ORIGINAL ARTICLE

EFFECT OF A TRIPLE BAGGING SYSTEM AND LEAVES OF AROMATIC PLANTS (*Lippia multiflora* AND *Hyptis suaveolens*) ON THE PHYSICOCHEMICAL PARAMETERS OF THE OIL OBTAINED FROM THE KERNELS OF CORN (*Zea mays* L.) STORED

| Ange Mesmer Akoun [1]* | Ibrahim Fofana [1] | Didier Narcisse Amané [1] | Kouamé Olivier Chatigre [1] |

[1] Felix Houphouet-Boigny University | Biosciences Training and Research Unit | Laboratory of Biotechnology | Agriculture and Development of Biological Resources | Côte d'ivoire |

| Received July 22, 2021 | | Accepted July 25, 2021 | | Published July 30, 2021 | | ID Article | Ange–Ref01-ajira240721 |

ABSTRACT

Background: Stakeholders in the corn sector are faced with a storage and / or conservation problem, which affects the quality of the fat in the grains. **Objectives:** to evaluate, during storage, the quality of the oil from corn kernels stored in a triple bagging system, whether or not associated with the leaves of aromatic plants. **Methods**: Ten batches including one control in polypropylene bag, one batch in triple bagging without biopesticides and eight batches in triple bagging with variable proportions and / or combination of *Lippia multiflora* and *Hyptis suaveolens* (between 1.01% and 5% and a combination 0 to 100% Lippia) were set up to follow the evolution of the quality indicators of the grains and oils extracted during six observation periods (0 ; 1 ; 4.5 ; 9.5 ; 14.5 and 18 months). **Results:** storage time and type of packaging have a significant effect on lipid quality. After 18 months of grains storage, the oil obtained from the grains of the triple bagging systems associated with at least 2.5% of biopesticides exhibits better physicochemical characteristics. These values are of the order of 0.912 (density), 52.65 mPa.s^{-1} (viscosity), 1.465, 110 g I2 / 100g, 4.07 meq O2 / kg and 190 mg KOH / g (respectively for refractive, iodine, peroxide and saponification indices), 3.31% (acidity) and 1.14% (unsaponifiable content). On the other hand for the oil obtained from the grains of the triple bagging system without biopesticides, these indices have respective values of 0.941 and 47.34 mPa.s^{-1}, 1.462, 90.04 g I2 / 100g, 10.70 meq O2 / kg 170.43mg KOH / g, 7.92 % and 0.80 %. In addition, in the triple bagging systems associated with biopesticides, the moisture and oil levels of the grains are around 12.35 % and 5 % against 13 % and 4 % for the triple bagging lot without biopesticides at the end of storage. **Conclusions**: a proportion of 2.5 % of *Lippia multiflora* and / or *Hyptis suaveolens* leaves is sufficient to preserve the quality of the oil obtained from the corn stored for 18 months.
Keywords: *corn storage, oil quality, biopesticides, triple layed bag*

1. INTRODUCTION

Maize is a widely cultivated cereal in Côte d'Ivoire [1]. Ivorian production has experienced strong growth in recent decades, reaching around one million tonnes [2]. In addition to the importance of its starch in human nutrition, corn kernels provide a better quality edible vegetable oil [3, 4]. In fact, this oil, which is mostly extracted from the germ and rich in nutrients (unsaturated fatty acids, tocopherols and phytosterol), has advantages for human health [5, 6]. Corn oil is heavily produced in the United States while in sub-Saharan Africa, where palm oil is king, it is hardly produced but rather imported. However, corn oil could be a complementary oil to fill the qualitative deficit in fat that has existed for years at the level of populations and industries [7-8-9]. To achieve this, it will not only be necessary to resolve upstream, the problem of huge post-harvest losses that producers have difficulty in dealing with [10]and which does not allow industries to continuously supply. Which does not arouse enthusiasm among these manufacturers looking for raw materials; but also downstream to remedy the difficulties of eliminating undesirable compounds resulting from poor storage practices of producers [11, 12]. Indeed the inadequacy of traditional storage methods such as the excessive use of chemical pesticides by producers [13, 14] lead to the presence of spoilage products, mycotoxins as well as pesticide residues in the industrial oils [15, 11]. Therefore, the quality of the oil depends on the quality of the grains from storage. The interest is therefore to find alternative conservation techniques and methods for corn kernels that are simpler and less expensive which guarantee the quality of the oil during storage.

In Ivory Coast, the use of aromatic plants and triple bottom bags (double polyethylene layer placed inside a woven polypropylene bag) made it possible to optimize storage conditions and maintain the nutritional quality of corn kernels over a long period [16, 17]. The objective of this study is to evaluate, during storage, the quality of the crude oil obtained from corn kernels stored in a triple bagging system, whether or not associated with the leaves of aromatic plants (*Lippia multiflora* and *Hyptis suaveolens*).

2. MATERIAL AND METHODS

2.1. Study site

The experimental trials were carried out in the conservation chamber of the Pedagogical and Research Unit of Biochemistry and Food Sciences at the Félix Houphouët-Boigny University. Within this enclosure, the temperature and relative humidity averages were of the order of 27.27ºC ± 1.41 and 81.58 ± 3.02%, respectively. The storage bags were placed on wooden pallets for support.

2.2. Biological material

2.2.1. Corn used in the study: The dry maize kernels used in this study were obtained from producers in the Hambol region in the Center-North of Côte d'Ivoire in the department of Katiola, between 8°10' North and 5°40' West, just after harvest. It is an improved GMRP-18 variety of the 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*, were collected in the region of Gbêkê (7°50 'North and 5°18' West). They were dried out of the sun for a week and then chopped into fine particles before use.

2.3. Packaging material: Polypropylene and polyethylene bags with a capacity of 120 kg were obtained from suppliers in the Adjamé market (municipality of Abidjan) for the storage of maize. The triple bagging system consists of a combination of two internal polyethylene bags (high density, 80 mm thick and not very permeable to air) and an external synthetic fabric bag (polypropylene).

2.4. Grain storage protocol: The experiment was carried out over a period of 18 months. It was implemented on the basis of an experimental design (central composite design) using the method of storage by bagging maize kernels with or without the leaves of *Lippia multiflora* and *Hyptis suaveolens*. Nine experimental batches and a control batch were made up as follows: TSP: control batch = 50 kg of maize stored in a woven polypropylene bag without biopesticides, MET 1: 50 kg of corn stored in a triple bagging system with 0% biopesticides, MET 2: 50 kg ofmaize stored in a triple bagging system with 1.01% biopesticides (79.73% *L. multiflora* and 20.23% *H. suaveolens*); MET 3 = 50 kg of corn stored in a triple bagging system with 1.01% biopesticides (20.73% *L. multiflora* and 79.73% *H. suaveolens*) ; MET 4 = 50 kg maize stored in a triple bagging system with 2.5% biopesticides (50% *L. multiflora* and 50% *H. suaveolens*); MET 5 = 50 kg of maize stored in a triple bagging system with 2.5% biopesticides (100% *L. multiflora* and 0% *H. suaveolens*); MET 6 = 50 kg of cornstored in a triple bagging system with 2.5% biopesticides (0% *L. multiflora* and 100% *H. suaveolens*); MET 7 = 50 kg of corn stored in a triple bagging system with 3.99% biopesticides (79.73% *L. multiflora* and 20.27% *H. suaveolens*); MET 8 = 50 kg of cornstored in a triple bagging system with 3.99% biopesticides (20.27% *L. multiflora* and 79.73% *H. suaveolens*) and MET 9 = 50 kg of maize stored in a triple bagging system with 5% biopesticides (50% of *L. multiflora* and 50% of *H. suaveolens*).

2.5. Sampling: Sampling for analyzes was carried out according to sampling times as foreseen by the central composite design applied by Akoun *et al*. [17]. Before conditioning the grains in the bags, a sample of 5 kg of corn was taken from the initial stock to determine the initial parameters of the oil. Thus, these initial values will serve as a reference for the values–obtained during storage. On the dates planned (1; 4.5; 9.5; 14.5 and 18 months) for the samples, five (5) kg of corn were taken from each batch. For each grain sampling period, sampling was done in triplicate and randomly in each lot throughout the period of the experiment. Then, the samples were ground in the laboratory to determine the physico-chemical parameters of the oils obtained from the grains during storage.

2.6. **Determination of moisture and oil levels in grain:**The moisture content of the corn kernels was determined by steaming the samples until a constant weight was obtained according to standard 952.08 of the AOAC method [18]. The extraction of the oil was carried out according to the method described by the French standard AFNOR [19], using Soxhlet as extractor and hexane as solvent after 6 hours of extraction. This made it possible to determine the content.

2.7. **Determination of the oil quality parameters of stored corn kernels:** Density was determined using the method described by UIPAC [20]. It consists in measuring the mass, at a given temperature, of a volume of fatty substance contained in a pycnometer previously calibrated at the same temperature. The viscosity was determined according to the French standard AFNOR [19] using the principle of gravity by means of a viscometer tube. The refractive index of oils was determined by the method described by IUPAC [20]. Thus after having calibrated the digital optical refractometer of ABBE brand, a drop of oil brought to 40 ° C was deposited between the prisms of the apparatus. The refractive index value is displayed automatically.

