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EFFECT OF THREE TYPES OF PLASTIC PACKAGING MATERIAL ON THE PRESERVATION OF PHYSICOCHEMICAL AND ORGANOLEPTIC QUALITY OF PLANTAIN BANANA CHIPS (*Musa spp*)

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ABSTRACT

Packaging plays a major role when choosing the food product. In this study, the impact of plastic packaging, of various materials, on the chemical and organoleptic quality of plantain chips has been realized in order to propose a better choice for marketing. Three types of plastic packaging material (PE, PP and PET) were used to preserve, over seven weeks, plantain chips from cultivar *Corne*. Investigation of monitoring of chemical (water content and peroxide index) and organoleptic (color, crustiness, aftertaste, taste of rancidity, odor and general evaluation) parameters evolution was carried out. The results indicate that the most suitable plastic packaging materials for the preservation of banana chips are respectively those in high density polyethylene (HDPE), in polypropylene (PP2: in bag form) and in low density polyethylene (LDPE1: 60 µm), in view of experimental and statistical analyzes carried out.

Keywords: banana (*Musa spp*), chips, preservation, packaging, chemical and organoleptic quality.

INTRODUCTION

Due to its importance (nutritional, food, economic, social …), the plantain is the only fruit classified as starch products of mass consumption worldwide (Adopo *et al.,* 1998). It has a high nutritional value with an important source of sugars, fibers and vitamins. But, it has a low fat content. Banana pulp, sometimes containing more than 75% water, is one of the richest heat sources (up to 110 kcal / 100g of fresh pulp) in fresh non-oleaginous fruits. The presence of a high content of sugars and often insoluble fibers (Da Mota et *al,* 2000), makes it a good source of regulation of intestinal transit. Plantains are also a fairly good source of vitamin B2 and proteins, but contain only low levels of certain essential minerals like iron, magnesium, potassium, calcium and phosphorus (Bello - Perez 1999; Eggleston *et al* 1992; Lii *et al* 1982). It contributes significantly to food security in Sub-Saharan Africa, where it is a major staple food for rural and urban populations (more than one hundred million people) (Frisian and Sharrock, 1998, INIBAP 2002). In the case of the valorization of this plantain, the production of flour is generally considered as a means of preserving the product. Plantain chips are also another means of valorization. They are obtained from the frying of very thin slices of plantain banana, not mature or at the beginning of maturation. Depending on customer requirements, sweet, savory or flavored plantain chips can be produced. The manufacture of plantain chips does not require specific equipment. On a small scale, common cooking utensils and a small electric welder for plastic bags are used. The chips can be stored for several months at room temperature without changes in their nutritional, hygienic, and organoleptic characteristics. The quality of the raw material, processing conditions, and the type of packaging have an influence on the quality of produced chips (Onyejegbu and Olorunda 1995). The production of chips breaks down into successive stages, perfectly linked together. The main unit operations of the manufacturing process are summarized as follows: sorting, washing, peeling, slicing, salting, frying, draining, cooling, packing in blister packs. Manufacturers of dried products such as chips use polyethylene bags (plastic packaging) as packaging. This for the essential reason which is the lack of knowledge of the nature of the sachet best suited to the merchandise proposed. After the refining of the crude oil, the separation of the various constituents and optionally introduction of new molecules (chlorine or oxygen), the obtained monomers (ethylene, propylene, etc.) are polymerized to give rise to the synthetic polymers. Among the materials used for food packaging, there are: polyethylene (PE), high density (HDPE) and low density (LDPE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene Polyvinyl chloride (PVC). Each plastic has its own properties and characteristics of gas and moisture permeability. The range of plastics, their properties and therefore their applications are very wide. The objective of this study is to investigate the impact of the type of plastic packaging material on the physicochemical and organoleptic quality of plantain chips. This, in order to develop practical solutions adapted to the needs of the operators of the plantain chip production chain, to improve the quality and presentation of the products placed on the market.

MATERIAL AND METHODS

Preparation of plantain chips

The plantain used is the immature *Musa sp*, (AAB cultivar *Corne*-Afoto) purchased from a market in Abidjan (Côte d'Ivoire). These fresh plantain bananas (at the green stage) are cut into 2 mm strips and fried in a restaurant deep fryer (SEB FR405400 FILTRA PRO, 3L) with refined palm oil (Dinor™, Côte d'Ivoire) at 170 °C for 10 minutes. The banana chips thus obtained are packaged in different types of packaging.

Types of plastic packaging used

Three types of plastic material made of polyethylene (PE), polypropylene (PP) and polyethylene terephthalate (PET) were used for packaging. For PE packaging: one is in high density (HDPE) with a standard monolayer 64.13 µm thick and the other in low density (LDPE). For this LDPE plastic, two type of thickness were used (LDPE 1: 60.4 µm and LDPE 2: 15 µm). Packaging in polypropylene (PP) was used either as a box (PP1) with a capacity of 400 g filled with 100 g of chips (Figure-1A) or in the form of a bag (PP2) (Figure-1B). The bags used are standard monolayers with a thickness of 52.88 µm. As for plastic packaging in PET (Figure-1C) is used in the form of trays (15x10,5x7 cm) with a transparent cover attached perfectly and with a capacity of 1000 g for studying the quality of the conservation of chips.


