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Drying of Cocoa Beans by Using Different Techniques

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Abstract **– Drying methods such as Tray dryer, solar cabinet dryer, Microwave oven and OYSD were used. Studies were undertaken to determine the effect of different drying methods on moisture content, drying time and quality. Experiments were conducted to determine most effective method of drying for suggesting to farmers. The results were analyzed to arrive at the most effective drying method. Based on experimental results, it was found that the time taken for drying of cocoa beans from an initial moisture content of 49.35%(w.b) to a final moisture content of 6.36 % (w.b) varied considerably right from 0.4 hours for microwave drying to 30 hours in OYSD. The time taken for drying in solar cabinet dryer and tray dryer was 16 h, 8 h respectively. The time taken in Tray drier was less for drying and there is a saving about 22 h of drying time as compared to OYSD. There is a saving about 14 h of drying time in solar cabinet dryer as compared to OYSD besides producing a better quality cocoa bean powder as determined by cut test score. The average drying rates for the tray dryer, solar dryer and OYSD are 0.0046, 0.0032 and 0.0020 kg/kg-h. The cut test score of tray dryer, solar cabinet dryer, microwave oven and OYSD was found to be 985, 970, 935 and 960 respectively. It is clear that the brown beans obtained in tray dryer were more in comparison to other drying methods. Although biochemical parameters such as pH, titrable acidity, acetic acid and free fatty acid content of samples in four different methods were determined, they are not conclusive.**

Keywords **– Drying, Cocoa, Dryer, Quality, Time**

I. INTRODUCTION

Cocoa beans is mainly consumed as chocolates and widely used in beverages, cosmetics, pharmaceuticals and toiletry products. It is also associated with many health benefits (Porter., 2006; Taubert et al., 2007).

The quality of cocoa beans is highly dependent on processing technologies and storage conditions for preventing the defective quality. Fermentation and drying are particularly important since they are largely responsible for the typical cocoa flavour precursors which develop later during the roasting of the beans and for the keeping quality of the raw beans (Niles., 1981).

Primary processing of cocoa beans, from the farmer's point of view is time-consuming, hard work. Primary processing of cocoa includes harvesting, gathering the ripe fruits at a central location in the farm, fruit opening, removing of the beans, fermenting the beans and drying the beans. 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 flavor precursors in the beans (Hii et al., 2009).

Fermentation may be carried out in baskets, heaps or boxes and may last from 36 h to 6 days and drying may be done naturally in the sun and last from 7-8days to 10-12 days depending on the harvest periods or season (Legrand., 1999). In quality control applications, cut test based on the colour changes in cotyledons during fermentation has been considered as good test (Shamsuddin and Dimmick., 1986) when determining the degree of cocoa beans fermentation, along with the formation of brown color (Misnawi et al., 2003).

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). Added to this, small farm holders are aware of what characterizes good quality beans, and they know strategies for obtaining the good quality. Hence, the cocoa farmers produce high quality of cocoa beans which have given them premium prices in the market (Aneani and Takrama., 2004).

Drying is an excellent way to preserve food and solar dryers are appropriate food preservation technology for sustainable development. Drying was probably the first ever food preserving method used by man, even before cooking. It involves the removal of moisture from agricultural produce so as to provide a product that can be safely stored for longer period of time.

To evaluate the drying characteristics of cocoa beans by

a) Tray dryer
b) Solar Cabinet dryer
c) Microwave oven
d) Open sun drying

II. METHODOLOGY

Raw Materials

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. 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 used in 2kg lot for conducting experiment

Variables

1. Independent Variables

1. The Drying Characteristics of Cocoa Beans By
   a. Tray dryer

b. Solar Cabinet dryer
c. Microwave Oven
d. Open Sun Drying
2. Drying Time: 3 days
3. Replications: 3

2. Dependent Variables

1. Moisture Content % (w.b)
2. Composition of FFA, Acetic Acid, pH.
3. Apparatus and Chemicals Used for the Study

The important apparatus used during the study includes the following:

1. Glass Thermometer - The temperature was recorded by using digital thermometer - 50^0C to 300^0C with 0.1 resolutions
2. Hygrometer - The relative humidity of air inside the Tray Dryer is measured using Barigo make hair hygrometer of range 0-100%.
3. Grinding Mill - WILLEY MILL supplied by M. B Instruments, Delhi.
4. Hand Refractrometer - It is used for determining Total Soluble Solids in Cocoa Beans.
5. PH Meter - Digital pH meter (Didisun Electronics, model: DI.707).

