa}
	1	2.07±0.12^{Bb}	2.44±0.22^{Aa}	2.53±0.07^{Aa}	2.55±0.15^{Aa}	2.56±0.13 ^{Aa}	2.43±0.10^{Bab}	2.57±0.03^{Aa}	2.57±0.07^{Aa}	2.53±0.18^{ABa}	2.57±0.03^{Aa}
	4.5	1.64±0.10^{Cc}	2.11±0.03 ^{Bb}	2.32±0.03^{Ba}	2.31±0.01^{Ba}	2.30±0.04 ^{Ba}	2.32±0.04^{BCa}	2.31±0.02 ^{Ba}	2.31±0.01^{Ba}	2.31±0.00^{BCa}	2.31±0.01^{Ba}
	9.5	1.46±0.01^{CDd}	1.97±0.04^{BCc}	2.26±0.00^{Bab}	2.28±0.00^{BCa}	2.28±0.00^{BCa}	2.24±0.07^{Cb}	2.26±0.00^{Bab}	2.28±0.00^{Ba}	2.27±0.00^{Cab}	2.26±0.00^{Bab}
	14.5	1.37±0.01^{Ef}	1.90±0.00^{BCe}	2.05±0.00^{Cc}	2.12±0.00^{CDab}	2.12±0.00^{CDab}	2.01±0.00^{Dd}	2.04±0.00^{Cc}	2.12±0.01 ^{Ca}	2.10±0.00^{CDb}	2.11±0.00^{Cab}
	18	1.30±0.01^{Ef}	1.77±0.01^{Ce}	1.90±0.00^{Dc}	2.02±0.01^{Da}	2.03±0.00^{Da}	1.88±0.00^{Dd}	1.90±0.00^{Dd}	2.03±0.01^{Ca}	2.00±0.00^{Db}	2.01±0.00^{Dab}

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 II continuation: Evolution of humidity and carbohydrate compounds during storage time according to the treatment.

