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Effect of Different Floor materials on the Drying behaviour of Cocoa Beans

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ABSTRACT

Studies were undertaken to establish the most effective floor material for drying of cocoa beans based on the drying time and physical visual evaluation of the quality. Experiments were conducted to determine drying rate, drying time and quality of the dried cocoa beans using different floor materials such as black polyethylene sheet, wooden plank, and concrete floor in open yard sun drying. Average composition of cocoa fruit was found to be shell (72.6%), pulp (20.7%) and beans (6.6%) suggesting that less than 10% of fruit component gets major economic return to the farmer. Average length, diameter, weight of fruit and the bulk density of cocoa bean were found to be 153.58 mm, 89.9 mm, 372.13 g and 0.6047 g/cm^3 respectively. Drying time required to reduce moisture content of cocoa beans from 17.1% (w.b) to safe moisture content of 6-10% is found to be 5-6 days on wooden plank, and 4-5 days on black polyethylene and concrete floor respectively. The average drying rates are 0.0778, 0.0971, 0.0974 Kg/Kg-h for wooden plank, concrete floor, and black polyethylene sheet respectively. It is concluded that black polyethylene sheet followed by concrete floor are better floor materials to reduce the drying time, giving good quality produce and also in view of the durability of black polyethylene sheet as floor material.

Key words: Cocoa beans, Drying rate, Floor materials, Open yard sun drying, Physical properties.

Cocoa is an important cash crop in many tropical countries. The original home of cocoa trees is Central and South America (Acquaah 1999). Today, more than two thirds of the world's cocoa beans are produced in West Africa, and Ghana specifically, earned in 2005 about 60% of its foreign income from export of coca beans (ICCO, 2009). Cocoa is an important commercial crop grown as inter crop in coconut gardens in coastal districts and parts of Anantapur district of Andhra Pradesh in India.

Primary processing of cocoa includes harvesting, gathering the ripen fruits at a central location in the farm, fruit opening, removing of the beans, fermenting the beans and drying the beans. One of the advantages of the primary processing of cocoa beans is that it is relatively inexpensive, and this gives good opportunities for small farm holders to use cocoa beans as a cash crop (Are & Gwynne-Jones, 1974). Fermentation of cocoa beans is very nonhomogeneous and difficult to control (Mossu, 1992; Amoa-Awua, 2007), and microbial understanding of some of the fermenting processes is still inadequate (Nielsen *et al*., 2007).

Drying, the removal of volatiles, generally water, to yield a stable product (Menon and Mujumdar, 1987) is perhaps the most widely used method of long term preservation of food products worldwide. The effects of temperature and humidity of drying air on moisture removal are interrelated. Increases in air temperature effectively lower the relative humidity of a given volume of air, and thereby increases its capacity to hold moisture. Higher air temperature adds the possibility of heat transfer to the product. When the latter occurs, the vapour pressure within the product increases and the evaporation of moisture from the surface is facilitated (Menon and Mumdar 1987; Brooker *et al*. 1992). Wasterman *et. al*. (1973) examined the effects of temperature and relative humidity in the range of 10 - 85% on the drying rate of corn. For the same temperature of drying air, drying rate was found to decrease with an increase in relative humidity. Artificially dried beans are inferior to sun dried beans in chocolate flavor development (Quesnel and Jugmohunsingh 1970; Shelton 1967). Artificial drying increases brittleness and produces a high proportion of cracked and broken beans (Urquhart, 1961; Ghosh, 1972) and beans with a wrinkled appearance.

Drying practices influence market quality, the development of flavour, final bean acidity, moldiness and the presence of off-flavour in the beans. Hence an attempt was made to undertake drying studies of cocoa beans by using different floor materials such as black polyethylene sheet, wooden plank, and concrete floor in open yard sun drying and physical visual evaluation of the quality.

MATERIALS AND METHODS

Raw material

Fresh cocoa fruits were obtained from local farmers in Ratnagiri village near Madakasira and Kondalaraopalem near Eluru. The fruits were cut open and beans were collected. Physical properties and Bulk density were determined. The beans were fermented in a fermentation basket and washed in water and pulp was left in the basket for 2-3 days for fermentation. Cocoa beans after fermentation are brought twice in 2 kg lot for conducting for experiment. Floor materials viz., Black polyethylene cover, Concrete floor and wooden plank are arranged for local sources.