The determination of the oil acidity of the corn samples was made according to standard 940.28 of the method of AOAC [18]. It consisted in titrating with a solution of diethyl / ethanoic corn oil with an ethanolic solution of sodium hydroxide using phenolphthalein as color indicator. The acidity was expressed as a percentage of oleic acid per gram of fat. The peroxide value of the oil of the corn samples was determined according to the method described by the

standard 965.33 of the method of AOAC (2000) [18]. This method consisted in treating a test portion of fat dissolved in a mixture of chloroform and acetic acid, with a saturated solution of potassium iodide, then in titrating the iodine released with a solution of sodium thiosulphate. The determination of the iodine number of the fat of the maize samples was carried out by the Wijs method described by standard 993.20 of AOAC (2000) [18]. This method consisted in treating the fat with an excess of iodine trichloride in acetic acid (Wijs reagent) and the excess of reagent was then titrated with a solution of sodium thiosulphate after liberation of the iodine. The saponification index was determined according to the 920.160 standard of the method of AOAC (2000) [18]. The method consisted in treating the fat with an excess of hot alcoholic potassium hydroxide solution and then in titrating the excess alcoholic potassium hydroxide with a hydrochloric acid solution.
The unsaponifiable content was determined using the method described by UIPAC (1979) [20]. This method consists in first saponifying the fatty substance with methanoic potash and then extracting the unsaponifiable material with a specific solvent. The evaporation of the solvent made it possible to obtain a dry residue of precise mass.

2.8. Statistical methods

The statistical analyzes of the data were carried out using SPSS "Statistical Program for Social Sciences" software version 22.0 and STATISTICA (version 7.1). All the tests for all the grain and oil quality parameters were carried out in triplicate and the results are expressed as a mean ± standard deviation. With SPSS, the analysis of variance (ANOVA) with two factors in this case the shelf life and the type of packaging, was carried out on all the results obtained in order to determine the existence of statistically significant differences between calculated mean values. Statistically significant differences were demonstrated by Tukey's test at the 5% significance level. Using the STATISTICA software (version 7.1), the correlations existing between the parameters were evaluated according to the Pearson index. Multivariate exploratory techniques such as principal component analysis (PCA) and hierarchical ascending classification (HAC) were used to process the data generated during storage.

3. RESULTS

3.1. Evolution of moisture and oil content of grains

The data from the statistical tests indicate a significant influence at the 5% level of both the duration and the type of conditioning on the moisture and fat content of the grains (Table 1). The moisture content of the corn kernels increases over time depending on the type of packaging. With an initial average rate of around 9.02 ± 0.01% at the start of storage (0 months), the humidity level reaches, after 18 months of storage, an average value of 17.10 ± 0.20 % in the control batch in polypropylene (TSP) (Table 2). In the triple bagging batch without biopesticides (MET 1), this value is 13.01 ± 0.10% against less than 13% in the batches with different proportions and / or combinations of biopesticides. However, significant differences ($P < 0.05$) were observed between the moisture levels of the grains of the batches triple bagged with biopesticides at the 18th month (Table 2).

Storage of the corn kernels also revealed a significant drop ($P < 0.05$) in lipid contents, depending on the different packaging. After 18 months of storage, the lowest values were recorded in the polypropylene control lot (3.33 ± 0.10%) and the tri-bagged lot without biopesticides (4.00 ± 0.06%). No significant variation ($P > 0.05$) was observed in the lipid levels of corn kernels stored in the triple bagging systems associated with a proportion of biopesticides greater than or equal to 3.99% (MET 7, MET 8 and MET 9) throughout the storage period (Table 2). After 18 months of storage, these samples show the highest values with a minimum average of 5.32 ± 0.02 %.

3.2. Characterization of grain oil quality: The variance analysis shows that the type of packaging and the shelf life have an influence on the quality parameters of the oil obtained from the stored grains (Table 2).

3.2.1. Evolution of the density, viscosity and refractive index of the extracted oils: Figures 1, 2 and 3 illustrate the evolution of the density, viscosity and refractive index of the oils obtained from the grains during storage. Concerning the density, a significant increase ($P < 0.05$) was generally observed in the oils obtained from the preserved grains. With an initial value of 0.910 ± 0.001 (at month 0), the density of the oils increases to reach, after eighteen months of storage, values 0.983 ± 0.001 and 0.941 ± 0.005 respectively for the TSP and MET 1 batches. In the different batches in triple bagging with different proportions and / or combination of biopesticides, the average density is 0.917 ± 0.001 (MET 4). As for the viscosity of the oils obtained from the stored corn kernels, a significant drop ($P < 0.05$) is observed at the batch level. Thus for an initial value of 58.10 ± 0.10 $mPa.s^{-1}$ at the start of storage, the lowest values were obtained after 18 months of storage in TSP (29.12 ± 0.01$mPa.s^{-1}$) and MET 1 (47.34 ± 0.04 $mPa.s^{-1}$). The oils obtained from the grains stored in the triple bagging systems with different proportions and / or combination of biopesticides have an average viscosity of between 50 and 56 $mPa.s^{-1}$ (Figure 3). In the refractive index of oils obtained from the grains, the lowest values were recorded after 18 months of storage in batches TSP (1.459 ± 0.00) and MET 1 (1.461 ± 0.000) with an initial value of 1.467 ± 0.000. On the other hand, oils obtained from grains preserved with a minimum proportion of 2.5% of biopesticides have a constant refractive index (1.465 ± 0.00) throughout the storage period.

3.2.2. Evolution of chemical parameters: The peroxide index and the acidity of the oils increase significantly ($p < 0.05$) during the storage period of the grains regardless of the type of packaging used. With respective initial averages of 1.12 ± 0.02meq O2/kg and 1.04 ± 0.02% (figures 4 and 5), the grain oil from the control batch in polypropylene bag recorded very high values (18.92 ± 0.04 meq O2/kg and 15.26 ± 0.32%) after eighteen months of storage. For the oil obtained from the grains stored in the triple bagging system without biopesticides, the peroxide number and the acidity are respectively of the order of 10.70 ± 0.07meq O2/kg and 7.92 ± 0,01%. The lower values were obtained with the oils obtained from the batches in triple bottom bag associated with a minimum proportion of biopesticides of 3.99% (3.43 ± 0.01meq O2/kg and 3.07 ± 0.01%). In addition, the averages of the iodine and saponification indices as well as the unsaponifiable content fell in all the lots. This decrease is more pronounced in the TSP batch than in the MET 1 batch. The initial values of these parameters are respectively 131.03 ± 0.03g I2/100g (iodine number), 205.70 ± 0.56mg KOH/g (saponification number) and 1.20 ± 0.01% (unsaponifiable content). At the end of storage, the oil from the grains of the TSP batch has the lowest values (respectively 70.45 ± 0.56g I2/100 g, 155.68 ± 0.55 mg KOH / g and 0, 68 ± 0.01%). For the oil obtained from the grains of batch MET 1, these values-are 90.04 ± 0.04 g I2/100 g, 170.43 ± 0.50 mg KOH / g and 0.80 ± 0.01%. On the other hand, the averages are higher for the oil obtained from the bagged batch of the triple bagging system with 5% of biopesticides (from 114.96 ± 1.01 g I2/100g, 191.43 ± 0.05mg KOH/g and 1.14 ± 0.00%) (Figures 6, 7 and 8).

3.2.3. Correlation between grain quality and quality parameters of extracted oils: Pearson's coefficients indicate positive and negative correlations between the 10 parameters evaluated (Table 3). Thus humidity is strongly and positively correlated with the peroxide number, acidity and density with correlation coefficients varying between 0.88 and 0.91. On the other hand, it is negatively correlated with the other parameters evaluated with respective correlation coefficients of -0.82 (oil content), -0.87 (viscosity), -0.93 (iodine number), - 0.94 (saponification index), -0.93 (refractive index) and -0.83 (unsaponifiable). Similarly the oil content is strongly and positively correlated with viscosity (0.93), iodine number (0.93), saponification index (0.94), refractive index (0.93) and the unsaponifiable content (0.96). On the other hand, it exhibits a negative correlation with the peroxide number, acidity and density respectively at the correlation coefficients –0.96, -0.95 and -0.94. As for the various oil quality parameters, the table reveals a strong positive correlation at two levels. On the one hand, a positive correlation exists between the viscosity, iodine index, saponification index, ~~the~~ refractive index and the content of unsaponifiables (between 0.87 and 1.00). On the other hand, a positive relationship between the peroxide number, acidity and density (0.97 and 1.00) has been demonstrated. However, these two groups of parameters remain negatively correlated with each other.

3.2.4. Differentiation of the type of packaging in relation to the quality parameters of the oil: The variability between the physico-chemical parameters of the oils and the types of conditioning of the corn kernels was structured through principal component analyzes (PCA). These analyzes were made with components (or factors) which record an eigenvalue greater than or equal to 1, according to Kaïser's rule. Then the specificities of the groupings resulting from the PCA were specified using the ascending hierarchical classification (AHC) carried out by the euclidean distance method with a truncation of the dendrogram at a euclidean aggregation distance of 50.

