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EFFECT OF FOUR TYPES OF PACKAGING ON THE PHYSICO-CHEMICAL QUALITY OF COCOA BEANS (*Theobroma cacao* L.) DURING THE CONSERVATION

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ABSTRACT

The influence of four types of packaging on the physico-chemical quality of cocoa beans during conservation has been studied. These are the jute bags (SJ), woven polypropylene bags (SP), and on the other hand polyethylene bags wrapped in jute bags (SPJ) and polyethylene bags wrapped in polypropylene bags (SPP). These batches of cocoa beans are preserved in natural atmosphere in a store during 51 weeks (one year). The temperature and relative humidity of the ambient air were the aerothermal parameters studied and the monitoring of the physico-chemical quality has been done through the water content, pH, total and volatile acidity and the free fatty acid (FFA) content. During the conservation, the average values of temperatures and relative humidity of the air were respectively 28.59 ±1.53°C and 70.90 ± 8.40 %. Overall, the four types of packaging are subdivided into two similar groups. These are on the one hand the batches of cocoa beans packed directly in the jute bags (SJ) and woven polypropylene bags (SP) and on the other hand lots of cocoa beans packed in polyethylene plastic bags wrapped in jute (SPJ) and polypropylene bags (SPP). By the third week of conservation, the characteristics of the lots SJ and SP differed from the initial quality unlike the lots of SPJ and SPP which have remained relatively stable. The average values of the water contents of these four beans lots, during the study, are approximately 9% for the first group (SP and SJ) against 6% for the second group (SPJ and SPP). As to FFA, the average values during the study, are around 2.62 ± 1.55 and 2.66 ± 1.57% of cocoa butter respectively for SP and SJ, and 0.89 ± 0, 20 and 0.88 ± 0.16% of cocoa butter respectively for SPP and SPJ. Thus, polyethylene plastic films can slow down the degradation of beans in storage.

Keywords: cocoa beans, conservation, packaging, physico-chemical quality.

INTRODUCTION

With a production of 1.65 million tons in 2012, Côte d'Ivoire is the first world cocoa producer (FAOSTAT, 2012). Thus, the culture of cocoa represents a sector of choice in the economy of Côte d'Ivoire because it provides to the economic plan approximately 31 % of the export earnings of the country and contributed to 10% of the Gross Domestic Product (GDP) (Anonyme1, 2013). However, if Côte d'Ivoire seems to have won the battle of the quantity, at the level of the quality, we notice that there are still worries. Indeed, the inflicted losses due to the poor quality of the merchantable cocoa are valued at more than 20 billion CFA francs per year for producers (Anonymous2, 2009). The merchantable cocoa is a produce which is difficult to preserve in tropical climate. The main problem is the resumption of humidity whose negative effects are: the development of mold, insect infestation and the oxidation of the fat which result in bad quality of cocoa butter (Barel and Iriebi, 1987; Transport Information Service, 2009). Thus, several studies were carried out on the storage/conservation of cocoa, in order to increase its duration of preservation, so as to maintain an acceptable level of quality of stocks. These studies were oriented, for the most part, on the controlled and modified atmospheres. These are: under vacuum sealed storage and insulated storage, the conservation in inert atmosphere and in bulk under neutral gas and bio-hermetic storage (Challot *et al.,* 1979; Guenot *et al.,* 1976; Navarro *et al.,* 1984; 1993; 1995; Varnava and Mouskos, 1997; Navarro, 2006; Sabio *et al.,* 2006; Jonfia-Essein, *et al.,* 2010). Although these works were successful, they pose difficulties in the use of these processes. Indeed, in Africa and particularly in Côte d'Ivoire the cocoa production is the main activity of smallholders on surfaces lower than 10 ha (Barel, 2005). Therefore, they don't have financial and technological means for the use of these methods which are expensive. Also, the jute bags are the authorized packaging for the export of cocoa beans. The exporters also use polypropylene bags and polyethylene plastic bags. However, no study shows the evolution of the quality of the cocoa beans stored in such packaging during a long-term storage. Thus, during this study, we propose to evaluate the evolution of the physico-chemical quality of the cocoa beans, packaged in various materials, during the conservation in natural ambient condition.