A B
C

Figure-1. Packaged chips in polypropylene plastic box (PP1) (A), in polypropylene bag (PP2) (B) and in polyethylene terephthalate: (PET) (C).

Effect of packaging on the physicochemical and organoleptic qualities of chips

Sixteen (16) packets of 100 g of chips per type of packaging were produced. After manual filling, all packed products were stored at an ambient temperature of 30 ° C and a relative humidity of 98% under natural lighting on a laboratory bench. Samples were taken weekly for seven (7) weeks for testing. The analyzes concerned the moisture content of the chips, which should not exceed 5%, the peroxide index with a standard of 10 meq / kg and sensory analyzes.

Determination of moisture content

The determination of the moisture content makes it possible to check the crunchy texture of the crisps. Indeed, when the chips increase in moisture, they lose in crispiness and therefore depreciate. The moisture content is determined using a moisture analyzer (TOLEDO, MA 73, Germany). 5 g of chips reduced in powder in a porcelain mortar are distributed on the bottom of an aluminum dish previously tared. By means of a mass loss of the product, the moisture analyzer gives the dry matter content (TMS) and we deduce the water content by the following relationship (measurements made in triplicate):

$$TMS(\%) = 100 - TH(\%) \quad (1)$$

With: TMS (%) (Percent dry matter content of the product), TH (%) (Water content of the product as a percentage).

Determination of peroxide number

The determination of the quantity of peroxides of a fatty substance shows its alteration by oxidation. Peroxide indices (PI) of plantain chips oils were determined according to AOAC (2000), described with some modifications (Cebi *et al*., 2017). Two grams of each chips sample were placed in a flask and dissolved with 10 mL of chloroform. 15 mL of glacial acetic acid and 1 mL of saturated KI solution were added to the flask. After shaking by hand for 1 min, the bottle was closed and placed in a dark place for 5 minutes. 15 mL of distilled water was added thereto and the mixture was titrated with a 0.002 M sodium thiosulfate solution with a starch solution as an indicator. A white was also titrated under the same conditions. The IP (meq O_2 active / kg) was determined using the following equation:

$$IP = \frac{1000 \times (V - V_0) \times N}{m} \quad (2)$$

With V: the volume of sodium thiosulphate used to assay the sample and V_0 the volume (mL) of sodium thiosulfate used for assaying white; m the mass of the sample (g) and N is the molar concentration (mol/L) of sodium thiosulfate. Three samples were analyzed separately for each test.

Sensory Evaluation

The purpose of sensory evaluation is to follow the evolution of the organoleptic characteristics of the chips according to the chosen packaging. For the evaluation of the intensity of the sensory parameters, descriptive analysis with the structured scale interval test was used (SSHIA, 1990). This analysis consists in measuring the intensity of the sensation perceived by each of the selected panelists. The panel of 15 people trained to evaluate the sensory attributes of plantain chips met once a week for 7 weeks in a tasting session to assess the sensory quality of the chips packaged in three (3) typical materials packaging (includes 6 forms of packaging). The tastings were conducted in specially equipped and in individual cabins comply with the NF V09-105 (1987). The products have been offered in random order and anonymously, identified by 3-digit codes defined using TASTEL +

software. Each subject tested the different samples presented according to the descriptors. A score (1 to 10) representing the perceived intensity was given by the panelists. The interval test was used to compare the characteristics one after the other. This made it possible to determine the least altered crisps, and thus the most suitable packaging for their preservation. The characteristics retained are: color, crisp texture, smell, taste of rancidity, aftertaste and general appreciation. Table-3 indicates the reference of the ratings of the sensory analysis. The responses were analyzed statistically using the TASTEL + sensory analysis software version 2013.

Table-1. Reference scale of lower and upper scores of different sensory criteria.

Characteristics	Lower bound	Upper bound
Color	1 = light yellow	10 = dark yellow
Smell other than banana	1 = no smell	10 = strong odor
Crispy texture	1 = not crispy	10 = very crispy
Taste of rancidity	1 = absent	10 = present
Aftertaste	1 = absent	10 = present
General appreciation	1 = unpleasant	10 = nice

* In grayed out the desired scores

Data analysis

Analysis of sensory tests

The results for each type of packaging are presented with average scores per product. More "general appreciation" ratings and that of "crisp texture" tend towards 10 plus the product is good. Regarding "the color", "the smell other than banana", "the aftertaste" and "the taste of rancid", the more they tend towards 1, the more the products are good. The results obtained were evaluated statistically in order to assess the level of significance of the differences observed in the chips over time. The letters a, b, c, d ... or ab or abc ... correspond to the different meaning groups obtained after the smallest significant difference (SSD) test. If two products are associated with the same letter, this means that they are not significantly different, but if they are assigned two different letters, they are significantly different (at the 5% threshold).

Analysis of variance (ANOVA) to a factor

One-factor ANOVA was used to compare the means of the different assay results. It is based on the Fisher test with a significance level of 0.05. If the calculated F value is greater than Fisher's F to a 5% threshold, the averages are significantly different. But if this calculated F is lower than Fisher's (5%) then the averages are significantly the same. The XLSTAT software, 2016 (trial version) was used for the average comparison tests, then these tests were applied in the TASTEL + 2013 software.

Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) was used to exploit the quantitative data. The purpose of this analysis is to summarize all the information graphically. The PCA makes it possible to transform p inter-correlated quantitative variables into p new uncorrelated variables called principal components. Thus, "the CPA builds new variables, artificial and graphs to visualize relationships between variables, and the possible existence of groups of individuals and groups of variables" (Xiao *et al*., 2017). The TASTEL + 2013 software was used for the PCA.

RESULTS AND DISCUSSIONS

Influence of the type of plastic packaging on the physicochemical characteristics

Evolution of banana chips water content

Figure-2 shows the evolution of moisture in banana chips during the 7 weeks storage at room temperature (30 ° C.) in the various types of plastic packaging (HDPE, PEBD1, PEBD2, PP1, PP2, PET).

Figure-2 shows overall sawtooth changes in the humidity of plantain chips in the four plastic packaging materials (HDPE, LDPE, PP and PET) during the 12 weeks of storage. This could be due to the permeation phenomenon wherein gas exchange (water vapor, O_2) between the outside (high humidity: 98%) and the food, but also between the food and the outside (Seyed-1998; Santoro et al, 2016.). The loss or gain chips moisture in packaging, low density polyethylene (PEBD1, LDPE 2) is due to the property of transmitting water vapor polyethylene bags (Akubor and Adejo, 2000). The first week showed a significant increase ($p <0.05$) in the moisture content of chips in all types of packaging except LDPE packaging (60). For the remaining 6 weeks, the moisture content of the chips in the PP2 (bag) packaging is significantly lower ($p <0.05$) than that of the initial crisps. There would have been a sorption reaction characterized by the transfer of water vapor from the plantain chips to the PP2 package. However, in the PP1 (box) packaging the increase in the humidity of the chips would be due to the

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quality of the sealing of the boxes. Indeed, poor sealing could lead to a massive entry of water vapor and air in this type of box packaging (with lid). What could cause rapid aging products (Perrin and Vigneron 2012)? At the analysis of Figure-2, only the packaging HDPE allows the water content of the chips to remain stable followed by a decrease of the water content to the week.

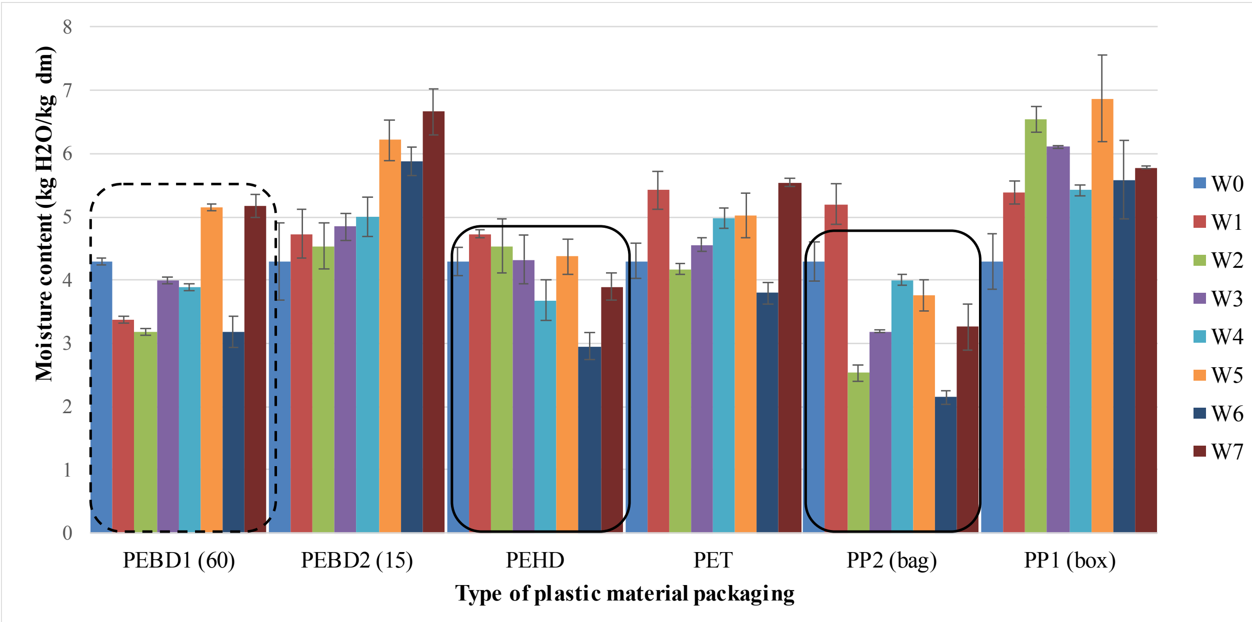

Figure-2. Influence of plastic packaging on changes in water content in plantain chips.