Parameters	Storage Time	TB0SP	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
***reducing sugar content* (%)**	**0**	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}	0.47 ± 0.00^{Aa}
	1	0.42 ± 0.02^{Ba}	0.45 ± 0.08^{ABa}	0.45 ± 0.02^{ABa}	0.45 ± 0.03^{ABa}	0.45 ± 0.01^{Ba}	0.45 ± 0.01^{Ba}	0.46 ± 0.01^{ABa}	0.46 ± 0.02^{ABa}	0.45 ± 0.02^{ABa}	0.47 ± 0.00^{Aa}
	4.5	0.34 ± 0.01^{Cc}	0.39 ± 0.00^{ABCb}	0.44 ± 0.01^{Ba}	0.44 ± 0.02^{Ba}	0.44 ± 0.01^{BCa}	0.44 ± 0.00^{Ba}	0.44 ± 0.00^{Ba}	0.45 ± 0.00^{BCa}	0.44 ± 0.00^{BCa}	0.44 ± 0.02^{Ba}
	9.5	0.30 ± 0.00^{Df}	0.36 ± 0.00^{BCe}	0.40 ± 0.00^{Bc}	0.43 ± 0.00^{Ba}	0.43 ± 0.00^{Ca}	0.39 ± 0.00^{Cd}	0.40 ± 0.00^{Ccd}	0.43 ± 0.00^{Ca}	0.42 ± 0.00^{CDb}	0.43 ± 0.00^{Bab}
	14.5	0.28 ± 0.00^{DEf}	0.33 ± 0.00^{Ce}	0.39 ± 0.00^{Cbc}	0.40 ± 0.00^{Cab}	0.40 ± 0.00^{Da}	0.38 ± 0.00^{CDd}	0.39 ± 0.00^{CDcd}	0.40 ± 0.00^{Da}	0.40 ± 0.00^{Dabc}	0.40 ± 0.00^{Cab}
	18	0.26 ± 0.00^{Ee}	0.30 ± 0.00^{Cd}	0.37 ± 0.00^{Cc}	0.40 ± 0.00^{Cab}	0.40 ± 0.00^{Da}	0.37 ± 0.00^{Dc}	0.37 ± 0.00^{Dc}	0.40 ± 0.00^{Dab}	0.40 ± 0.00^{Db}	0.40 ± 0.00^{Cab}
***starch content;* (%)**	**0**	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}	75.20 ± 0.63^{Aa}
	1	60.50 ± 1.44^{Bb}	67.90 ± 1.34^{Aa}	67.41 ± 0.52^{Aa}	67.00 ± 3.46^{ABa}	67.20 ± 1.91^{Aa}	67.00 ± 1.73^{Aa}	67.10 ± 1.55^{Aa}	67.53 ± 2.20^{Aa}	67.00 ± 2.64^{Aa}	67.67 ± 0.58^{Aa}
	4.5	55.74 ± 0.11^{Cb}	63.29 ± 0.55^{Ba}	63.59 ± 0.59^{Ba}	63.93 ± 0.51^{BCa}	63.82 ± 0.81^{Ba}	63.08 ± 1.34^{Ba}	63.41 ± 0.36^{Ba}	63.98 ± 0.33^{Ba}	63.60 ± 0.38^{Ba}	63.97 ± 0.78^{Ba}
	9.5	50.42 ± 0.58^{Dd}	61.42 ± 0.58^{BCc}	62.94 ± 0.06^{BCab}	63.48 ± 0.17^{BCab}	63.59 ± 0.20^{Bab}	62.25 ± 0.37^{BCbc}	62.58 ± 0.51^{Bab}	63.60 ± 0.51^{Bab}	62.97 ± 0.06^{Bab}	63.20 ± 0.17^{Bab}
	14.5	50.00 ± 0.01^{Dd}	60.12 ± 0.05^{CDc}	62.38 ± 0.50^{Cab}	62.90 ± 0.06^{Ca}	62.92 ± 0.06^{Ba}	62.09 ± 0.06^{BCb}	62.08 ± 0.13^{BCb}	62.96 ± 0.08^{Ba}	62.57 ± 0.52^{Bab}	62.91 ± 0.11^{Ba}
	18	46.10 ± 0.78^{Ef}	58.27 ± 0.61^{De}	60.60 ± 0.04^{Dbcd}	61.97 ± 0.06^{Ca}	62.03 ± 0.6^{Ba}	60.14 ± 0.02^{Cd}	60.30 ± 0.05^{Ccd}	62.03 ± 0.16^{Ba}	61.40 ± 0.53^{Babc}	61.62 ± 0.54^{Cab}

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 III: Macronutrient and energy content during storage time according to treatment.

