IMPACT OF THE CONSERVATION MODE ON THE NUTRITIONAL QUALITY OF THE OIL OF THE GRAINS OF THE CORN VARIETS (Zea mays L.) LOCAL AND AMELIORAL CULTIVATIONS IN CÔTE D'IVOIRE

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SUMMARY

The conservation of grains such as maize (Zea mays L.) takes into account the germination power, quantity and nutritional quality of the grains; This is not always guaranteed as storage and conservation are practiced in Côte d'Ivoire. The purpose of this study is to extend the shelf life and ensure the nutritional quality of corn grains. Observations were made on oils extracted from two varieties of local maize and improved (AC176 and GMRP18) that were kept for 4 months in three conservation modes (canary, attic and bag). After 4 months of conservation, only the fat content of the local variety AC176 (3.24 %MS) remains stable in the bag. The acid index is maintained for 4 months in the attic and bag, only for AC176 (2.01 mg KOH/g oil). The diode index, maintained for only 4 months for GMRP18 (137.60 g of I2/100g oil) in the attic and canary. The saponification index is preserved in the attic for 3 months for AC176 (189.15 mg KOH/g oil) and for 4 months for GMRP18 (205.70 mg KOH/g oil). The levels of palmitic and linoleic acids of AC176 remained stable for 2 months in the bag and 4 months in the attic, respectively, whereas the levels of oleic and linolenic acids remained stable for 4 months in the canary. For GMRP18, palmitic and linoleic acid levels remained stable for 2 months and 4 months respectively in the bag and oleic acid levels for 4 months in the attic and canary. For GMRP18, palmitic and linoleic acid levels remained stable for 2 months and 4 months respectively in the bag and oleic acid levels for 4 months in the attic and canary. Ultimately, the impact of duration and the method of conservation on the parameters of the corn grain oils studied depends on the variety.

Keywords: Corn, Method of Conservation, Physical, Chemical and Nutritional Characteristics, Oil.

INTRODUCTION

Many grasses (cereals) are grown for edible seeds (***FAO, 2001***). They are important staple foods in the tropical regions of Asia and Africa; and provide about two-thirds of energy needs and 70% of protein intake in an average diet (***Bartali et al., 1994***). Worldwide, two-thirds of maize produced is used for animal feed and 27% for human food. On the African continent, 50% of the population depends on maize, which is an important source of protein, vitamins and minerals (***WHO, 2003***). In Côte d'Ivoire, the annual production of maize (second cereal after rice) is estimated at 700,000 tons (***FAOSTAT, 2011***). This production is fully consumed, and remains insufficient to meet needs (***Akanvou et al., 2007***). Grain corn is popular as a feed for its high energy intake, starch richness and oil (***Vavilov, 1986***); (***FAO, 1992***). In addition to feed use, maize has several forms of feed recovery where grains can be directly consumed in fresh ears or in semolina (***Agbobli et al., 2007***). Germs are used to produce corn oil, which is a well-known oil in human nutrition (***FAO, 1993***).

For many people, cereal processing products such as maize are the most important components of their diet. Therefore, good grain conservation is necessary for the preservation of stocks in adequate quantity and quality. It is in this context that this study was designed to assess the qualitative behavior of corn varieties oils by duration and method of conservation. The overall objective of the study is to assess the effect of mode and shelf life on the nutritional characteristics of corn oils to reduce post-harvest losses of corn. Specifically, it will be:

-To determine the fat content of maize varieties during conservation,

-To evaluate the chemical indices of maize varieties according to different conservation methods;

-Evaluate the fatty acid levels of corn varieties oils during conservation.

1-MATERIAL AND METHODS

1-1-Plant material

The plant material studied consists of two (2) varieties of corn (Zea mays L.) (Figure 1 and Table I) that are part of the varietal collection of the National Center for Agronomic Research (CNRA). These varieties are made up of a local variety: AC 176 (Accession 176); and an improved variety (protein-rich varieties): GMRP 18 (Gagnoa Corn Rich in Protein).