Preparation of Black polyethylene sheet

The black polyethylene sheet was spread on the field covering an area of 1ft x 1ft. Weights were placed at four corners of sheet to protect the sheet from rising by wind. The cocoa beans after fermentation were spread on the sheet uniformly covering an area of 20 cm x 20 cm.

Preparation of Concrete floor

A concrete floor of normal flooring was taken for experimental setup and the floor is previously cleaned from debris materials. The cocoa beans after fermentation were spread on the floor uniformly covering an area of 20 cm x 20 cm. Care is taken to see that shadow and disruption for sun takes place on the beans.

Preparation of Wooden plank

A wooden plank of 1ft x 1ft prepared by local person is used for drying of cocoa beans. Cocoa beans after fermentation were spread on the wooden plank uniformly covering an area of 20 cm x 20 cm.

Experimental procedure

The study was conducted on three different floor materials viz., Black polyethylene cover, Concrete floor and Wooden plank. Ripe pods are taken of 0.5 kg each plot. The pods are spread with uniform thickness of 1.25 cm on each of the floor materials. Three samples of equal weights 0.5 kg were taken for experimentation. Each sample is spread uniformly with equal thickness of 1.25 cm on each plot. The experiments were conducted twice with similar hybrids of cocoa beans. Initial moisture contents were determined for each of samples before drying is started.

The first experiment was conducted on 18th October, 2011 and carried out for 4 drying days i.e., up to 21st October, 2011. The second experiment was conducted on 26th April, 2012 and carried out for 4 drying days i.e., up to 29th April, 2012. The experiment was conducted between 9.00 AM to 5.00 PM on each of these days. During this period of experiment samples were taken at 11:00 AM, 02:00 PM and 05:00 PM to determine the moisture content by on each day. Simultaneously, the ambient temperatures and relative humidity were measured using Equinox, temperature humidity meter (Equinox make, digital meter) three times a day at 11.00 AM, 2.00 PM and 5.00 PM.

Determination of bulk density

The rectangular box was used to determine the bulk density of dried cocoa beans. Volume of the box and weight of the material were measured and bulk density was calculated using the following formula.

$$\text{Bulk density} = \frac{\text{Weight of the dried cocoa beans (gm)}}{\text{Volume of the box (cm}^3\text{)}}$$

Determination of Moisture Content

Moisture content of the cocoa beans while drying on each plot is measured (AOAC, 1990). The samples are taken in moisture boxes from each plot to determine the moisture content. The boxes were kept in hot air oven at 105^{o}C± 3 for 24 hours and the weights are measured on electronic digital weighing machine having an accuracy of 0.01g. From the initial and final moisture box weights, the moisture content of samples is determined and expressed in percent (w.b.) by using the following formula:

$$\text{Moisture Content (w.b.)} = \frac{W_2 - W_3}{W_2 - W_1} X100$$

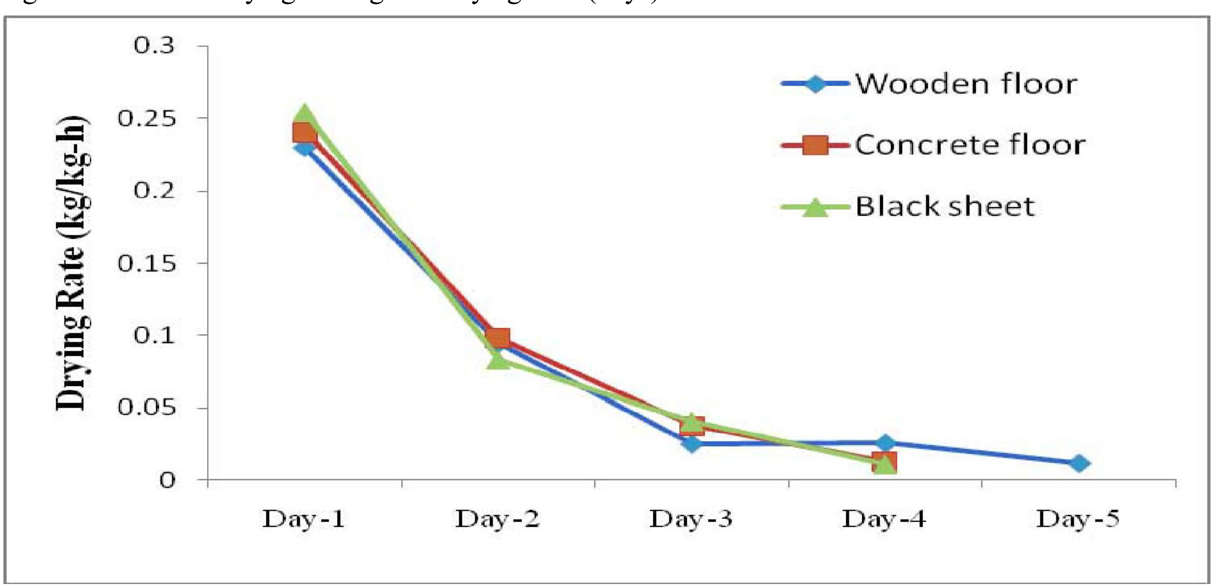
Table 1. Some physical properties of cocoa fruit.

