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Drying Characteristics of Cocoa Beans Using an Artificial Dryer

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Abstract: Artificial drying of cocoa beans has become imperative as a result of the drudgery and the spoilage of the beans when they are dried naturally viz-a-viz spreading the beans on a raised flat form to dry under the heat of the sun or using collector to collect the solar energy and use it to dry the beans. So, this study determined the drying characteristics of cocoa beans using artificial dryer and found that high dry rates are achieved when there is increase in drying air temperature and velocity.

Key words: Cocoa beans, artificial dryer, moisture ratio, drying air, temperature ,velocity, drying characteristics

INTRODUCTION

Cocoa is grown principally in West Africa, Central and South America and Asia. In order of annual production size, the largest coca producing countries at present are Cote d'voire, Ghana, Indonesia, Nigeria, Cameroon, Brazil Ecuador and Malaysia. These countries represents 90% of world population (http://unctad.org/ infocomm/anglais/cocoa/ market.htm). According to Hii *et al*. (2009), cocoa is widely consumed in the form of chocolates and consumption rate is rising due to the increasing popularity of chocolate confectionaries worldwide. Cocoa is also used in the manufacture of beverage, cosmestics, pharmaceuticals and toiletries products. After the harvest of cocoa, they are split opened and the beans are processed by fermentation and drying. Fermentation of the fresh cocoa beans are usually done by heap or box method for about 6 days depending on the conditions of the beans. The drying of the beans precedes the fermentation. According to Adeniyi *et al*. (2011), fermentation liquefies the pulp of the cocoa, allowing it to drain away to enhance the drying process. The essence of the drying is to forestall over fermentation which could result in product deterioration. Ndukwu (2009) however, opined that cocoa bean are dried to reduce mass losses, retain chocolate flavour and for safe storage.

Drying of the cocoa beans can be achieved by natural method or artificial method. The natural method of drying cocoa beans can be achieved by the use of solar energy. This include the spreading of the cocoa bean on the concrete floor or on a raised platform under the heat of the sun or the use of flat plate collectors to trap the solar energy and use it to dry the cocoa beans. This method has been used by the following reseachers, Fagunwa *et al*. (2009), Hii *et al*. (2006), Bonaparte (1995) and Clement *et al*. (2009). In any case, the beans are stirred manually to ensure even drying. The inconsistency in the weather condition and the frequent turning of cocoa beans associated with the natural method which is tiresome, necessitated the use of artificial method. The artificial method is achieved by using fan or blower, to drive air across heating elements which become heated to the bed of the cocoa beans, thereby drying or reducing the moisture content of the cocoa beans. The objective of this study was to determine the drying characteristics of cocoa beans in an artificial dryer. These drying characteristics included the drying constant, temperature, rate and air velocity. The knowledge of these aforementioned characteristics helps or aids the engineers who are engaged in the design of an artificial dryers and other post harvest machines for processing cocoa.

MATERIALS AND METHODS

Fresh cocoa beans were bought from cocoa farmers in Iruekpen, Ishan, Edo state Nigeria. They were fermented using Hii and Tukimon Method (Hii *et al*., 2009). The drying experiments were carried out using the artificial dryer designed and fabricated at the Department of Mechanical Engineering, Auchi Polytechnic, Auchi. The artificial dryer is capable of providing any desired drying air temperature in the range of 0.1-4.5 m sec^{-1}. Figure 1 shows pictorial view of the artificial dryer. It consisted of two constant speed motors of 0.5 hp each one for driving a centrifugal blower and the other for driving an extractor, the heating chamber consisting of the two heating elements for heating air and the drying trays of sizes 390×400×100 mm made up of galvanized wire mesh for holding the cocoa beans to be dried.

Theory: Where heated air is used as drying medium, the primary factor influencing the rate of drying is temperature

Fig. 1: Pictorial view of cocoa beans artificial dyer

Kajuna *et al*. (2001). In drying of thin layers of agricultural crops, Newtonian Model among others is used. However, the Newtonia Model is considered in this study. The Newtonia Model is given thus:

$$MR = \exp(-kt) \quad (1)$$

$$MR = \frac{M - M_e}{M_i - M_e} \quad (2)$$

Where:

MR = Moisture Ratio
M_i = Initial moisture content (%db)
M_e = Equilibrium moisture content (%db)
M = Moisture content in time, t (%db)
t = Drying time (h)
k = Drying constant

