

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

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6 **ABSTRACT**

7 This study, initiated in Côte d'Ivoire, aimed to evaluate the effectiveness of the triple bagging
8 system associated or not with biopesticides on the conservation of biochemical parameters, in
9 particular its nutritional potential according to a central composite design (CCD). It was carried in Côte
10 d'Ivoire at Laboratory of Biochemistry and Food Science from March 2016 to September 2017. Shelf
11 life, biopesticide rate and interactions between shelf life and biopesticides had a significant influence
12 on the biochemical characteristics of maize. The polypropylene bag (control) had the highest values
13 after eighteen (18) months of moisture storage (9.02% to 16.99%) and showed very high fibre losses
14 ($P < 0.001$) (5.78% to 4.28%), total sugars (2.62% to 1.30%), reducing sugars (0.47% to 0.27%), starch
15 (75.20% to 46.10%), fat (5.51% to 3.33%), protein (8.60% to 6.87%), total carbohydrate (75.20% to
16 71.51%), ash (1.68% to 1.30%) and energy value (384.78% to 343.48%). Concerning the triple
17 bagging system without biopesticides, the variation is similar to the treatments that received the
18 biopesticides up to 9.5 months of storage before presenting values almost similar to the control bag
19 after the 18 months of storage. While triple bagging systems with the presence of biopesticides after
20 18 months of storage show slight variations in moisture (9.02% to 12.47%), fibre (5.78% to 5.56%),
21 total sugars (2.62% to 1.88%), reducing sugars (0.47% to 0.37%), starch (75.20% to 60.03%), fat
22 (5.51% to 5.00%), protein (8.60% to 7.84%), total carbohydrates (75.20% to 72.69%), ash (1.68% to
23 1.50%) and energy value (384.78% to 368.93%). The results of these tests show that maize grains
24 stored in the presence of biopesticides best retain their biochemical characteristics. Also, the results
25 indicate that the rate of 1.01% biopesticides could be recommended for maintaining all biochemical
26 parameters up to 18 months of storage.

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

28 | 1. INTRODUCTION

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

57 | 2. MATERIAL AND METHODS

58 | 2.1 Experimental Site

59 The experiments were carried out in the storage room of the Laboratory of Biochemistry and
60 Food Sciences in Félix Houphouët-Boigny University, where the average temperature and relative
61 humidity were respectively ($27.27^{\circ}\text{C} \pm 1.41$ and $81.58 \pm 3.02\%$). Wooden pallets were placed on the floor
62 as a support for storing the bags.

63 | 2.2 Vegetable material

64 | 2.2.1 Maize used in the study

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

69 | 2.2.2 Selected plants

70 The leaves of *Lippia multiflora* and *Hyptis suaveolens*, harvested in the Gbêkê region ($7050'$
71 North and $5018'$ West). They were dried in the shade for a week and then chopped into fine particles.

72 | 2.2.3 Storage equipment

Comment [JR1]: if you can place what are the active ingredients of bioinsecticides and how they would act on pests and grains.

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

77 2.3 Methods

78 2.3.1 Bagging

79 The maize grain conservation methodology was implemented using a central composite design
80 CCD. It was based on mixing a proportion of crushed dried leaves with a defined amount of maize
81 grains. It is an alternating layering of maize grains and *Lippia multiflora* and *Hyptissuaveolens* leaves
82 so as to obtain leaves on the bottom and surface of the bags, thus covering the kernels. A total of nine
83 [9] experimental batches and one control batch were established as follows: TB0SP control treated
84 without biopesticides in the polypropylene bag, TB0P triple bagging with 0% biopesticides, TB1 triple
85 bagging with 2.5% biopesticides (0.625 kg *L. multiflora* and 0.625 kg *H. suaveolens*), TB2 triple
86 bagging with 3.99% biopesticides (0.40 kg *L. multiflora* and 1.60 kg *H. suaveolens*), TB3 triple bagging
87 with 3.99% biopesticides (1.60 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB4 triple bagging with
88 1.01% biopesticides (0.10 kg *L. multiflora* and 0.40 kg *H. suaveolens*), TB5 triple bagging with 1.01%
89 biopesticides (0.40 kg *L. multiflora* and 0.10 kg *H. suaveolens*), TB6 triple bagging with 5%
90 biopesticides (1.25 kg *L. multiflora* and 1.25 kg *H. suaveolens*), TB7 triple bagging with 2.5%
91 biopesticides (1.25 kg *L. multiflora*), TB8 triple bagging with 2.5% biopesticides (1.25 kg of *H.*
92 *suaveolens*). The experiment lasted 18 months.

