

Full Length Research Paper

Effect of forced-air artificial intermittent drying on cocoa beans in South-Western Nigeria

D. O. Oke* and K. F. Omotayo

Department of Agricultural and Bio-Environmental Engineering, School of Engineering, Federal Polytechnic, P. M. B 5351, Ado – Ekiti, Ekiti State, Nigeria.

Accepted 4 November, 2011

Drying experiments were carried out to investigate the effect of forced-air, artificial intermittent drying system on quality of fermented cocoa beans harvested in south-western Nigeria. The beans were dried naturally by using traditional sun drying method and artificially, by hot air inside an oven at air temperatures of 35, 40, 45, 50 and 55°C respectively. Fermented beans were exposed to 9 h of drying and 15 h of resting daily. The following quality parameters were assessed; free fatty acid (FFA), pH, moisture content and acetic acid for each drying temperatures and sun drying. From the test results, the free fatty acid and acetic acid levels increases with increase in drying temperature, also, the pH level decreases with increase in drying temperature. Optimum bean-quality was obtained for cocoa beans dried at 45°C oven temperature. A predictive equation was established that shows the relationship between oven temperature (°C) and free fatty acid level (mg/g) of the beans. Generally, it was also discovered that there is no known adverse effect on the quality of the beans dried under forced-air artificial intermittent drying system.

Key words: Effect, temperature, cocoa beans, forced-air, artificial, intermittent, free fatty acid, acetic acid quality, convection.

INTRODUCTION

Cocoa (*Theobroma cacao* L.) originated from Amazonian region of Brazil and grown in tropical countries like Nigeria, Ghana, Ivory Coast, Brazil, Malaysia, Venezuela and Indonesia (Beckett, 1994). Cocoa tree grows in a limited geographical zone, of approximately 20 degrees to the north and south of equator (Buijsse et al., 2006). It was introduced into Nigeria in 1874 through Equatorial Guinea by the Portuguese traders and has been grown extensively in the south-western part of the country as the main cash crop (Opeke, 1987). Cocoa tree is mainly consumed as chocolates and widely used in beverages, cosmetics, pharmaceuticals and toiletry products. It is also associated with health benefits such as anti-carcinogenic, anti-atherogenic, anti-ulcer, anti-thrombotic,

anti-inflammatory, immune modulating, anti-microbial, vasodilatory, and analgesic (Porter, 2006; Taubert et al., 2007). Cocoa processing consists of two major steps namely fermentation and drying. Fresh cocoa beans are usually fermented using the heap, tray or box methods for 5 to 7 days depending on the condition of the beans (Opeke, 1987). During fermentation, the temperature of the beans will rise from ambient to about 50 to 55°C due to the exothermic oxidation reaction (Wood and Lass, 1985). Fermentation is the initial step needed in the development of various flavour precursors in the beans (Hii et al., 2009). Drying techniques vary among the farmers and it ranges from the natural sun drying technique to the artificial hot-air technique. Currently, sun drying is mostly used in Nigeria by cocoa farmers due to its simplicity, low cost set up and requires only direct sunlight which is abundant (Opeke, 1987). Drying is usually terminated when the dried beans' moisture content is as low as 7.0% (wet basis).

Artificial, hot-air drying of fermented cocoa beans has

*Corresponding author. E-mail: dddoke1970@gmail.com or dddoke1970@yahoo.com. Tel: +234-8066781165.

been reported in literatures, they mostly concentrated on the removal of moisture from the beans at the shortest possible time (Nganhou et al., 2003; Wan Daud et al., 1996; Hii et al., 2002). This resulted in high drying rate but does not allow for the completion of needed oxidative reaction and acid diffusion process (McDonald et al., 1981). The large size of cocoa beans compared with most granular materials also result in high moisture gradient in the beans during and after drying when artificial and continuous systems are used. This has resulted in broken and cracked beans which are susceptible to fatty acid development due to high fat content of cocoa beans and the consequent reduction in bean quality. The focus of this work was to exploit the combined benefits in the traditional sun-drying practices and the forced-air artificial intermittent drying at low temperature, at about 35 to 55°C, in the drying of fermented cocoa beans. The effects of temperature on the quality of the dried beans were also investigated.

MATERIALS AND METHODS

Research philosophy

The philosophy of this research work is to explore the possibility of using artificial intermittent drying system to dry fermented cocoa beans, without the limiting effect posed by weather conditions in traditional sun drying system and also, without compromising the quality of the final product.