The eight parameters were correlated with eight factors. However, only the first factor, having an eigenvalue greater than or equal to 1, is considered for the interpretation of PCA data. It accumulates 94.75% of the total variability. Nevertheless, the second factor of eigenvalue 0.20 and total variability 2.49 % was associated with the first factor for the representation of PCA. The factor (F1) has an eigenvalue of 7.58 and is mainly formed by all the parameters considered. These are positively correlated with it for some (viscosity, refractive index, iodine index, saponification index, unsaponifiable content) and negatively for others (density, peroxide index and acidity) (Table 4). The projection of the oil samples of the stored corn kernels divides them into 3 groups (Figure 9). Group 1 consists of oil samples only from the control batch in polypropylene at 14.5 and 18 months of storage (noted A4 and A5). These samples are characterized by very high values of peroxide index, acidity and density, but also by low values of saponification, iodine and refractive indexes, unsaponifiables as well as a very low viscosity.

The second group consists of oil samples from the grains of the control lot in polypropylene bag at 4.5 and 9.5 months (marked A2 and A3 respectively) and two samples of oil from the corn lot of the triple bag background without biopesticides at 14.5 and 18 months of storage (noted B4 and B5) the samples of this group are characterized by median values for all the parameters and therefore by a less advanced alteration than that of the individuals of the first group. This second group also characterizes the limit of effectiveness between the methods of simple bagging in polypropylene and triple bagging without biopesticides. The third group consists of oil samples from all batches in a triple bagging system associated with biopesticides (noted C; D; E; F; G; H; I and J) throughout the storage period; oil samples from the lot in the triple bagged bag withoutbiopesticides at 1, 4.5 and 9.5 months (noted B1; B2; B3 respectively) and that of the grains of the lot in the polypropylene bag at 1 month (A1) and of the oil sample T0 from the initial lot. They have better characteristics for all the physicochemical parameters compared to the two previous groups. They characterize the efficiency limits of triple bagging with or without aromatic plants (biopesticides).

In addition, the ascending hierarchical classification (CAH) established by the Euclidean distance method confirms the variability observed at the PCA level and reveals three classes observed during storage of maize. The first class consists of the only individual which is the oil sample from the control batch of grains in the polypropylene bag at 18 months of storage (A5). This individual has the highest values for density, peroxide number and acidity and the lowest for the other parameters, ie very advanced degradation. The samples of oil from the grains of the polypropylene control batch taken during storage periods of 4.5 to 14.5 months (respectively marked A2, A3 and A4) and associated with the oil from the batch in triple bagging without biopesticides at 18 months (B5) constitute the second class. In this class, the values presented by these individuals are appreciably better for the set of parameters chosen, compare to A5. The third class is composed of the oil sample noted A1 from the polypropylene batch at 1 month, oil samples from the grains of the tri-bagged batches without biopesticides noted B1, B2, B3 and B4, oil samples from all batches in a triple bagging system associated with biopesticides (noted C; D; E; F; G; H; I and J) as well as T0, oil extracted from the initial batch. This class is distinguished by the best values of the parameters of all the oil samples. They are characterized by the lowest values for the density, the peroxide value of the acidity and the high values for the content of oil, iodine number, saponification number and for the content of unsaponifiables. However, if the aggregation distance is reduced to 40 instead of 50, only the samples of oils obtained from grains stored in the triple bagging systems in the presence of at least 2.5 % of aromatic plants leaves constitute the subclass exhibiting characteristics better physicochemicals.

Table 1: Statistical data of the parameters during storage according to the type of packaging

Sources of variation	Stat. Para.	MST	OCT	RFI	DEN	VIS	PEI	IOI	SPI	COU	ACD
Duration	dof	3.32	1.42	0.00	2.56	2.951	2.29	2.128	2.83	2.50	5
	SS	393.14	6.68	1.15	0.01	1398.809	633.81	14341.59	9114.69	0.46	378.32
	F	11724.27	366.69	1481.49	154.43	16312.53	11105.67	3658.68	5506.70	698.84	51793.62
	P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Error (duration)	dof	66.44	28.32	23.06	51.202	59.017	45.72	42.56	56.61	50.01	74.41
	SS	0.67	0.36	$2.65.10^{-6}$	0.001	1.715	1.141	78.40	33.10	0.013	0.15
Methods	dof	9	9	9	9	9	9	9	9	9	9
	SS	183.31	16.07	0.00	0.012	1557.46	842.85	16099.12	6245.56	1.28	542.43
	F	2469.52	426.89	289.81	132.81	7089.52	7891.19	1123.75	1678.33	982.22	20940.51
	P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Error (methods)	dof	20	20	20	20	20	20	20	20	20	20
	SS	0.17	0.08	$1.68.10^{-6}$	0.000	0.488	0.24	31.84	8.27	0.00	0.06
Duration X Methods	dof	29.90	12.75	10.38	23.041	26.558	20.57	19.15	25.47	22.50	45
	SS	73. 32	7.93	$5.66.10^{-5}$	0.008	1149.223	500.68	4271.44	2397.84	0.58	298.63
	F	242.97	48.36	48.20	18.608	1489.103	974.76	121.08	160.96	98.36	4542.74
	P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

***Stat.Para** = statistical parameters; **dof**: degree of freedom; **SS**: sum of squares; **F:** Fischer test; **P**: Probability value of statistical test. **MST** = moisture of grain; **OCT** = grain oil content; **IOI** = iodine index; **SPI** = Saponification index; **COU** = content of unsaponifiables; **PEI** = Peroxide index, **ACD** = Acidity, **RFI** = Refractive index; **DEN** = Density and **VIS** = Viscosity*

Table 2: Evolution of the moisture content and the oil content of the grains during storage for 18 months.

Parameters	Storage time (months)	TSP	MET 1	MET 2	MET 3	MET 4	MET 5	MET 6	MET 7	MET 8	MET 9
Moisture (%)	**0**	9.02±0.01^{aD}	9.02±0.01^{aF}	9.02±0.01^{aE}	9.02±0.01^{aE}	9.02±0.01^{aE}	9.02±0.01^{aE}	9.02±0.01^{aE}	9.02±0.01^{aE}	9.02±0.01^{aE}	9.02±0.01^{aE}
	1	10.20±0.10^{aC}	9.23±0.06^{bE}	9.17±0.06^{bcE}	9.12±0.03^{bcE}	9.10±0.02^{bcE}	9.14±0.04^{bcE}	9.09±0.03^{cE}	9.09±0.07^{cE}	9.07±0.04^{cE}	9.09±0.04^{cE}
	4.45	14.05±0.07^{aB}	11.40±0.08^{bD}	11.00±0.07^{cD}	10.50±0.06^{dD}	10.30±0.13^{dD}	10.45±0.07^{dD}	10.35±0.09^{dD}	10.40±0.06^{dD}	10.07±0.13^{eD}	10.07±0.07^{eD}
	9.5	16.67±0.27^{aA}	12.00±0.04^{bC}	11.75±0.08^{bcC}	11.51±0.05^{cdC}	11.10±0.03^{eC}	11.50±0.02^{cdC}	11.20±0.05^{deC}	11.17±0.02^{eC}	11.02±0.01^{eC}	10.95±0.02^{eC}
	14.5	16.97±0.07^{aA}	13.70±0.06^{bB}	12.30±0.06^{cB}	12.00±0.06^{dB}	11.68±0.05^{efB}	11.87±0.05^{deB}	11.60±0.02^{fB}	11.45±0.10^{fgB}	11.25±0.04^{fgB}	11.19±0.05^{gB}
	18	17.10±0.20^{aA}	13.05±0.10^{bA}	12.72±0.06^{eA}	12.45±0.18^{cdA}	12.35±0.02^{deA}	12.37±0.03^{deA}	12.29±0.06^{deA}	12.20±0.01^{deA}	12.07±0.02^{eA}	12.07±0.03^{eA}
Oil 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±0.04aA
	1	4.85±0.13^{bB}	5.38±0.16^{aA}	5.42±0.22^{aAB}	5.50±0.15^{aA}	5.50±0.25^{aA}	5.48±0.07^{aA}	5.50±0.021^{aA}	5.52±0.32^{aA}	5.51±0.29^{aA}	5.52±0.27^{aA}
	4.45	4.59±0.05^{dC}	5.25±0.39^{cB}	5.30±0.01^{cB}	5.48±0.01^{bcB}	5.47±0.01^{aA}	5.38±0.02^{aA}	5.49±0.03^{aA}	5.50±0.01aA	5.50±0.01^{aA}	5.51±0.01^{aA}
	9.5	4.53±0.00^{gC}	5.10±0.00^{fC}	5.20±0.00^{eD}	5.37±0.02^{cC}	5.40±0.01^{bA}	5.29±0.00^{dA}	5.40±0.01^{bA}	5.42±0.00^{bA}	5.49±0.01^{aA}	5.50±0.01^{aA}
	14.5	3.99±0.10^{gD}	4.70±0.78^{fD}	5.10±0.02^{eE}	5.20±0.01^{dD}	5.34±0.01^{cB}	5.23±0.01^{dB}	5.38±0.01^{bcA}	5.37±0.01^{bcA}	5.45±0.01^{aA}	5.48±0.01^{aA}
	18	3.33±0.10^{gE}	4.00±0.06^{fE}	5.00±.00^{eF}	5.11±0.02^{dE}	5.25±0.01^{bcC}	5.20±0.00^{cdB}	5.28±0.01^{bB}	5.32±0.02^{abA}	5.40±0.01^{aA}	5.40±0.01^{aA}