Parameters	Storage Time	TB0SP	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
fat content (%)	0	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}	5.51±0.04^{Aa}
	1	4.85±0.13^{Ab}	5.49±0.16^{Aa}	5.48±0.25^{Aa}	5.53±0.30^{Aa}	5.55±0.29^{Aa}	5.42±0.22^{Aab}	5.47±0.15^{Aab}	5.52±0.27^{Aa}	5.53±0.21^{Aa}	5.52±0.07^{Aa}
	4.5	4.59±0.05^{Bb}	5.43±0.39^{Aa}	5.49±0.01^{Aa}	5.51±0.01^{Aa}	5.5±0.01^{Aa}	5.50±0.01^{ABa}	5.50±0.01^{Aa}	5.01±0.01^{Aa}	5.49±0.03^{Aa}	5.51±0.02^{Aa}
	9.5	4.53±0.00^{Cd}	5.51±0.00^{ABa}	5.36±0.01^{ABc}	5.50±0.00^{Aab}	5.50±0.01^{Aa}	5.34±0.00^{ABc}	5.36±0.02^{ABc}	5.50±0.01^{Aa}	5.48±0.01^{Ab}	5.50±0.00^{ABab}
	14.5	3.99±0.02^{Dd}	4.97±0.07^{Bc}	5.18±0.01^{Bb}	5.42±0.01^{Aa}	5.42±0.01^{Aa}	5.17±0.02^{BCb}	5.18±0.01^{BCb}	5.42±0.01^{Aa}	5.40±0.01^{Aa}	5.41±0.01^{BCa}
	18	3.33±0.10^{Ee}	4.04±0.06^{Cd}	5.10±0.01^{Bbc}	5.36±0.02^{Aa}	5.37±0.01^{Aa}	5.00±0.00^{Cc}	5.11±0.02^{Cb}	5.38±0.00^{Aa}	5.35±0.01^{Aa}	5.36±0.00^{Ca}
protein content (%)	0	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}	8.60±0.10^{Aa}
	1	8.10±0.10^{Ba}	8.47±0.30^{Aa}	8.50±0.18^{Aa}	8.52±0.09^{Aa}	8.49±0.19^{Aa}	8.52±0.10^{Aa}	8.55±0.18^{Aa}	8.57±0.18^{Aa}	8.52±0.16^{Aa}	8.51±0.12^{Aa}
	4.5	7.55±0.09^{Cb}	8.07±0.24^{Ba}	8.18±0.4^{Ba}	8.20±0.06^{Ba}	8.20±0.01^{Ba}	8.15±0.05^{Ba}	8.20±0.06^{Ba}	8.20±0.01^{Ba}	8.19±0.06^{Ba}	8.21±0.00^{Ba}
	9.5	7.37±0.05^{Cd}	7.91±0.05^{Bc}	8.05±0.01^{BCb}	8.18±0.01^{Ba}	8.18±0.00^{Ba}	8.03±0.05^{Bb}	8.04±0.01^{BCb}	8.20±0.00^{Ba}	8.17±0.01^{Ba}	8.20±0.00^{Ba}
	14.5	7.05±0.04^{Dd}	7.82±0.05^{BCc}	7.10±0.00^{BCb}	8.10±0.00^{Ba}	8.10±0.00^{Ba}	7.99±0.00^{BCb}	8.00±0.00^{BCb}	8.10±0.01^{Ba}	8.10±0.00^{Ba}	8.10±0.01^{Ba}
	18	6.87±0.00^{Ee}	7.52±0.00^{Cd}	7.86±0.01^{Cc}	8.06±0.01^{Ba}	8.07±0.01^{Ba}	7.84±0.02^{Cc}	7.87±0.03^{Cc}	8.08±0.01^{Ba}	8.01±0.01^{Bb}	8.05±0.01^{Ba}
total sugar content (%)	0	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}	75.20±0.07^{Aa}
	1	75.32±0.18^{Ba}	75.16±0.18^{Aa}	75.24±0.41^{Aa}	75.20±0.22^{Aa}	75.23±0.42^{Aa}	75.26±0.28^{Ba}	75.20±0.29^{Aa}	75.16±0.34^{Aa}	75.18±0.19^{Ba}	75.21±0.19^{Aa}
	4.5	72.38±0.11^{Cb}	73.55±0.31^{Ba}	73.66±0.15^{Ba}	73.68±0.03^{Ba}	73.68±0.14^{Ba}	73.64±0.01^{BCa}	73.70±0.14^{Ba}	73.72±0.08^{Ba}	73.68±0.08^{BCa}	73.70±0.03^{Ba}
	9.5	70.05±0.23^{CDc}	73.13±0.2^{BCb}	73.69±0.05^{Ba}	73.56±0.03^{BCa}	73.59±0.02^{BCa}	73.70±0.13^{Ca}	73.69±0.04^{Ba}	73.60±0.07^{Ba}	73.53±0.04^{Ca}	73.53±0.03^{Ba}
	14.5	70.62±0.09^{Dd}	73.41±0.08^{BCa}	73.37±0.07^{Cab}	73.20±0.09^{CDbc}	73.21±0.04^{CDabc}	73.13±0.07^{Dc}	73.26±0.05^{Cabc}	73.40±0.07^{Ca}	73.12±0.01^{CDc}	73.16±0.02^{Cc}
	18	71.51±0.10^{De}	74.17±0.09^{Ca}	73.16±0.05^{Db}	72.87±0.01^{Dcd}	72.89±0.02^{Dcd}	73.13±0.06^{Db}	73.01±0.17^{Dc}	72.86±0.05^{Ccd}	72.69±0.04^{Dd}	72.82±0.04^{Dcd}

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 III continuation: Macronutrient and energy content during storage time according to treatment.