Fruit No.	Length (mm)	Dia (mm)	Weight of fruit (g)	Weight of pulp (g)	Weight of beans (g)	Weight of shells (g)
1	141.0	94.0	316.7	63.8	24.0	252.3
2	143.8	84.6	315.6	51.0	17.33	260.6
3	143.4	76.4	334.2	67.8	20.8	265.4
4	162.0	110.0	605.0	101.6	36.3	500.8
5	198.0	106.0	478.4	85.3	30.79	390.8
6	167.0	84.2	357.3	68.7	24.02	287
7	165.0	86.4	389.42	94.15	38.98	293.2
8	146.2	88.4	331.8	99.2	33.52	233.2
9	139.0	96.6	338.82	104.0	15.68	232.3
10	130.4	72.4	254.08	34.4	7.52	217.8
Average	153.58	89.9	372.132	76.495	24.894	293.34

Table 2. Composition of beans, pulp and shells in a cocoa fruit.

Fruit	Beans (%)	Pulp (%)	Shells (%)
1	7.5	20.14	79.66
2	5.4	16.15	82.57
3	6.2	20.28	79.41
4	6	16.79	82.77
5	6.4	17.83	81.68
6	6.7	19.22	80.32
7	10.00	24.17	75.29
8	10.1	28.39	70.28
9	4.6	30.69	68.56
10	2.9	13.53	85.72
Average	6.58	20.71	78.62

Fig. 1 Variation of drying rate against drying time (days) on different floor materials.



W_1 = weight of empty box
W_2 = weight of moist sample + box
W_3 = weight of dried sample + box

The drying of cocoa beans was continued until the cocoa beans are completely dried and attains moisture level of about 6 % to 10%.

Measurement of floor temperature

The surface temperatures of the floor materials used for drying are taken with the help of digital thermometer. The temperature gradient of each floor is obtained from the difference of the maximum and minimum temperatures measured during the day. The ambient temperatures of the day at three intervals (11.00 AM, 2.00 PM and 5.00 PM) are taken with digital thermometer.

Calculation of drying rate

Drying rate is defined as the ratio of moisture removed per kg of dry weight of material in unit time. The amount of moisture removed on each of experimentation is initially determined and then the drying rate is calculated. It is computed for different plots during experiment for each day using the following formula:

$$R = \frac{dm}{d\theta} = \frac{amount\ of\ moisture\ removed}{time\ taken\ (h)\ X\ Bone\ dry\ weight\ of\ the\ sample}$$

The overall drying rate of each drying method is also calculated by considering initial and final moisture content of the cocoa beans.

RESULTS AND DISCUSSION

Determination of physical properties of cocoa fruit and beans

Composition of cocoa fruit and processing of beans

The seeds are fermented, which causes many chemical changes in both the pulp surrounding the seeds and within the seeds themselves. These changes cause the chocolate flavour to develop and the seeds to change colour. The seeds are then dried and dispatched to processors as the raw material for the production of cocoa mass, cocoa powder and cocoa butter. The first stage of processing includes roasting the beans, to change the colour and flavour, and shell removal. After roasting and deshelling an alkalizing process can take place, to alter flavour and colour. The physical properties of cocoa fruit after fermentation and drying were shown in Table 1.

It was observed from the Table 1, the average length, diameter and weight of cocoa fruit was 153.58 mm, 89.9 mm and 372.132 g respectively. From the study, it was also found that the average of cocoa fruits pulp, beans and shell was 76.495 g, 24.894 g and 293.34 g respectively on weight basis. From the Table 2, the average composition of shell, pulp and beans is 78.62%, 20.71%, and 6.58%. Suggesting that less than 10% get fruit only makes main economic returns to farmers. The bulk density of dried beans is shown to be 0.6047g/cm^3.

