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Research Article

Impact of Solar and Microwave Oven Drying on A Few Chemical Parameters of Market Value Quality of Fermented Forastero (*Theobroma Cacao L.*)

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Abstract: This study aims to compare the impact of cocoa beans drying in the Microwave Oven (MO) and that made in the sunshine. This was to make 4 sets of drying tests through two devices: 30 samples for the solar drying (on tray) and 90 samples in the MO in the ratio of 30 samples per power levels (2400W, 2800 W and 3200W). Chemical parameters of quality were used for the comparative study. At the level of the volatile acidity parameter, the following value are recorded for the tray (0.62±0.03), MO 3200W (0.63±0.02), MO 2400 W (0.85±0.04) and MO 2800W (0.79±0.01). The values obtained are half less than that of the batch acceptability criteria (1-1.5 mL of 0.1N NaOH per gram of cocoa powder). The tray values (1.25±0.03); M.O 3200 W (1.25±0.03); MO 2400W (1.62±0.04) and MO 2800W (1.58±0.07) were noted for the free fatty acid test. They are smaller than the proscribed limit (1.75% of *FFA* oleic). Concerning the pH, are recorded for the tray (5.02±0.05) and 4.85±0.07; 4.72±0.05; 4.67±0.02 by power level assessment in the microwave oven. Only the values of dried beans on tray and MO 3200W are satisfactory. Total acidity obtained are: tray (5.47±0.02), MO 3200W (5.48±0.01), MO 2400W (5.25±0.01) and MO 2800W (5.32±0.01).

Keywords: Cocoa beans, drying, microwave oven

INTRODUCTION

Drying is one of the oldest food preservation methods (Gowen *et al*., 2008). It consists in evaporating water and volatiles matters, reducing the growth of microorganisms and unwanted chemical reactions such as the enzymatic browning in order to increase the lifetime of the product (Gowen *et al*., 2008). It helps to get a dry and homogeneous product at the end of drying (Bonazzi *et al*., 2008). Several tropical products such as coffee, cocoa beans are submitted to drying for good conservation.

At maturity, the cocoa pods are harvested; cut and the beans are fermented before drying (Hii *et al*., 2008). Fermentation lasts about six days and is done with banana leaves or wooden crates (Akmel *et al*., 2008). After fermentation occurs drying. Two methods are commonly used. Solar or natural drying (direct or indirect) and says artificial drying using a non-solar source and generally practiced in industry (Augier *et al*., 1998). The natural drying takes place in the sun, at free air and has a strong dependence on climatic conditions. During the drying, additional biochemical reactions in cocoa beans continued (Pointillon, 1997). Thus drying constitutes a crucial step in the post-harvest treatment. Sun drying of cocoa beans is undertakes on a tray (one of the recommended devices) and requires a relatively long drying time (7-21 days) (Wood, 1975). With the variability in observed seasons, the recovery of the moisture by beans induces the structural alteration of fat. It sometimes gives lower quality of cocoa beans (Pointillon, 1997). In industry, cocoa beans drying undertake by convection (forced) mode within 24 to 48 hours. However, this method of thermal transfer has sometimes the disadvantage of keeping the volatile acids in the beans (Guehi *et al*., 2010). It leads to an acid and destructurized cocoa butter (Nganhou, 1996). Convection drying is also responsible for increasing bitterness, the appearance of smell cause by the presence of acrolein and an undesirable flavor of burnt cocoa beans (Afoakwa *et al*., 2008). The beans are dried until the moisture content reaches 8% (accepted standard) with a free fatty acid content not exceeding 1.75% which is the