Sample preparation

Fresh cocoa beans were obtained from Obafemi Awolowo University, Teaching and Research Farm and fermented using heap-basket method for 5 days. The harvested cocoa pods were processed for fermentation the same day they were harvested. After 5 days of heap-basket fermentation, the fermented beans were divided into six streams dried at varied temperature (35, 40, 45, 50 and 55°C and sun drying temperature). These were replicated thrice and their average values were recorded.

Drying methods

Sun drying

The fermented cocoa beans were spread thinly on a concrete slab (50 x 50 x 15 cm) inclined at angle of 10° to ease water drainage in case of accidental rain wetting. The beans were turned every 2 h to ensure uniformity and improve moisture diffusion from inner core of the beans to the outer surface. Ambient temperature and relative humidity was measured using Casella-hand sling hygrometer. Drying was conducted between 8.00 to 17.00 h daily.

Artificial intermittent forced-air drying

The beans were artificially dried using an air-ventilated oven (Galle Kamp Oven Model 300 series) at temperatures 35, 40, 45, 50 and 55°C respectively. The cocoa beans were spread thinly in single layer on a meshed sample tray (0.4 x 0.4 cm). The average relative humidity of the oven were 38, 29, 21, 14 and 8% respectively. Heat

was provided by the heater embedded at the base of the oven and hot air flow through the samples. The exhaust air escaped through the ventilation hole at the top of the oven. The beans were mixed every 2 h to ensure uniformity. Drying was conducted for 9 h daily and the beans were left to rest at room temperature overnight. This was done to help moisture redistribution in the beans before next day drying commences. This is to reduce bean breakage associated with drying without tempering (Steffe and Singh, 1982).

Test procedure

Moisture content

A known weight of beans was dried in the oven at 103°C for 16 h as recommended by International Standard Organization (ISO) table of standard 2291 – 1972 (E) and AOAC (1984). The moisture content (MC) of the beans was determined with reference to wet weight of the beans using equation (1).

$$MC \text{ (wet basis)} = \frac{w_o - w_d}{W_o} \times 100\% \quad (\text{Hii et al., 2009}) \dots\dots\dots (1)$$

Where the terms w_o and w_d refers to initial and dry weight of the beans respectively. The equilibrium moisture content (EMCs) were determined by drying until no further change in weight was observed by the beans in each heat treatment. The EMC values determined were 6.2, 6.3, 6.5, 6.9, 7.1 and 7.6% (wet basis) for sun drying and oven drying temperatures 35, 40, 45, 50 and 55°C respectively.

Quality assessment of dried beans

The dried beans were examined for colour, taste, and occurrence of slate or mould. Quality assessment was based on the pH, acetic acid value and free fatty acid (FFA) level of the dried beans. The pH and acidity were determined according to Duncan et al. (1989). Ten grammes of the nibs were homogenized in 200 ml distilled water; the homogenate was filtered and the pH of the supernatant was measured using a digital pH meter. A 25 ml aliquot was titrated to pH of 8.0 with sodium hydroxide (0.01M) to determine the acidity of the beans. The free fatty acid content was determined according to AOAC (1984). One gramme of grounded cocoa nib was poured into a conical flask (250 ml); 50 ml of 0.5 M ethanonic potassium hydroxide were added to each of the samples. Heat was applied to dissolve the solution and allowed to cool. One to two drops of phenolphthalein indicator was added and the solution was titrated with 0.5 M HCl until the colour changed. The percentage FFA was then determined as the percentage molar equivalent of the KOH titre to the mass of cocoa nib sample.

The acetic acid content was determined according to AOAC (1984). A forty grammes grounded cocoa nib was mixed with 80 ml of de-ionized water in a conical flask. The mixture was distilled and allowed to cool. One to two drops of phenolphthalein indicator was added and the solution was titrated with 0.5 M potassium hydroxide (KOH) until the colour changed. The percentage FFA was then determined as the percentage molar equivalent of the KOH titre to the mass of cocoa nib sample.

Statistical analyses

All experimental treatments were conducted in three replicates. The experimental data were subjected to manual regression analysis and correlation between the oven temperature and free fatty acid levels of the beans were calculated.