93 2.3.2 Samples collection

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

100 2.3.3 Biochemical Analysis

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

$$114 \text{ Raw fibre} = \frac{(P_1 - P_2)}{P_0} \times 100$$

115 The lipid content was determined by solvent (hexane) extraction using a Soxhlet device. The protein
116 content was determined using the Kjeldhal method. As for the values of total sugars, the determination
117 was carried out using phenol and sulphuric acid using the method of Dubois and colleagues [12]. Total
118 carbohydrates and energy value were estimated using formulas indicated by FAO 2002[14] as follows:

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

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

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

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123 And finally, the energy value was determined as follows.

124 **Energy Value (%) = [(% protein X 4) + (% carbohydrates X 4) + (% fat X 9)].**

125 The results of moisture, carbohydrate compounds, macronutrients and energy values were expressed
126 on a dry weight basis.

127 **2.4 Statistical analysis.**

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

134 **3.RESULTS AND DISCUSSION**

135 **3.1 Results**

136 **3.1.1 Evolution of nutrient parameters**

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

141 **3.1.2 Moisture and carbohydrate compound content.**

142 The moisture content increases very significantly ($P < 0.001$) during storage (Table II). With an
143 initial value of $9.02 \pm 0.00\%$, the highest values were recorded in the polypropylene bag ($16.99 \pm 0.20\%$)
144 and the triple bagging system without biopesticides ($12.76 \pm 0.10\%$) after 18 months. The moisture
145 content of the maize grains recorded in the bags that have received the various treatments is
146 increasing to a maximum of $12.47 \pm 0.06\%$ in the TB4 batch containing 1.01% biopesticides (0.10 kg of
147 *L. multiflora* and 0.40 kg of *H. suaveolens*). For fibres, the value recorded at the beginning of storage
148 was $5.78 \pm 0.02\%$ and this value gradually decreased after 4,5 months of storage to reach the values of
149 $4.28 \pm 0.04\%$ and $5.23 \pm 0.06\%$ after 18 months of storage respectively for the control and the triple
150 bagging system without biopesticides. On the other hand, in triple bagging systems with biopesticides
151 added in general, no significant difference is observed ($P = 0.05$) for fibre contents (Table II). The
152 storage of maize grains in polypropylene bags and the triple bagging system also revealed a significant
153 decrease ($P = 0.05$) in total sugar levels. For an initial value of $2.62 \pm 0.07\%$, the total sugar content
154 drops to values of $1.30 \pm 0.01\%$ and $1.77 \pm 0.01\%$ for batches not treated with the leaves respectively
155 (TB0SP and TB0P). In experimental batches with different proportions of biopesticides, the average
156 value is about $1.97 \pm 0.06\%$. In addition, the reducing sugar contents of the stored maize grains
157 showed significant differences ($P < 0.05$) during storage. These levels decrease from the eighth month
158 of storage, to reach values of $0.26 \pm 0.00\%$ (TB0SP) and $0.30 \pm 0.00\%$ (TB0P) for untreated batches
159 after 18 months of storage (Table II). For batches treated with biopesticides (*L. multiflora* and *H.*
160 *suaveolens*), the average values recorded are in the order of ($0.39 \pm 0.02\%$) (Table II). The starch
161 contained in maize at the beginning of storage 75.20 ± 0.63 g/100 g MS drops to 46.10 ± 0.78 and
162 58.27 ± 0.61 g/100 g MS respectively in the control batch and the treatment that did not receive
163 biopesticides after 18 months. While the values obtained for biopesticide systems range from
164 60.14 ± 0.02 to 62.03 ± 0.16 g/100 g of MS (Table II). While the values obtained for biopesticide systems
165 range from 60.14 ± 0.02 to 62.03 ± 0.16 g/100 g of MS (Table II).