III. Determination of Moisture Content

Moisture content of the cocoa beans while drying on each method is measured (AOAC, 1965). The samples are taken in moisture boxes from each lot to determine the moisture content. The boxes were kept in hot air oven at 105^0C$\pm$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:

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

where,

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 safe moisture level of about 6 % to 7.5%.

3.1 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 methods of drying during experiment for each day using the following formula:

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

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

IV. Results and Discussion

Experiments were carried out using four different drying methods viz., Tray dryer, Solar cabinet dryer, Micro oven and Open yard sun drying to evaluate drying performance of the cocoa beans. The drying parameters are determined and comparisons have been made between all the four methods. The effects of the various variables are also studied on each of the drying method.

4.1. Drying

Drying is traditionally defined as that unit operation which converts a liquid, solid or semi-solid feed material into a solid product of significantly lower moisture content. In most cases, drying involves the application of thermal energy, which causes water to evaporate into the vapor phase. The requirements of thermal energy, phase change and a solid final product distinguish this operation from mechanical dewatering, evaporation, extractive distillation, adsorption and osmotic dewatering.

Drying is one of the cheapest and easiest methods for preservation of high moisture foods or fruits. The major advantage of drying food products in the reduction of moisture content to a safe level that allows to extend the shelf life of dried products. Many methods of drying such as air drying, freeze drying, tray drying, solar drying, tunnel drying, spouted bed drying, foam mat drying, osmo-air drying etc. are in industrial practice in India to dry high moisture foods/fruits. Depending on suitability, economical value and quality of end product the method of drying is selected.

4.1.1. Tray drying

The samples of cocoa beans were dried in tray dryer and moisture content was calculated at different drying time intervals as shown in Table 1 and data were analyzed.

Fig. 1 shows that the variation in moisture content against drying time for samples. It was observed that the moisture content of samples decreases with increase in drying time. The drying was carried out at the temperature of 60^0C. The moisture content decreased from 49.35 to 7.5% in total drying period of 8 h respectively.

Table 1. Variation of moisture content against drying time of cocoa beans in tray dryer

Drying time, h	Moisture content (w.b), %
0	49.35
1	32.95
2	21.82
3	18.79
4	14.29
5	8.42
6	7.65
7	7.45