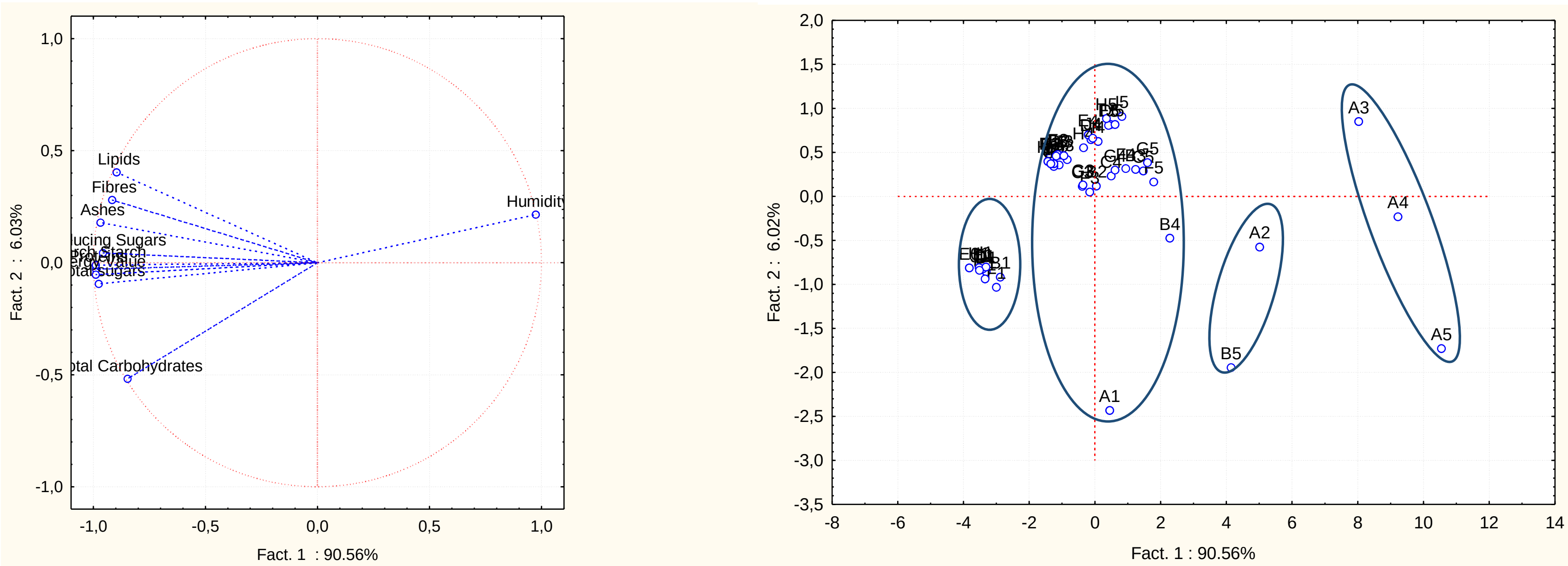
Parameters	Storage Time	TB0SP	TBOP	TB1	TB2	TB3	TB4	TB5	TB6	TB7	TB8
***ash content* (%)**	**0**	1.68±0.00^{Aa}	1.68±0.00 ^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}	1.68±0.00^{Aa}
	1	1.52±0.02^{Bb}	1.65±0.02^{Aa}	1.67±00^{Aa}	1.65±0.02^{ABa}	1.66±0.01 ^{Aa}	1.64±0.00^{Ba}	1.66±0.02^{ABa}	1.66±0.02^{ABa}	1.66±0.02^{ABa}	1.67±0.03^{Aa}
	4.5	1.43±0.02 ^{Cc}	1.57±0.01^{Bb}	1.64±0.01^{Ba}	1.65±0.02^{ABa}	1.65±0.01^{ABa}	1.63±0.01^{Ba}	1.63±0.02^{BCa}	1.65±0.01^{BCa}	1.65±0.00^{ABa}	1.65±0.03^{ABa}
	9.5	1.38±0.04^{CDc}	1.53±0.03^{BCb}	1.60±0.00^{Ca}	1.64±0.01^{ABa}	1.65±0.01^{ABa}	1.60±0.01^{Ca}	1.62±0.01^{CDa}	1.65±0.01^{BCa}	1.63±0.01 ^{Ba}	1.63±0.01^{ABCa}
	14.5	1.37±0.02^{Dd}	1.53±0.03^{BCc}	1.60±0.00^{Cab}	1.61±0.01^{BCa}	1.62±0.02^{BCa}	1.56±0.01^{Dbc}	1.59±0.01^{Dab}	1.63±0.00^{CDa}	1.60±0.00^{Cab}	1.61±0.02^{BCa}
	18	1.30±0.01^{DEf}	1.50±0.01^{Ce}	1.57±0.00^{Dcd}	1.60±0.00^{Cab}	1.60±0.00^{Cab}	1.55±0.01^{Dd}	1.56±0.00^{Ed}	1.61±0.00^{Da}	1.58±0.01^{Cbc}	1.59±0.01^{Cbc}