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proscribed limit content (Akmel *et al*., 2008). More and more studies about the impact of the artificial drying using electromagnetic waves on the quality of different products are led and very satisfactory results have been achieved. Derya and Mehmet (2010) showed that the onion drying kinetics by electromagnetic waves has better quality characteristics than those obtained by the methods of solar drying and convection. The inorganic constituents (K^+, Ca^{2+}) obtained during their work have higher concentrations, best rectangular coordinates L*a*b*. The phenolic content has evolved in the same direction as the previous. Furthermore, the work done by Koné (2011) has shown that the tomato could be dried in electromagnetic environment intermittently with a specific power steering. The results of this work showed improved retention rate of the lycopene. Lucchesi (2005) showed that the extraction of vegetable oil from the mint assisted by microwave heating showed a reduced extraction time factor 9 compared to hydro distillation process. Microwave technology present many advantages, namely the considerable reduction in drying time, the homogeneity of the dried material and efficiency in the energy transfer compared to convection and infrared (Sorour and El Mesery, 2014). The waves accelerate moisture loss from the inside to the outside of the biological material by the phenomenon of dipolar rotation (Lucchesi, 2005; Wang and Sheng, 2006; Sorour and El-Mesery, 2014). It is in full growth and is variously used in the field of drying industry. The waves are passed directly on agricultural products to be dried or used as an adjunct treatment (Krysiak, 2011). To our knowledge, very few studies on the cocoa beans drying of electromagnetic environment were conducted. The study realized by Krysiak (2011) is an adjunct to convection drying method of cocoa beans. This experimental study aims to determine and compare the impact of microwave drying on chemical quality parameters (volatile acidity, free fatty acidity, pH and total acidity) compared to solar drying from the experimental tray and microwave oven devices.

MATERIALS AND METHODS

Sample preparation: Thirty Kilograms of cocoa beans were purchased in the month of October 2013 with three growers of Yamoussoukro (a town in the center of Cote d'Ivoire, West Africa) and put into fermentation for six days in banana leaves. Then the fermented beans were cleared of waste before drying.

Drying procedure: Two devices were used: an experimental tray of one square meter in size raised one meter above the ground and a microwave oven (Guangzhou Qualiway LTD 510630, China) with three power levels: 2400W; 2800W and 3200W. On the tray, 30 samples of 200 g each were spread in thin layer (3-4 cm thick). For the drying in the microwave oven, three sets of 30 samples of 200 g were dried at the three powers mentioned above. The weight loss was recorded regularly (every hour for solar drying and an interval of one minute of application in the MO). It was recorded using a scale (Sartoruis A200S, ± 0.001 g, Germany) until the mass difference between three successive weighing does not exceed 0.01g (Belahmidi *et al*., 1993). The temperature and humidity were recorded with the thermo-hygrometer (Auriol IAN 71010, France). For microwave drying temperatures were recorded using the portable thermometer (HANNA HI 935005, France). Dried beans were stripped of their shells then crushed (Universalmu M20 IKA, Germany).

Chemical analyses: The volatile acidity was measured by ISO method 1114 (1969). One (1) gram of cocoa powder was introduced in a round bottom flask of 500 mL with addition of 2 to 3 drops of fuming sulfuric acid. After adding 400 mL of distilled water, the flask was placed in a heating tank with electrothermal and then adjusted in an extractor. A refrigerant-distillation column was placed in the upper part of the extractor. An erlenmeyer of 500 mL containing 50 mL of distilled water was placed at the exit of the condenser to collect the distillate. The round bottom flask was heated up to getting 300 mL of distillate in the Erlenmeyer. The distillate was measured in the presence of phenolphthalein, with a freshly prepared solution of 0.1N NaOH placed in a micro-dosing 2 mL (accuracy 0.01 mL). The volatile acidity (V.A) was expressed in mL of NaOH per gram of cocoa powder according to this relationship:

$$V.A = \frac{Volume\ in\ mL\ of\ NaOH}{Weight\ of\ cocoa\ powder}$$

The determination of Free Fatty Acids (FFA) was performed according to the method OICCC No. 42 (OICCC, 1996). It consisted initially to extract cocoa butter with soxhlet using hexan for eight hours. In a second step, the cocoa butter was separated from hexan using a rotary evaporator (Buchi No. 1161, Switzerland) to 68.7°C and weighed. To this amount of butter was added 150 mL of ethanol/diethyl ether (50/50) previously neutralized with 0.1 N alcoholic potassium hydroxide in the presence of phenolphthalein. The assay of mixture (butter+ethanol/diethyl ether) was done under constant stirring; drip pouring alcoholic potassium hydroxide solution already titrated with potassium phthalate acid contained in micro-dosing. The judgment of the assay was marked by a shift from yellow to pink in butter solution. The content of Free Fatty Acids (FFA) represented by the oleic acid alone was expressed in percentage of free fatty acid per gram of fat according to the following relationship:

$$FFA = \frac{Volume\ in\ mL\ of\ KOH\ X\ N_{KOH}}{Weigth\ of\ cocoa\ powder} X\ 282$$