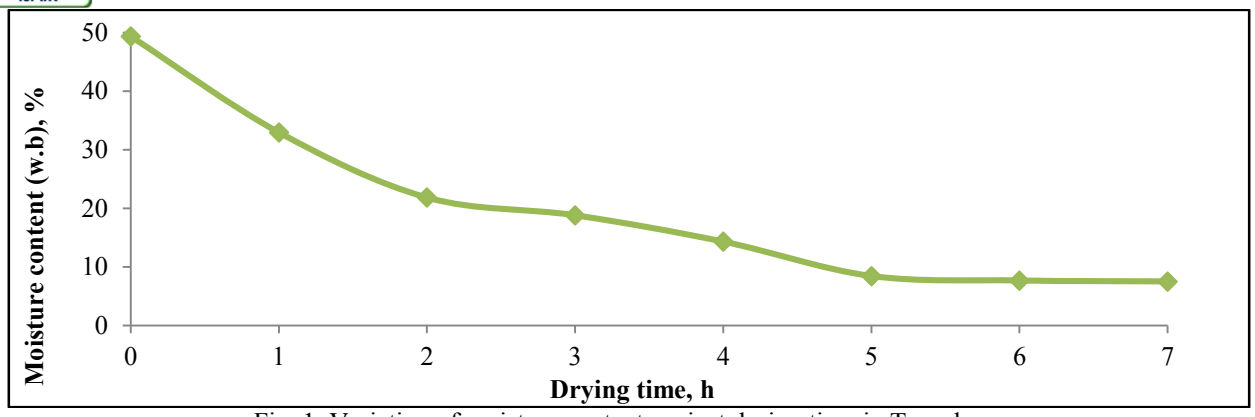

Fig. 1. Variation of moisture content against drying time in Tray dryer

4.1.2. Solar drying

The sample containing 0.5 kg of cocoa beans at 49.88% (w.b) moisture content was taken in to perforated stainless steel trays and placed inside the solar cabinet dryer and the dryer was exposed to sun on the bright sunny day and drying is started from 9.00 AM and continued till 5.00 PM. During drying process, at every 2 h interval, the moisture content of cocoa beans were determined and tabulated as shown in Table 2.

The variation of moisture content with respect to drying time was shown in Fig. 2. The moisture content of samples decreased from 49.88% (w.b) to 6.36% (w.b) in a total drying period of 16 h. From the Fig. 2, it is clear that the moisture content of beans decreased with increase in drying time.

Table 2. Variation of moisture content against drying time of cocoa beans in Solar cabinet dryer

Drying time, h	Moisture content (w.b), %
0	49.88
2	46.82
4	40.49
6	25.00
8	19.33
10	16.38
12	11.21
14	9.84
16	6.36

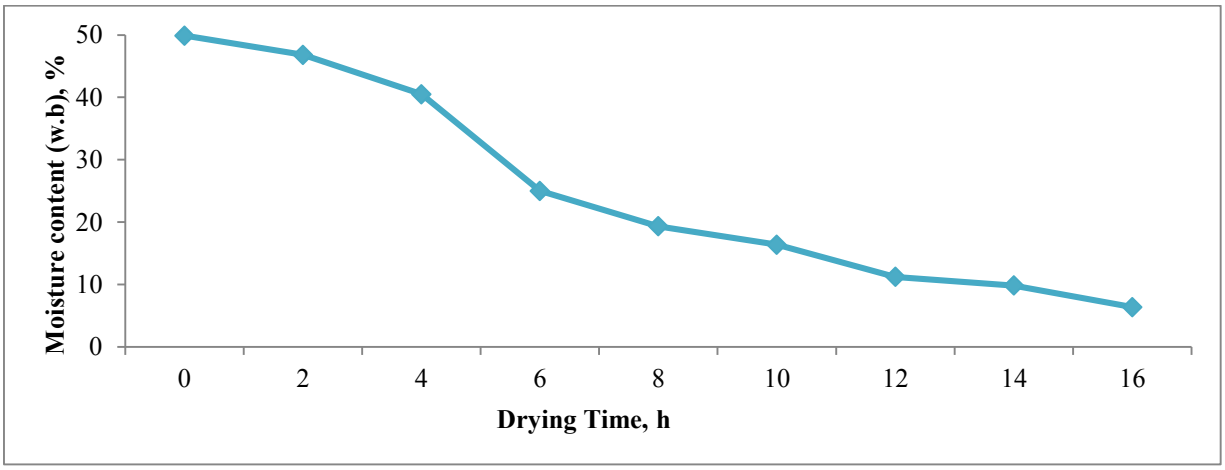

Fig. 2. Variation of moisture content against drying time in Solar cabinet dryer

4.1.3. Micro wave oven drying

The sample containing 0.5 kg of cocoa beans at 49.43% (w.b) moisture content was taken and drying is started from 1.00 PM and continued till 1.10 PM. During drying process, at every 5 min. interval, the moisture content of cocoa beans were determined and tabulated as shown in Table 3.