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METHODS AND MATERIALS

Biological material

The biological material is composed of a mixture of cocoa beans collected from three (3) smallholders of Yobouékro, a village located on the Yamoussoukro-Bouaflé road. These beans were fermented under banana leaves for six (6) days and then dried up during five (5) days in the sun on a cemented ground.

Packaging and conservation

The packaging material is composed of jute bags (60 Kg), woven polypropylene bags (50 Kg) and a polyethylene plastic packaging (length 100 cm, width 75 cm, Thickness 0.080 mm) sold on the market, and then resized in capacity of 500g. To make the plastic packaging more airtight they were doubled. Thus, four (4) types of packaging have been defined and codified as follows (Figure-1): the batch SJ whose beans are packed directly in jute bags, the batch SP whose beans are packed directly in woven polypropylene bags, the batch whose cocoa beans were packaged in polyethylene plastic hermetically closed in jute bags and the lot SPP whose cocoa beans were packaged in polyethylene plastic hermetically closed in woven polypropylene bags. Each Type of packaging were composed of 75 bags of 500 of cocoa beans; each bearing the code (SJ, SP, SPJ and SPP) followed by a number ranging from 1 to 75. The four different batches, prepared on pallets (1m x 70cm), have been stored in a store, at ambient temperature, on the farm of the Higher School of Agronomy (ESA) of the Institut National Polytechnique Felix Houphouet Boigny (INP-HB) of Yamoussoukro (RCI).

Sampling

For the realization of the physico-chemical analyzes, every 15 days, three bags were selected at random on each of the lots. This study was conducted over a period of 51 weeks.

Aerothermal parameters

The temperature and relative humidity of the ambient air of the store have been measured daily in the store of storage using a thermal-hygrograph brand MAXANT (93100 MONTREUIL, FRANCE).

Analytical methods

Determination of the water content of the beans

The evolution of the water content of the beans during the conservation was determined by oven method according to the international standard ISO 2291-1972 (Galvez *et al.*, 2007). To determine this, 5 g of cocoa powder were dried at 103 ± 2 °C during 16 hours ± 15 minutes. The water content is expressed according to the percentage of the dry mass.

Figure-1. Different types of packaging.

SP = Bag of polypropylene ; SJ = Jute Bag ; SPJ = Plastic Films + Jute Bag ; SPP = Plastic Films + Bag of polypropylene.

Determination of pH

The pH was determined according to the method OICCC N°9 (1963). Ten grams of cocoa powder were dissolved in 90 mL of boiling distilled water and the whole is left cooled to ambient temperature. The pH was measured using a HANNA HI 98240 brand pH-meter.

Determination of the titratable acidity

The total acidity was determined according to ISO method 1114 (1989). Thus, five grams of cocoa powder were dissolved in 50 mL of distilled water boiled and cooled under stirring during 1 hour. The titratable acidity was done by monitoring pH-metrique with a fresh solution of 0.1 N soda up to pH = 8.3.

Determination of volatile acidity

The ISO method 1114 (1989) allowed to measure the dose of the volatile acidity. It consisted in dissolving 1 g (to the nearest 0, 001 g) of cocoa powder in 400 mL of distilled water. Then, the set has been made to distil after adding 3 drops of fuming sulfuric acid. The distillate is collected in 50 ml of distilled water when it reaches 300 mL. The titration was carried out using a fresh solution of 0.1 N soda placed in a microburette of 2 mL in the presence of phenolphthalein.