166 **3.1.3 Macronutrient and energy content**

167 Statistical analysis indicates that the lipid content of maize grains recorded at the beginning of
168 storage ($5.51\pm 0.04\%$) decreases significantly ($P=.05$) both at the control level (TB0SP) and in the
169 triple bagging system without biopesticides (TB0P) with values of $3.33\pm 0.10\%$ and $4.04\pm 0.06\%$
170 respectively. For triple bagging systems with different proportions of biopesticides, the values
171 decrease with the proportions of biopesticides provided. However, for treatments that received 3.99
172 and 5% biopesticides respectively, the values remain constant ($P=.05$) (Table III). However, for
173 treatments that received 3.99 and 5% biopesticides respectively, the values remain constant ($P=.05$)
174 (Table III). Concerning the protein content, the values drop significantly to values fluctuating between
175 $8.60\pm 0.10\%$ and $6.87\pm 0.00\%$ and then between $8.60\pm 0.10\%$ and $7.52\pm 0.00\%$ of MS respectively for
176 maize grains stored in the polypropylene bag and the triple bag without biopesticides after 18 months
177 of storage. In batches treated with *L. multiflora* and *H. suaveolens* leaves, the values vary between
178 8.60 ± 0.10 and $7.84\pm 0.02\%$ in the treatment treated with 1.01% biopesticides (0.10 kg *L. multiflora*
179 and 0.40 kg *H. suaveolens* noted TB4) With regard to the proportions of 3.99 and 5% of biopesticides, the
180 variation is small and remains in the order of 8.60 ± 0.10 to $8.08\pm 0.01\%$ (Table III). In terms of total
181 carbohydrate content, the initial values recorded for maize grains (75.20 ± 0.20) decrease significantly
182 during storage to reach average values of 71.51 ± 0.10 , respectively for the control (TB0SP) and
183 untreated (TB0P) batches. For the batches processed the average value is $72.69\pm 0.04\%$. The ash
184 value is $1.68\pm 0.00\%$ at the beginning of storage and drops significantly ($P=.05$) to $1.30\pm 0.01\%$ after 18
185 months of storage in the simple bagging system (polypropylene bag). However, these values gradually
186 increase after 4.5 months of storage in the triple bagging system without biopesticides to reach
187 $1.50\pm 0.00\%$ after 18 months of storage. On the other hand, these values remain constant over time in
188 triple bagging systems with different proportions of biopesticides, where the variation in ash value is
189 not very pronounced. All stored batches also show a decrease in the energy value, these values are
190 estimated at 384.95 ± 0.78 kcal at the beginning of storage, gradually decrease to 343.48 ± 0.43 and
191 366.49 ± 0.53 kcal for untreated batches and to average values ranging from 368.93 ± 0.22 to
192 369.54 ± 0.78 kcal for treated batches.

193 **3.2 Correlations between nutrient parameters**

194 **3.2.1 Principal Component Analysis (PCA)**

195 The main component analysis of the different maize samples is correlated to the 10
196 biochemical parameters. Under the Kaiser rule, factors with an eigenvalue greater than or equal to 1
197 are taken into account when interpreting PCA data (Fig 1). Only the first factor F1 which has an
198 eigenvalue greater than 1 was considered for the interpretation of the PCA data. It expresses 90.56%
199 of the total variability. The second factor F2 having an eigenvalue of 0.60 with a total variability of
200 6.02% is coupled to the first factor and both will be used to represent the PCA. The factor F1 with an
201 eigenvalue of 9.06 establishes negative correlations with the 9 biochemical parameters that are: the
202 contents of ash, fibre, protein, fat, total and reducing sugars, total carbohydrates, starch, and energy
203 value and a positive correlation with moisture content. As for character projection, 4 groups were
204 formed. Group 1 consists only of the TB0SP control at 9.5; 14.5 and 18 months of storage noted
205 respectively A3; A4 and A5. These individuals have the highest moisture values and the lowest values
206 for all other parameters. The second group shows individuals rated A2 and B5, which are respectively
207 the control samples (TB0SP) at 4.5 and triple single bagging (TB0P) at 18 months storage. Its
208 samples are similar to those of individuals A3, A4 and A5 in terms of changes in biochemical
209 parameters. Group 3 consists of samples from the control lot (TB0SP) after one month of storage,
210 triple bagging without biopesticides (TB0P) up to 14.5 months of storage and triple bagging with
211 different proportions of biopesticides at different storage times (T0, T1, T2, T2, T3, T4, T5). These are
212 characterized by high values for biochemical parameters and low moisture values. The last group
213 contains all experimental batches with or without biopesticides (except the control batch) after one
214 month of storage. They have essentially the same variations in the parameters studied in group 3.