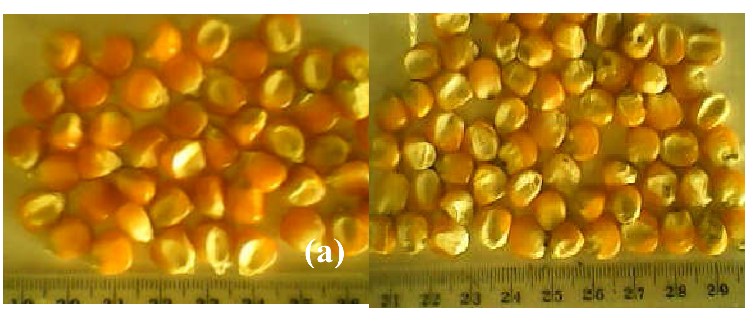

Figure 1: the local and improved maize varieties studied: AC176 (a), and GMRP18 (b)

Table I: Origin and morphological characteristics of the eight maize varieties

VARIETIES	TYPE	COLOR	TEXTURE	OBTAINERS
AC 176	local	yellow	cornate	CNRA-CI
GMRP 18	improved	yellow	cornate	CNRA-CI

CNRA-CI: National Agricultural Research Center of Côte d'Ivoire. **Local variety**: The protein content of corn grains is characterized by a deficiency in certain amino acids (lysine and tryptophan), with an average yield of 3 to 4 t/ha (***Chmaraev, 1982***). **Improved Variety**: The protein content of corn grains is characterized by richness in certain amino acids (lysine and tryptophan), with an average yield of 4 to 5 t/ha (***Agbobli et al., 2007***).

1-2-Methods

1-2-1-Sampling

The maize varieties presented above were harvested in December-2011 at an experimental station of the National Center for Agricultural Research (CNRA) in Côte d'Ivoire, more specifically in Abidjan (Anguédédou). The sampling method used is that of ENSA, 2006. Corn ears at full maturity (glassy stage) were manually harvested on all lines of the experimental plot for each maize variety, then the different samples obtained were put into carefully labeled polypropylene bags (a total of two (2) 80 Kg sample lots), and then returned to the CNRA technology research laboratory in Bingerville.

Once in the laboratory, five hundred (500) g of corn grains are collected from each sample batch for a first analysis prior to conservation. Next, ten (10) kg of corn grains are stored in triples in canaries and polypropylene bags, then ten (10) kg of corn ears of each variety are stored directly in triples in attics. Then, samples (500g of corn grains) are taken from each of the tripled stocks (bag, canary and attic) and then homogenized (to give 1.5 Kg of subsample) every 30 days and for 120 days. A total of 13 sub-samples were analyzed in the laboratory.

1-2-2-Fat

The fat content was determined using the ***BIPEA*** method (***1976***) using SOXHLET at 80°C. Three (3) g of the sample are weighed (Pe). An empty glass crucible is also weighed (P1) and 70 ml of hexane is added. The extraction takes place at the solvent reflux for 6 hours. The crucible containing the fat (P2) is weighed after evaporation of traces of solvent in the oven at 105°C for 24 hours.

1-2-3-Chemical Characteristics of Corn Oils

1-2-3-1-Acid Index

The Acid Index of Oils is determined using the ***AOAC*** (***1984***) method. One (1) g of oil from each sample was dissolved in 40 ml of a solvent ethanol/diethyl oxide system (25/25 (v/v)). Then 2 drops of phenolphthalein were added. The mixture is then titrated with ethanolic potassium hydroxide solution (0.5 N) until the color indicator turns.

1-2-3-2-Iodine Index

The Iodine Index of oil samples was determined using the ***AOAC*** (*1997*) method using the Wijs reagent. A mass of 0.5 g of oil was dissolved in 15 ml of chloroform. Then 20 ml of Wijs reagent is added. All of this was kept out of light for 1 hour. Subsequently, 10 ml of 10 % potassium iodide solution (m/v) and 150 ml of distilled water were added successively. The new mixture was then titrated with 0.1 N sodium thiosulfate solution in the presence of starch pods until full discoloration.