282: Molecular weight of oleic acid

The pH was determined according to the AOAC (2005). The preparation was made for 10 gram of cocoa powder in 90 mL of boiling distilled water; homogenized and then cooled to 25°C. A pH meter (HANNA HI 98240, Portugal) calibrated with buffer solution (pH 4 and 7) has helped read the pH of the solution placed under magnetic stirring.

The Total Acidity (TA) was obtained according to ISO 1114 (1969) method. It was made on a sample of 5 gram of cocoa powder, which was dissolved in 50 mL of boiled distilled water and cooled. The whole was stirred magnetically for 1 hour. The assay was carried out with a freshly prepared solution of 0.1N NaOH to reach pH value 8.3 under magnetic stirring. The total acidity was expressed in mL of NaOH/gram of cocoa powder according to the following relationship:

$$TA = \frac{Volume\ in\ mL\ of\ NaOH}{Weight\ of\ cocoa\ powder}$$

Statistical analysis: The comparison method of the effect of two drying devices was obtained by performing an ANOVA 1 followed by a post hoc test (LSD) at 5% (Feinberg, 1996). Statistica 7.1 software was used.

RESULTS AND DISCUSSION

For 35 cumulative sunshine hours of solar drying, the daily relative humidity fluctuated between 52 and 74%. The temperature fluctuated between 27.4 and 36.2°C. The cocoa beans drying in microwave oven undertaken in 16, 12 and 8 minutes respectively at 2400W, 2800W and 3200W. The temperatures recorded by power levels have oscillated from 30 to 80.2°C for MO 2400W device with 65.42±12.48°C as average drying temperature of cocoa beans. At the MO 2800W device, it was noted a mean value of 67.49±12.53°C and a maximum value of 84.40°C reached. Finally, the average value for the MO 3200W device was 79.55±20.42°C with a maximum value of 98.5°C. Table 1 is a summary of the average values of chemical parameters of market value of cocoa beans from the two drying devices.

The average values of the volatile acidity content of the beans may vary from 0.64 to 0.85 mL of 0.1N NaOH per gram of cocoa powder. They are inferior to batch acceptability criteria (1-1.5 mL of 0.1N NaOH per g of cocoa powder, ISO 1114 (1969)). Therefore the microwave drying of the cocoa beans did not increase the volatile acidity values beyond the batch acceptability criteria. They evolve in decreasingly as powers grow. Thus, the average value obtained from M.O 3200W (0.64±0.02) is statistically identical to that obtained on tray (0.62±0.03). All noted values are lower than those of Jacquet *et al*. (1980) (0.72 to 2.52 mL of 0.1N NaOH per gram of cocoa powder) obtained using a convection oven under warm air and those obtained by Guehi *et al*. (2010) (1-2.4 mEq of NaOH per gram of cocoa powder). Studies have shown that the volatile acid content of the beans increases with high temperatures as in the case of industrial dryers (Bopaiha, 1991; Nganhou, 1996). Indeed during this drying, there occurs encrusting that traps acids. However, during microwave drying of the beans, the occurrence of micro cracks allows the release of volatile substances (Chekroune, 2009). This would explain the observed low acidity. The recorded values for the solar drying device are half equal to those reported by Akmel *et al*. (2008) (1-1.4 mL of 0.1N NaOH per gram of cocoa powder). The recorded values are however more similar to those obtained by Guehi *et al*. (2010) on tray (volatile acidity values below 1 mEq of NaOH per gram). This result could be due to the very long time of drying. Indeed, the thirty hours of sunshine which allowed the end of drying (water content below 8%) were obtained over a period of two weeks (seven days). This long time would have favored the moving of the main volatile acid (acetic acid) present in the cocoa beans as shown in the works of Akmel *et al*. (2008).