The variation of moisture content with respect to drying time was shown in Fig. 3. The moisture content of samples decreased from 49.43% (w.b) to 7.59% (w.b) in a total drying period of 10 min. From the Fig. 3, it is clear that the moisture content of beans decreased with increase in drying time.

Table 3. Variation of moisture content against drying time of cocoa beans in Micro wave oven method

Drying Time, min	Moisture content (w.b), %
0	49.43
5	24.76
10	7.59

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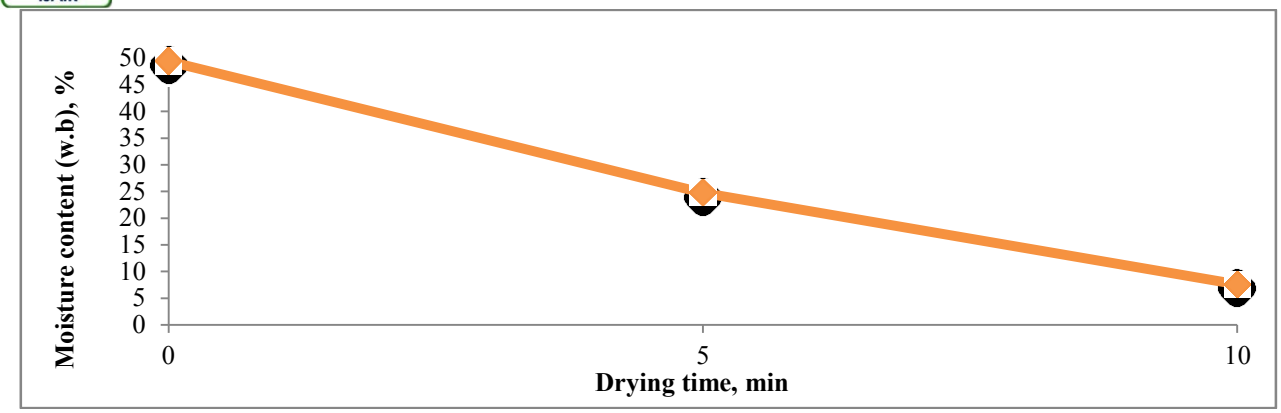

Fig. 3. Variation of moisture content against drying time in Micro oven method of drying

4.1.4 Open yard sun drying

The sample containing about 0.5 Kg of cocoa beans (49.86%) was dried in open sun drying for total period of 30 h. In open sun drying, the sample was kept at 9:00 AM on the sunny day and continued up to 5:00 PM. The partly dried cocoa beans was wrapped in polyethylene cover and kept it room temperature. On the next day, the partly dried beans were again exposed to open sun and it is dried to a final moisture content of 7.14 % (w.b). During drying process at every two hour interval, the moisture content of sample was determined tabulated as shown in Table 4.

Fig. 4 shows the variation of moisture content with respect to drying time and moisture content of samples decreased from 49.86 to7.14% in total drying period of 30 h. From the Fig. 4, it is clear that the decrease in moisture content slowly up to 12 h (34.49%) of drying periods and later it was found faster and it took 30 h time to loose moisture content from 49.86% to 7.14%. Though the different moisture levels, observed after a total drying period of 30h (7.14%), is very small, the drying experiment was continued for another one hour duration at which the dried cocoa beans could be easily made in to powder. As compared to open sun drying, the solar drying method saved about 16 h of drying time besides giving a best quality final product.

Table 4. Variation of moisture content against drying time in Open yard sun drying

Drying time(h)	Moisture content (w.b), %
0	49.86
2	48.89
4	43.65
6	39.63
8	38.87
10	36.10
12	34.49
14	25.33
16	22.64
18	21.32
20	19.72
22	17.48
24	11.11
26	9.74
28	8.57
30	7.14

