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Fatty Acid Profiles of Oil Obtained from Corn Kernels (*Zea Mays* L.) Preserved by a Triple Bagging System and Aromatic Plants (*Lippia multiflora* and *Hyptis suaveolens*)

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Corn oil is considered one of the best edible vegetable oils. Unfortunately, the storage of corn kernels as practiced in rural areas affects the quality of the fat. However, the triple bagging system and aromatic plants remain alternatives to the poor storage practiced by certain players in the ivorian maize sector. However, their influence on the quality of the fat in the grains remains to be elucidated. This study aims to evaluate, during storage, the fatty acid (FA) profile of the oil obtained from corn kernels packaged in a triple bagging system with or without the leaves of Lippia multiflora and Hyptis suaveolens. Thus, 6 batches including one control in polypropylene bag, one batch in triple bagging without biopesticides and four batches in triple bagging with variable proportions and/or combination of Lippia multiflora and Hyptis suaveolens (2.5 % and 5 % and a combination 0 to 100 % Lippia) were made up to follow the evolution of the fatty acid (FA) composition of the extracted oils during six observation periods (0 ; 1 ; 4.5 ; 9.5 ; 14.5 and 18 months). The estimated intake and fatty acid contribution were also evaluated after 18 months of storage. The storage time and the type of packaging have a significant influence on the fatty acid profile of oils. During grain storage, the FA profile of the oils obtained from the grains stored in the triple bagging with the biopesticides varied very little. At the end of storage, their average composition was 13.40 % saturated fatty acids (SFA), 31.76 % monounsaturated fatty acids (MUFA) and 50.45 % polyunsaturated fatty acids (PUFA). On the other hand, at the end of grain storage, the grain oil from the triple bagged batch without biopesticides consists of 16 % SFA, 38.85 % MUFA, and 45.70 % PUFA. The contribution to meeting energy needs is ensured from the consumption of oil from grains stored for 18 months in triple bagging systems associated with biopesticides. Therefore the combination of these aromatic leaves with triple bagging is more advantageous to preserve the FA profile of the grains during storage.

Keywords: Corn Oil; Fatty Acid ; Hyptis Suaveolens; Lippia Multiflora; Triple Bagging.

In Côte d'ivoire, corn kernels are a staple food for a large part of the rural population for whom they represent the main source of energy due their high starch content [1]. Yet the oil extracted from the germ of the grains is highly regarded and considered to be one of the best edible vegetable

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oils. The richness of the corn oil in unsaturated and essential fatty acids such as oleic (OLA) and linoleic (LA) [2, 3, 4] give it nutritional benefits noticeable through excellent digestibility and cholesterol lowering effect. It contributes to the fight against cardiovascular diseases, coronary heart and other metabolic diseases as well as to the improvement of the functioning of the skin and the hair [5, 6, 7]. These beneficial effects of corn oil observed could constitute an asset for the health of vulnerable populations living in Côte d'Ivoire if good grain storage and conservation practices are mastered.

Unfortunately, storage practiced by producers in rural areas poses many problems for actors in the maize sector who experience enormous post-harvest losses throughout the year [8].

To want to store and preserve corn over a long period to spare populations from the risk of food shortages during the agricultural off-season, producers have resorted to synthetic chemical pesticides to treat stocks. These chemical inputs, beyond their dangerousness for the environment and human health, are currently a major concern for oil manufacturers [9]. The excessive and unregulated use of these synthetic pesticides results in the presence of pesticide residues in industrial oils [9]. These situations have argued for the use of new storage technologies in recent years as an alternative to the use of synthetic pesticides. Aromatic plants in this case the leaves of *Lippia multiflora* and *Hyptis suaveolens* so well known to rural populations for various uses [10,11] are increasingly used in the field of cereal conservation and legumes [12,13,14]. Moreover, the use of triple bottom bags is effective in extending the storage life of cowpeas and maize in Côte d'Ivoire [15,16,17,18,19,20]. Moreover, the work of Akoun *et al*.[21] on the conservation of corn kernels in triple bagging systems in the presence of at least 2.5% of biopesticides of plant origin reported effective preservation of the physicochemical quality of the oil obtained from the kernels during the 18 months of storage. Thus, the objective of this study is to evaluate during storage the influence of triple bagging systems associated or not with the leaves of aromatic plants on the fatty acid profile of the oils obtained from the preserved grains.

MATERIAL AND METHODS

Biological material

Corn used in the study

The dry maize kernels used were of the improved GMRP-18 variety of yellow morphotype and with a short production cycle of 90-95 days. They were collected just after harvest from producers in the department of Katiola in the Hambol region in the Center-North of Côte d'Ivoire, between 8 ° 10 'North and 5 ° 40' West.

Selected plants

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.

Packaging material

The storage of maize required the use of woven polypropylene bags and others in polyethylene with a total capacity of 120 kg. In this study, they served to constitute teh triple bagging system which is a combination of two internal high density polyethylene bags very waterproof and an outer bag in woven polypropylene.

Grain storage protocol

During 18 months, the dry maize kernels were stored by triple bagging system with or without the leaves of *Lippia multiflora* and *Hyptis suaveolens* from five experimental batches and a control batch were constituted as presented in Table 1.

PPSB : Control batch of 50 kg of maize grains stored in a polypropylene woven bag without biopesticides,

TEB_A : Lot of 50 kg of maize grains stored in a triple bagging system with 0% biopesticides,

TEB_B : Lot of 50 kg of maize grains stored in a triple bagging system containing 2.5% of biopesticides including 0% of Lippia multiflora and 100% of Hyptis suaveolens ;

TEB_C : Lot of 50 kg of maize grains stored in a triple bagging system containing 2.5% of biopesticides including 50% of Lippia multiflora and 50% of Hyptis suaveolens ;

TEB_D : Lot of 50 kg of maize grains stored in a triple bagging system with 2.5% biopesticides including 100% Lippia multiflora and 0% Hyptis suaveolens ;

TEB_E : Lot of 50 kg of maize grains stored in a triple bagging system with 5% biopesticides including 50% Lippia multiflora and 50% Hyptis suaveolens.

Grains sampling

Sampling for analyzes was performed respectively at 1 ; 4.5; 9.5; 14.5 and 18 months based on a composite central plan as applied by Akoun *et al*.[20]. Before conditioning the grains in the bags, a 5 kg corn sample was taken from the initial stock to determine the initial fatty acid profile of the oil, which will be compared with that of the oils from the grains during storage. On the dates scheduled for the samples, one (1) kg of corn was taken from each lot. The samples were taken in triplicate from all these batches for eighteen months. Sampling was done at random. And the samples were ground to extract oil and determine the fatty acid composition.

Grain oil extraction

The grain oil wes extracted with Soxhlet as extractor and hexane as solvent for 6 hours according AFNOR [22].