***energy value* (kcal/100g)**	**0**	384.78±0.23^{Aa}	384.78±0.23^{Aa}	384.78±0.23^{Aa}	384.78±0.23^{Aa}	384.78±0.23^{Aa}	384.78±0.23^{Aa}	384.78±0.23^{Aa}	384.78±0.23 ^{Aa}	384.78±0.23^{Aa}	384.78±0.23^{Aa}
	1	377.37±1.03^{Bb}	383.88±0.83^{Aa}	384.33±1.31^{Aa}	384.65±1.66^{Aa}	384.80±1.58^{Aa}	383.85±1.32^{Aa}	384.20±0.63^{Aa}	384.62±1.39^{Aa}	384.57±1.18^{Aa}	384.58±0.31^{Aa}
	4.5	361.01±0.40^{Cb}	375.37±2.27^{Ba}	376.80±0.52 ^{Ba}	377.10±0.28^{Ba}	377.05±0.58 ^{Ba}	376.63±0.23^{Ba}	377.14±0.22 ^{Ba}	377.24±0.16^{Ba}	376.90±0.52^{Ba}	377.23±0.26^{Ba}
	9.5	350.47±1.02^{De}	373.73±0.19^{Bd}	375.24±0.12^{Bbc}	376.48±0.09^{Ba}	376.61±0.07^{Ba}	375.01±0.34^{Cc}	375.16±0.19^{Cbc}	376.74±0.05 ^{Ba}	376.11±0.19^{Bab}	376.35±0.12 ^{Ca}
	14.5	346.60±0.46^{Ef}	369.66±0.47^{Ce}	372.16±0.21^{Cc}	373.98±0.44^{Cb}	374.06±0.10 ^{Cab}	371.04±0.24^{Dd}	371.74±0.14^{Dcd}	374.84±0.18^{Ca}	373.45±0.14^{Cb}	373.78±0.16^{Db}
	18	343.48±0.43 ^{Fe}	366.49±0.53^{Df}	369.94±0.10^{Dcd}	371.93±0.09 ^{Dab}	372.14±0.11^{Da}	368.93±0.22^{Ed}	369.54±0.78^{Ed}	372.16±0.24^{Da}	370.92±0.16^{Dbc}	371.71±0.15^{Eab}