1-2-3-3-saponification index

The saponification index was determined using the ***AOAC*** method (***1997***). 2 g of oil is solubilized in 25 ml of 0,5 N alcoholic potash. The mixture was then boiled in a boiling water bath for 1 h. After cooling, excess alcoholic potash was titrated with 0.5 N hydrochloric acid solution in the presence of 3 drops of phenolphthalein, until turning to colorless.

1-2-3-4- Fatty acid composition

The qualitative and quantitative analysis of fatty acids in oils was performed by gas chromatography (GPC). This analysis was carried out in two stages: the preparation of methyl esters and the chromatographic analysis of these methyl esters. Methyl esters were prepared by cold trans-esterification, using the method described by ***UICPA*** (***1979***). The chromatographic analysis of these methyl esters enabled the fatty acids to be identified by comparing their retention time with those of the controls. Each identified fatty acid was quantified using a standard curve, established with erucic acid (2 µg/µl).

1-3-Statistical Analyzes

The analyzes were performed in triplicate and the data were collected on the EXCEL 2007 software. Statistical analyzes were performed according to STATISTICA 7.0 software. A two-factor variance analysis (ANOVA) was conducted to determine the effect of mode and shelf life. Significant statistical differences in averages were highlighted by the Duncan test at the 5% threshold.

2- RESULTS

2-1- Fat content of corn varieties oils during conservation

Variation in the fat content (MG) of local maize grains and improved maize grains conserved by three methods for 4 months differs significantly at the 5% threshold for each variety (Table II). The fat content of corn grains of the variety AC176 (3.24% MS) increased significantly at the 5% threshold after 2 months of conservation in the canary and after 3 months in the attic (Table II). This rate decreased significantly at the same threshold after 4 months of storage in the bag (2.01% MS versus 3.24% MS). Maize grain MG did not vary significantly at the 5% threshold in all three modes for this variety. For the improved variety GMRP18, the fat content of corn grains (3.39% MS) increased significantly at the 5% threshold after 1 month of conservation in the canary (5.35% MS), attic (5.14% MS) and bag (5.45% MS) (Table II). In addition, the loss of fat is observed only in the 4th month in the canary with 2.89 %MS compared to 3.39 %MS at harvest. It should be noted that the fat content of local and improved varieties varies differently in each conservation mode.

Table II: Variation in the fat content of local maize varieties during conservation

Variéties	Period(day)	Preservationmethods		
		Canary	**Attic**	**Bag**
AC 176	**Day 0**	3.24 ± 0.03 ^{b}	3.24 ± 0.03 ^{b}	3.24 ± 0.03 ^{b}
	30	5.77 ± 0.18 $^{d\,B}$	5.17 ± 0.10 $^{d\,B}$	3.29 ± 0.03 $^{b\,A}$
	60	4.63 ± 0.55 $^{c\,B}$	5.59 ± 0.22 $^{d\,C}$	3.82 ± 0.05 $^{b\,A}$
	90	2.65 ± 0.00 ^{aA}	4.01 ± 0.19 $^{c\,B}$	2.85 ± 0.34 ^{aA}
	120	2.11 ± 0.05 ^{aA}	2.01 ± 0.00 ^{aA}	2.91 ± 0.51 ^{aA}
GMRP18	**Day 0**	3.39 ± 0.48 ^{b}	3.39 ± 0.48 ^{a}	3.39 ± 0.48 ^{a}
	30	5.35 ± 0.55 $^{c\,C}$	3.99 ± 0.50 $^{b\,A}$	4.92 ± 0.64 $^{b\,B}$
	60	4.00 ± 0.70 $^{b\,A}$	5.14 ± 0.29 $^{c\,B}$	5.45 ± 0.18 $^{c\,B}$
	90	3.77 ± 0.00 $^{b\,A}$	5.12 ± 0.57 $^{c\,B}$	5.38 ± 0.16 $^{c\,B}$
	120	2.89 ± 0.20 ^{aA}	4.39 ± 0.40 $^{bc\,B}$	5.09 ± 0.47 $^{b\,C}$

Medium ± standard deviation; n = 3

On rows (uppercase letters) and columns (lowercase letters), the assigned averages of the common letter were not significantly different between them at the 5% threshold according to the Duncan test. In bold in the same column, maximum and minimum averages.