Quantitative determination of fatty acids in corn oil

The determination of the fatty acid composition (FA) of the oils was carried out by gas chromatography (GPC). The methyl esters of fatty acids (FAME) were obtained by trans-esterification of the fatty acids of oils according to method 5 of standard ISO 5509 : 2000 [23]. Thus, isooctane was used to dissolve triglycerides from oil samples through gentle warming (solution A). Then a methanolic solution of potassium hydroxide was added to solution A, and the resulting mixture (solution B) was stirred vigorously. Then sodium hydrogen sulfate was added to solution B and the stirred mixture was allowed to stand until two phases were obtained. The upper isooctane phase containing the fatty acid methyl esters was transferred to a flask for analysis with a Clarus 580 GC brand gas chromatograph (PerkinElmer® ; USA). This device was equipped with flame ionization detectors (FID) and automatic programmable "split / splitness" capillary injectors (PSSI). The column used is an Rt-2560 brand capillary column (RESTEK® ; United States) made of fused silica, the stationary phase of which is biscyanopropylpolysiloxane. The dimensions of this column are 100 m long, 0.25 mm internal diameter and 0.2 µm thick. The carrier gas in the column was hydrogen (H_2) with a flow rate set at 10 mL/min. The detector gas flows were H_2 at 44 mL/min combined with an air flow of 450 mL/min. The oven was programmed according to the following procedure : an initial temperature of 140 ° C for 4 min followed by speeds of 4 ° C/min up to 240 ° C then maintained for 15 min (ie a total of 44 min). The volume of FAME injected was 1 ìL and the temperatures of the injector and the detector used were set at 225 ° and 250 ° C respectively. The identification of fatty acids was carried out by comparing their retention time with those of standard fatty acids of known chromatogram and the content of fatty acids (in % of total FAME) was directly determined by the value of the area of the peaks observed. Three determinations were made per sample.

Estimation of fatty acid intake of oils from stored corn kernels

The methods of WHO [24] and FAO [25] were used to estimate the fatty acid intakes and to deduce the energy value and the contributions to the satisfaction of the needs. It takes into account the proportions of the various fatty acids found in the oils obtained from the grains and the equivalent daily consumption (or availability) of crude palm oil by an Ivorian adult. According to Cheyns *et al*.[26], this availability is 27.40 g/d.

$$EDI = C \times DC \; ; \; EV = EDI \times 9 \text{ Kcal};$$

$$\text{Contribution (\%)} = [\, EDI / RNI \,] \times 100$$

EDI : Estimated daily intake of fatty acids for the equivalent daily consumption of corn oil in Ivorians (g/d) ; C : content of the fatty acid found in stored corn oil (g/kg of product) ; DC : daily consumption of equivalent crude oil consumed in grams per day in Ivory Coast = 27.40 g/d [26]. EV : energy value of estimated intake per fatty acid. RNI : recommended nutritional intake for a fatty acid (mg/day).

Statistical analyzes

The data were analyzed with two software which are SPSS "Statistical Program for Social Sciences" version 22.0 and STATISTICA (version 7.1) software. Determination of the fatty acid profile for each maize kernel oil sample were carried out in triplicate and the results are expressed as the mean ± standard deviation per fatty acid. An analysis of variance (ANOVA) with two factors - the storage duration and the type

of conditioning of the grains - on all the results obtained were carried out with SPSS software to determine the existence of statistically significant differences between the values averages calculated with Tukey's test at the 5% significance level. The STATISTICA software made it possible to evaluate the existing correlations between FAs according to the Pearson index firstly. In a second time, a group of the different oil samples from the preserved corn kernels based similarity in profiles in fatty acids were carried out with principal component analysis (PCA) and hierarchical ascending classification (HAC).

RESULTS

Fatty acid composition of oils from grain storage

Storage duration and the type of grain conditioning as well as their interaction significantly influence ($P < 0.05$) the fatty acid profile of crude oils accordind ANOVA (Table 2).

The initial proportion of saturated fatty acids (SFA TOTAL) is 15.13%. At the end of storage, this level of saturated fatty acids increased significantly ($P < 0.05$) in the oil obtained from the grains of the batch in the propylene bag (PPSB ; 26.05 ± 2.34%). After 18 months of storage, the proportion of total saturation of the oils obtained from the maize kernels triple bagged with the leaves of aromatic plants remained of the order of 13.30% against 16% for that of the oil grains stored in the triple simple bagging (Figures 1, 2, 3, 4, 5 and 6). Palmitic acid (C16 : 0 or PLA) is the majority saturated fatty acid. It is followed by stearic (C18 : 0 ; STA) and margaric (C17 : 0 ; MGA) acids. At the start of storage, the oil obtained contains average contents of 12.71 ± 2.34%, 1.4 ± 0.00% and 0.02 ± 0.00% respectively for PLA, STA and MGA.

The PLA content decreases sharply ($P < 0.05$) in the oil obtained from the grains of the PPSB batch to reach a value of 4.14 ± 0.55%, followed by the oil of the TEBA batch with a value of 9.95 ± 0.88%. While in the samples of oils obtained from the grains of the triple bagging batches with the addition of different proportions of biopesticides (TEB_B, TEB_C, TEB_D and TEB_E), the PLA content is around 12 % at the end of the eighteen months of storage of the grains (Table 3). The variation in the percentage of STA in the oils obtained from the grains depends on the type of conditioning of the corn. At the level of the PPSB and TEBA batches, significant reductions in the STA content in the oils were observed with respective values of 0.39 ± 0.00 % and 0.95 ± 0.00 %. In the other batches (triple bagging with biopesticides), the STA value of the oils is 1.20% on average. During grain storage, the percentage of MGA increases considerably ($P < 0.05$) in the oil obtained from grains of the PPSB batch to reach the value of 20.98 ± 2.12 %, followed by the oil of the TEB_A batch (5.24 ± 0.09 %). In the batches with biopesticides no significant variation was observed in the percentage of MGA.

Oleic acid (C18 : 1 ; OLA) remains the only monounsaturated fatty acid (MUFA) with an average content of 28.54 ± 11 % at the start of storage. This content increases significantly ($P < 0.05$) in the oil from the grains of the PPSB batch and very little in the oils obtained from the grains preserved with triple bagging systems containing biopesticides. At the end of storage, the percentages of OLA recorded are 43.54 ± 0.25%, 35.30 ± 1.60% and less than 32% respectively in the oils from the grains of the PPSB batch, of the TEBA batch and those stored in the presence of biopesticides (Table 3 and Figures 1 to 6).

The polyunsaturated fatty acids (PUFAs) of the oils obtained from the corn kernels of the different packaging are dominated by linoleic acid (C18 : 2 ; LA). With an initial value of 52.67 ±

Table 1. Summary of the different study packaging and their biopesticide composition

Lots	Conditioning	Biopesticides (%)	*Lippia m.* (%)	*Hyptis s.* (%)
PPSB	Polypropylene	0	0	0
TEB_A	Triple bagging	0	0	0
TEB_B		2.5	0	100
TEB_C			50	50
TEB_D			100	0
TEB_E		5	50	50

Table 2. Statistical data of grain oil fatty acids during storage according te type of packaging