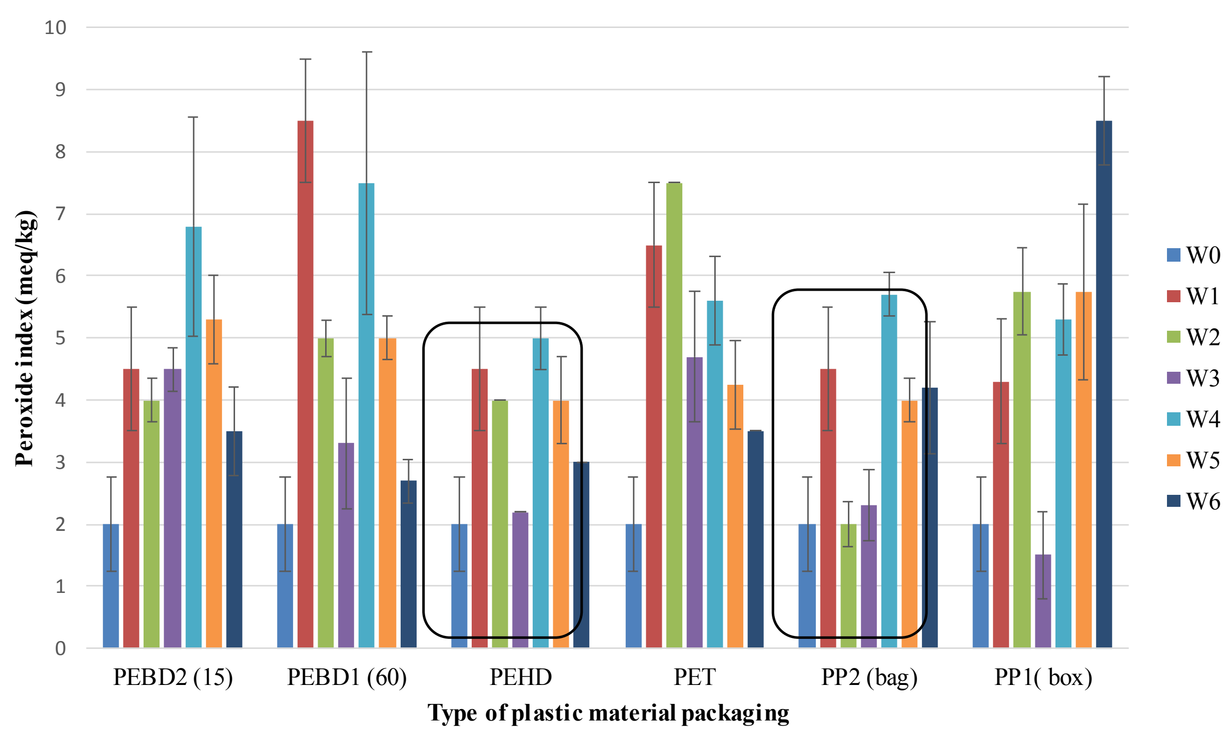

Figure-3. Influence of plastic packaging on the evolution of the peroxide index in plantain chips.

The moisture content influences the physical properties (crispiness or not) of the crisps. This rate indicates that the chips intended for marketing have the desired properties (such as storage potential,

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microbiological stability and commercial quality). Unlike glass or metal, plastic packaging is not completely impervious to gases and water vapors. They have a certain permeability (Pe) which is expressed by volume of oxygen (O_{2}) per area and per unit time, for a given oxygen pressure difference between the outside and inside of the packaging (Perrin and Vigneron 2012). In conclusion, plastic materials that stabilize the water content in plantain chips as well as maintaining their organoleptic quality (especially crispness) of the chips are PP2 (bag) and then HDPE.

Evolution of chips peroxide value in the different types of packaging

To evaluate the influence of the different packaging used on the oxidation of the fat of the chips, a peroxide dosage was carried out. The peroxide (PI) indices in the chips during their storage for 7 weeks in plastic packages are shown in Figure-3.

Chips, before packaging had a peroxide value of 2 meq O_2 / kg oil. Figure-3 shows that in the PET, PP1 and PP2 packaging, the peroxide index, as well as the moisture content in the chips, has changed in a sawtooth fashion. The increase in moisture levels in PET, PP1 and PP2 packaging could have contributed to an increase in the availability of oxygen in them and thus in the oxidation of the fat. In the presence of oxygen in the air, the unsaturated fatty acids entering the composition of the fatty substances oxidize to give peroxides. This phenomenon occurs during the storage of fatty substances: it is rancidity. Increasing the PI value chips during storage could be due to the oxidation reaction of lipids in the presence of light and oxygen (Che *et al*. 2003). Figure 4 also shows an increase in the peroxide number in the packaging of LDPE1, LDPE2 and HDPE. There is also an evolution of sawtooth IP for these three types of plastic packaging. However, the plastic packaging made of HDPE allows a smaller evolution of the IP in banana chips compared to that of LDPE. As a result, HDPE would be less gas permeable. Also, despite the increase in the peroxide value in the chips as a whole, it is still in compliance with the standard. Indeed, the average of the peroxide value of the studied chips remained less than 9 meq O_2 / kg oil. ISO 3960 (2001) concerning the peroxide value of the fats of animal and vegetable origin fixed limit value 10 meq oxygen actif.kg^{-1}. The peroxide index of less than 25 meq.kg^{-1} is the safe limit for the storage chips (Ikpeme *et al.* 2007) and in all samples. Thus, in this study, the peroxide index is within the safe limit. In the analysis of Figure-4, it is the PP2 (bag) and the HDPE packaging which stabilize the IP in the plastic packages. The latter two types of plastic packaging could make it possible to preserve the organoleptic quality of the chips by reducing their rancidity in the face of oxygen.

Influence of the type of packaging on the organoleptic characteristics

High density polyethylene (HDPE)

The sensory profile of the plantain chips highlighted in Figure-4 shows the evolution of the organoleptic characteristics during the 7 weeks of storage.