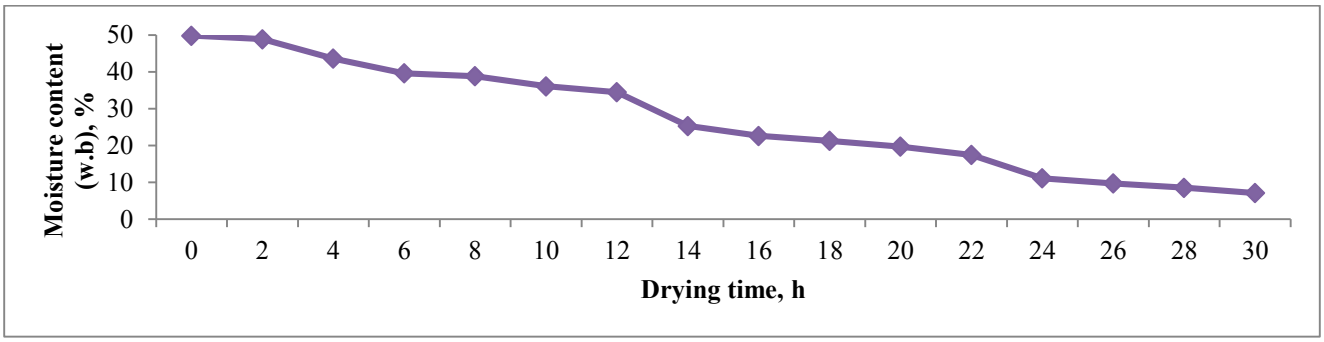

Fig. 4. Variation of moisture content against drying time in Open yard sun drying

Table 5. Final moisture content of cocoa beans and drying time for different drying methods

S. No	Drying methods	Final moisture content (% w.b)	Drying time (h)
1	OYSD (Black Sheet)	7.14	30
2	Tray dryer at 60^0c	7.4	8
3	Micro oven	7.5	0.1
4	Solar cabinet dryer	6.36	16

4.2. Drying Rate

The variations of drying rate with drying time and drying methods are shown in (Fig. 5). The graphs indicate that, drying is taking place in falling rate regime irrespective of type of drying method. The absence of initial constant rate of drying suggests that drying may have occurred both by diffusion and capillary action as observed in most agricultural materials (Chakravarthy., 1987). It is clear that, average drying rate is more in tray dryer followed by solar dryer and open yard sun drying (Fig. 5). The drying rate in microwave oven drying is quite high (Fig 6), suggesting that microwave oven drying is quite fast.