Source of variation	Statistical parameters	PLA	MGA	STA	SFA	OLA	MUFA	LA	ALA	GLA	DDA	ARA	PUFA
Duration	Ddl	5	1.42	5	5	2.74	5	2.41	5	1.56	5	5	5
	SC	130.71	197.18	2.69	44.71	521.37	517.38	1068.83	1.82	0.02	0.39	0.04	1142.59
	F	478.06	51661	38.04	158.41	40.10	3919.27	909.44	45.76	38.75	90.94	30.25	4278.40
	P	< 0.001											
Error (duration)	Ddl	60	16.99	60	60	32.91	60	28.91	60	18.76	60	60	60
	SC	3.28	0.05	0.85	3.39	156.02	1.58	14.10	0.477	0.01	0.05	0.02	3.21
Methods of packaging	Ddl	5											
	SC	74.41	453.08	3.66	140.11	438.97	562.29	1879.04	2.735	0.02	0.09	0.07	1911.24
	F	178.54	17950.56	24.44	398.31	36.98	270.93	840.17	15.188	51.98	7.21	16.50	735.18
	P	< 0.001											
Error (methods)	Ddl	12											
	SC	1.00	0.01	0.36	0.84	28.49	4.98	5.37	0.432	0.01	0.03	0.01	6.24
Duration XMethods	Ddl	25	7.08	25	25	13.71	25	12.04	25	7.82	25	25	25
	SC	79.61	958.85	2.24	418.04	326.54	374.41	1366.14	0.737	0.03	0.32	0.03	1278.85
	F	58.23	50244.75	6.34	296.20	5.02	567.26	232.48	3.712	8.35	14.80	4.15	957.72
	P	< 0.001											

dof: degree of freedom, SC: sum of squares, P: Probability, F: Fischer test, PAL = Palmitic acid MGA = Margaric acid; STA = Stearic acid; ; SFA = Saturated fatty acids; OLA = Oleic acid; MUFA = Total monounsaturated fatty acids; LA = Linoleic acid; DDA = docosadienoique acid; ALA = Alpha-Linolenic Acid; GLA = Gamma-Linolenic Acid; ARA = Arachidonic acid and PUFA = Total polyunsaturated fatty acids

Table 3. Evolution of grains oil fatty acid composition during storage

Fatty acids	Duration	PPSB	TEBA	TEBB	TEBC	TEBD	TEBE
C 16:0 (%)	0	13.71±1.04aA	13.71±1.04aA	13.71±1.04aA	13.71±1.04aA	13.71±1.04aA	13.71±1.04aA
	1	12.05±1.45aB	13.10±0.91aAB	13.50±1.00aAB	13.39±0.12aAB	13.52±2.00aAB	13.60±0.81aA
	4.45	11.86±0,89bC	12.66±1.56aAB	13.01±0.53aAB	13.01±1.27aAB	13.11±1.45aBC	13.23±0.34aAB
	9.5	10.43±0.27cD	12.07±1.23aBC	12.61±0.13aBC	12.54±0.22abBC	12.77±1.67aCD	12.98±0.56aBC
	14.5	9.99±0.89cD	11.50±1.01aC	12.25±0.40aC	12.24±0.21aC	12.56±0.91aD	12.71±0.04aC
	18	4.14±0.55cE	9.95±0.88aC	12.00±0.90aC	11.98±0.48aC	12.00±0.54aE	12.12±0.07aD
C 17:0 (%)	0	0.02±0.00aD	0.02±0.00aE	0.02±0.00aD	0.02±0.00aC	0.02±0.00aC	0.02±0.00aB
	1	0.05±0.00aD	0.03±0.00bDE	0.03±0.00bcC	0.02±0.00bcBC	0.01±0.00dD	0.02±0.00cB
	4.45	0.14±0.01aD	0.07±0.00bC	0.02±0.00dD	0.03±0.00cB	0.03±0.00cdB	0.01±0.00eC
	9.5	0.70±0.01aC	0.05±0.00bCD	0.04±0.00bB	0.05±0.00bA	0.04±0.00bA	0.02±0.00bB
	14.5	11.34±1.78aB	0.12±0.05bB	0.02±0.00bD	0.03±0.00bBC	0.03±0.00bC	0.03±0.00bA
	18	20.98±2.12aA	5.24±0.09bA	0.05±0.00cA	0.05±0.00cA	0.03±0.00cB	0.02±0.00cB
C 18:0 (%)	0	1.40±0.00aA	1.40±0.00aA	1.40±0.00aA	0.00±0.00aAB	1.40±0.00aA	1.4±0.00aA
	1	1.28±0.05aAB	1.30±0.01aA	1.40±0.05aA	1.37±0.02aAB	1.39±0.01aA	1.40±0.01aA
	4.45	1.01±0.03cB	1.17±0.00bcAB	1.33±0.04bA	1.32±0.04aA	1.35±0.00bA	1.33±0.00aA
	9.5	0.57±0.00bC	1.13±0.00aA	1.28±0.09aA	1.18±0.02aB	1.33±0.00aA	1.31±0.00aA
	14.5	0.47±0.07cC	0.92±0.01bB	1.20±0.11aA	1.29±0.00aB	1.18±0.00aA	1.28±0.00aA
	18	0.39±0.00cC	0.95±0.00bB	1.18±0.01aA	1.21±0.00aB	1.15±0.02aA	1.25±0.02aA
C 18 ;1 (%)	0	28.54±1.01aA	28.54±1.01aA	28.54±1.01aA	28.54±1.01aA	28.54±1.01aA	28.54±1.01aA
	1	30.63±2.11aB	29.11±2.51bA	29.03±1.71bA	29.00±2.24bA	29.10±2.11bA	28.85±1.25bA
	4.45	34.12±3.19aC	30.01±1.27aAB	29.95±1.25aB	29.56±2.25aA	30.01±0.95aA	29.92±1.19aB
	9.5	38.12±3.18aD	31.18±2.19bAB	30.05±2.02bB	30.12±1.02bA	30.79±1.72abA	30.54±0.34bBC
	14.5	40.34±1.01aE	32.51±3.07bAB	31.29±0.56cC	30.54±1.06dA	31.14±1.04bcA	31.01±1.09bcC
	18	43.54±2.45aF	35.30±1.60bB	32.36±0.61bD	30.89±0.39bB	31.23±0.08bA	31.22±0.71bc
C 18 ;2 (%)	0	52.67±3.01aA	52.67±3.01aA	50.67±3.01aA	50.67±3.01aA	52.67±3.01aA	52.67±3.01aA
	1	49.08±1.83bB	52.01±1.13aAB	52.65±1.10bA	52.52±3.10bA	52.55±1.41bA	52.64±1.04bA
	4.45	45.09±2.21dC	49.87±2.07cBC	51.23±1.24aB	50.94±2.15aA	51.44±3.03aA	52.01±2.81aB
	9.5	39.99±1.04dD	47.17±1.81cC	50.09±1.05bB	50.34 ±1.35bA	51.11 ±2.01abA	51.54 ±1.74bBC
	14.5	29.44±1.22bE	46.78±0.82aCD	49.30±1.01cC	49.59±1.51dA	49.42±1.94bcA	50.21±1.23bcC
	18	21.56±0.81dF	44.69±2.04cD	48.96±0.32bD	48.51±0.37bB	48.90±0.89bA	50.43±1.41bC
C 22 :2 (%)	0	0.15±0.00aC	0.15±0.00aB	0.15±0.00aAB	0.15±0.00aAB	0.15±0.00aA	0.15±0.00aC
	1	0.17±0.02abC	0.07±0.00bBC	0.17±0.00aAB	0.16±0.00aAB	0.16±0.00aA	0.15±0.01abBC
	4.45	0.09±0.00bC	0.04±0.00cC	0.11±0.00bAB	0.10±0.00bB	0.15±0.00aA	0.15±0.00aBC