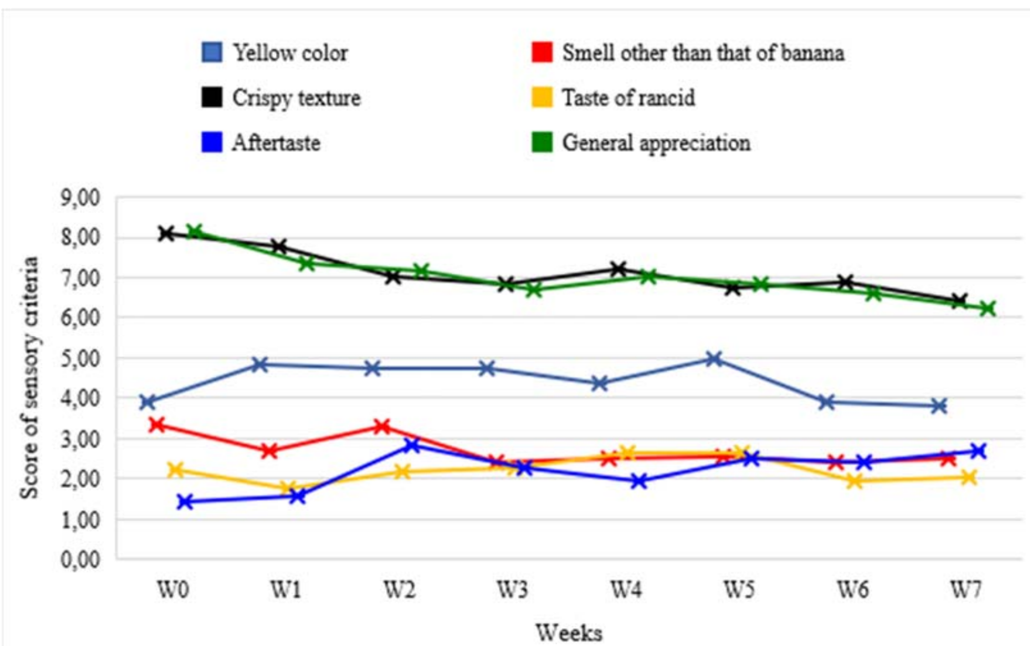

Figure-4. Sensory profile of chips conditioned for seven (7) weeks in plastic HDPE packaging.

At the end of the results of the sensory evaluation tests, it appears that the mean scores obtained in terms of color, odor, rancidity, aftertaste and crispy texture are all significantly identical ($p > 0.05$) and less than 5 (mean

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score). The evolution of these parameters during the 7 weeks of storage in HDPE packaging is not significant. For color the score varies between 3.79 and 4.93, meaning that the chips, all along the conservation have a color between light yellow and dark yellow. As for the aftertaste of chips, the score varies between 1.39 and 2.79. This means that the aftertaste of the crisps is weakly present (as close to 1: absence). The rancid taste has a score that ranges between 1.73 and 2.6, also indicating a low taste of rancid in plantain chips. Finally, for the odor other than that of the banana, the score varies between 2.39 and 3.33. This means that the chips kept after 7 weeks continue to have a fairly good banana smell. As for the general assessment of banana chips, the average scores obtained are significant. For crunchy texture, it did not evolve during conservation ($p > 0.05$) and the score remains close to 10 (as it varies between 6.4 and 8.06), meaning that it is quite good at the end of 7 weeks of storage. Only the general appreciation of banana chips shows a significant change ($p < 0.05$) during the 7 weeks of storage (Table 2) with a score ranging between 8.13 and 6.2. However, the score remains above 5 during conservation, meaning a good general appreciation at the beginning of conservation and a moderately good appreciation towards the end of conservation. These results could be explained by the properties of HDPE packaging. Indeed, the rate of transmission to water vapor in this type of plastic is very low 4.7 g / m² / 25 µm compared to other plastic materials (Paine and Paine, 1992). For cons, the HDPE has a high transmission rate to oxygen and does not have good resistance to light (Chen and Li, 2008). The time of the study therefore did not make it possible to bring out these parameters.

Table-2. Example of results of the analysis of variance of the scores obtained of the chips packaged in the HDPE.

Variables	W0	W1	W2	W3	W4	W5	W6	W7
Crispy texture	$8.06 \pm 1.03^{a*}$	7.73 ± 1.33^{a}	7.2 ± 1.81^{a}	7 ± 1.78^{a}	6.86 ± 1.70^{a}	6.79 ± 1.87^{a}	6.73 ± 1.64^{a}	6.4 ± 1.80^{a}
General appreciation	8.13 ± 1.30^{a}	7.33 ± 1.35^{ba}	7.13 ± 1.46^{cba}	6.66 ± 1.68^{cb}	7 ± 1.69^{cb}	6.79 ± 1.26^{cb}	6.59 ± 1.45^{cb}	6.2 ± 1.74^{c}

* When letters in front of the digits are the same, then the averages are significantly the same, otherwise they are significantly different.