According to Meisami-Asl and Rafiee (2009), the moisture ratio can be simplified to:

$$MR = \frac{M}{M_i} \quad (3)$$

From Eq. 1:

$$K = \frac{\text{In } MR}{t} \quad (4)$$

The drying constant K can be computed from the slope of the negative natural log of the moisture ratio against time. The drying rate of the cocoa bean is given as:

$$M = \frac{M_{i-m}}{t} \quad (5)$$

Drying method: About 2.2 kg of cocoa beans having initial moisture content of 81.2% (db) was put in the

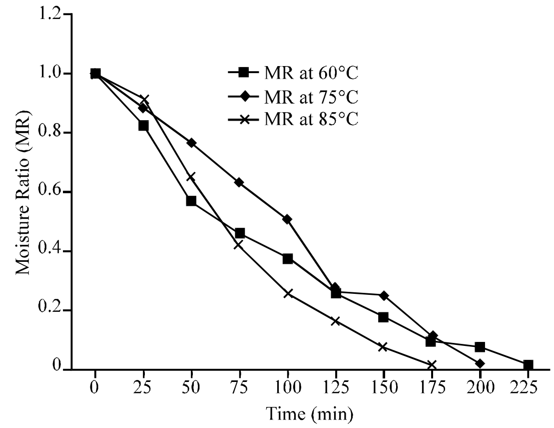

Fig. 2: Variation of moisture ratio of the cocoa beans with drying time at air elocity of 1.8 m sec^{-1} at different temperature

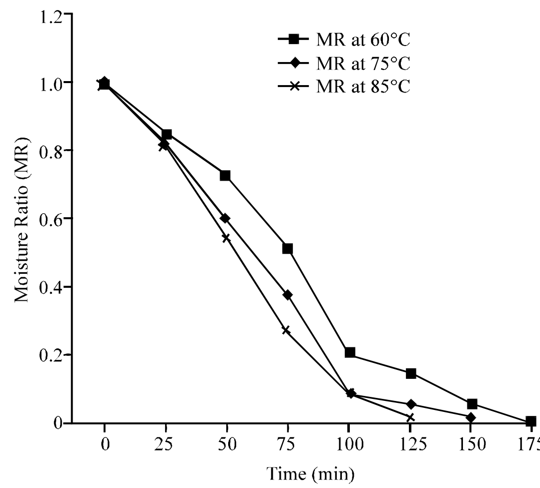

Fig. 3: Variation of moisture ratio of the cocoa beans with drying time at air velocity of 2.7 m sec^{-1} and different temperature

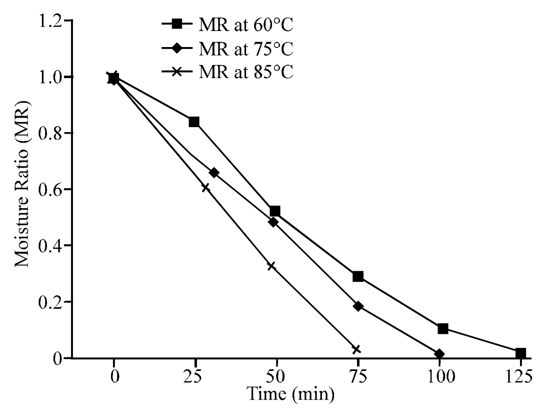

Fig. 4: Variation of moisture ratio of the cocoa beans with drying time at air velocity of 3.8 m sec^{-1} and different temperature

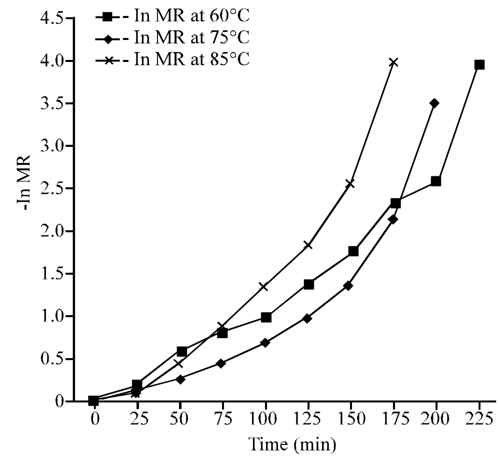

Fig. 5: Variation of the negative natural log of the Moisture Ratio (MR) of the cocoa beans with time at air velocity of 1.8 m sec^{-1} and at different temperature