Effect of floor material in open yard sun drying

For cocoa bean, moisture content about 6-10% (w.b) has been suggested as safe for storage. In Open Yard Sun Drying (OYSD), the floor materials such as black polyethylene sheet, concrete floor and wooden plank, which are generally used by farmers are considered for the experiment and are compared with normal drying on concrete floor. Most of the farmers are drying the beans on concrete floor only.

The variations of ambient temperature, surface temperatures of different floor materials of cocoa beans are shown in Table 3. Generally, the surface temperature of the field floor has a temperature gradient of 10-15^{0}C, while that of the different floor materials are obtained in between 15-25^{0}C, with highest gradient achieved by black polythene sheet and concrete floor.

The drying time of the cocoa beans is influenced by the surface temperature of the floor material and thus decreases with increase in surface temperature of the floor. The maximum surface temperature during a typical day is obtained on black polyethylene sheet and closely followed by concrete floor. The temperature of concrete floor is closer and next to wooden plank. The floor temperatures of black and concrete floor are observed to be higher about 0.3^{0}C to 1.0^{0}C than other floor material thus, facilitating higher drying rates.

Drying rate

The variations of drying rate against drying time on different floor materials are as shown in

Table 3. Surface temperatures of cocoa beans on different floor materials.

Days	Time	Ambient Temp. (⁰C)	Black Polyethylene Cover			Concrete Floor			Wooden Plank		
			Floor (⁰C)	Cocoa beans (⁰C)		Floor (⁰C)	Cocoa beans (⁰C)		Floor (⁰C)	Cocoa beans (⁰C)	
				Surface	Centre		Surface	Centre		Surface	Centre
Day-1	11:00	40.0	45.0	43.5	42.5	44.0	43.0	42.8	42.2	42.0	42.0
	14:00	37.3	42.3	41.2	41.0	40.2	39.3	39.0	39.5	38.0	39.5
	17:00	35.5	40.0	39.6	39.0	39.5	39.6	39.0	38.5	37.6	38.5
Day-2	11:00	35.1	39.2	38.5	37.9	38.5	37.2	37.0	35.6	35.0	34.6
	14:00	32.6	42.0	40.0	39.0	40.0	39.5	39.3	39.0	38.2	39.2
	17:00	29.6	31.5	32.5	31.9	30.9	30.6	30.0	30.0	30.2	30.1
Day-3	11:00	32.3	37.3	35.6	35.0	36.0	35.6	35.3	35.0	36.2	30.9
	14:00	33.7	43.0	41.5	40.5	42.0	41.5	41.0	43.0	42.6	42.0
	17:00	31.0	31.5	31.0	30.9	30.9	31.0	30.5	30.5	30.0	30.5
Day-4	11:00	31.5	38.0	37.5	37.0	37.0	36.5	36.0	36.0	36.2	35.5
	14:00	33.1	44.5	42.0	41.3	43.0	43.0	43.2	42.3	42.0	42.1
	17:00	31.0	34.5	32.0	31.5	33.4	33.0	33.1	32.6	32.2	32.0
Day-5	11:00	33.4	39.0	35.3	35.1	35.7	35.3	35.0	37.0	37.3	36.3
	14:00	31.1	41.0	40.0	39.5	40.5	40.0	40.6	40.2	40.5	40.0
	17:00	32.6	31.0	32.6	32.0	30.8	32.6	32.2	30.9	30.2	30.5

Fig. 1. In general, the moisture content decreases with increase in drying time. The graphs indicate that, drying takes place in falling rate period irrespective of type of floor material. The absence of initial constant rate of drying suggests that drying may occurred both by diffusion and capillary action as observed in most agricultural materials (Chakravarthy, 1987).

The drying rates of cocoa beans on different floor materials during the experiments were found to be 0.2299, 0.0949, 0.0253, 0.0258, 0.0121 kg/kg-h; 0.2405, 0.0981, 0.0374, 0.0126 kg/kg-h and 0.2542, 0.0833, 0.0406, 0.0110 kg/kg-h for wooden plank, concrete floor and black polyethylene cover respectively. The average drying rates for the open yard sun drying are 0.0778, 0.0971 and 0.0974 kg/kg-h for wooden plank, concrete floor and black polyethylene cover respectively. It is clear that, average drying rate is more in black polyethylene sheet followed by concrete floor and wooden plank. Observation showed that, drying rates were relatively uniform in black polyethylene sheet and concrete floor when compared to wooden plank.

Effect of ambient conditions on drying rate using different floor materials

The drying rates using different floor materials are almost same when the variations in ambient conditions are almost constant from day to day (Table 4). The rate of drying is constantly reduced with minimum variations of ambient conditions during the experiment (Fig. 2).