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 IV: Correlation table between nutrient parameters according to treatment during storage time.

	Humidity	Ashes	Fibres	Lipids	Proteins	Total sugars	Reducing Sugars	Total Carbohydrates	Starch Starch	Energy Value
Humidity	1									
Ashes	-0.901196	1								
Fibres	-0.840716	0.958225	1							
Lipids	-0.793037	0.914978	0.902979	1						
Proteins	-0.967449	0.938397	0.876525	0.880654	1					
Total sugars	-0.961322	0.933741	0.843145	0.831675	0.967342	1				
Reducing Sugars	-0.910889	0.937026	0.839882	0.870964	0.956036	0.956843	1			
Total Carbohydrates	-0.941902	0.733211	0.658945	0.546885	0.841778	0.860907	0.766327	1		
Starch Starch	-0.968968	0.955250	0.920639	0.881633	0.979330	0.953586	0.918679	0.850348	1	
Energy Value	-0.980546	0.932208	0.876878	0.887018	0.985404	0.964156	0.943973	0.865553	0.979327	1



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

Figure 1: Projection of biochemical parameters (a) and individuals (b) in the factorial plan 1-2 of the main 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. A3: polypropylene bag at 9.5 months, 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.

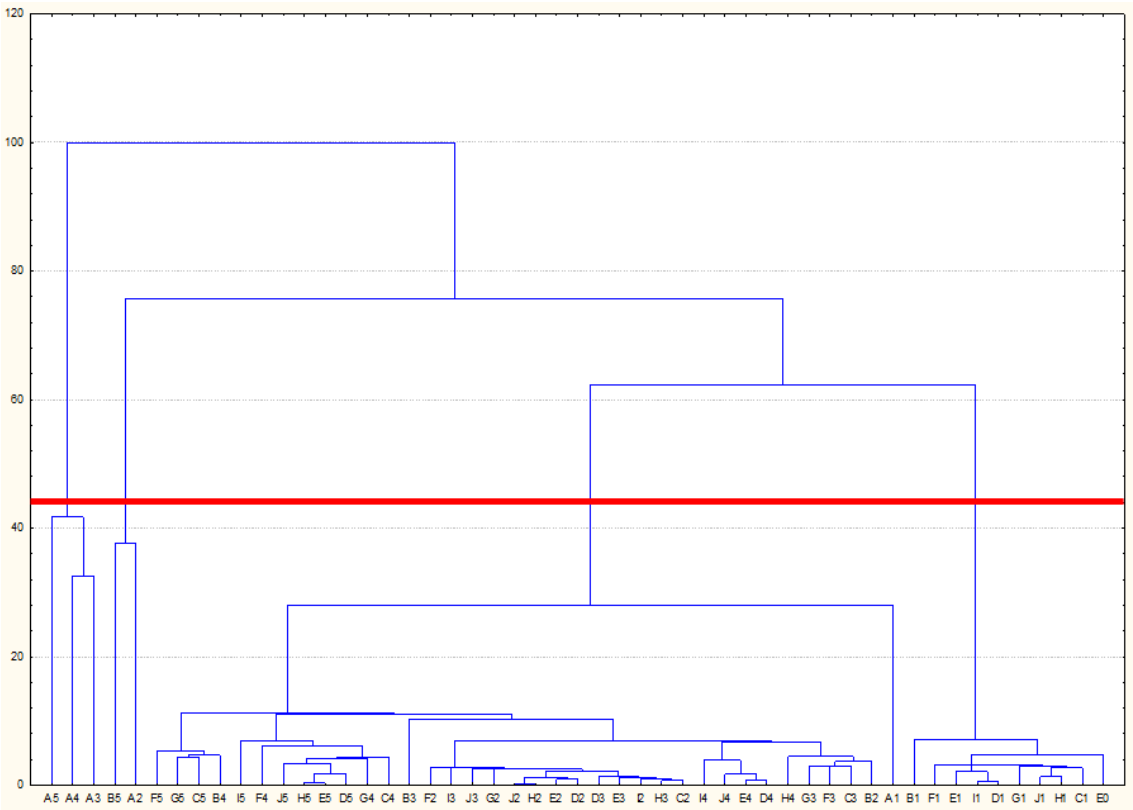


Figure 2: Dendrogram of nutrient parameters according to treatments during storage time

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. A3: polypropylene bag at 9.5 months, 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.