Packaging in low density polyethylene (LDPE)

The evolution of organoleptic characteristics of packaged banana chips in plastc LDPE1 (60 µm) and LDPE2 (15 µm) polyethylene plastics was studied. A degradation more pronounced of the organoleptic parameters of the chips in the LDPE2 plastic compared to LDPE1 was observed. This observation indicates that, the thickness of the PE packaging could play a role in the evolution of the characteristics of the chips. Thus, the lower the thickness of the plastic packaging, the faster the plantain chips are depreciated in the time. As a result, only the results of ANOVA of the plantain chips packaged in the LDPE1 plastic are presented in Table-3.

Table-3. Results of the analysis of variance of the notes obtained by the chips packaged in the LDPE1.

Variables	W0	W1	W2	W3	W4	W5	W6	W7
Yellow color	3.86 ± 1.46^{ed}	5.73 ± 1.74^{ba}	5.33 ± 2.25^{cba}	6 ± 1.75^{a}	5.06 ± 2.06^{dcba}	4.4 ± 1.91^{edc}	4.73 ± 2.0^{edc}	3.79 ± 1.61^{e}
Aftertaste	1.39 ± 0.51^{c}	$1{,}66 \pm 0{,}74^{cb}$	2.73 ± 1.90^{a}	2.26 ± 1.44^{cba}	$2{,}39 \pm 1{,}10^{ba}$	2.73 ± 1.68^{a}	1.93 ± 1.4^{cba}	2.33 ± 1.68^{ba}
Crispy texture	8.06 ± 1.03^{a}	7.86 ± 1.33^{a}	7.73 ± 1.81^{ba}	$6{,}73 \pm 1{,}78^{cb}$	7.13 ± 1.70^{cba}	6.33 ± 1.87^{c}	6.33 ± 1.64^{c}	6.06 ± 1.8^{c}
General appreciation	8.13 ± 1.30^{a}	7.06 ± 1.35^{a}	6.53 ± 1.46^{a}	6.53 ± 1.68^{a}	6.59 ± 1.69^{a}	6.4 ± 1.26^{a}	6.4 ± 1.45^{a}	6.4 ± 1.74^{a}

* When letters in front of the digits are the same, then the averages are significantly the same, otherwise they are significantly different.

At the analysis of Table-3, the color of the chips packed in the plastic in LDPE1 evolved significantly after one week of storage. The sensory analysis score increased from 3.86 to 5.73. And throughout the conservation of banana chips, the color has evolved significantly into sawtooth. This could be explained by the entry of oxygen through the packaging which led to oxidation of the chips and cause a change in color. Ammawath *et al.* (2002) also observed large variations in the color values of banana chips packed in low density polyethylene films during storage. Analysis of variance (Table-3) shows that the observed differences in color, crisp texture and aftertaste are significant. The loss of crispiness can be explained by the high water vapor transmission rate of 16-24 g / m² / 25 µm (Paine and Paine, 1992). On the other hand, there was no major difference in the smell, the taste for rancidity and the general appreciation of potato chips. Notes on general appreciation and crispy texture declined over time from 8 to 6. Differences observed did not influence the appreciation of banana chips by panelists.

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Packaging in polypropylene (PP)

PP1 and PP2 come from the same material. The difference is that the PP1 is boxed and the PP2 is in a bag (or sachet). Only the evolution of the sensory profiles of the chips packed in the PP2 bags will be represented in Figure-5. The notes relating to color, odor, texture, rancidity and taste after taste have progressed in sawtooth. In general, PP films are clear and more transparent than other polymer films. Thus, light is able to enter the package and influence the color of the packaged product (Kirwan and Strawbridge 2003).

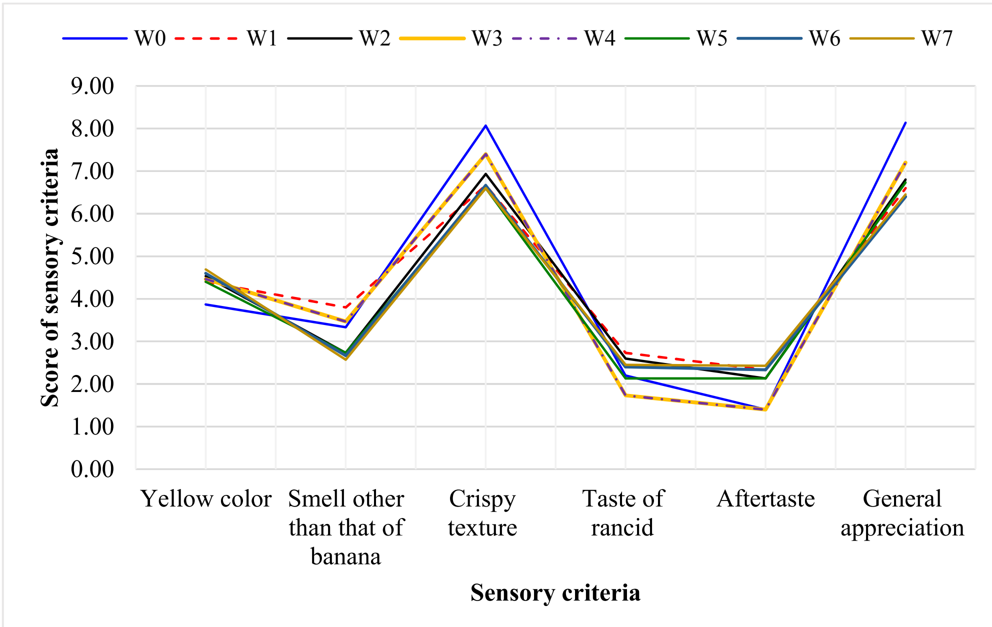

Figure-5. Sensory profile of chips conditioned for seven (7) weeks in plastic PP2 packaging.