2-2-Chemical properties of oils of preserved maize varieties

2-2-1- Acid index

Corn oil acid indices vary over time depending on variety type and method of conservation (Table III). The acid index of local varieties shows no significant change at the 5% threshold for 120 days of storage in the attic and bag. In canary, however, the acid index of local varieties (2.01 mg KOH/g) increased significantly at the same threshold after 30 days (3.55 mg KOH/g) and then decreased significantly at the same threshold of 60 to 120 days of conservation. However, when improved varieties are preserved in the attic, the acid index of maize varieties (2.52 mg KOH/g) increased significantly at the 5% threshold after 30 days (2.80 mg KOH/g) and then decreased significantly at the same level of 60 to 120 days of conservation. In canaries, the acid index of maize varieties was significantly at the 5% threshold every 30 days of conservation. At the bag level, the acid index of maize varieties decreased significantly at the same threshold after 30 to 90 days of conservation (values ranging from 1.65 to 1.84 mg KOH/g), and then increased significantly after 120 days of conservation.

2-2-2- Iodine Index

The Iodine Index of corn grains of local varieties (120.18 g of I2/100 g) increased significantly to the 5% threshold after 1 month of conservation in the attic (124.13 g of I2/100 g), canary (131.1 3 g of I2/100 g) and bag (138.44 g of I2/100 g); then remain stable until the end of conservation in the attic and bag, but decrease significantly at the 5% threshold in the canary after 4 months of conservation (Table III). However, the corn grain iodine index of the improved varieties (137.60 g of I2/100 g) showed no significant variation in the attic and canary for the entire shelf life. At the bag level, this index decreased significantly at the same threshold after 1 month (122.30 g of I2/100 g) and then remained stable until the end of conservation.

2-2-3- Saponification index

The saponification index for oils extracted from local maize varieties (180.15 mg KOH/g) showed no significant variation during 3 months of storage in the attic, before increasing significantly to the 5% to 120days threshold (192.03 mg KOH/g) (Table III). Local varieties preserved in the canary and sack had higher saponification indices after 1 month of conservation (203.18 and 210.18 mg KOH/g, respectively), and then decreased significantly at the 5% threshold until end of conservation. For improved maize varieties (205.70 mg KOH/g), significant differences at the 5% threshold were observed only at the level of conservation in the bag with higher indices after 1 month of conservation (215.86 mg KOH/g); and in the canary, with higher indices after 2 months of conservation (211.20 mg KOH/g), then decrease the rest of the time. In the attic, however, the corn grain saponification index did not show any significant differences throughout conservation.

Table III: Chemical properties of oils extracted from varieties (local and improved) of maize during conservation