Determination of the rate of free fatty acids

The determination of the rate of free fatty acids, consisted first in the extraction of the cocoa butter to the soxlhet hexane during 8h (OICCC, 1996). Then, 100 ml of alcohol at 95% previously neuralised with a solution of soda ash to 0.1 N, in the presence of phenolphthalein, are added to 5 g of this butter to 10^{-3} g near. Finally, the dosage of the butter has been carried out under permanent agitation, using a solution of Alcoholic potash (0.5 g/L), already Titraded, and contained in a microburette. The rate in free fatty acids (FFA), expressed as the percentage of oleic acid per gram of fat content, was calculated according to the following relationship:

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$$FFA = \frac{Volume\ in\ mL\ of\ KOH \times N_{KOH} \times 282}{butter\ mass}$$

Molar Mass of the oleic acid = 282 g/mol

Statistical analysis of the data

The data obtained at the end of the various analytical methods were studied statistically by analysis of variance and the test of the smallest significant difference (LSD) with the threshold to 5 %, using the software Statistica 10. The multidimensional scaling (MDS) is a method of graphical representation of a set of similarities or highest dissimilarities from in the data. It has allowed us to follow globally the similarities, in time, of the four types of packaging.

RESULTS AND DISCUSSIONS

Evolution of aerothermal parameter

The average annual temperature of air on the period of studies (March 2012 to April 2013) was around 28.59 ± 1.53 °C. The highest average temperature was observed at December 2012 (32.43 ±1.15 °C), while the lowest average temperature in store at July 2012 (26.30 ±1.25 °C) (Figure-2). With regard to the relative humidity average of the air, it was 70.90 ± 8.40 per cent during the period of study. The lowest values were recorded in January (56.00 ±11.03 %), February (60.33 ± 1.75 %) and March 2013 (67.01 ± 3.35 %) against the highest value in the month of November 2012 (95.66 ± 2.44 %) (Figure-2).

The analysis of the coefficients of variation shows that the average relative humidity (11.84 %) has a variability which is almost equivalent to the double of that of the temperature (5.36 %) (Table-1).

Table-1. Statistical Analysis of the aerothermal parameters.

	T (°C)	**HR** (%)
Average	28.59±1, 53	70.90±8.40
CV (%)	5.36	11.84

T = Air Temperature; HR = Relative air humidity

Evolution of the physico-chemical parameters

Multidimensional scaling

The evolution in time and in a common space of the four modes of packaging is represented in Figure-3. The graph shows globally two groups; on the one hand the batches SP and SJ and on the other hand SPP and SPJ. A very large variation, in time, of the SP and SJ batches was observed contrary to batches SPP and SPJ whose physico-chemical characteristics remained appreciably stable. Indeed, up to 8 weeks of conservation, the physico-chemical parameters remained slightly close to those of the initial sample (T0) (cf circle C1) and then a slight evolution was observed since the 9th week before stabilizing (cf circle C2). These observations are confirmed by the results of the analysis of variance ($P < 0.05$) which shows that there is a significant difference between the parameters of the SP and SJ lots on the one hand and the parameters of SPP and SPJ on the other hand (Table-2).

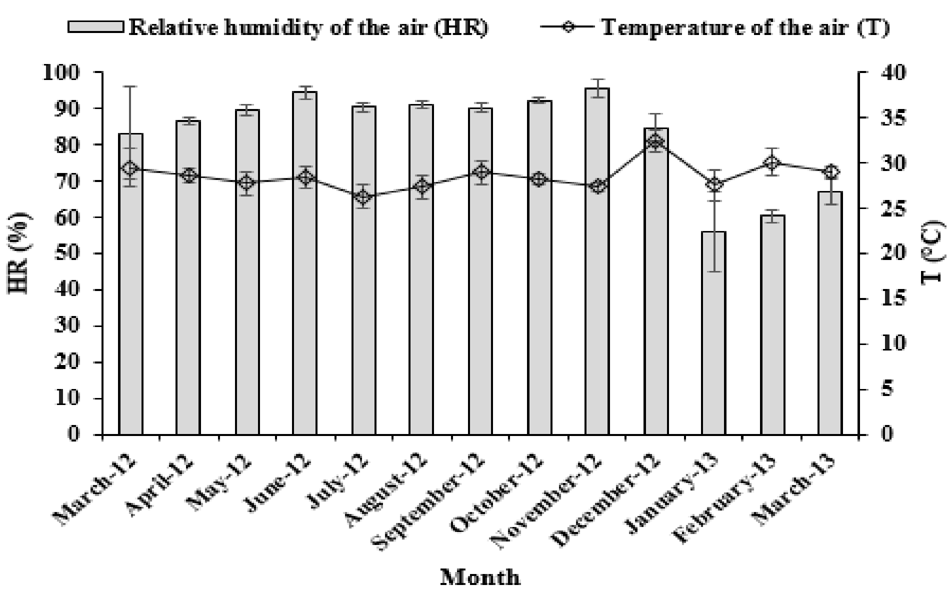

Figure-2. Average variation in air temperature and relative humidity in the store during the study period.

