

# Assessing drying rates of cacao beans using small samples

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## Introduction

Drying forms a very important part of post-harvest processing in the cocoa production chain. The water content of the bean must be reduced from about 60% at the end of fermentation to less than 8% to obtain beans in good condition for storage and transport (Mossu, 1992). Drying also facilitates a reduction in the bitterness and astringency of the beans, and it encourages the development of the chocolate brown colour characteristic of well-fermented beans. Proper drying also ensures that off-flavours do not develop within the beans (Mossu, 1992).

Extremes of drying rates must be avoided because of the negative impacts they tend to have on the beans. If drying is done too slowly, moulds may develop. This can cause serious problems for industry because of the off-flavours created if the moulds penetrate the testa. If the drying is too rapid however, the oxidation of acetic acid can be prevented and this leads to excess acid trapped within the beans. This acid content will ultimately adversely affect the flavour of the nib.

Drying rate depends on three factors:

- Heat transfer into the bean
- Movement of water vapour into the surrounding air from the bean and,
- The surface area of beans exposed to the air.

To investigate flavour of small samples of beans from a single genotype or treatment, micro-fermentations are carried out in an effort to expose the samples to the same conditions as the larger fermenting mass. In micro-fermentation the bean samples are kept physically separate from the fermentation mass by the use of netted nylon bags. In this way, both sets of beans experience similar conditions. For the drying regime, the same conditions should ideally be experienced by both the small samples and the larger fermented mass. To date, the micro-fermented samples have been dried in small wooden trays on the floor of the cocoa house adjacent to the beans from the fermentation mass that are spread out on the drying floor.

In a 2005 study, drying rate measurements done at San Juan and Manickchand Estates showed that tray dried micro-fermented samples dried twice as fast as those of the floor-dried fermented mass. This creates the possibility for case hardening and acid trapped in the beans of the small samples. This is cause for concern when there are few pods available from the accession used, the quantity of beans is quite small and the drying mass may be only one bean layer thick. The evidence gathered so far has shown that the rate of drying in trays – especially of very small samples – is not representative of the rate of drying of the fermented mass on the floor of the cocoa house.

Two experiments were therefore designed to explore the extent of the problem of drying small samples, and to test possible solutions to it.

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## Methodology

### Experiment 1

*Aim:* To compare the drying rates on the cocoa house floor of beans in nylon net sacks with those of the bulk fermentation mass.

1. Nine 3kg samples of well-fermented wet cocoa (mixed Trinitario beans) were placed into nylon net bags (30cm × 20cm), and labelled according to their location on the drying floor.
2. Three bags were placed at each of 3 locations on the drying floor (one at each end and the other in the middle) within the fermentation mass from which the samples were taken. Beans in the bags were turned in a similar way to the fermentation mass (agitated both laterally and vertically to move the lower beans to the top of the drying mass and upper beans to the bottom layer). The beans were spread out along the length of the bag in such a way as to imitate the thickness of the surrounding layers. In this case, it was about 7 bean layers thick.
3. Sampling from the bags was done at the same time every day (14.00 h).
4. For each day of drying starting from Day 0, 10 beans were removed from each sample bag by emptying the contents into a large plastic bag, shaking it thoroughly for 1 minute, and removing 10 beans in random fashion.
5. For each day of drying starting from Day 0, 10 beans were randomly sampled from the floor at each of the drying positions of the floor (both ends and the middle).
6. This sampling procedure was continued until the 6<sup>th</sup> day of sun drying.
7. All the samples were removed and placed in labelled (sample id and day of drying) snap-seal plastic bags, immediately sealed and put into a mini-cooler to avoid direct sunlight.
8. The samples were then transported to the laboratory at CRU with minimal delay.
9. At CRU, foil boats were prepared and weighed (in grams to 3 decimal places) using an analytical balance (Sartorius).
10. Individual bean samples were then added to the foil boat and the combined weight of container and sample recorded.
11. The weighed samples were then placed in a mechanical convection oven (Shel Lab 1350 FX) set at 135°C.
12. The foil container and sample were weighed every day at the same time until a constant weight was reached. The final weight was recorded.
13. On the final day of sun drying, the moisture content of a 150g sample was measured with a moisture meter (Burrows Digital Moisture Computer 700) using the recommended manufacturer's procedure.