Notes referring to texture and general appreciation decreased during storage. Table 4 shows the results of the analysis of the variance of the scores obtained. The statistical treatment of these notes shows that the results obtained reflect a significant difference in the aftertaste and the general appreciation of the crisps.However, these characteristics tend to be stable between the 6th and 7th week of conservation. This could be explained by the rate of transmission of oxygen from polypropylene which is very high and ranges between 2400 and 3800 $cm^3 / m^2 / 25\mu m$ (Paine and Paine, 1992). A massive intake of oxygen into the packaging has led to oxidative aging. Indeed, the oxygen present in the packaging reacts with the lipids and will cause their oxidation. These oxidations will lead to a modification of the taste of the food and give a rancid taste to the crisps, hence the observed aftertaste.

Packaging made of polyethylene terephthalate (PET)

Table-5 shows the evolution of the sensory profile of the chips packaged in PET during the 7 weeks shelf life. The color, odor, aftertaste, the taste of rancid have had scores below 5 throughout the storage period. The scores ranged serrated and have not changed significantly. The crispy texture and overall assessment of chips have scores above 5 but decreased over time and increased from 8 to 6. Table 5 shows the results of analysis of variance. A statistical analysis allowed to see that at the color level, the scores are not significantly different. These results are not surprising, since PET has good resistance to light (Paine and Paine, 1992). This helped slow the browning of chips. In addition, the rate of oxygen transmission as compared to other plastic materials is the lowest and is between 47 and 94 $cm3 /m^2/25\ \mu m$ (Paine and Paine, 1992). At the odor and aftertaste, the difference became apparent after two weeks of storage. Indeed, PET has a high compatibility with fragrances (CSEMP, 2004). An odor present in the storage site could contaminate the packaging and therefore the chips. As for the crunchy texture and overall assessment, the difference has been felt already after one week of storage. This decline in the appreciation of chips is explained by the loss of crispness observed. Indeed, the correlation coefficient between the general appreciation and texture is 0.82. This reflects a strong correlation between these two characteristics. The loss of crispness in turn, can be explained by the intrinsic properties of the material itself. Indeed, the vapor transmission rate of water PET is between 16 and 20. This value is relatively high compared to other materials used in this study. This transmission rate could therefore lead to a massive ingress of water into the packing which resulted in softening of the chips.

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Table-4. Results of the analysis of variance of the grades obtained by the chips packaged in PP 2.

Variables	W0	W1	W2	W3	W4	W5	W6	W7
Aftertaste	1.39 ± 0.51 ^{b}	2.33 ± 1.5 ^{a}	2,13 ± 1,30 ^{ba}	1.39 ± 0.63 ^{b}	1.39 ± 0.63 ^{b}	2.13 ± 1.19 ^{ba}	2.33 ± 1.23 ^{a}	2.33 ± 1.23 ^{a}
General appreciation	8.13 ± 1.30 ^{a}	6.59 ± 1.59 ^{b}	6.79 ± 1.70 ^{b}	7,2 ± 1,21 ^{ba}	7,2 ± 1,12 ^{ba}	6.73 ± 1.75 ^{b}	6.4 ± 1.68 ^{b}	6.4 ± 1.68 ^{b}

Table-5. Results of analysis of variance of the scores obtained by the chips packaged in PET.

Variables	W0	W1	W2	W3	W4	W5	W6	W7
Odor other than bananas	3.33 ± 1.35 ^{a}	2.39 ± 1.55 ^{ba}	3.73 ± 2.25 ^{a}	2,6 ± 1,45 ^{ba}	2.6 ± 1.35 ^{ba}	2,6 ± 1,72 ^{ba}	2,6 ± 1,80 ^{ba}	2.2 ± 1.47 ^{b}
crunchy texture	8.06 ± 1.03 ^{a}	8 ± 1,00 ^{ba}	7.26 ± 1.44 ^{cba}	6.86 ± 1.19 ^{dcb}	6.53 ± 2.07 ^{dc}	7.06 ± 1.53 ^{dcb}	6.53 ± 1.88 ^{dc}	6.06 ± 2.12 ^{d}
Aftertaste	1.39 ± 0.51 ^{c}	1,86 ± 1,25 ^{cb}	2.39 ± 1.40 ^{cba}	2.26 ± 1.16 ^{cba}	2.93 ± 1.22 ^{a}	3.26 ± 2.02 ^{a}	2.53 ± 1.36 ^{ba}	2,73 ± 1,79 ^{ba}
General appreciation	8.13 ± 1.30 ^{a}	7.06 ± 1.91 ^{ba}	6.53 ± 1.55 ^{b}	7 ± 1.56 ^{ba}	6.2 ± 1.61 ^{b}	6.13 ± 2.00 ^{b}	6.13 ± 2.07 ^{b}	6 ± 2.48 ^{b}