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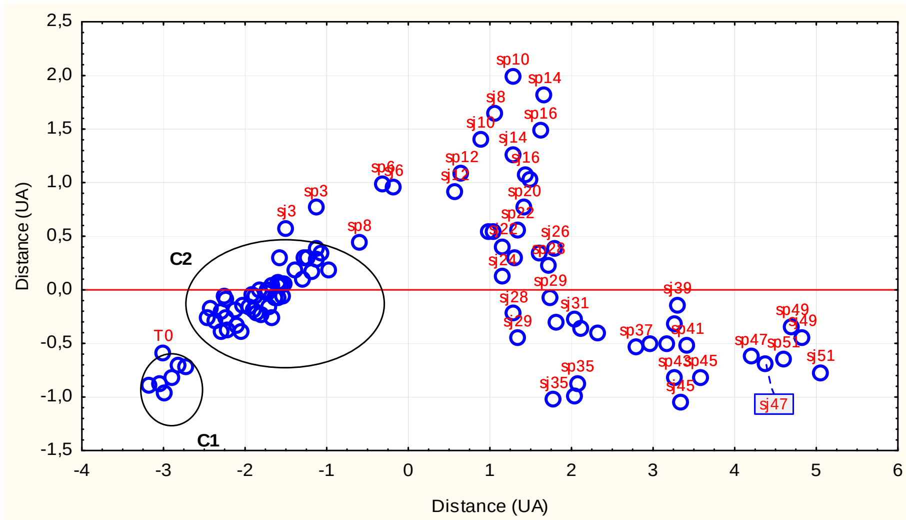

Figure-3. Multidimensional scaling: representation of the evolution of the four modes in the plan.

SP = Bag of polypropylene; SJ = Jute Bag; SPJ = Plastic Films + Jute Bag; SPP = Plastic Films + Bag of polypropylene. T0: sample in the initial state and SP 3: sample of the batch SP to the 3nd week of conservation.
(C1: T0, SPP3, SPJ3, SPP6, SPJ6, SPP8, SPJ8; C2: all SPP and SPJ).

Water content

Figure-4 shows the evolution of the water content of the cocoa beans of the four types of packaging. During the 51 weeks of conservation, the water content of the cocoa beans of batches SJ and SP increased up from 4.88 ± 0.30% to 10.59 ± 0.16% and 10.86 ± 0.11% respectively for SJ and SP. As for the cocoa beans of SPJ and SPP batches, the water content remained practically stable. They increased slightly from 4.88 ± 0.30% to 5.85 ± 0.24% and 5.98 ±0.10 % respectively for SPJ and SPP. The average values of the water content of the cocoa beans of the 4 batches, during of the study, are about 9% for the first group (SP and SJ) against 6 % for the second group (SPJ and SPP) (Table-2). This shows that the polyethylene plastic better protect the cocoa beans against the resumption of moisture. Indeed, the latter therefore constitute a barrier against moisture in the ambient air, which hampers the exchanges between the beans with the ambient air thus providing a good conservation inspite of the very unfavourable aerothermal conditions (Asiedu, 1991). These results are similar to the work on controlled and modified atmospheres, mainly SuperGrainbag™ (Challot *et al.*, 1979; Guenot *et al.*, 1976; Navarro *et al.*, 1984; 1993; 1995; Varnava and Mouskos, 1997; Fadamiro, 1998; Dramaputra, 2000; Navarro, 2006; Sabio *et al.*, 2006; Jonfia-Essein *et al.*, 2010).