Thus ambient conditions have profound impact in the open sun drying of cocoa beans using different floor materials. Variations in rate of drying are significant with wooden plank due to changes in daily average temperature, relative humidity, solar intensity and wind speed, suggesting poor heat retention by wooden plank in comparison to other floor materials.

To maintain a sustainable drying rate throughout the drying process, it was observed that black polyethylene sheet and concrete floor were better floor materials. The drying rate fluctuated significantly in the case of wooden plank. This may be perhaps due to poor retention of heat by wooden plank. Therefore, black polyethylene sheet and concrete floor materials appear to give better heat dissipation perhaps due to effective retention and utilization of heat.

Effect of drying method on product quality
Quality standards

Quality of cocoa is determined by a combination of factors that determine the acceptability of the cocoa to a buyer. These factors

Table 4. Ambient conditions and drying rates for different floor materials.

Days	Time	Ambient Temperature (^{0}C)	Relative Humidity (%)	Drying Rate (kg/kg-h)		
				Wooden floor	Concrete floor	Black sheet
Day-1	11:00	40.0	24	0.2299	0.2405	0.2542
	14:00	37.3	27			
	17:00	35.5	33			
Day-2	11:00	35.1	57	0.0949	0.0981	0.0833
	14:00	32.6	48			
	17:00	29.6	60			
Day-3	11:00	32.3	67	0.0253	0.0374	0.0406
	14:00	33.7	56			
	17:00	31.0	57			
Day-4	11:00	31.5	60	0.0258	0.0126	0.0110
	14:00	33.1	54			
	17:00	31.0	55			
Day-5	11:00	33.4	55	0.0121		
	14:00	31.1	41			
	17:00	32.6	42			

Table 5. Comparison of surface mould (%) in cocoa beans dried using different floor materials.

Floor material	None	Light	Moderately Heavy	Heavy	Extremely Heavy
Black Sheet	92	5	3	0	0
Concrete floor	90	6	4	0	0
Wooden plank	88	8	4	0	0

Table 6. Determination of quality of cocoa beans.

Different floors	No of beans	Slaty beans	Mouldy beans	Insect damaged/ germinated/flat beans	Brown beans
Black sheet	100	3	2	0	95
Concrete floor	100	6	7	10	77
Wooden plank	100	7	6	8	79

include proper fermentation, dried to the desired moisture level, free from abnormal odours and free from mould contamination. Cocoa is graded on the basis of the count of defective beans in the 'cut test'. The cut test reveals the presence of certain defects which may cause off-flavours and indicates the degree of fermentation of the beans which has a bearing on the flavour and quality of the beans. The International Standards Organization cut test procedure states that for a complete determination of bean quality, beans shall be opened or cut lengthwise through the middle, so as to expose the maximum cut surface of cotyledons.

Surface mould assessment

The dried cocoa beans were assessed qualitatively for external mould at levels such as none, light, moderately heavy, heavy and extremely heavy. The intensity at each level was based on the amount of mould covered on the dried bean surface, ranging from none (0%) to extremely heavy (100%) at 25% coverage interval. The data found

Fig. 2. Comparison of drying rates with ambient conditions.