	9.5	0.25±0.07aBC	0.09±0.00bBC	0.15±0.00bB	0.17±0.04aAB	0.13±0.00aA	0.13±0.00aAB
	14.5	0.34±0.07aB	0.14±0.02bBC	0.13±0.02bAB	0.19±0.00aA	0.18±0.00abA	0.18±0.00abAB
	18	0.54±0.11aA	0.25±0.08bA	0.18±0.05cA	0.20±0.00bcA	0.11±0.00bcA	0.15±0.00bcA
C 18:3 3 (%)	0	0.80±0.01aA	0.80±0.01aA	0.80±0.01aA	0.80±0.01aA	0.80±0.01aA	0.80±0.01aA
	1	0.41±0.06aB	0.65±0.01aAB	0.75±0.02aA	0.70±0.00aA	0.78±0.10aA	0.78±0.05aA
	4.45	0.29±0.09bBC	0.53±0.07aAB	0.69±0.00aA	0.72±0.00aA	0.71±0.03aA	0.72±0.03aA
	9.5	0.10±0.00cC	0.34±0.00bB	0.67±0.00aA	0.65±0.00aA	0.68±0.00aA	0.69±0.00aA
	14.5	0.01±0.00cC	0.30±0.00bB	0.61±0.00aA	0.57±0.00aA	0.65±0.09aA	0.70±0.00aA
	18	0.00±0.00cC	0.30±0.00bB	0.54±0.00aA	0.50±0.01aA	0.55±0.04aA	0.60±0.00aA
C 18:3 6 (%)	0	0.10±0.01aA	0.10±0.01aA	0.10±0.01aA	0.10±0.01aA	0.10±0.01aA	0.10±0.01aA
	1	0.12±0.02bBC	0.11±0.01abB	0.08±0.00abA	0.08±0.00abAB	0.09±0.00aAB	0.10±0.00aA
	4.45	0.06±0.00bB	0.05±0.00cC	0.02±0.00aA	0.07±0.00bBC	0.08±0.00aAB	0.08±0.00aAB
	9.5	0.04±0.00eCD	0.04±0.00aAB	0.12±0.03bcA	0.06±0.00cBC	0.05±0.00dC	0.08±0.00bAB
	14.5	0.00±0.00eD	0.03±0.00dC	0.10±0.00bcA	0.08±0.00abAB	0.08±0.00aAB	0.07±0.00cB
	18	0.00±0.00dCD	0.03±0.00bcB	0.09±0.01aA	0.05±0.00cC	0.06±0.00bcBC	0.08±0.00aAB
C 20:4	0	0.15±0.00aA	0.15±0.00aA	0.15±0.00aA	0.15±0.00aA	0.15±0.00aA	0.15±0.00aA
	1	0.12±0.00aAB	0.13±0.00aAB	0.17±0.00aA	0.16±0.00aA	0.14±0.00aA	0.14±0.00aA
	4.45	0.09±0.00bBC	0.11±0.00abBC	0.15±0.00aA	0.14±0.00aA	0.15±0.00aA	0.15±0.00aA
	9.5	0.05±0.00cCD	0.09±0.00bCD	0.14±0.00aA	0.13±0.00aA	0.14±0.00aA	0.14±0.00aA
	14.5	0.00±0.00dD	0.06±0.00cD	0.12±0.00abA	0.12±0.00bA	0.12±0.01bA	0.12±0.00aA
	18	0.02±0.00bD	0.05±0.00bD	0.10±0.00aA	0.11±0.00aA	0.14±0.00aA	0.13±0.00aA

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, PPSB = Control without biopesticides with polypropylene bag; TEBA = Control without biopesticides with triple bagging bag; TEBB = Bag to .triple bagging with 2.5% biopesticides (50% L. multiflora and 50% H. suaveolens); TEBC = triple bagged bag with 2.5% biopesticides (100% L. multiflora and 0% H. suaveolens); TEBD = triple bagged bag with 2.5% biopesticides (0% L. multiflora and 100% H ..suaveolens); TEBE = triple bagged bag with 5% biopesticides (50% L. multiflora and 50% H. suaveolens).

3.01%, the LA content decreases significantly in the oils of the grains of the PPSB batch to reach an average value of 21.56 ± 0.81% at the end of storage. The LA contents of the oils extracted from the corn kernels packaged in the triple bottom bags are respectively 44.69 ± 2.04 % for the TEB_A batch and around 49% for the batches with biopesticides after 18 months of grain storage. Moreover, the initial percentages of á-linolenic (C18 : 3 ù3 ; ALA), ã-linolenic (C18: 3 ù6 ; GLA), arachidonic (C20: 4 ; ARA) and docosadienic (C22: 2 ; DDA) acids are respectively 0.80 ± 0.01 % ; 0.10 ± 0.01 % ; 0.15 ± 0.00% and 0.15 ± 0.00 %. In the oil of the PPSB grains, the average contents of ALA, GLA and ARA decrease significantly ($P < 0.05$) with a tendency to disappear in ALA and GLA (0.00%) at the end of storage. While the DDA content increases significantly in this same batch to reach a value of 0.54 ± 0.00%. At the end of grain storage, the oils from batches with biopesticides record values of 0.55 %, 0.07 %, 0.12 % and 0.16% respectively for ALA, GLA, ARA and DDA.

Correlation between fatty acids in oil

The correlation analysis shows that the evolution of the overall saturation of oils is strongly dependent on that of margaric acid (MGA). Thus, an increase in the MGA content leads to saturation of the oil ($r^2 = 0.91$). While the increase in this fatty acids coincides with a decrease in the percentage of PLA and STA acids ($r^2 = -0.81$ and $r^2 = -0.75$).

According to Table 4, the variation in the content of OLA or even MUFA in oils is closely related both to those of saturated fatty acids PAL, STA and MGA as well as of polyunsaturated acids LA, ALA, ARA and PUFA TOTAL. Thus, the increase in the percentage of OLA in oils is justified by the increase in the content of MGA ($r^2 = 0.82$) coupled with the decreases in the proportions of acids PLA ($r^2 = -0.90$), STA ($r^2 = -0.95$) and polyunsaturated acids (between $r^2 = -0.88$ and $r^2 = -0.97$). At the level of polyunsaturated acids, their individual evolutions mostly coincide with the exception of DDA acid.

Chemometric distribution of types of conditionning in relation to the fatty acid profile of oil during storage

The variability between the fatty acid profile of the oils and the types of conditioning of the corn kernels was structured through principal component analysis (PCA) and ascending hierarchical classification (HAC). These analyzes were carried out for the grouping and classification of the selected packaging. These are the woven polypropylene bag (PPSB), the triple simple bagging (TEB_A) and the triple bagging packaging coupled with the different proportions and / or combinations of biopesticides (TEB_B, TEB_C, TEB_D and TEB_E).

Twelve parameters were correlated with 12 factors. According to Kaïser's rule, only the first two factors (F1 and F2) with an eigenvalue greater than 1 are considered to explain the variability of the oil samples. Factor 1 has an eigenvalue of 9.33 and expresses 77.71 % of the total variability. It is mainly formed by all the parameters. It is positively correlated with MGA, SFA TOTAL, OLA, MUFA TOTAL, DDA and negatively with PLA, STA, LA, ALA, GLA, ARA and PUFA TOTAL. As for the factor F2, it records a variance of 10.16 % and an eigenvalue of 1.22. It shows a medium and negative correlation only with SFA. The projection of parameters and oil samples is made in the plane formed by factors 1 and 2, which accumulate 87.88 % of the total variability