The moisture content of each oven-dried sub-sample was calculated using equation 1:

$$MC = \frac{WWS}{IWW} \times 100 \quad (1)$$

where

Initial weight of wet beans (IWW) = Initial weight of wet beans and container (A) –  
Weight of empty container (B)

Final weight of dried beans (FWD) = Final weight of dried beans and container (C) –  
Weight of empty container (B)  
Weight of water in sample (WWS) = IWW – FWD  
Moisture Content (MC) is expressed as a percentage.

## Experiment 2

*Aim:* To compare response curves for drying rates with different amounts of cocoa in the drying tray.

Two experiments were carried out, one (2a) with large samples (2 and 3 kg) in individual square drying trays, and the other (2b) with small samples (ranging from 50 to 800 g) in multi-celled drying trays.

### *Procedure for experiment 2a*

1. Triplicate sets of 2 kg and 3 kg samples were weighed, and placed in 60 × 60 cm trays the beans were spread out one layer thick.
2. Replicate sets of 2 kg and 3 kg were placed in the halved trays, and the bean samples were left in heaps.
3. The trays were placed in a convenient location on the floor of the drying house.
4. On each day of drying start from Day 0, 10 beans were randomly removed from all four treatments.

### *Procedure for experiment 2b*

1. Samples of well-fermented wet cocoa were weighed to give ten sets each of 50g, 100g, 200g, 400g and 800g. Each set was laid out in a cell 14 cm × 14 cm and 5 cm deep.
2. The bean samples for each mass were spread such that for the smaller masses, the beans were laid out one layer thick and for the larger masses, the beans filled the entire volume of the cells evenly.
3. The trays were placed in a convenient location on the floor of the drying house.
4. On each day of drying starting from Day 0, a 10-bean sub-sample was taken from one of the ten sets for each mass, and labelled according to the mass and the day of drying.

### *Common procedure for experiments 2a and 2b*

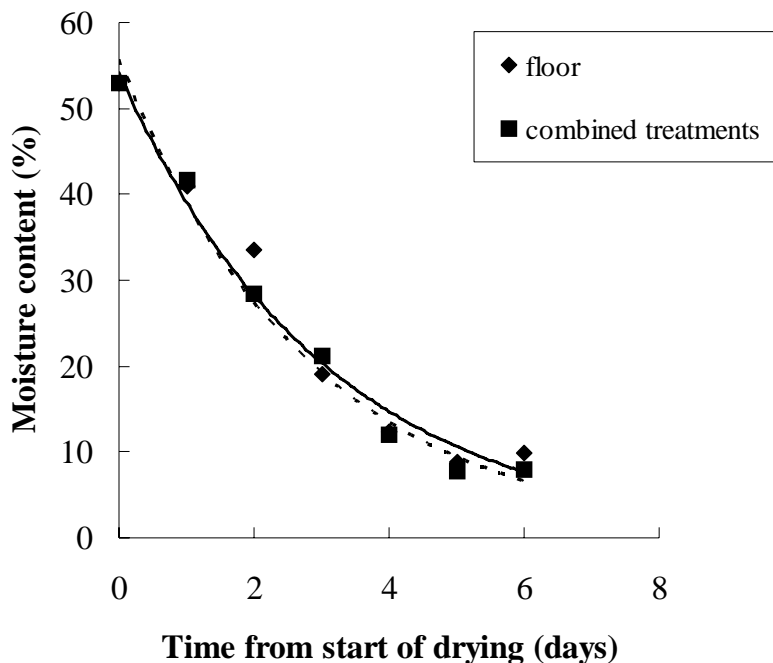
1. For each day of drying starting from Day 0, 10 beans were randomly sampled from the floor at each of three locations (one at each end and one in the middle).
2. The sampling procedure was continued until the 6<sup>th</sup> day of sun drying.
3. All the treatment and floor samples were removed and placed in labelled (sample id and day of drying) snap-seal plastic bags, immediately sealed and put into a mini-cooler to avoid direct sunlight.
4. The samples were transported to the laboratory at CRU with minimal delay.
5. In the laboratory, foil boats were prepared and weighed (in grams to 3 decimal places) using an analytical balance (Sartorius).
6. Individual bean samples were then added to the respectively labelled foil boat and the combined weight of container and sample recorded.