*The tests were carried out in triplicate.the means (± standard deviation) with different lowercase / uppercase letters on the same row / in the same column are different at the 5% probability test; **TSP** = Control without biopesticides with polypropylene bag; **MET 1** = Control without biopesticides with triple bagging bag; **MET 2** = bag oftriple bagging with 1.01% biopesticides (79.73% L. multiflora and 20.23% H. suaveolens); **MET 3** = triple bagged bag with 1.01% biopesticides (20.73% L. multiflora and 79.73% H. suaveolens); MET 4 = Triple bagged bag with 2.5% biopesticides (50% L. multiflora and 50% of H. suaveolens); **MET 5** = triple bagged bag with 2.5% biopesticides (100% L. multiflora and 0% H. suaveolens); MET 6 = triple bagged bag with 2.5% biopesticides (0% L. multiflora and 100% H. suaveolens); **MET 7** = Triple bagged bag with 3.99% ofbiopesticides (79.73% of L. multiflora and 20.27% of H. suaveolens); **MET 8** = triple bagged bag with 3.99% biopesticides (20.27% L. multiflora and 79.73% H. suaveolens) **MET 9** = triple bagged bag with 5% biopesticides (50% L . multiflora and 50% of H. suaveolens).*

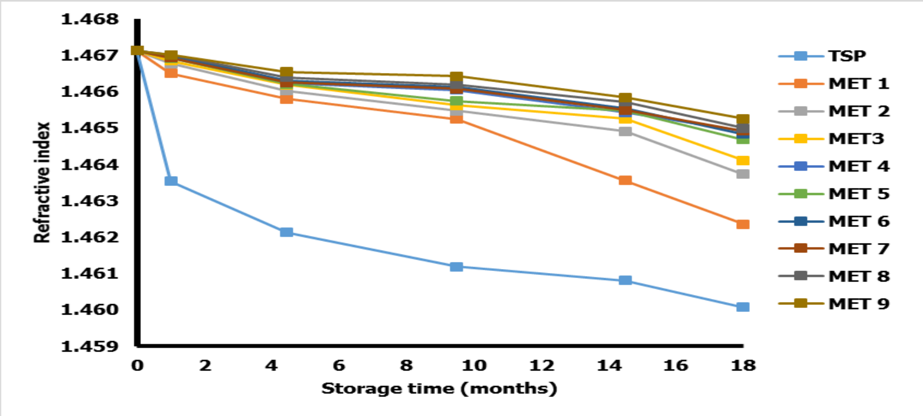

Figure 1: Evolution of the refractive index of oils in grains stored for 18 months.

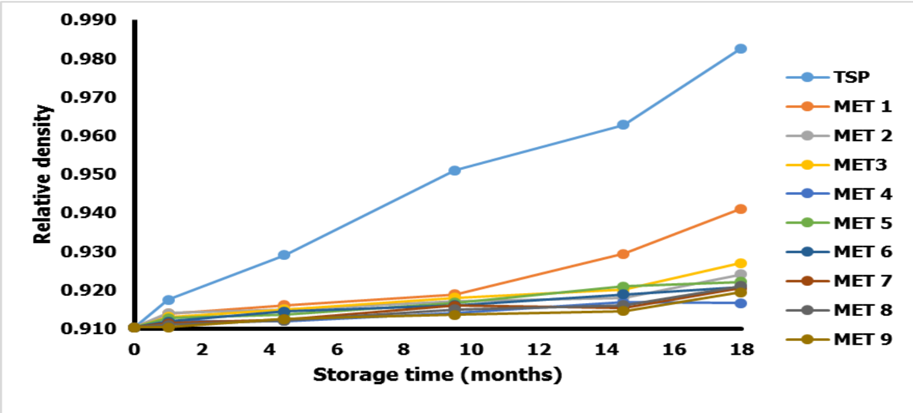

Figure 2: Evolution of the density of the oils in the grains stored for 18 months.

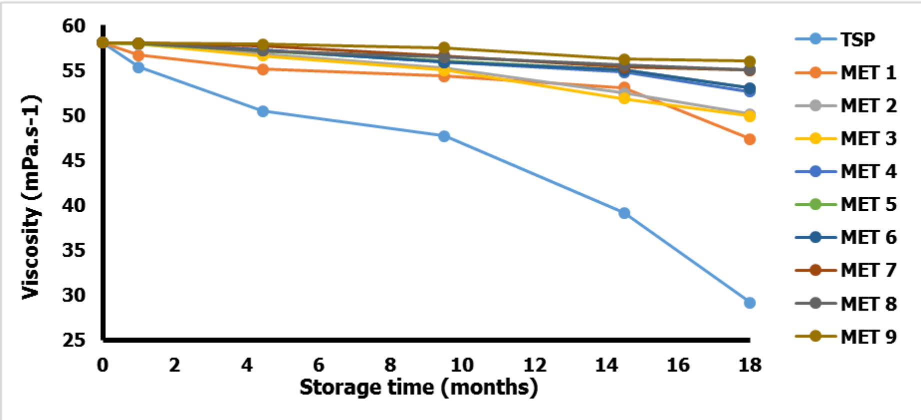

Figure 3: Evolution of the viscosity of the oils of the grains stored for 18 months.

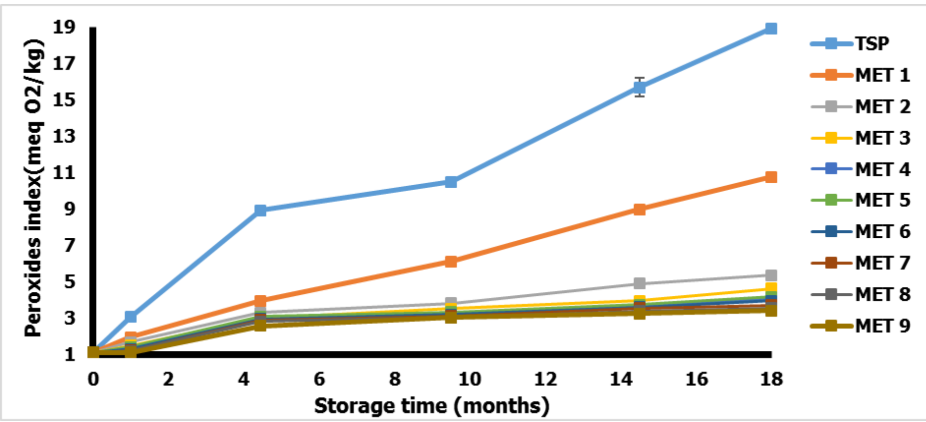

Figure 4: Evolution of the peroxide index of grain oils stored for 18 months.

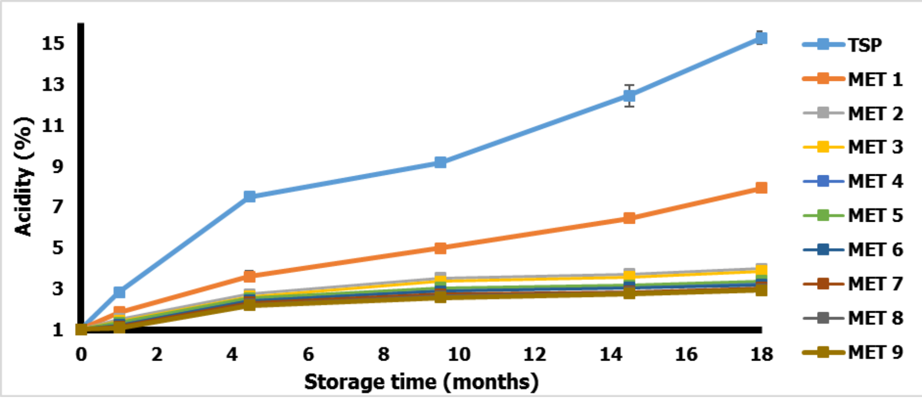

Figure 5: Evolution of the acidity of the oils of the grain stored for 18 months.