Table 4. Correlation matrix between grain oil fatty acids

	PLA	MGA	STA	SFA	OLA	MUFA	LA	DDA	ALA	GLA	ARA	PUFA
PLA	1.00											
MGA	-0.81	1.00										
STA	0.85	-0.75	1.00									
SFA	-0.51	0.91	-0.48	1.00								
OLA	-0.90	0.82	-0.95	0.58	1.00							
MUFA	-0.91	0.84	-0.95	0.59	1.00	1.00						
LA	0.80	-0.92	0.83	-0.80	-0.89	-0.90	1.00					
DDA	-0.81	0.74	-0.59	0.55	0.67	0.68	-0.63	1.00				
ALA	0.79	-0.64	0.93	-0.37	-0.91	-0.91	0.75	-0.42	1.00			
GLA	0.53	-0.58	0.64	-0.47	-0.61	-0.61	0.73	-0.30	0.62	1.00		
ARA	0.80	-0.62	0.91	-0.34	-0.88	-0.88	0.74	-0.43	0.95	0.67	1.00	
PUFA	0.89	-0.91	0.93	-0.71	-0.97	-0.98	0.94	-0.66	0.89	0.67	0.87	1.00

Table 5. Matrix of the eigen values of the factors resulting from the analysis in principal components and correlation with fatty acids of the oil from the grains stored

Facteurs	1	2	3	4	5	6	7	8	9	10	11	12
Eigen values	9,33	1,22	0,79	0,37	0,10	0,07	0,05	0,05	0,02	0,00	0,00	0,00
Variance (%)	77,71	10,16	6,55	3,07	0,86	0,62	0,42	0,40	0,17	0,03	0,00	0,00
Cumulative Variance (%)	77,71	87,88	94,43	97,50	98,36	98,98	99,40	99,80	99,97	100,00	100,00	100,00
PLA	-0,92	0,00	0,30	-0,13	-0,17	-0,11	0,01	0,10	0,01	0,00	0,00	0,00
MGA	0,90	-0,41	0,07	-0,08	0,09	-0,02	0,00	-0,04	-0,01	-0,01	0,00	-0,01
STA	-0,94	-0,24	0,06	0,04	0,12	0,14	0,07	0,13	0,00	0,00	0,00	0,00
SFA	0,68	-0,64	0,29	-0,19	0,05	-0,07	0,01	0,02	-0,02	-0,01	0,00	0,00
OLA	0,98	0,11	-0,10	-0,08	-0,10	0,07	0,03	0,03	-0,06	-0,01	-0,01	0,00
MUFA	0,98	0,09	-0,10	-0,07	-0,09	0,06	0,03	0,02	-0,06	-0,01	0,01	0,00
LA	-0,94	0,17	-0,20	0,02	0,10	-0,13	0,09	-0,02	-0,08	0,01	0,00	0,00
DDA	0,70	-0,40	-0,48	0,31	-0,05	-0,08	0,02	0,07	0,03	0,00	0,00	0,00
ALA	-0,88	-0,41	0,00	0,14	-0,04	0,04	-0,13	0,00	-0,07	0,02	0,00	0,00
GLA	-0,70	-0,14	-0,56	-0,42	0,00	0,01	-0,04	0,01	0,02	0,00	0,00	0,00
ARA	-0,87	-0,43	-0,01	0,01	-0,13	0,06	0,12	-0,11	0,01	0,00	0,00	0,00
PUFA	-0,99	0,01	-0,02	0,09	-0,01	-0,01	-0,04	-0,03	-0,01	-0,05	0,00	0,00

PLA = Palmitic acid ; MGA = Margaric acid ; STA = Stearic acid ; LCA = Lignoceric acid ; SFA = Saturated fatty acids ; OLA = Oleic acid ; MUFA = Total monounsaturated fatty acids ; LA = Linoleic acid ; DDA = Docosadienoic acid ; ALA = Alpha-Linolenic Acid ; GLA = Acidgamma-Linolenic ; ARA = Arachidonic acid and PUFA = Total polyunsaturated fatty acids

Table 6. Estimation of the fatty acid intake, energy value et contributions to meeting fatty acid requirements of oil from stred corn kernels from the consumption of 27,40 g of oil

Fatty acids	Recommandations		Consumption of 27,40 g of oil from corn grain stored during 18 month		
	RNI	REI	RNI	Energy value	Contribution
Satured Fatty Acids	24.5 g/d	220 Kcal/d	3.67 g/d	33.04 kcal/d	14.98 %
Monounsatured Fatty Acids	37 g/d	331 Kcal/d	8.70 g/d	78.32 kcal/d	23.51 %
Polyunsatured Fatty Acids	21 g/d	187 Kcal/d	13.70 g/d	124.42 kcal/d	65.24 %
Linoléic Acid	10 g/d	88 Kcal/d	13.74 g/d	121.33 kcal/d	137.40 %
Linolénic Acid	2.5 g/d	22 Kcal/d	0.15 g/d	1.39 kcal/d	6.00 %
Oleic Acid	37 g/d	330 Kcal/d	8.52 g/d	77.49 kcal/d	23.02 %

RNI : recommended nutritional intake per fatty acid ; REI : recommaded energy intake per fatty acid ; EDI : Estimated daily intake of fatty acids

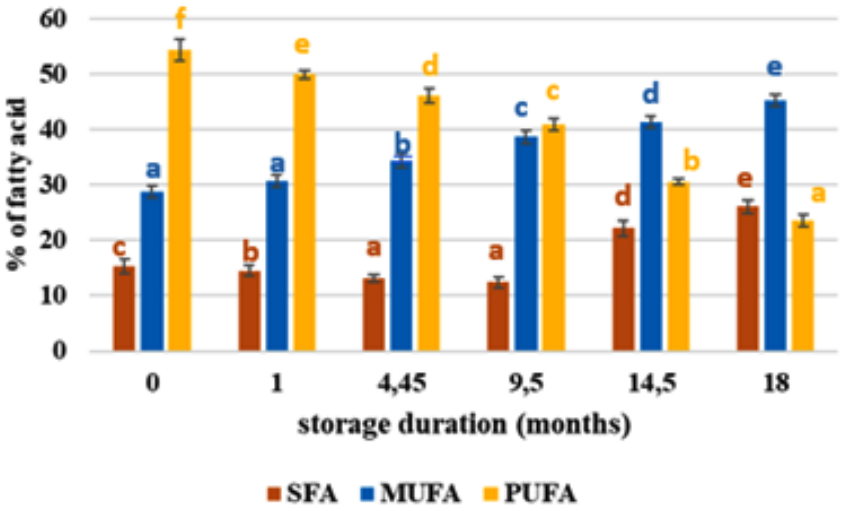

Fig. 1. Evolution of SFA, MUFA and PUFA content of the oil from the grains of lot PPSB stored for 18 months

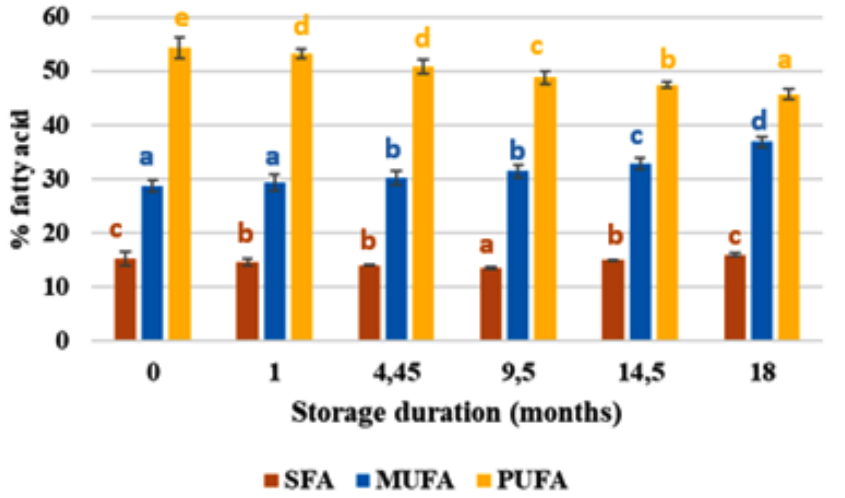

Fig. 2. Evolution of SFA, MUFA and PUFA content of oil from the grains of lot TEB_A stored for 18 months