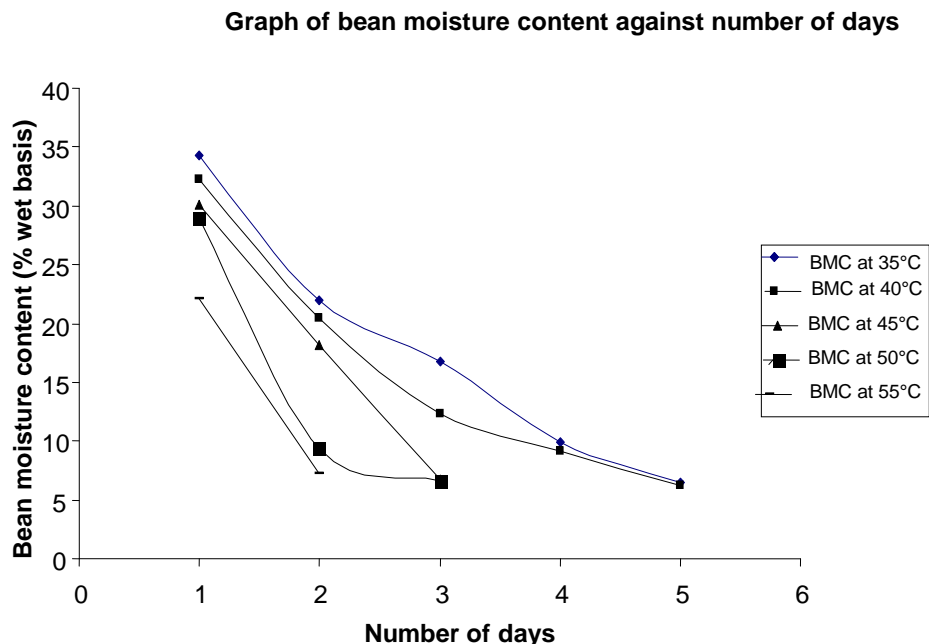


Figure 1. Bean moisture content against drying days in artificial drying.

RESULTS AND DISCUSSION

Moisture content fluxes

The moisture content of the cocoa beans at the time of the experiment was found to be 53.4% (wet basis). Although, the beans were apparently wet there was no free surface water on the bean. Moisture variation was observed in the oven for a 24 period, starting from 8 to 17 h of drying period and 15 h of resting (Figure 1). The relative humidity in the oven ranged from an average of 74% at 8 am to a maximum of 35% at 5 pm. The corresponding range of ambient temperature was 25 to 30° C. The prevailing ambient relative humidity was a minimum of 58% during the daytime whilst, it was relatively stable at 98% during the night (rest period). The moisture loss was high for the first two days in all the samples (Figure 1), the loss was marginal in the third day (between 2 and 8%) for beans dried at 35 to 50°C. After the third day, most beans have reached the storage moisture content (7% wet basis) except the sample dried at 35°C that reaches the storage moisture content on the fifth day of drying. This is consistent with what was reported by Fagunwa et al. (2009).

Physical and chemical analyses of dried cocoa beans

The physico-chemical characteristics of the beans, using the forced – air artificial intermittent drying system are shown in Table 1. In all the tested attributes, the artificial intermittently dried samples compared favourably with the

sun-dried samples. The qualities of both the forced-air artificial intermittently dried and sun-dried samples are within the acceptable level in international standards with respect to free fatty acid, acetic acid, pH, and taste flavour. All the samples under forced convection in the oven were properly dried showing dark reddish beans.

Test results show that the beans under forced-air artificial intermittent drying is more acidic (pH value of 4.7 to 5.2, acetic acid value of 3.9 to 8.7 mg/g and mildly bitter taste) against the corresponding attributes of 5.3 for pH and 3.5 mg/g and mildly bitter taste for sun dried beans. This may be due to a sealing of the beans testa under the vortex of flowing air, thus, preventing the diffusion of the acetic acid from the beans (Fagunwa et al., 2009). Consequently, a balance of the diffusion of moisture and its removal by the flowing air will present an optimum condition. Future research should investigate the quality of by-products (chocolate, confectioneries, etc.) from forced-air artificial intermittently dried beans and compare same with by-products from sun dried beans.

There was no difference in the flavour of the sun-dried and the forced-air artificial intermittently dried samples at the five different oven temperatures. Such observations had been reported by Thien et al. (1994) in the comparison of the qualities of sun-dried and air blown cocoa beans.

Conclusions

It can be concluded from this experiment that forced-air

Table 1. Quality test results.

Condition	Free fatty acid value (mg/g)	Acetic acid value (mg/g)	pH value	Taste	Colour
Sun dried	0.40	3.50	5.30	Mildly bitter	Light brown
Oven dried (35°C)	0.41	3.90	5.20	Mildly bitter	Very light brown
Oven dried (40°C)	0.46	4.70	5.10	Mildly bitter	Light brown
Oven dried (45°C)	0.48	6.50	5.00	Mildly bitter	Dark brown
Oven dried (50°C)	0.55	7.30	4.80	Bitter	Dark brown
Oven dried (55°C)	0.61	8.70	4.70	Bitter	Dark brown

Table 2. Statistical data analysis.