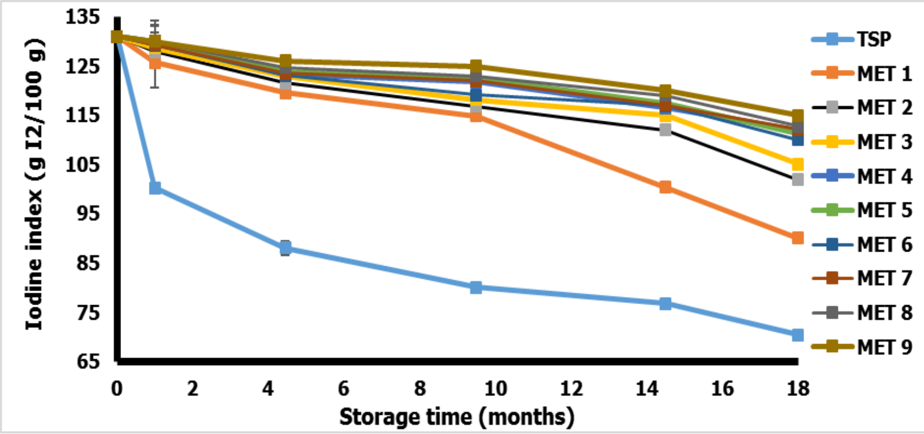

Figure 6: Evolution of the iodine index of the oils of the grain stored for 18 months.

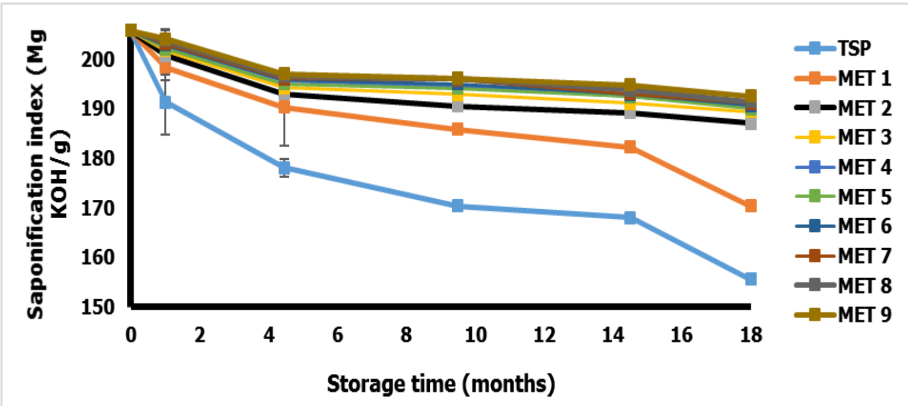

Figure 7: Evolution of the saponification index of the oils of the grains stored for 18 months.

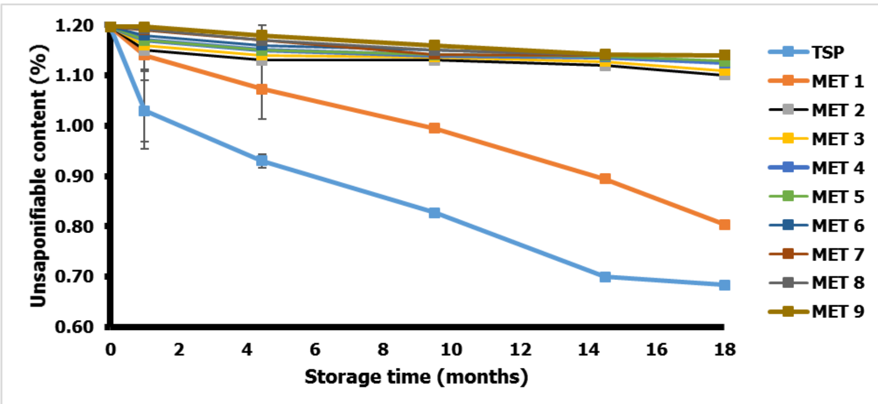

Figure 8: Evolution of the unsaponifiable content of the oils of the grains stored for 18 months.

Table 3: Correlation matrix between the studied parameters.

	Moisture	Oil content	Peroxide index	Iodine index	Saponification index	Unsaponifiable content	Acidity	Refractive index	Density	viscosity
Moisture	1.00									
Oil content	**-0.82**	1.00								
Peroxide index	**0.90**	**-0.96**	1.00							
Iodine index	**-0.93**	**0.93**	**-0.93**	1.00						
Saponification index	**-0.94**	**0.94**	**-0.97**	**0.96**	1.00					
Unsaponifiables content	**-0.83**	**0.96**	**-0.96**	**0.92**	**0.94**	1.00				
Acidity	**0.91**	**-0.95**	**1.00**	**-0.93**	**-0.97**	**-0.96**	1.00			
Refractive index	**-0.93**	**0.93**	**-0.93**	**1.00**	**0.96**	**0.92**	**-0.93**	1.00		
Density	**0.88**	**-0.94**	**0.97**	**-0.91**	**-0.93**	**-0.93**	**0.97**	**-0.91**	1.00	
viscosity	**-0.87**	**0.93**	**-0.95**	**0.90**	**0.92**	**0.87**	**-0.95**	**0.90**	**-0.97**	1.00

Table 4: Matrix of the eigenvalues of the factors resulting from the analysis in principal components and correlation with physicochemical parameters of quality of the oils during the storage of the grains.

Factors	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Eigen value	7.58	0.20	0.13	0.05	0.02	0.01	0.00	0.00
Variance (%)	94.75	2.49	1.62	0.65	0.27	0.17	0.04	0.00
Cumulative Variance (%)	94.75	97.24	98.86	99.51	99.78	99.95	100.00	100.00
Moisture	-0.99	0.09	-0.08	-0.06	0.01	-0.06	-0.04	0.00
Oil content	0.97	0.23	-0.09	-0.04	-0.00	0.02	-0.00	-0.01
Peroxide index	0.98	0.08	0.02	0.16	0.03	-0.06	0.00	-0.00
Iodine index	0.96	0.02	0.25	-0.09	-0.05	-0.04	-0.00	-0.00
Saponification index	-0.99	0.09	-0.07	-0.05	-0.02	-0.06	0.04	-0.00
Unsaponifiables content	0.97	0.23	-0.09	-0.04	-0.00	0.02	0.00	0.01
Acidity	-0.97	0.17	0.05	0.10	-0.10	0.02	-0.01	-0.00
Refractive index	0.96	-0.20	-0.20	0.00	-0.08	-0.03	-0.00	-0.00

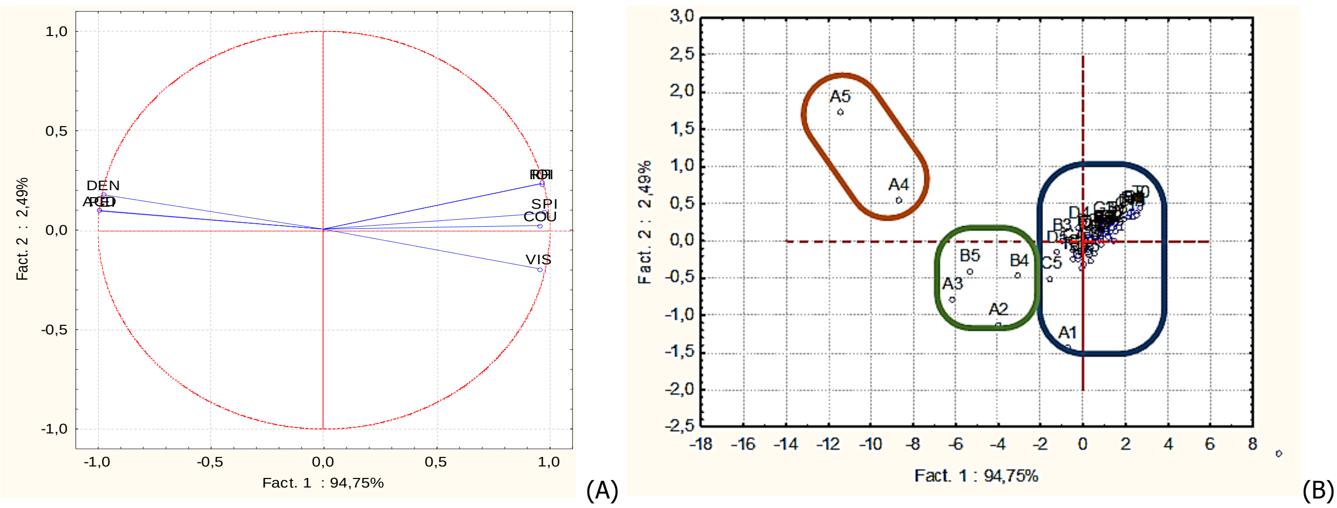

Figure 9: Projection of the variables (A) and of the individuals (B) deriving from the corn kernels stored in the factorial plane 1-2 of the principal component analysis.
With IOI = iodine index; SPI = Saponification index; COU = content of unsaponifiables; PEI = Peroxide index, ACD = Acidity, RFI = Refractive index; DEN = Density and VIS = Viscosity