The close results of the SJ and SP batches are concordant with the work published by Renard (1960), according to which the cocoa beans stored in woven polypropylene bags present results close to those obtained with the jute bags. In effect, the jute bags (SJ) and woven polypropylene bags (SP) contain spaces which favour a direct contact of the beans with the ambient air (Dodemont, 2007) and therefore exposes the cocoa beans (4.88 ±0.30 % water) to a direct contact with the water of the surrounding air (70.90 ± 8.40 %) justifying the resumption of moisture of beans because of the strong hygroscopicity of the latter (Burle, 1962 ; Barel, 1995 ; Kebe *et al*., 2005; Barel, 2013).

pH

The evolution of the pH of the 4 types of packaging during the conservation is presented in Figure-5. The pH of the SP and SJ batches on the one hand and SPP and SPJ on the other hand evolve in the same direction. They increase from 5.0 ±0.0 to 6.4 ± 0.1 and 6.3 ± 0.1 respectively for SP and SJ. As regards to SPP and SPJ their pH fall respectively to 4.7 ± 0.2 and 4.6 ±0.0 from the10th week and then stabilize until the 51st week. Throughout the study, the average pH of cocoa beans of SP and SJ lots were still higher than those of the SPP and SPJ lots with an average pH of 5.7 ±0.5 and 5.7± 0.4 respectively for SP and SJ and then 4.7 ±0.2 and 4.7 ± 0.2 respectively for SPP and SPJ (Table-2).

The sharp decline in pH observed up to the 10^{th} week could be due to the formation of new components, including those responsible for the aroma of cocoa. In addition, the elimination of organic acids (precursors of the aroma of the cocoa) led to the emergence of new compounds and the increase of the levels of compounds such as the pyrroles. It is also that fact which may justify the stability of the pH of the beans in the bags SPJ and SPP during the rest of the conservation. With regard to the pH of the SJ and SP lots, their trends to rise might be due to the strong decrease in the acidity of the beans (Afoakwa *et al.*, 2008; Portillo *et al.*, 2013; Barel, 2013).

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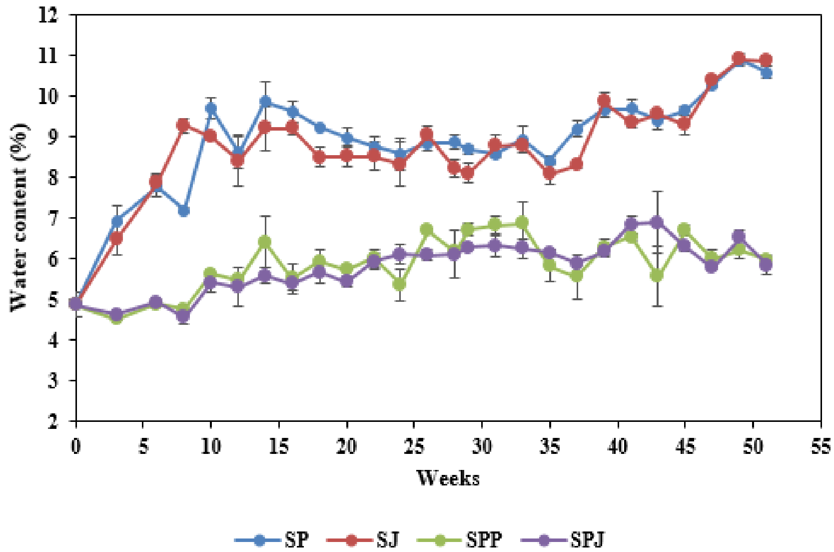

Figure-4. Evolution of cocoa beans water content average over time.

SP = Bag of polypropylene ; SJ = Jute Bag ; SPJ = Plastic Film + Jute Bag ; SPP = Plastic Film + Bag of polypropylene.

Table-2. Average values of the physico-chemical parameters during conservation.