(Table 5). She divided the individuals into three (3) groups (Figure 7). Group 1 consists of oil samples obtained only from the polypropylene control batch in the 14th and 18th month of storage (noted A4 and A5). These samples are characterized by higher contents of total SFA, in particular MGA and OLA. Also, these oil samples have a very low content of polyunsaturated fatty acids.the second group comprises oil samples from the grains of the control batch in polypropylene bag at 4.5 and 9.5 months (marked A2 and A3 respectively) and two samples of oils from the batch of grains from the triple bagged bag without biopesticides stored for more than 10 months (B4 and B5). They are characterized by mean values of MUFA including acid OLA and PUFA in this case LA, ALA, GLA. The third group consists of oil samples from all the batches of grains in a triple bagging system associated with biopesticides (C, D, E and F) throughout the experimental period, oil samples from the batch in a triple bagging system bagging without biopesticides at 1, 4.5 and 9.5 months (B1 ; B2 ; B3 respectively), of the oil sample from the grains of the control batch in polypropylene bag at 1 month (A1) and of the oil sample from the grains of the initial batch (T0). These oils are characterized by a strong unsaturation. This last group is therefore distinguished by a high percentage of PUFA, especially in LA and ARA. It also has a high content of MUFA and PLA.

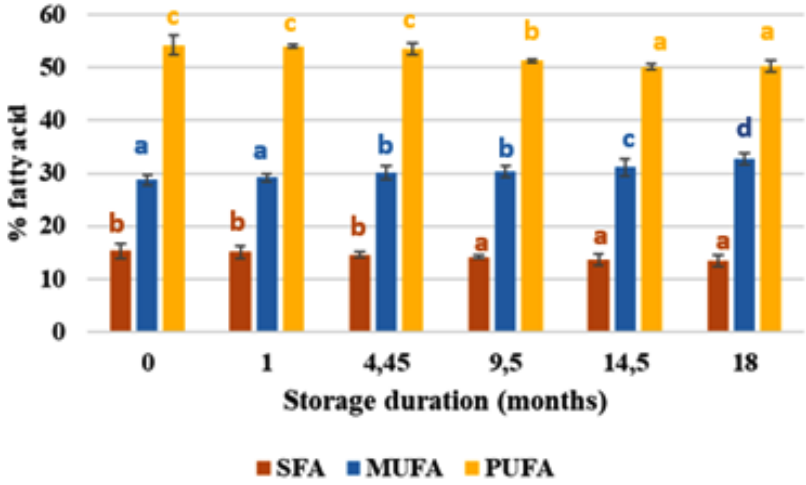

Fig. 3. Evolution of SFA, MUFA and PUFA content of oil of from the grain of the lot TEB_B stored for 18 months

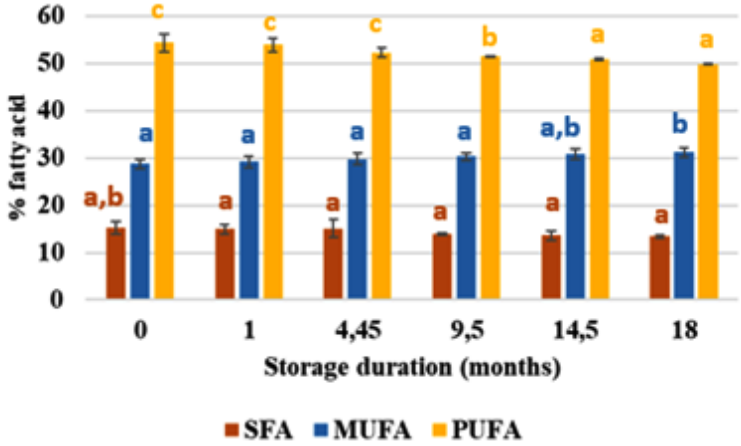

Fig. 4. Evolution of SFA, MUFA and PUFA content of oil from the grains of the lot TEB_C stored for 18 month

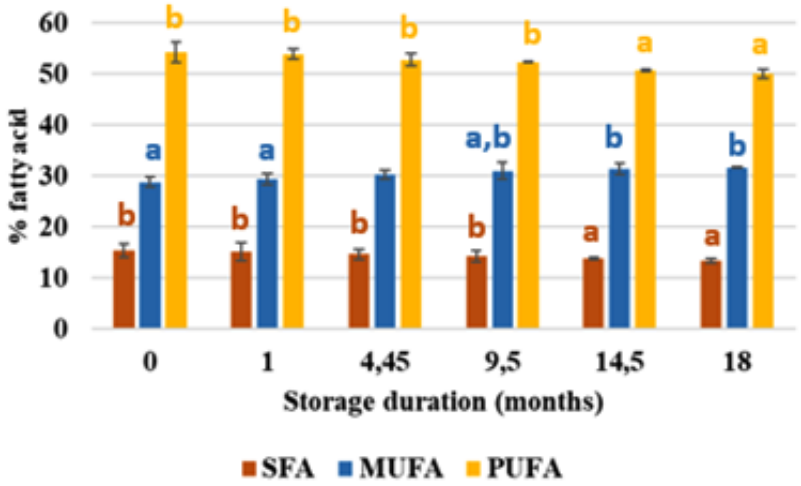

Fig. 5. Evolution of SFA, MUFA and PUFA content of of oil from the grains of the lot TEB_D stored for 18 months

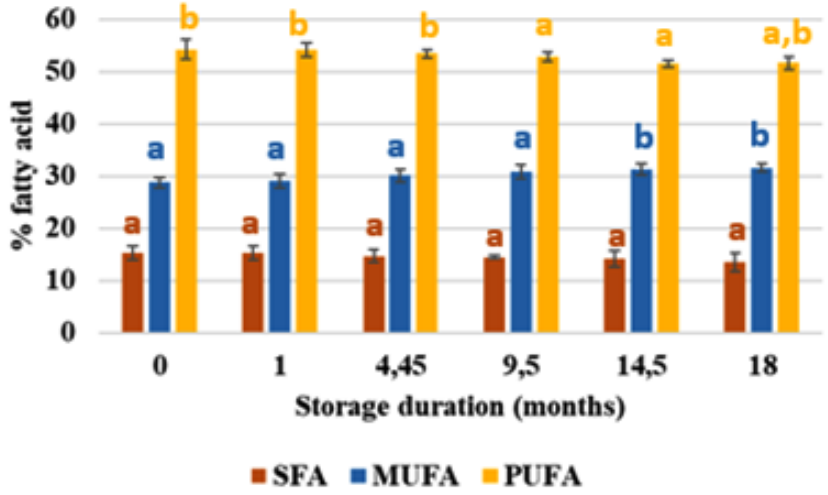

Fig. 6. Evolution of SFA, MUFA and PUFA content of oil from the grains of the lot TEB_E stored for 18 months

In the FIG 1 to 6, the tests were carried out in triplicate. For each fatty acid, means (± standard deviation) with different lowercase are different at the 5% probability test with a<b<c<d<e. PPSB = Control without biopesticides with polypropylene bag ; TEBA = Control without biopesticides with triple bagging bag ; TEBB = Bag to .triple bagging with 2.5% biopesticides (50% L. multiflora and 50% H. suaveolens); TEBC = triple bagged bag with 2.5% biopesticides (100% L. multiflora and 0% H. suaveolens); TEBD = triple bagged bag with 2.5% biopesticides (0% L. multiflora and 100% H ..suaveolens); TEBE = triple bagged bag with 5% biopesticides (50% L. multiflora and 50% H. suaveolens).