215 **3.2.2 Increasing Hierarchical Classification (HAC)**

216 The Hierarchical Ascendant Classification (HAC) established by the Euclidean distance method
217 confirms the variability observed at the PCA level (Fig 2).Indeed, truncation of the dendrogram at an
218 Euclidean aggregation distance of 44 reveals four classes observed according to the different
219 treatments (untreated, triple bagging without biopesticides and triple bagging with different proportions
220 of biopesticides) in storage time. The first class consists of samples from the control lot TB0SP at 9.5;
221 14.5 and 18 months of storage noted respectively A3; A4 and A5. These individuals are characterized
222 by high humidity values and low values for all other parameters. The second group shows individuals
223 rated A2 and B5 which are respectively TB0SP samples at 4.5 and TB0P (triple single bagging) at 18
224 months storage. Individuals in this class are distinguished from other treatments and mark the
225 boundary by which the difference between the two modes of preservation is distinguished. The third
226 group consists of the control at 1 month storage, the triple bagging without biopesticides up to 14.5
227 months storage and the triple bagging with different proportions of biopesticides at different storage
228 times. The samples in this group have similar values to those in the fourth and last group, allowing
229 samples of bags with or without biopesticides to be seen after one month of storage except for the
230 B0SP control lot. The values of these samples thus make it possible to distinguish the efficiency of the
231 storage system used.

UNDER PEER REVIEW

232 **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	VE
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	<i>p</i> <0,001									
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	<i>p</i> <0,001									
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	<i>p</i> <0,001									

233 **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:**
234 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.
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240 **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 ^{Ac}	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 ^{Ac}	5,67±0,01 ^{Ab}	5,60±0,01 ^{Cd}	5,62±0,01 ^{BCcd}	5,68±0,01 ^{Aa}	5,64±0,04 ^{Bab}	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}	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 ^{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 ^{Cc}	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}

242 The means (\pm standard deviation) with different lowercase / upper case letters on the same row/in the same column are different in the 5% probability
 243 test.
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245 TB0SP: control treated without biopesticides in the polypropylene bag, TB0P: triple bagging with 0% biopesticides, TB1: triple bagging with 2.5%
 246 biopesticides (i.e. 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.
 247 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
 248 (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:
 249 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)
 250 and TB8: triple bagging with 2.5% biopesticides (1.25 kg H. suaveolens)
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Table II continuation: Evolution of humidity and carbohydrate compounds during storage time according to the treatment.

Parameters	Storage Time	TB0SP	TB0P	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 ^{Eo}	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}

258 The means (\pm standard deviation) with different lowercase / upper case letters on the same row/in the same column are different in the 5% probability
 259 test.

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262 TB0SP: control treated without biopesticides in the polypropylene bag, TB0P: triple bagging with 0% biopesticides, TB1: triple bagging with 2.5%
 263 biopesticides (i.e. 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.*
 264 *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
 265 (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:
 266 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*)

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

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Parameters	Storage Time	TB0SP	TB0P	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 ^{Eo}	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 ^{Eo}	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}

282 *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.*

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284 *TB0SP: control treated without biopesticides in the polypropylene bag, TB0P: triple bagging with 0% biopesticides, TB1: triple bagging with 2.5%*
 285 *biopesticides (i.e. 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),*
 286 *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*
 287 *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*
 288 *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*
 289 *H. suaveolens)*

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

Parameters	Storage Time	TB0SP	TB0P	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±0,00 ^{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 ^{Ud}	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 ^{Ucd}	1,60±0,00 ^{Cab}	1,60±0,00 ^{Cab}	1,55±0,01 ^{Ud}	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 (\pm 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 (i.e. 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*)

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

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	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

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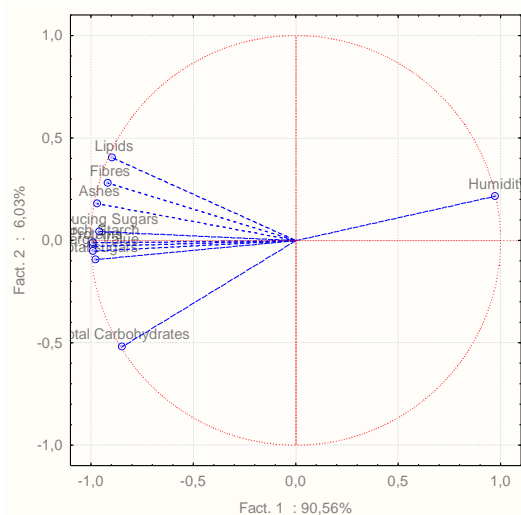
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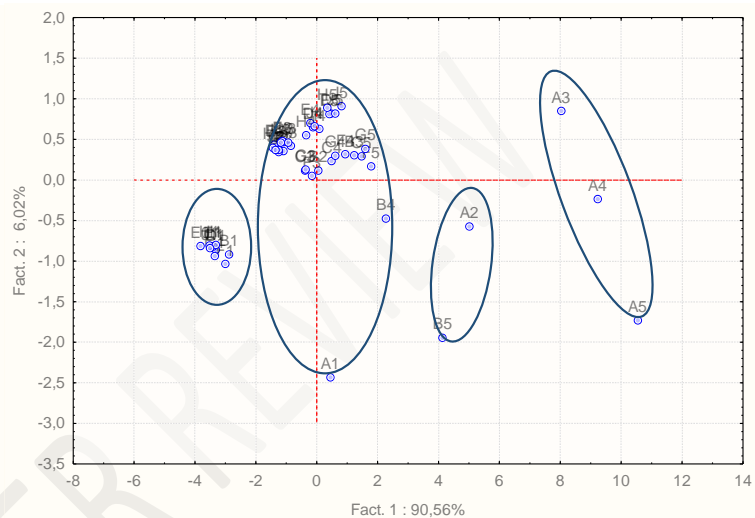
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a-Projection of variables