Parameters / Type of packaging	Water content (%)	pH	Total acidity (mL NaOH 0,1N/g)	Volatile acidity (mL NaOH 0,1N/g)	Free Fatty Acids (FFA) (% oleic acid)
SP	8.92±1.20a	5.7±0.5a	0.68±0.21a	0.38±0.27a	2.62±1.85a
SJ	8.76±1.21a	5.7±0.4a	0.70±0.20a	0.36±0.25a	2.66±1.57a
SPP	5.89±0.65b	4.7±0.2b	1.17±0.15b	0.80±0.21b	0.89±0.20b
SPJ	5.82±0.60b	4.7±0.2b	1.17±0.16b	0.79±0.19b	0.88±0.16b

In each column, the averages followed by the same lowercase letter are not significantly different at the threshold 5 %.

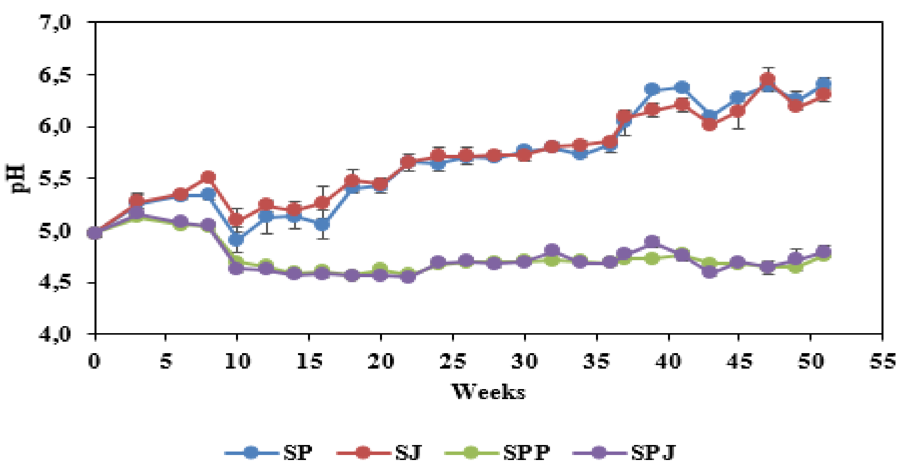

Figure-5. Evolution of cocoa beans pH average over time.

Total acidity (Act) and Volatile (ACV)

The total acidity of SP and SJ and then of SPP and SPJ evolve in the same direction (Figure-6). Contrary to the previous parameters it is the total acidity of the SPP and SPJ batches which remain above those of SP and SJ during the study. A decrease of the total acidity of the two groups is observed with stabilization from the 16th week. Indeed, for an initial value of 1.37 ± 0.06 mL 0.1N NaOH / g, the total acidity of the different types of packaging was stabilized around the following mean values: 0.68 ± 0.21 and 0.70 ± 0.2 ml 0.1 N NaOH / g respectively for SP and SJ and 1.17 ± 0.13 and 1.17 ± 0.11 mL 0.1N NaOH / g (Table-2). As in the case of total acidity, volatile acidity decrease gradually before stabilizing in the 20th to 51th week (Figure-7). Indeed, for common initial volatile acidity of 1.39 ± 0.20 mL 0.1N NaOH / g, the different packaging methods are stabilize around the following average values: 0.38 ± 0.27 and 0.36 ± 0.27 mL 0.1N NaOH / g respectively for SP and SJ and 0.80 ± 0.21 and 0.79 ± 0.21 mL 0.1N NaOH / g (Table-2).

The acidity of the cocoa beans is an important parameter for the chocolate manufacturers because at an excessive level it reduces the flavor of the finished product. Both acids involved, acetic acid and lactic acid, the former volatile, the latter non-volatile, coexist in the beans in free or combined form. The decline of the volatile acidity, regardless of the type of packaging, could be regarded as a good result, because the acetic acid which forms during fermentation must then be eliminated from the cocoa beans (Ngangue, 2011). The sharp decline in volatile acidity of the SP and SJ batches may be due to the ease with which the organic volatile acids can be transported by the ambient air and to the recovery in humidity (facilitates the dissemination) by the beans because the latter decreases the quantity in organic acids, which is not the case with the SPJ and SPP lots because they are protected by the plastics which hamper the exchange with the ambient environment and while promoting the elimination of organic acids volatile (Barel, 1995 & 2013; Dodemont, 2007). Even if this decline is much more noticeable with the SJ bags, that observed with the s SPJ and SPP bag is considerable (43% of the volatile acidity initial). The decrease in total acidity of the different batches may result from the decrease of the content of volatile acids and alcohols in the cocoa beans (Portillo *et al.,* 2013). In effect, a reduction of the volatile acidity leads to a reduction of the total acidity.