Classification of packaging according to the organoleptic quality

To determine the existence of a difference between the different types of packaging used to package plantain chips, a grouped treatment of the scores obtained by types of packaging was carried out. The results are shown in Figure-6. The Principal Component Analysis (PCA) performed was intended to synthesize all the information graphically in axes constituting the sensory descriptors. The first main axis representing 62.33% consists positively the following attributes: dark yellow color, crispy texture, general appreciation; and in a negative way the following attributes: rancid taste, aftertaste. The second main axis represents 22.15% and consists of positive the following attributes: odor other than bananas and negatively the following attributes: dark yellow color. There are strong positive correlations to over 80% between "after taste" and "rancid taste" descriptors, and between "general appreciation" and "crunchy texture". There are also strong negative correlations to over 80% between "general appreciation" and "rancid taste", then between "general appreciation" and "after-taste". The analysis of figure 6 shows that plantain chips which were the least appreciated with a less good crispy texture and a more pronounced rancidity are the chips packed in LDPE 2 (15µm). Thus, the chips packaged in the plastic LDPE1 (60 µm) are those which have evolved the less. In view of the previous results, it should be noted that: whatever the type of packaging used, more a product evolves, the more notes of aftertaste and rancidity appear and the less it is appreciated. As for chips packaged in HDPE, they have been generally appreciated and kept a good crispy texture. The chips packed in plastic PP2 have also been well appreciated and kept a good crispy texture.

More plantain chips evolve during the seven weeks of storage, the more notes of aftertaste and rancidity appear Thus, chips packaged in plastic HDPE and PP2, have the least evolved over time retaining their crispness, the initial moisture content with a low peroxide value and a good appreciation. The chips packed in LDPE2 plastic are those that have evolved strongly over time (in terms of moisture content and the peroxide index). They are the most rancid with a aftertaste, so the least appreciated. And the chips packaged in HDPE plastic, have evolved weakly over time (in terms of moisture content and peroxide index) while maintaining their crispness. They were therefore the most appreciated. Chips packaged in PP2 plastic have also evolved weakly over time (in terms of moisture content and peroxide index); but taking a smell other than that of banana.

In conclusion, the most suitable packaging for the conservation of these chips after 7 weeks of storage are in order of preference HDPE, PP2 and. LDPE 1. These opaque bags protect the chip against light. Polypropylene packaging has easy welding. Thermo-welders ordinary can be used for closing bags. In addition, the PP is chemically inert and resistant to most chemicals that are commonly found in both organic and inorganic. This is a barrier to oil and has good resistance to grease. PP is not subject to environmental stress cracking and its cost is relatively low (Kirwan et Strawbridge 2003).

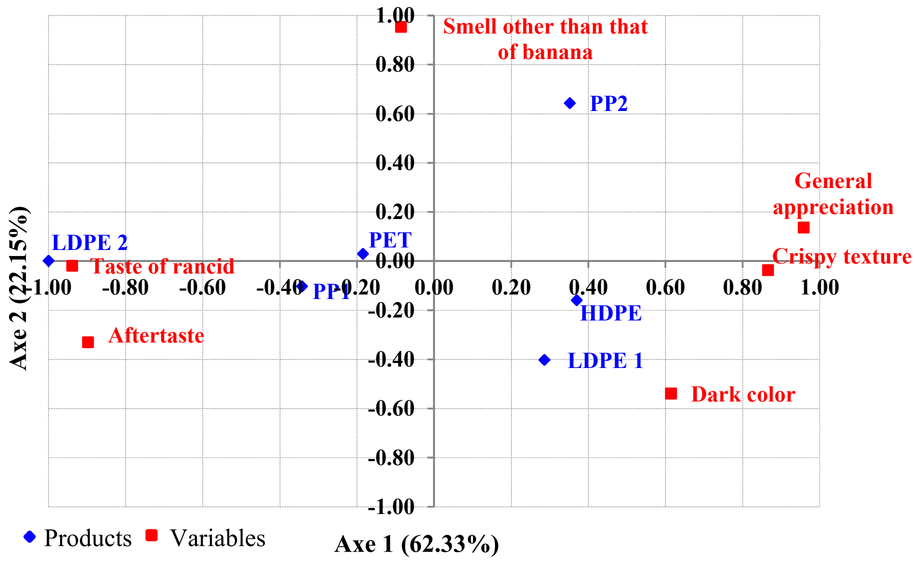

Figure-6. Classification of plastic packaging (HDPE, PEBD1 PEBD2, PP1, PP2, PET) as a function of the organoleptic quality of chips.

CONCLUSIONS

The three plastic packaging materials (PE, PP, PET) with 6 types of packaging (HDPE, LDEP1, LDPE 2, PP1, PP2 and PET) were tested to conserve plantain chips on 7 weeks. The results indicate that packaging of high density polyethylene (HDPE), polypropylene (PP2) bag (53 µm) and low density polyethylene (LDPE1: 60 µm) are less permeable to water and air vapor. Plastic packaging PET, PP, HDPE and LDPE, the color change, the appearance of browning, increasing the water content and the peroxide value are even more important than the oxygen permeability and the water vapor of the material is high. Monitoring the sensory profile of the chips has shown that the evolution of the organoleptic characteristics of the chips was highly correlated with the duration of storage. Indeed, whatever the packaging used, the more the product evolves, the less appreciated. The study of changes in the water content of the peroxide value and sensory characteristics showed that PP allow the best keeping quality chips for seven (7) weeks of storage at room temperature.

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