ChimicalsParameters	Period (day)	Local Variéty AC176			ImprovedVariéty GMRP18		
		Attic	Canary	Bag	Attic	Canary	Bag
Acid Index (mg KOH/g of oil)	0	2.01 ± 0.00 [a]	2.01 ± 0.00 [a]	2.01 ± 0.00 [a]	2.52 ± 0.20 [b]	2.52 ± 0.20 [c]	2.52 ± 0.20 [c]
	1	2.06 ± 0.04 [a]	3.55 ± 0.17 [c]	2.16 ± 0.30 [a]	2.80 ± 0.01 [c]	2.34 ± 0.01 [b]	1.84 ± 0.00 [a]
	2	2.11 ± 0.30 [a]	2.34 ± 0.20 [b]	2.12 ± 0.02 [a]	2.61 ± 0.22 [b]	2.53 ± 0.02 [c]	1.65 ± 0.00 [a]
	3	2.18 ± 0.55 [a]	2.46 ± 0.03 [b]	2.05 ± 0.11 [a]	2.69 ± 0.03 [b]	1.98 ± 0.02 [a]	1.78 ± 0.11 [a]
	4	2.22 ± 1.27 [a]	2.40 ± 0.19 [b]	2.08 ± 0.04 [a]	2.33 ± 0.00 [a]	2.01 ± 0.04 [b]	2.01 ± 0.02 [b]
Iodine Index (g de I_2/100g of oil)	0	120.18 ± 1.26 [a]	120.18 ± 1.26 [a]	120.18 ± 1.26 [a]	137.60 ± 1.22 [a]	137.60 ± 1.22 [a]	137.60 ± 1.22 [b]
	1	124.13 ± 0.08 [b]	131.13 ± 1.15 [b]	138.44 ± 1.53 [b]	136.50 ± 1.23 [a]	138.60 ± 1.04 [a]	122.30 ± 1.43 [a]
	2	122.50 ± 0.09 [ab]	122.66 ± 0.46 [a]	133.30 ± 0.24 [b]	138.55 ± 1.04 [a]	136.55 ± 1.05 [a]	122.50 ± 0.05 [a]
	3	124.20 ± 0.29 [b]	122.73 ± 0.27 [a]	134.16 ± 0.38 [b]	134.62 ± 0.25 [a]	136.40 ± 0.26 [a]	122.33 ± 0.07 [a]
	4	122.33 ± 1.10 [ab]	119.19 ± 1.48 [a]	137.20 ± 1.26 [b]	134.09 ± 0.06 [a]	138.09 ± 0.07 [a]	122.18 ± 0.00 [a]
SaponificationIndex (mg KOH/g of oil)	0	189.15 ± 0.44 [a]	189.15 ± 0.44 [a]	189.15 ± 0.44 [a]	205.70 ± 1.62 [ab]	205.70 ± 1.62 [ab]	205.70 ± 1.62 [a]
	1	187.85 ± 0.00 [a]	203.18 ± 1.33 [c]	210.22 ± 0.93 [c]	208.43 ± 0.13 [b]	205.75 ± 0.06 [ab]	215.86 ± 0.15 [d]
	2	189.32 ± 0.14 [a]	194.48 ± 0.04 [b]	209.43 ± 1.01 [c]	203.90 ± 0.24 [a]	211.20 ± 0.22 [c]	211.00 ± 0.26 [c]
	3	187.25 ± 0.01 [a]	189.08 ± 1.05 [a]	203.52 ± 0.05 [b]	204.88 ± 0.60 [a]	207.82 ± 0.35 [b]	209.28 ± 0.61 [bc]
	4	192.03 ± 0.10 [b]	188.22 ± 1.66 [a]	207.83 ± 1.06 [b]	204.78 ± 1.56 [a]	203.93 ± 0.66 [a]	206.33 ± 0.28 [ab]

Medium ± standard deviation, n=3; in columns, the averages assigned to the same lowercase letter are not significantly different ($p<0.05$)

2-2-4- Chemical composition of oils of preserved maize varieties (local and improved)

The most abundant fatty acids of oils of maize varieties are palmitic (C16:0), oleic (C18:1), linoleic (C18:2) and linolenic (C18:3). The palmitic acid content of corn grains of the local variety (Figure 2-A) decreased significantly to the 5% threshold over the last 3 months of conservation in the attic and canary. In the bag, C16:0 content of corn grains decreased significantly at the 4th month of conservation (8.93%). In improved varieties, the C16:0 content remains statistically stable after 2 months in the attic and after 1 month of storage in the bag and then decreases the remainder of the shelf life. In canary, however, the C16:0 content of corn grains decreased significantly 1 month after conservation.

Levels of oleic acid (C18:1) in corn grains (Figure 2-B) are dependent on variety type and method of conservation. At the local variety level, this content remains statistically stable throughout the shelf life of the canary. In the attic, the oleic acid rate decreased significantly to the 5% threshold after 1 month of storage, but remained statistically constant for 1 month of storage in the bag, then decreased until the 4th month. At the level of the improved variety, the C18:1 content of corn grains decreased significantly at the 5% threshold only in the attic every month for 4 months of conservation. Linoleic acid (C18:2) levels of corn grains of the local maize variety preserved in the attic decreased significantly to the 5% threshold after 3 and 4 months of conservation (Figure 2-C). The linoleic acid content varies monthly in the canary and bag. The linoleic acid content of the improved variety decreased significantly at the 5% threshold in canary and attic.