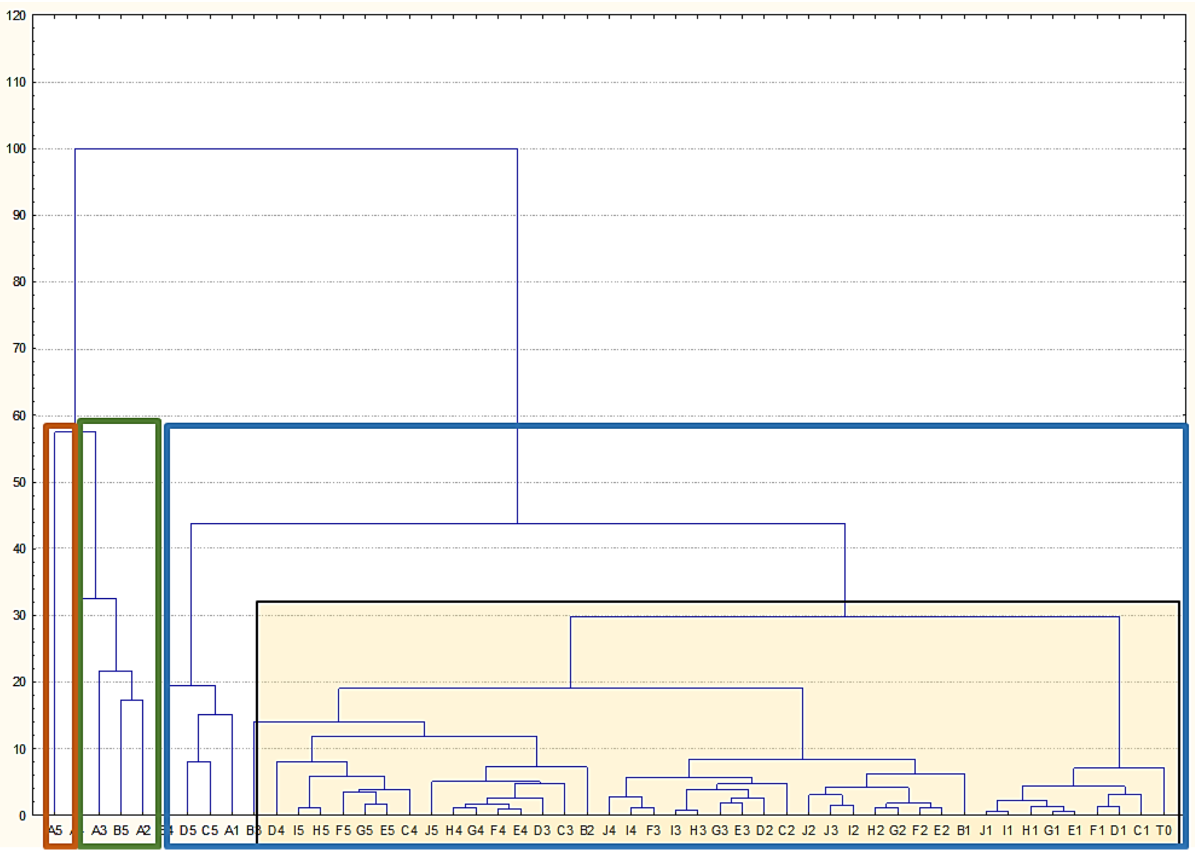

Figure 10: Ascending hierarchical classification (dendrogram) of the different types of packaging with the different parameters of grain and oil quality during storage.

Various uppercase letters indicate the storage methods. A: Batch TSP = Control without biopesticides with polypropylene bag; B: batch MET 1 = Control without biopesticides with triple bagging bag; C: batch MET 2 = triple bagged bag with 1.01% biopesticides (79.73% L. multiflora and 20.27% H. suaveolens); D: Lot MET 3 = triple bagging bagwith 1.01% of biopesticides (20.27% of L. multiflora and 79.73% of H. suaveolens); E: batch MET 4 = Triple bagged bag with 2.5% biopesticides (50% L. multiflora and 50% H. suaveolens); F: batch MET 5 = triple bagged bag with 2.5% biopesticides (100% of L. multiflora et0% H. suaveolens); G: batch MET 6 = triple bagged bag with 2.5% biopesticides (0% L. multiflora and 100% H. suaveolens); H: MET batch 7 = Triple bagged bag with 3.99% biopesticides (79.73% L. multiflora and 20.27% H. suaveolens); I: MET batch 8 = triple bagbagging with 3.99% biopesticides (20.27% L. multiflora and 79.73% H. suaveolens); J: batch MET 9 = triple bagged bag with 5% biopesticides (50% L. multiflora and 50% H. suaveolens). With the periods: (0) = 0 month; (1) = 1 month; (2) = 4.5 months; (3) = 9.5 months; (4) = 14.45 months and (5) = 18 months. And T = initial lot

4. DISCUSSION

This study showed that the preservation of corn kernels in triple bagging systems with the leaves of *Lippia multiflora* and *Hyptis suaveolens* is effective in maintaining the physicochemical quality of the oil. Triple bagging makes it possible to maintain grain moisture at the threshold rate (13%) recommended for good conservation [21,22]. Thus, triple bagging would constitute a barrier against gas exchange between the surrounding ambient humidity and that of the grains, limiting the water exchanges of the grains with the ambient air [23,24]. This efficiency is reinforced by the incorporation of the leaves of aromatic plants (biopesticides). Niameketchi *et al.* (2015) and Ezoua *et al.* (2017) also observed such results with corn kernels stored respectively in improved granaries (11.85%) and in polypropylene bags (less than 13%) in the presence of these plant species [24,25]. In fact, the sheets would act as films on top of the grains protecting them against the effective uptake of moisture.

Concerning the oil content of the grains, it remains constant in the triple bagging systems having a proportion of biopesticides greater than 2.5% and significantly decreases in the other batches and in particular the control batch (TSP). Di Domenico *et al.*, (2015) observed a similar decrease in the fat content of corn kernels stored in polypropylene bags, metal silos and airtight bags [26]. These reductions could come from the natural degradation of grains linked to the processes of respiration and to the enzymatic activity of the grains [27] also to the metabolism of insects and molds [26-28]. In fact, these stock pests produce lipolytic enzymes allowing them to degrade lipids and use them for their growth [29]. Moreover, this moisture uptake and the loss of fat from the grains explains the significant variations observed in the physicochemical parameters of the oils extracted during storage in the TSP and MET 1 batches, given the correlations existing between the grain quality parameters and extracted oil.

These results corroborate the remarks of O'Brien (2009) according to which the quality of vegetable oils is consecutive to the quality of grain storage practices [30]. Also Alencar and Faroni (2011) reported a positive correlation between the damage suffered by the grains and the poor quality of these extracted oils [12]. During storage, the density values increase significantly while those of the viscosity and the refractive index decrease at the level of the extracted oils. This drop rate depends on the type of packaging. In fact, after a period of eighteen months of storage, these indicators have respective values of 0.983; 29.12 mPa.s^{-1} and 1.459 for the oil from the grains of the polypropylene packaging (TSP), 0.941; 47.34 mPa.s^{-1} and 1.462 for that obtained from the grains of the batch of the simple triple bagging (MET 1). On the other hand, the oils obtained from the batches kept in the triple bottom bags with a minimum proportion of biopesticides of 2.5% recorded averages of the order of 0.917, 52. 65mPa.s^{-1} and 1.465 respectively for density, viscosity and refractive index. These values thus remain in conformity with the identification recommendations which are 0.917 (maximum value) for the density and 1.465 (minimum value) for the refractive index of corn oil [31,32] then 50 mPa.s^{-1} (minimum value) for the viscosity of vegetable oils [33]. The triple bagging method associated with biopesticides makes it possible to inhibit the development of acidity and the peroxide index. Usually, failure to master good storage practices results in an exponential increase in these indices during grain storage under the effect of grain moisture and pest activity as evidenced by the results of oils obtained from grains of the bag inpolypropylene (TSP). Under these conditions, the grains are victims of hydrolysis and oxidation reactions. According to Whetje and Adlercreutz (1997), Aïssi *et al*. (2011) and Ahouanou *et al*. (2013), the increase in acidity and the peroxide index observed would be consecutive respectively to the hydrolysis of triglycerides as well as to the oxidation of fatty acids catalyzed by the action water and enzymes from grains and molds [34,35,36]. Joaquim and Carmen (2002), Laguerre *et al*. (2007) and Rahmani (2007) reported the very negative impact of oxidation and acidity on the nutritional, organoleptic and health properties of oils [37,38,39]. They promote the degradation of essential fatty acids, a negatively modified flavor, and the formation of cytotoxic, mutagenic and carcinogenic secondary oxidation compounds. The effectiveness of the leaves of *Lippia multiflora* and *Hyptis suaveolens* in limiting the rancidity of the fat of the grains would have been reported by Niamkétchi *et al.* (2016) and Ezoua *et al.* (2017) [40-25]. This makes it possible to have an oil having a peroxide number well below the maximum of 10 meq O2 / kg recommended for a vegetable oil by Codex Alimentarus [32].