The ascending hierarchical classification (HAC) established by the Euclidean distance method reveals a variability of the parameters studied that is more explicit than that observed at the level of the PCA. Indeed, figure 8 reveals two superclasses of fatty acid profile of oils obtained during storage of corn from a truncation of the dendrogram at a Euclidean distance of aggregation of 50. The first super-class consists of individuals from the polypropylene control batch at 14.45 and 18 months of storage (A4 and A5). This super-class is characterized by a high content of

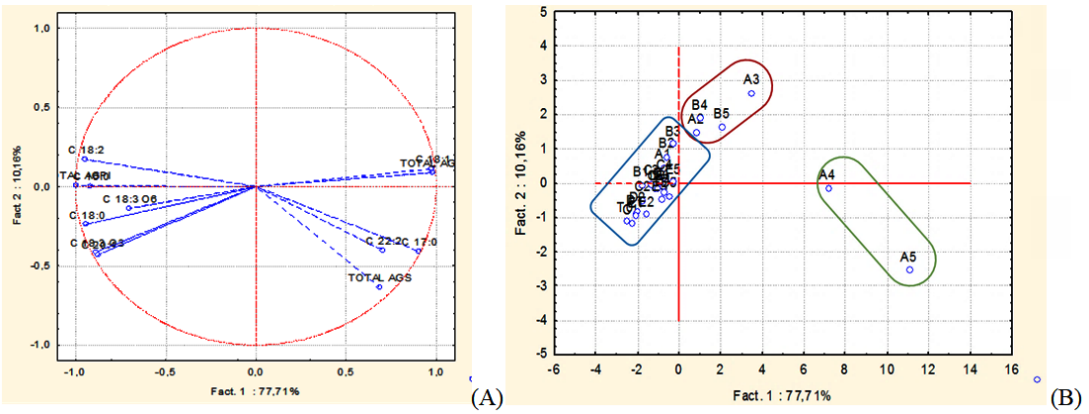

Fig. 7. Projection of the fatty acids (A) and of the oil samples (B) from the corn kernels stored in the factorial plane 1-2 of the principal component analysis

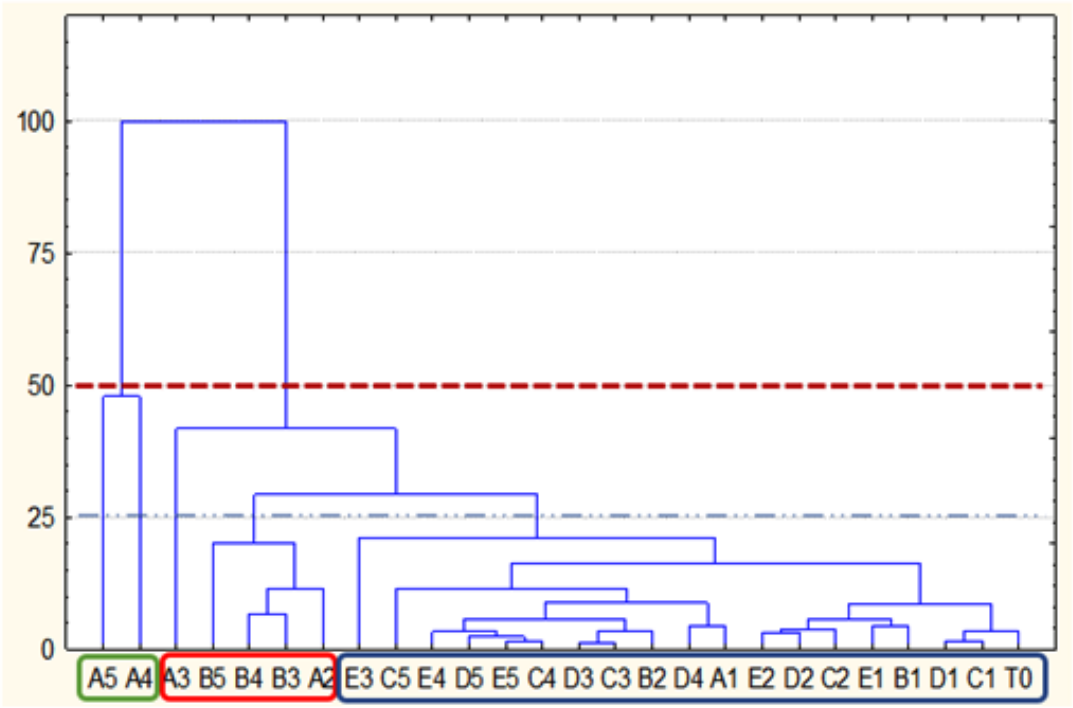

Fig. 8. Ascending hierarchical classification (dendrogram) of the different types of packaging according to the fatty acid profile of oils from stored corn grains

A: Oil from batch PPSB (Control without biopesticides with polypropylene bag); B : Oil from the TEB_A batch (Control without biopesticides with triple bagging bag); C : Oil from the TEB_B batch [Triple bagged bag with 2.5% biopesticides (50% L. multiflora and 50% H. suaveolens)] ; D: Oil from TEB_C [triple bagged bag with 2.5% biopesticides (100% L. multiflora and 0% H. suaveolens)]; E: Oil from the TEB_D batch [triple bagged bag with 2.5% biopesticides (0% L. multiflora and 100% H. suaveolens)]; F: Oil from the TEB_E batch [triple bagged bag with 5% .biopesticides (50% of L. multiflora and 50% of H. suaveolens)].With the sampling 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 = Oil of the initial batch

saturated and monounsaturated fatty acids. The other oil samples are the second superclass with more pronounced unsaturation. However, when the aggregation distance is reduced to 25, samples A2, A3, B3, B4 and B5 stand out from the batch samples with high PUFA contents ; thus standing out from the batch of samples exhibiting the best characteristics of the fatty acid profile. They constitute an intermediate subclass between the oil samples from the polypropylene batch of 9.5 to 18 months, rich in SFA and the other oil samples from the grains preserved with biopesticides, rich in PUFA.

Estimation of FA dairy intake, energy value and satisfaction of dietary needs

Multivariate analysis (PCA and HAC) showed that after 18 months of storage, the oils from the corn kernels stored in the triple bagging systems with the leaves of *Lippia multiflora* and *Hyptis suaveolens* had the best fatty acid profiles. Their profiles being also similar, the average values of the fatty acid percentages of these oils were chosen to estimate their contributions and their contributions. Therefore, from the consumption of oil extracted from corn kernels stored for 18 months in the presence of biopesticides, the results of the estimated daily intakes, their energy value and the contribution to meeting the needs in SFA, MUFA, PUFA, OLA, LA and ALA acids are reported in Table 6. The recommended daily intakes of fatty acids are on average 24.5 g/d, 37 g/d, 21 g/d, 37 g/d, 10 g/d and 2.5 g/d respectively for SFA, MUFA, PUFA, OLA, LA and ALA acids. This represents respective energy intake of 220, 331, 187, 330, 88 and 22 kcal. After 18 months of storage, the average daily intake of fatty acids is of the order of 3.67 g/d, 8.70 g/d, 13.82 g/d, 13.74 g/d, 0,15 mg/d and 8.52 g/d respectively for SFA, MUFA, PUFA, OLA, LA and ALA acids. The consumption of 27.40 g of oils from grains preserved with biopesticides provides 33.04 kcal/d, 78.32 kcal/d, 124.42 kcal/d, 121.33 kcal/d, 1.39 kcal/d, 1.39 kcal/d and 77.49 kcal/d respectively for SFA, MUFA, PUFA and acids OLA, LA and ALA. These contributions help meet the needs of SFA, MUFA, PUFA, OLA, LA and ALA acids up to 14.98% (SFA), 23.51% (MUFA), 65.24% (PUFA), 137.40 % (LA), 6.00% (ALA) and 23.02% (OLA).