During the microwave drying of the beans, although the drying time is much shorter (16, 12 and 8 min, respectively for the devices: MO 2400W, MO 2800W and MO 3200W), the mean values of recorded oleic FFA are relatively high (from 1.25 to 1.62%). However, they are less than the proscribed limit (1.75% of free fatty acid oleic, OICCC No. 42 (OICCC, 1996)). The analysis of the free fatty acid values indicates a decrease of this one depending on the submitted power. It is much lower in power 3200W MO (1.25±0.03) compared with MO 2800W (1.58±0.07) and MO 2400W (1.62±0.04). These results can be accounted for by the fact that most of the poly-atomic molecules have a non-zero dipole moment, weak and direction do not necessarily coinciding with that of one of the polar bonds (Arnaud, 1998). Furthermore, during the phenomenon of dipolar rotation, the energy dissipation by shivering water molecules generates heat causing a rise of the temperature in the beans (Lucchesi *et al*., 2004). This rise of temperature (maximum values of 80.2; 84.4 and 98.5°C, respectively in ascending order

Table 1: Mean values of chemical parameters of market value quality of cocoa beans

Devices	(V.A) (ml of NaOH/g)	FFA (% oleic acid)	pH	T.A (ml of NaOH /g)
Tray	0.62a±0.03	1.25a±0.03	5.02a±0.05	5.25a±0.05
MO 2400W	0.83b±0.04	1.62b±0.04	4.67b±0.02	5.48b±0.03
MO 2800W	0.80c±0.03	1.58c±0.07	4.72c±0.05	5.48b±0.06
MO 3200W	0.64a±0.02	1.25a±0.03	4.85d±0.07	5.32c±0.02

of wave power) is likely to break some ester bonds (glycerol-fatty acid), releasing fatty acid molecules responsible for these relatively high rates. Otherwise, the average value of MO 3200W (1.25±0.03) is statistically identical to that of the tray (1.25±0.03). The mean value obtained is double that reported in the work of Akmel *et al*. (2008) (0.64%±0.07, for a period of five consecutive days of drying). This difference would be due to the combined effect of the drying time (two weeks) and mostly the relative humidity above 65%, humidity value favoring the growth of moldlysis lipid activity likely to cause the hydrolysis of fat (Hayma, 2004). The results are strengthened by Barel (2013) and Guehi *et al*. (2008) studies which showed that the content of free fatty acid increases during storage (conservation).

The mean values of the potential Hydrogen (pH) of dried beans in the microwave device increase with increased powers. They range from 4.67 to 4.85. PH values of MO 3200W (4.85±0.07) devices and tray (5.02±0.05) are satisfactory acceptability criteria of batches (pH of 4.8-5.2, ISO 1114 (1969)). It is relatively higher with the solar drying than those obtained by drying in a microwave oven. However, in agreement with those reported by Guehi *et al*. (2010). The pH was between 4.5-5.5. Similarly, the total acidity values obtained for the MO device, decrease with increase of power. They vary from 5.32 to 5.48 mL of 0.1 N NaOH per gram of cocoa powder. Total acidity noted on the tray has an average value of 5.25 mL of 0.1NNaOH per gram of cocoa powder and is relatively lower than those obtained by drying in a microwave oven. This difference observed could be explained by the fact that the total acidity is the result (addition) of all acidity (volatile acidity and free fatty acid) and strongly depends on it (R^2 respectively 0.92 and 0.86 greater than 0.85) (Jinaps *et al*., 1994; Akmel *et al*., 2008).

CONCLUSION

The study showed that the two drying methods (solar and microwave oven) produce at the end of drying cocoa beans those contents of free fatty acids are less than 1.75% FFA of oleic. As regards volatile acidity, total acidity and pH, the results are satisfactory as they comply with the accepted criteria for selecting batches of beans.

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