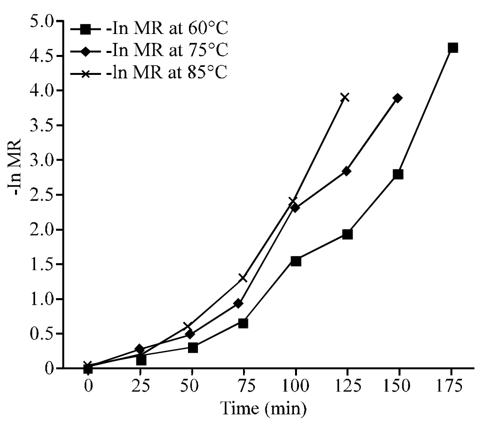

Fig. 6: Variation of negative natural log of the Moisture Ratio (MR) of the cocoa beans with time at air velocity of 2.7 m sec^{-1} and at different temperature

drying tray and spread to form three layers. The artificial dryer was switched on, air was forced by the blower through the heating elements and after attaining the desired temperature of 60, 75 and 85 and velocity of 1.8, 2.7 and 3.8 m sec^{-1}, passed through the drying chamber. Drying air temperature was determined with a type K thermocouple at the exhaust duct. The drying air velocity was also measured directly in the exhaust duct with a hot wire digital Anemometer.

The drying tray with the beans were removed in an interval of 25 min and weighed to obtain the data for the loss of moisture. This was done for the desired drying air velocities and temperatures 3 times and average results were taken. The tests were performed until there were no changes in mass. That was, the point the moisture content

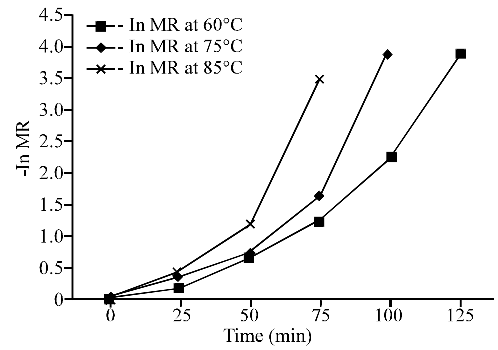

Fig. 7: Variation of negative natural log of the Moisture Ratio (MR) of the cocoa beans with time at air velocity of 3.8 m sec^{-1} and at different temperature

Table 1: Computed average cocoa bean drying rates (kg h^{-1}) at the desired air velocities and drying air temperatures

	Drying air temperature (°C)		
Air velocity (m sec^{-1})	600	750	850
1.8	0.186	0.218	0.335
2.7	0.208	0.242	0.351
3.8	0.217	0.283	0.376

of the beans reached equilibrium with the surrounding. Drying curves were fitted to the experimental datas using Eq. 3 and 4 and shown in Fig. 2-7. The drying rates of the cocoa beans at the desired drying air temperatures and velocities were computed, using Eq. 5. The results are shown in Table 1.

RESULTS AND DISCUSSION

It can be seen from Fig. 2-4 that the moisture ratio decreased as the drying time increased, irrespective of the desired drying air velocities and temperatures. All drying processes resulted in falling rate drying periods, starting from the initial moisture content prior to drying to the final moisture content at the end of the drying. These are evident in Fig. 2-4.

Similar results have been reported for different crops by Meisami-Asl and Rafiee (2009). From Fig. 5-7, the slopes of the curves which denoted the drying constants were found to be 0.0186, 0.0194, 0.0225 min^{-1} for air temperatures of 60, 75 and 85°C, respectively at air velocity of 1.8 m sec^{-1}, 0.0297, 0.0298 and 0.0371 min^{-1} for air temperatures of 60, 75 and 85°C, respectively at air velocity of 2.7 m sec^{-1}, 0.0374, 0.0476 and 0.0616 min^{-1} for air temperatures of 60, 75 and 85°C, respectively at air velocity of 3.8 m sec^{-1}. It was observed that drying constants increased with increased drying air temperature irrespective of the drying air velocity. Similar experience was observed in the research of Ndukwu (2009). It can be seen from Table 1 that the drying rates of the cocoa beans increased as the drying air temperature and velocity increased.

The minimum drying rate of 0.186 kg h^{-1} was obtained when the cocoa beans were dried at a temperature of 60°C with a velocity of 1.8 m sec^{-1} while the maximum drying rate of 0.376 kg h^{-1} was obtained when the cocoa beans were dried at a temperature of 85°C with air velocity of 3.8 m sec^{-1}. This shows that the dryer can dry off about 9.024 kg of water in the cocoa beans in a day with the above desired drying conditions.

CONCLUSION

From the determined drying characteristics of cocoa beans, it can be concluded that drying cocoa beans at high air temperature and velocity leads to high drying rates. The finding in this research will enhance the knowledge of an engineer or a designer who is interested in producing an artificial dryer for cocoa beans and other similar agricultural produce.

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