b- Projection of individuals

Fig 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 biopesticide 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 biopesticide at 1 month conservation *A2* : polypropylene bag at 4.5 months, *B2* : triple bagging without biopesticide 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% biopesticide at 4.5 months storage. *A3*: polypropylene bag at 9.5 months, *B3*: triple bagging without biopesticide at 9.5 months *C3, D3, E3, F3, G3, 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% biopesticide at 9.5 months storage. *B4*: triple bagging without biopesticide 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% biopesticide at 14.5 months storage. *B5*: triple bagging without biopesticide 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% biopesticide at 18 months storage.

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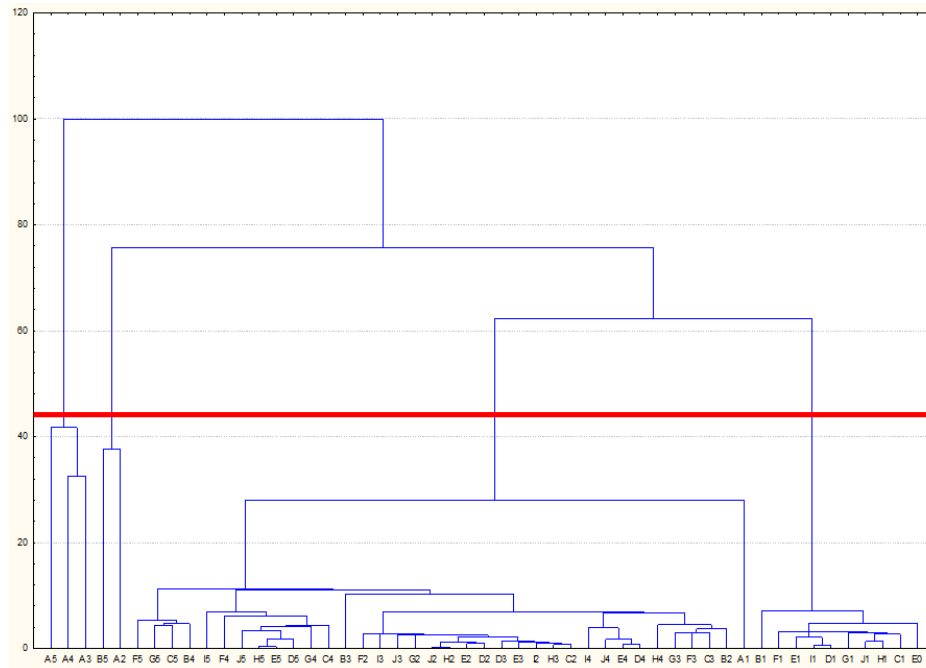


Fig 2: Dendrogram of nutrient parameters according to treatments during storage time

E0 : initial sample, A1 : polypropylene bag at 1 month, B1 : triple bagging without biopesticide 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 biopesticide at 1 month conservation A2 : polypropylene bag at 4.5 months, B2: triple bagging without biopesticide 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% biopesticide at 4.5 months storage. A3: polypropylene bag at 9.5 months, B3: triple bagging without biopesticide at 9.5 months C3, 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% biopesticide at 9.5 months storage. B4: triple bagging without biopesticide 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%, 5%, 2.5% and 2.5% biopesticide at 14.5 months storage. B5: triple bagging without biopesticide 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% biopesticide at 18 months storage.

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349 3.4 Discussion

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

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

400 4 CONCLUSION

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

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

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