Moreover, this degradation is also reflected in the drop in the iodine and saponification indices and in the unsaponifiable content. The small variations of these indicators for oils obtained from grains stored in triple bagging systems containing biopesticides would inform the capacity of *Lippia multiflora* and *Hyptis suaveolens* leaves to retain the lipid quality of the grains. Crude oils produced from grains preserved by such a technology are of high quality because the initial values remain better preserved or remain within the recommendations of Apertei and Apertei (2015) and Codex Alimentarus (1999) [41-32]. According to these sources, the minimum values for corn oil are 103 g I2 / 100 g, 187 mg KOH / g and 1% respectively for the iodine number, the saponification number and the content of unsaponifiable. These different forms of degradation would be the source of enormous losses (greater than 4%) during the oil refining process, particularly in the context of high acidity [42]. Thus biopesticides, by promoting good storage, would guarantee a vegetable oil with better physical characteristics, of low hydrolytic and oxidative rancidity, rich in fatty acids and unsaponifiables like the work of Arujo (2004) and Alencar *et al*. (2010) on soybeans [43,44]. Moreover, the oil would be exempt from residues of synthetic pesticides [11].

These plant species would contribute to further inhibit the changes in nutritional value, functionality, integrity and safety of fat as mentioned by Silva *et al*. (1999), Arujo (2004), Naz *et al*. (2004) and Ramalho and Jorge (2006) [45-43-46,47]. Consequently, the use of triple bagging associated with the leaves of *Lippia multiflora* and *Hyptis suaveolens* would be advantageous for the actors of the maize sector. Producers will be able to speculate more easily. For the oil industry, the practice of such a method would ensure economical refining [11].

5. CONCLUSION

The objective of this study was to assess the quality of the oils extracted from the corn kernels stored in a triple bagging system, whether or not associated with biopesticides in order to offer actors in the corn sector a sustainable technology, accessible and capable of guaranteeing the quality of these oils. The results of this study confirm the importance of establishing an adequate storage system to preserve grain quality. The triple bagging has the particularity of extending the shelf life of the grains while the effectiveness of the leaves of *Lippia multiflora* and *Hyptis suaveolens* lies in maintaining the lipid quality and the physicochemical properties of the grain oil. The methodology used in this study from triple bagging containing biopesticides is more advantageous for producers and oil mills who should benefit from it. Nevertheless, this study could be deepened for the preservation of minority compounds of oils during grain storage.

6. REFERENCES

1. Akanvou L., Akanvou R., Anguété K. and Diarrassouba L. Bien cultiver le maïs en Côte d'Ivoire. *Centre National de Recherche Agronomique(CNRA).* 2006 ; 4p. Available on: http://www.cnra.ci

2. FAO, Organisation des Nations Unies pour l'Alimentation et l'Agriculture. Global information and early warning system on food and agriculture (GIEWS) country brief: Côte d'ivoire; 2017, 2p. Available on: http://www.fao.org/giews/countrybrief/country.jsp?code=CIV

3. Hartings H., Fracassetti M. and Motto M. Genetic enhancement of grain quality-related traits in maize. In : InTech. Transgenic plants – advances and limitations; 2012 .p. 191-218. Available on: https://www.intechopen.com/chapters/30877

4. Deffan K.P., Nemlin G.J., Akanvou L., Deffan Z.A.B. and Kouamé P. Effect of conservation methods on the mineral contents of some maize varieties (*Zea mays* L.) produced in Côte d'Ivoire. *Journal of Applied Biosciences*. 2015; 94 : 8825-34. Available on: https://www.ajol.info/index.php/jab/article/view/127707
5. Dubois V., Breton S. Linder M., Fanni J. and Parmentier M. Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. *European Journal of Lipid Sciences and Technology*. 2007; 109:710 -732. Available on : https://onlinelibrary.wiley.com/doi/pdf/10.1002/ejlt.200700040
6. Shende D. and Sidhu K.G. Methods used for extraction of maize (*Zea mays*, L.) germ oil- A review. *Industrial Journal of Science Resources and Technology*. 2014; 2 (4): 48-54. Available on: https://www.researchgate.net/publication/314258539_METHODS_USED_FOR_EXTRACTION_OF_MAIZE_ZEA_MAYS_L_GERM_OIL-A_REVIEW
7. Sam S.M., Akonye I.A., Mensah S.I., and Esenowo G.J. Extraction and Classification of Lipids from Seeds of *Persea Americana* (MILLER) and *Chrysophyllum albidum* (G.DON). *Scientia Africana.* 2008 ; *7* (2) : 35-38. Available on: https://www.ajol.info/index.php/sa/article/view/46014
8. Koh M.Y. and Mohammed T.I.G. A review of biodiesel production from *Jatropha curcas* L.oil. *Renewable and Sustainable Energy Reviews.* 2011; 15 : 2240-2251. Available on: https://sciencedirect.com/science/article/pii/s1364-0321(11)00055-4
9. Laventurier M. Impact des formulations de margarines sur le process en boulangerie et patisserie artisanales et industrielles. *Oilseeds and fats, Crops and Lipids*. 2013 ; 20 : 160-164. Available on: https://www.ocl-journal.org/articles/ocl/full_html/2013/03/ocl2013203p160/ocl2013203p160.html
10. Johnson F., N'Zi K.G., Seri K. and Foua Bi K. Aperçu des Problèmes de Stockage et Incidences des Insectes sur la Conservation du Riz et du Maïs en Milieux Paysan: Cas de la Région de Bouaflé, Côte d'Ivoire. *European Journal of Scientific Research.* 2012; 83 (3): 349-363. Available on: http://www.europeanjournalofscientificresearch.com/ejsr-issues.html
11. Pagès X., Morin O., Gaud M., Fazeuilh S. and Gouband M. Raffinage des huiles et des corps gras et elimination des contaminants. *Oilseeds and fats, Crops and Lipids*. 2010 ; 17 (2) : 86-99. Available on : https://www.ocl-journal.org/fr/articles/ocl/full_html/2010/02/ocl2010172p86/ocl2010172p86.html
12. Alencar E.R. and Faroni L.R.D. Storage of Soybeans and Its Effects on Quality of Soybean Sub-Products, Recent Trends for Enhancing the Diversity and Quality of Soybean Products. In: Recent Trends for Enhancing the Diversity and Quality of Soybean Products, Edited by Dora Krezhova; 2011. p. 47-66. Available on: https://www.intechopen.com/chaters/22596
13. Camara A. Lutte contre *Sitophylus oryzae* L. (Coleoptera : Curculionidae) et *Tribolium castaneum* Herbst (Coleoptera : Tenebrionidae) dans les stocks de riz par la technique d'étuvage traditionnelle pratiquée en basse-Guinée et l'utilisation des huiles essentielles végétales. Thèse, Université du Québec à Montréal, Canada ; 2009. Available on: https://archipel.uquam.ca/4878/
14. Toumnou A.L. Gestion intégrée des principaux insectes ravageurs des céréales par l'utilisation des métabolites secondaires des plantes indigènes du Sénégal et de Centre afrique, Thèse de Doctorat en Biologie, Physiologie et Pathologie végétales, Ecole Doctorale Sciences de la Vie, de la Santé et de l'Envoronnement, Université Cheick Anta Diop de Dakar, Dakar, Sénégal, 2013.
15. Van Duijn G. Industrial experiences with pesticide removal during edible oil refining. *European Journal of Lipid Sciences and Technology*. 2008 ; 110 : 982-989. Available on: https://onlinelibrary.wiley.com/doi/pdf/10.1002/ejlt/200890038
16. Die G.R., Chatigre K.O., Fofana I.and Biego G.H.M. Nutritive Parameters Evolution of Maize Seeds Conserved by Triple Bagging System and Biopesticides (*Lippia multiflora* and *Hyptis suaveolens* Leaves) in Cote d'Ivoire. *International Journal of Biochemistry Research & Review*. 2019 ; 28 (3) : 1-15. Available on : https://journalijbcrr.com/index.php/IJBCRR/article/view/30146
17. Akoun A.M., Chatigre K.O., Fofana I., Abouo N.V. and Biego G.H.M. Use of Triple Bagging System and Biopesticides for the Optimization of Storage Methods of Corn Grains for an Application in Oil Industry. *International Journal of Engineering Research & Science*. 2020 ; 6 (6): 1-11. Available on : https://ijoer.com/issue-detail/issue-june-2020
18. AOAC. Official Methods of Analysis of the Association of Analytical Chemists. 17th Edition. Washington, DC, USA; 2000.
19. AFNOR, Agence Française de NORmalisation. Recueil de Norme Française, corps gras, grains oléagineuses, produit dérivé. AFNOR Ed., Paris, France ; 1986.
20. UICPA, Union Internationale de Chimie Pure et Appliquée (1979). Methodes d'analyses des matieres grasses et derivés. *Technique et Documentation Edition*, Paris, France ; 2013.
21. Baudet L.M.L. Armazenamento de sementes. In: Peske S.T., Villela F.A. & Meneghello G.E. 3. ed. Pelotas. Sementes: fundamentos científicos etecnológicos : UFPel ; 2012. p. 370-418
22. Mohale S., Medina A., Rodriguez A., Sulyok M. and Magan N. Mycotoxigenic fungi and mycotoxins associated with stored maize from different regions of Lesotho. *Mycotoxin Research*, 2013 ; 29 : 209-219. Available on : https://link.springer.com/article/10.1007/s12550-013-0176-9
23. Santos S.B., Martins M.A., Faroni L.R.D. and Brito Junior V.R. Dry matter loss in corn grains stored in airtight bags. *Ciencia Agronomica*? 2012 ; 43 : 674-682. Available on : https://www.scielo.br/j/rca/a/HjxjLBpSrMDkYZWsth3Pvkw/abstract/?lang=pt
24. Niamketchi L., Biego H.G., Chatigre O., Amané D., Koffi E. & Adima A. (2015). Optimization of post-harvest maize storage using biopesticides in granaries in rural environment of Côte d'Ivoire. *International Journal of Science and Research*, 4 (9):1727-1736. Available on : https://www.researchgate.net/publication/282606072_Optimization_of_Post-Harvest_Maize_Storage_using_Biopesticides_in_Granaries_in_Rural_Environment_of_Cote_d%27Ivoire
25. Ezoua P., Coulibaly A., Konan Y., Sidibé D., Chatigre K.O. and Biego G.H.M. Efficacy of *Lippia multiflora* (Verbenaceae) and *Hyptis suaveolens* (Laminaceae) leaves on merchant quality of stored maize grain (*Zea mays* L.) in Côte d'Ivoire. *Journal of Agriculture and Ecology Research Intrenational*. 2017 ; 11(3) : 1 -10. Available on : https://www.journaljaeri.com/index.php/JAERI/article/view/3362
26. Di Domenico S.A., Christ D., E.H. Hashimoto, C. Busso and Coelho S.R.M. Evaluation of quality attibutes and the incidence of *Fusarium* sp. and *Aspergillus* sp. in different types of storage. *Journal of Stored Product Research*. 2015; 61: 59-64. Available on : https://www.sciencedirect.com/science/article/abs/pii/S0022474X14001209?via%3Dihub
27. Chattha S.H., Hasfalina C.M., Lee T.S., Mirami B.N. and Mahadi M.R. A study on the quality of wheat grain stored in straw-clay bin. *Journal of Biodiversity and Environnment Sciences.* 2015; 6(1) : 428-437.http://www.innspub.net/wp-content/uploads/2015/01/JBES-Vol6No1-p428-437.pdf
28. Wang T. and White P.J. Lipids of the kernel. In : *Corn*, Elsevier ; 2019.p. 337-368. (chapters 13). Available on: https://www.elsevier.com/books/corn/serna-saldivar/978-0-12-811971-6
29. Sravanthi B., Jayas D. S., Alagusundaram K., Chelladurai V. and White N. D. G. Effect of storage conditions on red lentils. *Journal of Stored Products Research*. 2013 ; 53: 48-53. Available on : https://www.sciencedirect.com/science/article/abs/pii/S0022474X13000209?via%3Dihub
30. O'Brien R.D. *Fats and Oils Formulating and Processing for Applications*, CRC Press, Boca Raton, United States ; 2009. Available on : https://www.taylorfrancis.com/books/mono/10.1201/9781420061673/fats-oils-richard-brien
31. Noureddini H., Teoh B.C. and Clements D.L. Densities of Vegetable Oils and Fatty Acids. *Journal of the American Oil Chemists' Society*. 1992 ; 69 (12) : 1184 – 1188. Available on : https://link.springer.com/article/10.1007/BF02637677
32. Codex Alimentarius. Céréales, légumes secs, légumineuses et matières protéiques, 1ère édition, Organisation des Nations Unies pour l'alimentation et l'agriculture, Rome, Italie ; 1999.
33. Besbes S., Blecker C., Deroanne C., Lognay G., Drira N.E. and Attia H. Heating effects on some quality characteristics of date seed oil. *Food Chemistry*. 2005 ; 91: 469-476. Available on : https://orbi.uliege.be/bitstream/2268/76813/1/Besbes.FoodChemistry%28PostPrintAut%29.2005.pdf
34. Wehtje E. and Adlercreutz P. Water activity and substrate concentration effects ion lipase activiy. *Biology and Bioengineering*. 1997 ; 55 : 798-806. Available on : https://onlinelibrary.wiley.com/doi/10.1002/(SICI)1097-0290(19970905)55:5%3C798::AID-BIT10%3E3.0.CO;2-8
35. Aïssi M.V., Tchobo F.P., Natta A.K., Piombo G., Villeneuve P., Sohounhloué D.C.K. and Soumanou M.M. Effet des prétraitements post-récolte des amandes de *Pentadesma butyracea* (Sabine) sur la technologie d'extraction en milieu réel et la qualité dubeurre. *Oilseeds and fats, Crops and Lipids.* 2011 ; 18(6):384-392. Available on : https://www.ocl-journal.org/articles/ocl/full_html/2011/06/ocl2011186p384/ocl2011186p384.html
36. Ahouannou C., Tchobo F.P., Toukourou C.A., Kougbadi F. and Soumanou M.M. Influence des opérations thermiques impliquées dans les procédés traditionnels d'extraction du beurre de karité au Bénin. *International Journal of Biological and Chemical Sciences*. 2013 ; 7(5) : 2151-2164. Available on : https://www.ajol.info/index.php/ijbcs/article/view/102198
37. Joaquín V. and Carmen D. Oxidative stability of virgin olive oil. *European Journal of Lipid Sciences and Technology*. 2002; 104 : 661–676. Available on : https://www.researchgate.net/publication/341131735_Oxidative_stability_of_virgin_olive_oil
38. Laguerre M., Lecomte J. and Villeneuve P. Evaluation of the atability of antioxidants to counteract lipid oxidation: Existing methods, new trends and challenges. *Progress in Lipid Research*. 2007; 46 (5) : 244-282. Available on :