Drying temperature (°C) (x)	FFA mg/g (y)	xy	x ²	y ²
35.00	0.41	14.35	1225	0.1681
40.00	0.46	18.40	1600	0.2116
45.00	0.48	21.60	2025	0.2304
50.00	0.55	27.50	2500	0.3025
55.00	0.61	33.55	3025	0.3721
225.00	2.50	115.40	10375	1.2847

artificial intermittent drying is appropriate for drying of cocoa beans to safe moisture level (7% wet basis) between 2 to 5 days depending on the oven temperature (35 to 55°C). The essential quality attributes of the beans are comparable with the product from the traditional sun drying system. From data analyses, an equation was established that predict the impact of oven temperature on the free fatty acid level of the beans (Table 2). This help in establishing a safe drying temperature for the beans.

$$y = m x + c \text{ (AOAC, 1984)} \quad (1)$$

$$\text{Slope (m)} = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} \quad (2)$$

From Table 2,

$$m = 0.0098$$

$$c = \frac{\sum x - m \sum y}{n} \quad (3)$$

Therefore, $c = 0.061$

Thus, the regression equation,

$$y = 0.0098x + 0.061 \quad (4)$$

Correlation equation,

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{\{n \sum x^2 - (\sum x)^2\} \{n \sum y^2 - (\sum y)^2\}}} \quad (5)$$

$$= 0.98633$$

This is highly and truly correlated. Equation 6 can be used to predict the level of free fatty acid (y) in mg/g in the dried beans for any oven temperature (x) in degree Celsius.

REFERENCES

- AOAC (1984) Official Methods of Analysis, Association of Official Analytical Chemists, 4th Edition, Washington, D.C. USA.
- Beckett ST (1994). Industrial Chocolate Manufacture and Use (2nd Ed.). Blackley Academic and Professional, Glasgow, UK.
- Buijisse B, Feskens EJ, Kok FJ, Kromhout D (2006). Cocoa intake, blood pressure and cardiovascular mortality: the Zutphen elderly Study, Arch. Med., 166(4): 411-417.
- Duncan RJ, Godfrey EG, Yap TN, Pettipher GL, Tharu-marajah T (1989) Improvement of Malaysian cocoa bean flavour by modification of harvesting, fermentation and drying method. The Planter (Malaysia), pp. 57-65.
- Fagunwa AO, Koya OA, Faborode MO (2009). "Development of an Intermittent Solar Dryer for Cocoa Beans". Agricultural Engineering International: the CIGR E. J., 2: 1-14.
- Hii CL, Tukimon MB (2002). Evaluation of fermentation techniques practical by the cocoa smallholders. The Planter, 78(910): 13-22.
- Hii CL, Law CL, Cloke M, Suzannah M (2009). Thin layer drying kinetics of cocoa and dried product quality. J. Bio-sys. Eng. Elsevier Ltd, pp. 153-161.
- International Standard Organisation (1972). Table of Standard, 2291-1972(E).
- McDonald CR, Lass RA, Lopez ASF (1981). Cocoa drying-a review. Cocoa Grower's Bulletin, 31: 5-41.
- Nganhou J, Njomo D, Benet JC, Augier F, Berthomieu G (2003).

- Perfecting a method of micro-analysis of water and acetic acid in a cocoa bean in the course of drying: applying to determine transportation coefficients. *Heat and mass transfer*, 39: 797-803.
- Opeke LK (1987). *Tropical Tree Crops*. John Willey and Sons, Chichester, pp. 67-213.
- Porter LL (2006). Benefits of cocoa polyphenols. *Manufacturing Confectioner*, 86(6): 49-53.
- Steffe JF, Singh RP (1982). Diffusion Coefficients for predicting rice drying behaviour. *J. Agric. Eng. Res.*, 27: 489-493.
- Taubert D, Roesen R, Schomig E (2007). Effect of cocoa and tea intake on blood pressure: a meta-analysis. *Arch Intern. Med.*, 167(7): 626-634.
- Wan Daud WR, Meor Tabib MZ, Ibrahim MH (1996). Characteristic drying curves of cocoa beans. *Drying Technol.*, 14: 2387-2396.
- Wood GAR, Lass RA (1985). *Cocoa* (4th Edition). Longman Inc., New York, USA.