For linolenic acid (C18:3) content of oils extracted from corn grains of the local variety, it is higher and varies with shelf life in the bag, unlike canary and attic where linolenic acid levels in corn grains show no significant variation during the 4-month shelf life. The linolenic acid content of the improved variety decreased significantly to the 5% threshold in the first month of conservation regardless of the method of conservation (Figure 2-D).

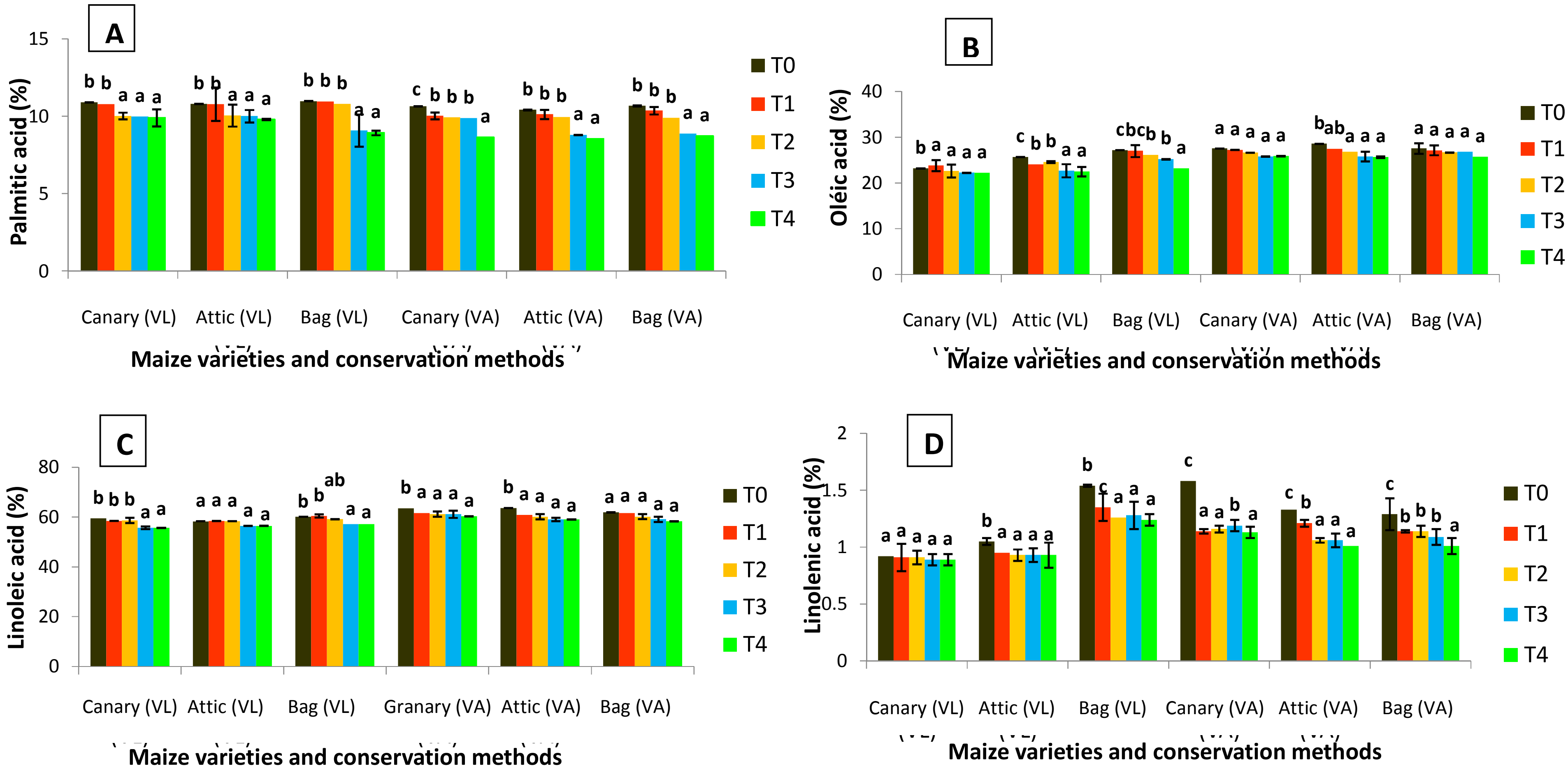

Figure 2: Proportions of fatty acids of oil extracted from varieties (local and improved) of corn during conservation The histograms affected by the same letter were not significantly different at the 0.05 threshold according to the Duncan Test. T= Day Retention Time (T0: initial status; T1: 30 days of storage; T2: 60 days of storage; T3: 90 days of storage and T4: 120 days of conservation); VL: Local Varieties VA: Improved Varieties

3-Discussion

The fat content of the tow maize varieties ranging from 2.01 % to 5.77 % MS is similar to that of ordinary maize (***St-Pierre et al., 2014***); according to the author, the lipid rate of corn grains varies between 3 and 5% MS. During the 4 months of storage, it was generally noted that there was a decrease in fat. This would be due to insect attacks on the corn germ, or to the possible oxidation of the fat due to the increase in the temperature of the medium. Corn, which is mainly composed of unsaturated fatty acids (86%), is weakened by its double bonds that oxidize to air during conservation ((***Cheftel and Cheftel, 1992***); ***This, 2007***). Oxidation rates are based on conditions in the conservation environment, including pH, temperature, and water content (***Jeantet et al., 2006***). The improved variety has higher fat content in the bag. It should be noted that Grain Oil is an important source of essential fatty acids (***Weber, 1987***). The iodine indices for oils extracted from maize varieties in each conservation mode are similar to those of maize oils grown in Pakistan (***Qasim et al., 2013***) and soybean oils (120-143 g I2/100 g) and sunflower oils (110-143 g I2/100 g) (***Codex-Alimentarius, 1993***). The high Iodine Index is directly related to the richness of polyunsaturated fatty acids in corn oils (***Njoku et al., 2001***).