Free Fatty Acids (FFA)

The evolution of averages of FFA percentages are shown in Figure-8. The SP and SJ batches stand out from the 6th week while exceeding the norm of 1.75% from the 16th week to reach respectively 5.11 ± 0, 03 and 5.55 ± 0.09% of cocoa butter. As for SPP and SPJ batches, their levels of free fatty acids (% FFA) increased slowly and generally reached 1% cocoa butter. The average values in FFA, during the study, were around 2.62 ± 1.55 and 2.66 ± 1.57% cocoa butter respectively for SP and SJ, and 0.89 ± 0.20 and 0 88 ± 0.16% of cocoa butter respectively for SPP and SPJ (Table-2).

The levels of free fatty acids (FFA) remains a very important parameter for the chocolate manufacturers. Indeed, a high level of FFA greater than 1.75%, hydrolysis index of triglycerides, result in a softening of butter which is prejudicial in chocolate making. The high rate of FFA observed on the SJ and SP lot maybe due to two factors: lipolytic enzymes and molds by enzymes of the bean in the degradation of fat (Guénot *et al.,* 1976; Barel, 1995, 2013). Polyethylene plastic packagings were able to stabilize the rate of FFA in the SPP and SPJ lots. This is concordant with the principle of bio-generation in which the oxygen in the sealed chamber is consumed by microorganisms (resulting in a small increase) while producing carbon dioxide inhibiting their development (Navarro *et al*. 1984; 1993; 1995; and MouskosVarnava, 1997; Navarro, 2006 and 2007; Sabio *et al.,* 2006; Guehi *et al.,* 2008; Jonfia-Essein, *et al*, 2010).

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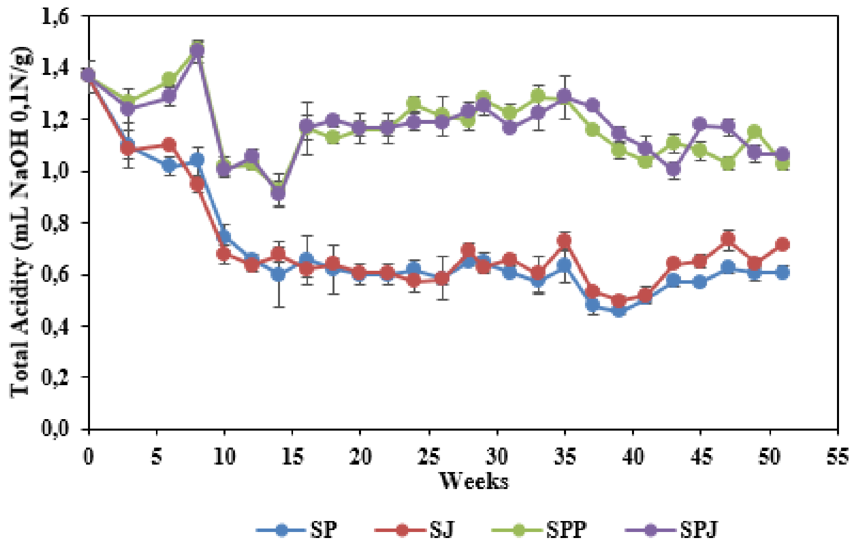

Figure-6. Evolution of cocoa beans total Acidity average over time.

SP = Bag of polypropylene ; SJ = Jute Bag ; SPJ = Plastic Film + Jute Bag ; SPP = Plastic Film + Bag of polypropylene.