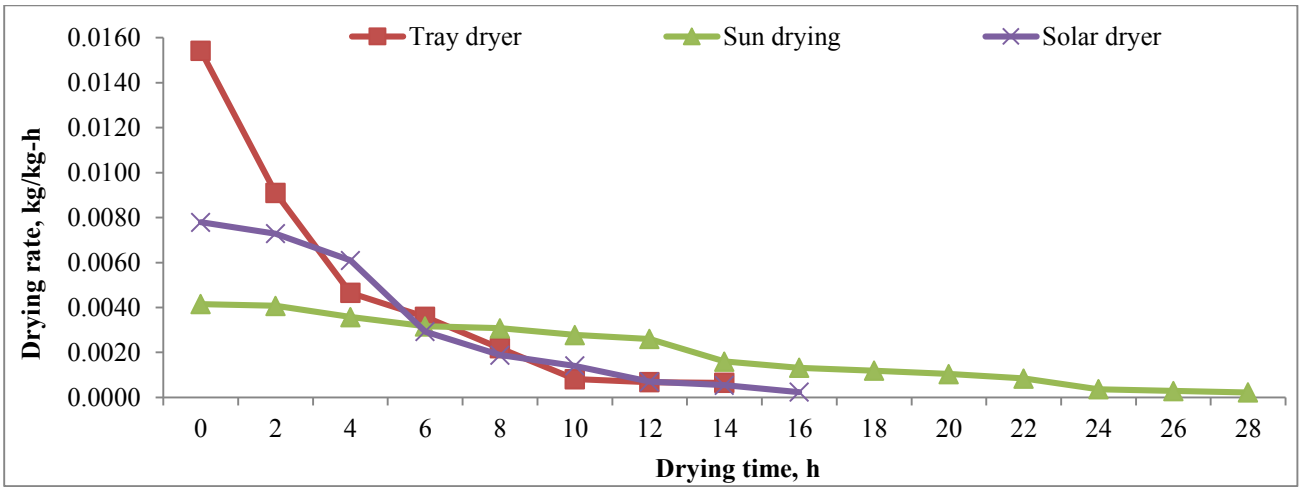

Fig. 5. Variation of drying rate with drying time in different drying methods

The average drying rates for the Tray dryer, solar dryer and open yard sun drying are 0.0046, 0.0032 and 0.0020 kg/kg-h.

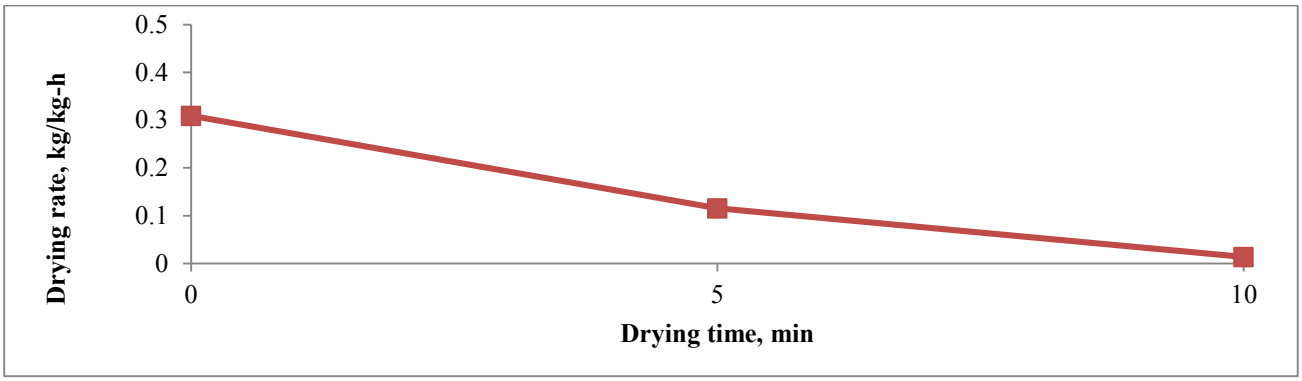

Fig. 6. Variation of drying rate with drying time in Microwave oven method

4.3 Effect of drying method on product quality

4.3.1 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 were 92%, 1%, 1%, 0%, 0%; 97%, 2%, 1%, 0%, 0%; and 95%, 3%, 2%, 0%, 0%,92%,4%,3%,0%,0% tray dryer, solar dryer, micro wave oven, open yard sun drying (Fig. 6 & Table 7).

Table. 6. Comparison of surface mould (%) in cocoa beans dried using different drying methods

Drying method	None	Light	Moderately Heavy	Heavy	Extremely Heavy
Tray dryer	92	1	1	0	0
Solar dryer	97	2	1	0	0
Micro oven	95	3	2	0	0
Open yard sun drying	92	4	3	0	0