The levels of polyunsaturated fatty acids (AGPI) in maize varieties are higher than those of tropical vegetable fats such as avocado oil (15,5 %), palm oil (10,5 %) and peanut oil (30,8 %) ((***Codex-alimarius, 1999***); ***Chalon, 2001***). The linoleic acid content of corn varieties oils can be considered as essential fatty acids, as can ordinarily corn oil (***Dubois et al., 2007***). The values of saponification indices determined during conservation and at the level of each method of conservation are higher than that of ordinary corn oil (187-193 mg KOH/g) (**Strecker et al., 1996**). A high value of the saponification index indicates an equally high molecular weight of the constituent fatty acids (***Wolf, 1968***). The dietary value of a vegetable oil is linked to the acid indices which constitute degradation parameters. The oils studied have acid indices (regardless of time and method of conservation) of less than 6 mg KOH/g, which is the recommended limit value for the use of vegetable oils for culinary purposes (***Onyeike and Acheru, 2002***).

Conclusion

This study, which examined the chemical characteristics of maize oils of local varieties and improved during conservation, showed that the conservation of maize varieties grains in the attic and bag would be of great benefit to maintaining the acid index of the local variety oils; This is not the case for the improved variety where the oil acid index is not preserved in any mode. In contrast, the attic and canary are better suited for the conservation of the iodine index of oils of the improved variety. For both varieties (local and improved), the maize grain saponification index is maintained longer in the attic. With respect to fatty acids, the conservation in the bag and attic of maize grains of local varieties and improved would be the most appropriate for maintaining the palmitic acid content. Levels of oleic, linoleic and linolenic acid are conserved longer in canaries and attics for the local variety. In addition, the conservation of the improved variety in the canary and attic ensures a good level of oleic acid.

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