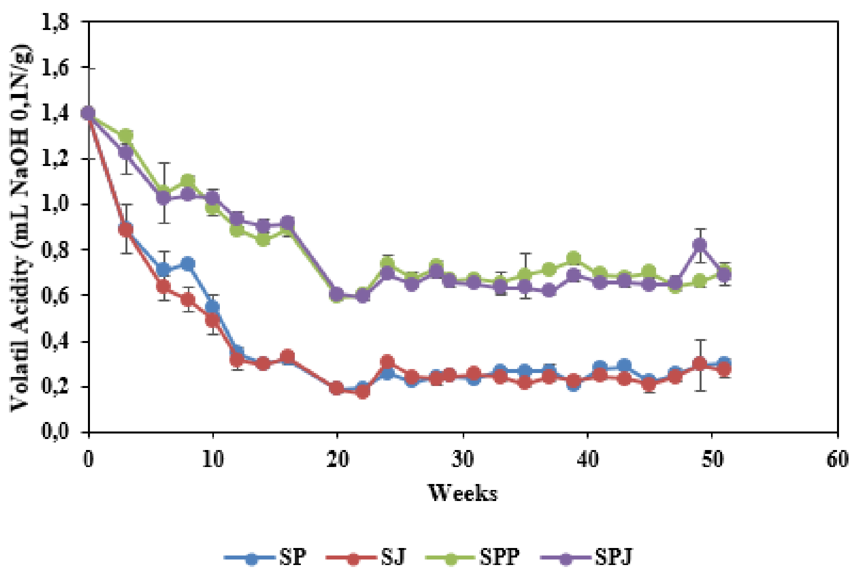

Figure-7. Evolution of cocoa beans Volatil Acidity average over time.

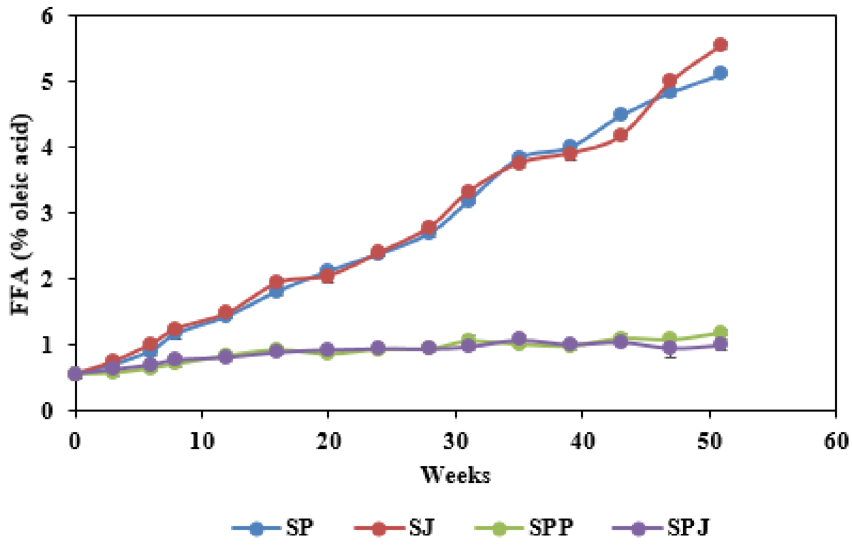

Figure-8. Evolution of cocoa bean Free Fatty Acids (FFA) average over time.

SP = Bag of polypropylene ; SJ = Jute Bag ; SPJ = Plastic Film + Jute Bag ; SPP = Plastic Film + Bag of polypropylene.

CONCLUSIONS

The study of physical and chemical parameters showed that there is no difference one the hand both between the cocoa beans of batches stored directly into jute bags and woven polypropylene bags (SJ and SP) and in the other hand between the beans of batches packaged first in plastic polyethylene films (SPP and SPJ). Also, jute bags and woven polypropylene are not able to ensure proper conservation of the cocoa beans. Indeed, after only 16 weeks (4 months) all physicochemical parameters are out of standards.

As for SPP and SPJ lots, they were able to remain below acceptable standards the physicochemical quality of the beans during the period of study. In addition, these types of packaging have slowed the hydrolysis of the cocoa butter triglycerides thereby maintaining the levels of free fatty acids.

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