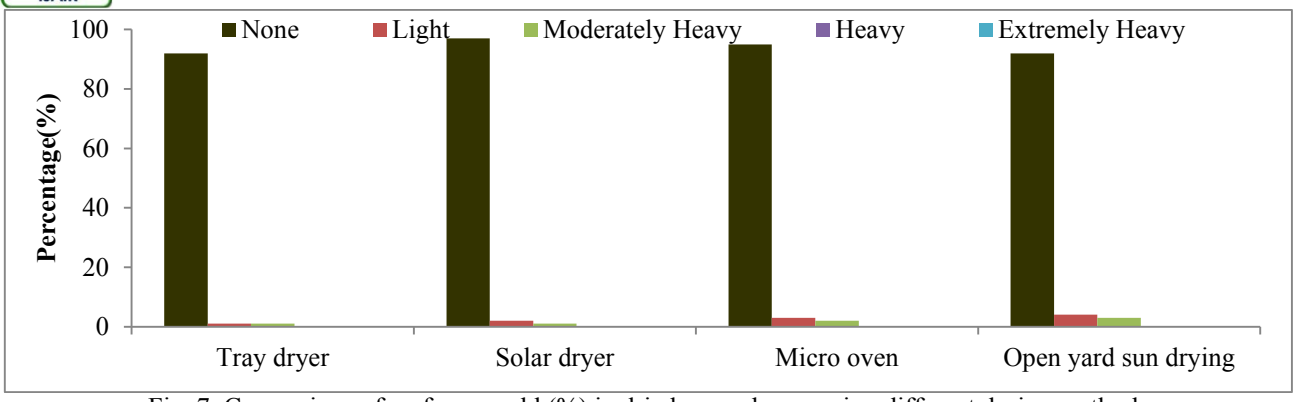

Fig. 7. Comparison of surface mould (%) in dried cocoa beans using different drying methods

4.4 Quality standards

Quality of cocoa is determined by a combination of factors that determine the acceptability of the cocoa to a buyer. These factors include proper fermentation, dried to the proper 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-flavors' and indicates the degree of fermentation of the beans which has a bearing on the flavor 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.

4.4.1 Determination of quality by Cut test

The cut test scores of cocoa beans for different drying methods are shown in Table 7. The cut test score of tray dryer, solar cabinet dryer, Micro oven and Open yard sun drying was found to be 985, 970, 935 and 960 respectively. It is clear that the brown beans obtained in tray dryer were more in comparison to other drying methods.

Table 7. Determination of quality of cocoa beans by using cut test score

Drying method	No of beans	Fully Brown	Partly-Purple-Brown	Fully Purple and Slaty	Cut Test Score
Tray dryer	100	98	1	1	985
Solar cabinet dryer	100	96	2	2	970
Micro oven	100	92	3	5	935
Open yard sun drying	100	95	2	3	960

4.5 Analysis of cocoa beans

The variations of pH, Titratable acidity, Acetic acid, free fatty acids of sample dried in four different methods are shown in Table. 8 The tray drier samples contain high amount of free fatty acids as compared to the solar dryer sample, Microwave oven, Open yard sun drying. Among the four methods i.e. solar cabinet, Microwave oven and Open yard sun drying methods the solar drier samples contain higher amount of acetic acid respectively. The micro wave oven has high content of titratable acidity as compared to tray drier, solar cabinet and open yard sun drying. The pH value was low in open yard sun drying as compared to tray drier, solar cabinet and microwave oven.

From the results of drying experiment, analysis of the cocoa bean powder produced tray dryer followed by solar cabinet dryer and OYSD are considered as better quality product. If drying time is given weightage, then the cocoa bean powder produced in microwave oven may be chosen.

Table 8. Analysis of cocoa beans

	Tray dryer	Solar cabinet dryer	Micro oven	Open Yard Sun drying
PH	5.181	6.251	7.181	5.081
Titratable acidity	67.8	67.6	70.6	65.9
Acetic acid	1.68	1.73	1.68	1.51
Free fatty acids	9.42	7.74	5.49	3.92

V. Conclusions

[1] The time taken for the complete drying in open sun drying was 30 h whereas the time taken for complete drying in solar cabinet and tray dryer was 16 h, 8 h respectively.

[2] The time taken for Tray drier was very short for complete drying and there is saving about 23 h of drying time as compared to open sun drying.

[3] The time taken for Tray drier was very short for complete drying and there is saving about 8 h of drying time as compared to solar cabinet dryer.

[4] There is saving about 14 h of drying time in solar cabinet dryer as compared to open sun drying besides producing a better quality cocoa bean powder having less bacteria and more content Acetic acid, Titratable acidity, pH, Free fatty acids.

[5] The cocoa powder in dryer may be considered as a better quality product for human consumption.

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