https://www.researchgate.net/publication/224478344_Evaluation_of_the_ability_of_antioxidants_to_counteract_lipid_oxidation_Existing_methods_new_trends_and_challenges
39. Rahmani M. Méthodes d'évaluation de la stabilité oxydative des lipides. *Les Technologies de Laboratoire*. 2007 ; 2 (2) : 18-21. Available on : https://revues.imist.ma/index.php/technolab/article/view/326
40. Niamketchi L., Chatigre O., Coulibaly A., Konan Y. and Biego M.H.G. Change in the quality of maize (*Zea mays* L.) post-haevest stored in granaries with the biopesticides from rural conditions in Côte d'Ivoire. *Global of Biology, Agriculture & Health Sciences*. (2016); 5(2) : 74-87. Available on : https://www.researchgate.net/publication/304772305_Changes_in_the_Quality_of_Maize_zea_mays_l_Post-Harvest_Stored_in_Granaries_with_the_Biopesticides_from_Rural_Conditions_in_Cote_d%27Ivoire
41. Apetrei C. and Apetrei I.M. Chemical composition of corn oil. In: Apetrei C. Editior. Corn and coconut oil, New York, United States of America: Nova Science Publishers; 2015.p. 1- 28
42. Wilson R.F., Novitzky W.P. and Fenner G.P. Effect of fungal damage on seed composition and quality of soybeans. *Journal of the American Oil Chemists' Society*. 1995 ; 72 (12) :1425-1429. Available on : https://link.springer.com/article/10.1007/BF02577832
43. Araújo J.M.A. Oxidação de lipídios em alimentos. In: Araújo J. M. A. Edição 3. Química de Alimentos: Teoria e Prática, Viçosa, Brasil : Editora UFV ; 2004. p 1-64.
44. Alencar E.R., Faroni L.R.D., Peternelli L.A., Silva M.T.C. and Costa A.R. Influence of soybean storage conditions on crude oil quality, *Revista Brasileira de Engenharia Agrícola e Ambiental*. 2010 ; 14(3) : 303-308. Available on : https://www.scielo.br/j/rbeaa/a/bbrgsxhjG7MzFJf64WVrSww/?lang=en
45. Silva F.A.M., Borges, M.F.M. and Ferreira, M.A. Métodos para avaliação do grau de oxidação lipídica e da capacidade antioxidante. *Química Nova.* 1999 ; 22 (1) : 94-103. Available on : http://quimicanova.sbq.org.br/detalhe_artigo.asp?id=2056
46. Naz S., Sheikh H., Siddiqi R. & Sayeed S.A. Oxidative stability of olive, corn and soybean oil under different conditions. *Food Chemistry*. 2004; 88 (2) : 253-259. Available on : https://www.sciencedirect.com/science/article/abs/pii/S0308814604001104?via%3Dihub
47. Ramalho V.C. and Jorge N. Antioxidantes utilizados em óleos, gorduras e alimentos gordurosos. *Química Nova*. 2006 ; 29 (4) : 755-760. Available on : https://www.researchgate.net/publication/242324297_Antioxidantes_utilizados_em_oleos_gorduras_e_alimentos_gordurosos

Cite this article: Ange Mesmer Akoun, Ibrahim Fofana, Didier Narcisse Amané and Kouamé Olivier Chatigre. EFFECT OF A TRIPLE BAGGING SYSTEM AND LEAVES OF AROMATIC PLANTS (Lippia multiflora AND Hyptis suaveolens) ON THE PHYSICOCHEMICAL PARAMETERS OF THE OIL OBTAINED FROM THE KERNELS OF CORN (Zea mays L.) STORED. *Am. J. innov. res. appl. sci. 2021; 12(1): 320*-331.