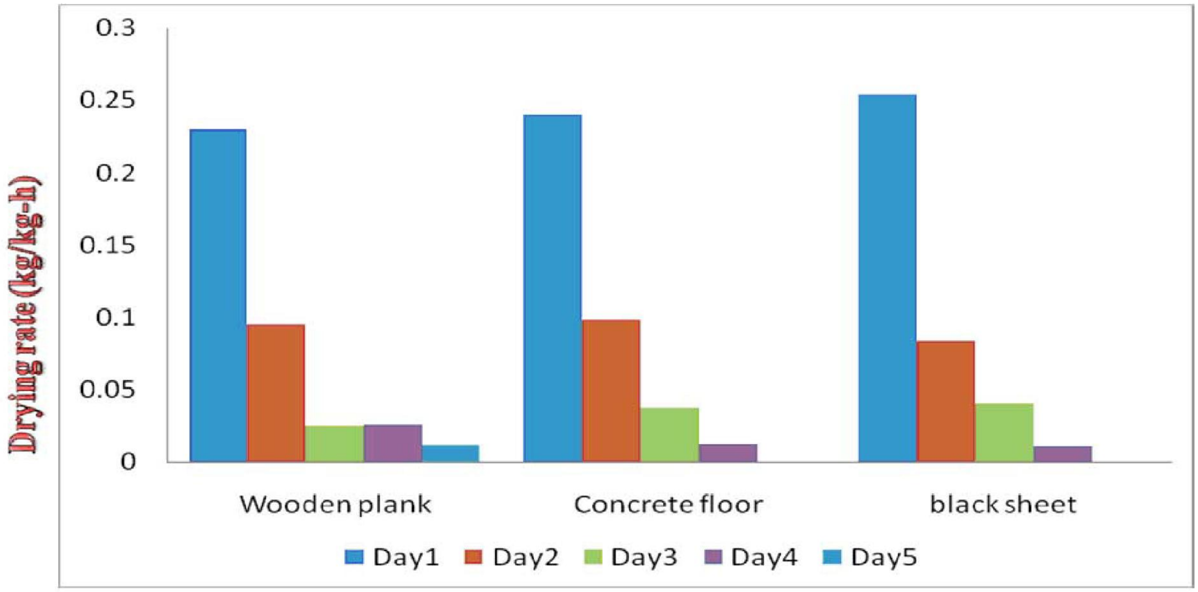
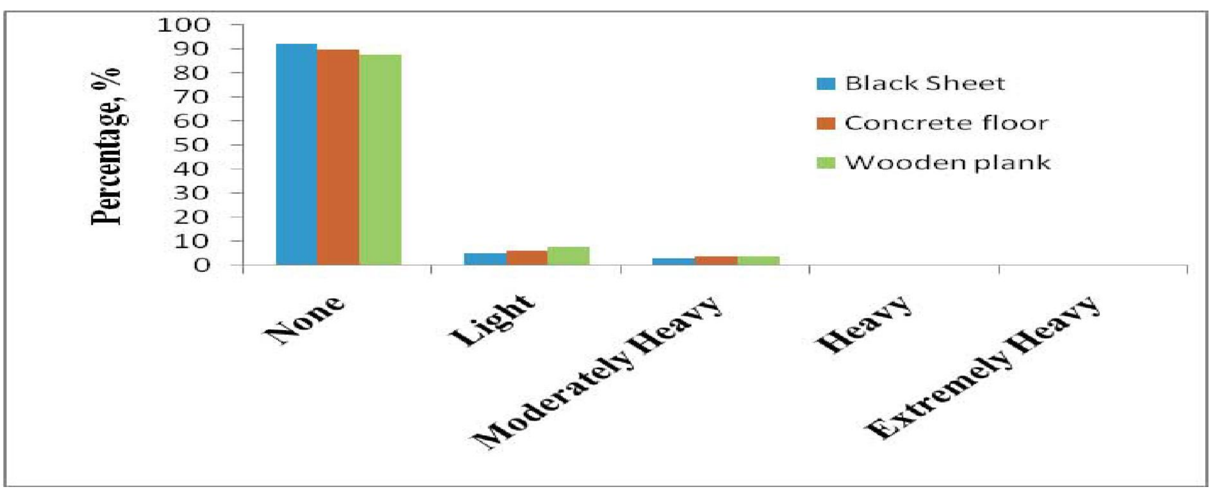


Fig. 3. Comparison of surface mould (%) in cocoa beans dried on different floor materials.



were 92%, 5%, 3%, 0%, 0%; 90%, 6%, 4%, 0%, 0%; and 88%, 8%, 4%, 0%, 0%; for black polyethylene sheet, concrete floor and wooden plank as shown in Fig. 3.

Determination of quality by cut test

Defective beans include slaty, insect damaged, flat beans, over fermented and mouldy beans. According to international standards, mouldy beans should not exceed 3%; slaty beans should not exceed 3% and insect damaged, germinated or flat beans 3% by count. In Vietnam, buyers prefer to purchase cocoa with around 80% of brown beans and usually pay a premium for this type. Adherence to the scientific methods of fermentation would generally result in cocoa with high percentage of fully brown beans (Table 6).

CONCLUSIONS

The study revealed that type of floor materials has effect on drying rate and drying time during the open yard sun drying. It was concluded that black polyethylene sheet followed by concrete floor and wooden plank were better floor material to reduce the drying time. However, concrete floor was found to be more suitable floor material when compared with wooden plank. Based on the experiment, the black polyethylene sheet was suggested for farmers due to better durability than wooden plank and also because of its similar drying effectiveness. The black polythene sheet was recommended as a floor material in place where concrete floor is expensive to prepare for drying yard.

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