3.4 Discussion

This study was carried out according to two parameters: the storage time and the storage method. It showed a decrease in ash, fibre, fat, protein, total sugar, reducing sugars, starch, total carbohydrate and energy content with an increase in moisture content. It showed a decrease in ash, fibre, fat, protein, total sugar, reducing sugars, starch, total carbohydrate and energy content with an increase in moisture content. According to O'quinn and colleagues [15] the duration and method of storage are important factors influencing the composition of stored cereals. Similar studies have been carried out by Niamkechi and colleagues [16], which reported changes in the same order by assessing the quality of maize stored in different types of traditional and improved granary storage. Also, the proper storage of cereal grains depends on their water content because a high moisture content causes very significant degradation of the grains. In addition, the recommended humidity value for good storage is set at 13% according to studies by Mohale and colleagues [17]. Analyses carried out indicate an increase in moisture content in the batch of maize stored in the polypropylene bag after 4.5 months of storage (14.05±0.07%). On the other hand, maize grains stored in the triple bagging system with or without biopesticides have a moisture content between 12.07±0.02 and 12.76±0.10 during storage. This increase in recorded humidity could be explained, on the one hand, by the recovery of humidity due to the high hygroscopicity of maize grains and, on the other hand, by the activity of insects and microorganisms. The ash content decreases significantly during storage depending on the storage method. This variation may be due to the mineral proportion that is concentrated much more in the shells than in the sprouts (Doukani, 2015) [18]. Indeed, stockpile enemies most often develop inside the grain and consume almost all of its mineral content. The fat content of grain maize varies depending on the storage method. This variation is between 5.51±0.04 and 3.33±0.10% MS in the single bagging system and between 5.51±0.04 and 4.04±0.06% SM in the triple bagging system and between 5.51±0.04 and 5.00±0.00% SM in the systems that received the plants. The results of this study are similar to those of the work of St-Pierre *et al*., 2014 (3 and 5% SM) [19]. During the 18 months of storage, there was generally a decrease in fat content. This would be due to insect attacks on the maize germ, or to a possible oxidation of the fat due to the increase in the temperature of the medium. Indeed, maize composed mainly of unsaturated fatty acids (86 0/0) is weakened by its double bonds which oxidize in contact with the air during storage (This, 2007) [20]. Oxidation has a detrimental effect on the nutritional value of the product (reduction in the content of antioxidant vitamins or polyunsaturated fatty acids), as well as on its organoleptic value (by releasing volatile compounds with a rancid odour). Oxidation rates are a function of the conditions of the storage medium, including pH, temperature and water content of the product (Jean *et al*., 2006) [21].

The protein level observed during storage varies according to the three storage methods. This could be explained by the variation in temperature during storage. Indeed, grain moisture and storage conditions could cause protein losses (Schuh, 1999) [22]. Also, depending on the part of the grain consumed by insects and microorganisms, protein fractions in the grains may increase or decrease during storage (Niamkechi *et al*, (2017) [23]. As far as the total sugars and reducing the progressive decreases in levels are concerned, they are said to be due to the activities of insects and micro-organisms. With regard to total carbohydrates, the results show a significant decrease in regardless at all times and in all types of packaging, reaching 73.13±0.06%. These results are almost in line with the content of varieties popularized by IITA in Nigeria, which is 74.43% (Edema *et al.,* 2005) [24]. The starch content of maize grains has decreased considerably during storage for both untreated and treated lots. This considerable deterioration in starch content could be due to the growth of insects and moulds. Indeed, the work of Chattha *et al*, (2015) [25] showed a significant reduction in the percentage of starch in wheat grains due to the presence of insects. Also, one could associate the attack of moulds of the genus *Aspergillus sp* and *Fusaruim sp* which quantitatively affects the quality of stored maize and reduces starch levels [26]. In addition, the decrease in starch levels in stored maize would be related to the increase in temperature (Maillard oxidation reactions) and humidity during storage. Energy values are logically affected and gradually decrease during storage, as indicated by the close correlations between maize energy values and protein and fat contents.

4. CONCLUSION

The objective of this study was to propose to the actors of the maize sector in Côte d'Ivoire an alternative solution to the use of chemical pesticides for the conservation of the biochemical parameters of maize. The results obtained confirm the use of triple bagging technology as an appropriate solution. Indeed, triple bagging systems have made it possible to maintain maize nutrients over a period of 9.5 months. However, the addition of *Lippia multiflora* and *Hyptis suaveolens* leaves at a proportion of 1.01% as biopestices allows the biochemical parameters of corn to be maintained for 18 months.

Thus, these biopesticides effectively control stock pests and thus provide a solution to synthetic pesticides. This triple bagging method is promising for producers in Côte d'Ivoire and is in line with the sustainable development objectives of preserving the environment. However, further studies are needed to assess the sensory characteristics and acceptability of maize during storage.

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