DISCUSSION

During the experiment, storage significantly affected the fatty acid profile of crude corn oils depending on the type of packaging. In fact, at the end of the 18 months of storage, the oils obtained from the corn kernels packaged in triple bagging systems with biopesticides exhibit unsaturation rates of 83 % and 13.50 % of saturation against 81 % of unsaturation and 16 % of saturation for the oil obtained from the grains of corn stored in the triple bottom bag without biopesticides. As for the corn oil extracted from the kernels stored in the control bag (polypropylene), the level of unsaturation was 63 % for a level of saturation of 26.51 %. These variations in the rate of total unsaturation and saturation of the fat would be due to the quality of the storage of the corn kernels. In fact, the progressive reductions in the PLA, STA and PUFA contents in general correlated with a significant increase in the MGA and OLA contents of the oils obtained from the corn kernels stored in the control batch and the simple triple bagging at the end of storage could be due to interactionand the exchange of fatty acids carried out by microorganisms [27,28]. Similar observations were made by Al-Abdalall and AL-Juraifani [29], then Yin *et al*. [30] and De Carvalho *et al*. [31] during the respective storage of coffee beans, corn and sunflower seed. Also, Ortega *et al*. [32] recorded losses of 70-90% PLA, 65-90% STA during storage of wheat grains. For these different authors, microorganisms, through their metabolism, produce lipolytic enzymes which allow them to break down the fat in grains in order to use fatty acids for their growth [33]. N'kouam [34], Al-abdalall and Al-Juraifani [29] and De Carvalho *et al*. [31] also mentioned the effect of storage on fat composition during the respective storage of aiele fruit, coffee seeds and sunflower seeds. Moreover, Tamendjari *et al*. [35] then Ortega *et al*. [32], in their study on bacterial and fungal infestations during storage of olive seeds and wheat grains, under conditions of relative humidity between 50 and 100%, would have indeed shown that the actual presence of these microorganisms negatively affected the PUFA content of the extracted oils. As for the slight variations in the SFA (PLA, STA

and MGA), MUFA (OLA) and PUFA (LA, ALA, GLA, DDA and ARA) contents of the oils extracted from the triple bagging samples associated with biopesticides, they reflect the conservation the FA profile of the fat in the grains during storage

Correlation analysis performed on the fatty acid profile of the different corn oil samples revealed strong positive relationships between the fatty acids PLA, STA, LA, ALA, ARA and PUFA. Also, the contents of these acids and OLA, MGA and SFA acids. Thus, a decrease in PUFA content leads to an increase in SFA and MUFA, reflecting the deterioration in the quality of the fat. However, the excessive loss of PUFAs had been linked to oxidation and hydrolysis. The work of Urban-Alandete [36] found that a drop in the AGI content of grains during storage favored an increase in the percentage of SFA in the crude oils extracted. This assertion seems to be confirmed by the multivariate analysis (PCA and HAC) which made it possible to highlight the significant differences in efficacy observed at the level of different types of packaging (polypropylene bag, triple simple bagging and triple bagging with biopesticides). In fact, after 18 months of storage, only the oils obtained from the corn kernels packaged in the triple bagging systems associated with the leaves of aromatic plants (biopesticides) have the best fatty acid profiles. These high PUFA contents coupled with a low total saturation recorded in these oil samples could be explained by the combined effects of the triple bagging systems and the leaves of aromatic plants. According to Akoun *et al*. [21], this combination would effectively inhibit hydrolysis and oxidation of grain fatty acids during storage. Because, the principle of triple bagging is based on controlled and modified atmospheres which promote atmospheric conditions lethal for insects [37,38]. While the leaves of Lippia multiflora and Hyptis suaveolens are rich in volatile compounds which are the source of their insecticidal, bactericidal and fungicidal powers [39,40,41].

Like the work of Dubois *et al*.[2] the study of the fatty acid profile of the oils extracted from corn kernels stored for 18 months in triple bagging systems with biopesticides made it possible to confirm that these oil samples are from the "AGI" group, more precisely from the "LA + MUFA" sub-group. However, the consumption of a fat rich in unsaturation constitutes an advantage for the maintenance of the human organism insofar as the consumption of a highly saturated oil would be associated with an increased risk of cardiovascular and coronary diseases [42,43,44]. Thus, PUFAs such as LA, ALA and in a pinch ARA would be essential for the development and growth, prevention and management of coronary heart disease, hypertension, diabetes, cancer, arthritis and other inflammatory conditions and autoimmune [45,46]. In the body, these acids are converted in very small quantities, thanks to the action of desaturases and elongases, into ARA, EPA and DHA [47,48] which also remain precursors highly specific oxygenated lipid mediators in this case the thromboxanes, leukotrienes and prostaglandins. These molecules modulate hemostasis, platelet aggregation, immune system activity, neuronal activity, inflammation in the nervous system, cell growth and differentiation and lipolysis [49,50,51]. Similarly, studies have reported that the consumption of corn oil would be more advantageous, under certain conditions, than that of cinnamon, coconut, extra-virgin olive oil and olive oil / sunflower oil [52,53,7,54,55].

After 18 months of storage, in the triple bagging systems associated with the leaves of aromatic plants, the total contributions of saturated, monounsaturated, polyunsaturated fatty acids and of linoleic, oleic and linolenic acid contribute 14.98% respectively, 23.51 %, 65.24 %, 137.40 %, 23.02 % and 6.00 % of the daily recommendations which are respectively estimated at 24.5, 37, 21, 10, 37 and 2.5 g / d (RDI of SFA, MUFA PUFA, LA, OLA and ALA). Therefore, these fatty acid contributions obtained from the consumption of 27.40 g of oil from stored grains appear sufficient to meet the recommended energy intake. .thus, knowledge of the nutritional intake of essential fatty acids in oil from stored corn kernels could help manufacturers to offer quality oil to vulnerable populations.

CONCLUSION

The fatty acid profile assessment of the oils extracted from the corn kernels stored in a triple bagging system with or without the leaves of aromatic plants has been assessed in this study. It appears that the combination of triple bagging system and the leaves of aromatic plants remain a technology capable of guaranteeing quality and

the presence of fatty acids in these oils. The triple bagging extend the storage duration of the grains. And the leaves of *Lippia multiflora* and *Hyptis suaveolens* preserve the fatty acid composition of the fat of the grains. In addition, the fatty acid contributions obtained from the consumption of 27.40 g of oil from the grains conditioned in these storage systems seem sufficient to meet the recommended energy intakes.

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Conflict of interest

The authors mention that this article presents no conflict of interest.

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