7. The weighed samples were then placed in a mechanical convection oven (Shel Lab 1350 FX) set at 135°C.
8. The foil container and sample were weighed every day at the same time until a constant weight was reached. The final weight was recorded.
9. On the final day of sun drying, the moisture content of a 150g sample was measured with a moisture meter (Burrows Digital Moisture Computer 700) using the recommended procedure.
10. The moisture content of each oven-dried sub-sample was calculated using equation 1 (above).

## Results

### Experiment 1

There was no day by location interaction in the moisture content of samples ( $P = 0.513$ ), and there were no significant difference between bulk floor samples and beans dried in net bags ( $P = 0.243$ ). Since there were no statistically significant differences among the samples from different locations on the floor, the mean moisture content of these samples was calculated for each day. These are plotted together with the moisture content of the fermentation mass in Figure 1.

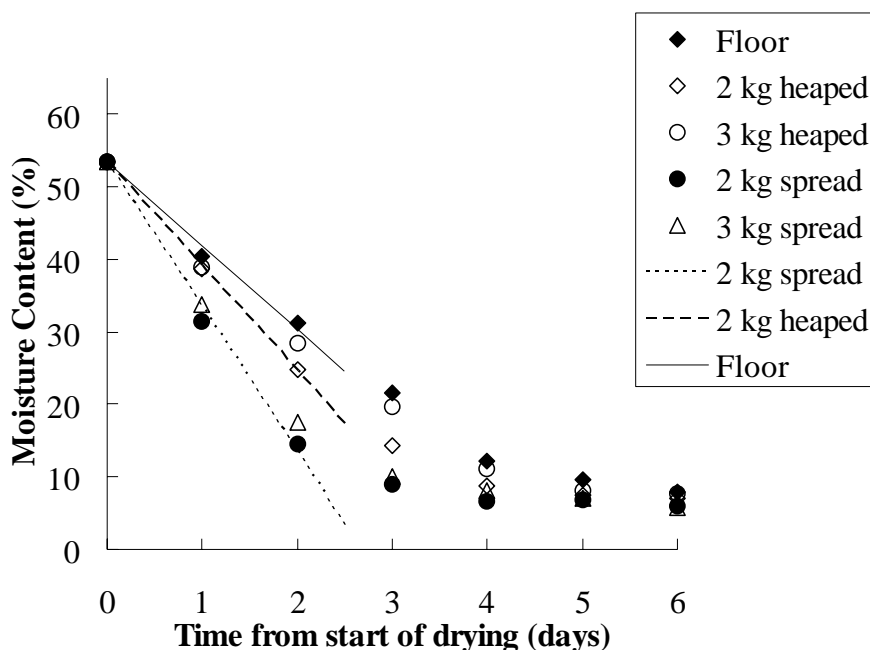


**Figure 1. Comparison of moisture contents of the bulk floor sample and the average of samples in netted bags placed at each end and in the middle of drying floor.**

The moisture content of both the bulk beans and the bagged samples decreased exponentially, reaching a value of about 8% on day 5. For all locations there was no significant change in moisture content from day 5 to day 6 ( $P = 0.686$ ).

### Experiment 2a.

Although all the treatments and the bulk floor samples had reached a similar moisture of 7-8% content by day 6, clear differences were observed in the rate of drying during the first two days (Figure 2). Between the start of drying (day 0) and day 2, the decrease in moisture content was approximately linear, and linear regression lines, with a fixed intercept of the initial value, were fitted to the points over this restricted period. Lines for the bulk floor sample, 2 kg spread and 2 kg heaped are shown in Figure 2 (the other lines are omitted for the sake of clarity), and the slopes of all the lines are given in Table 1 with the coefficients of determination ( $r^2$ ).



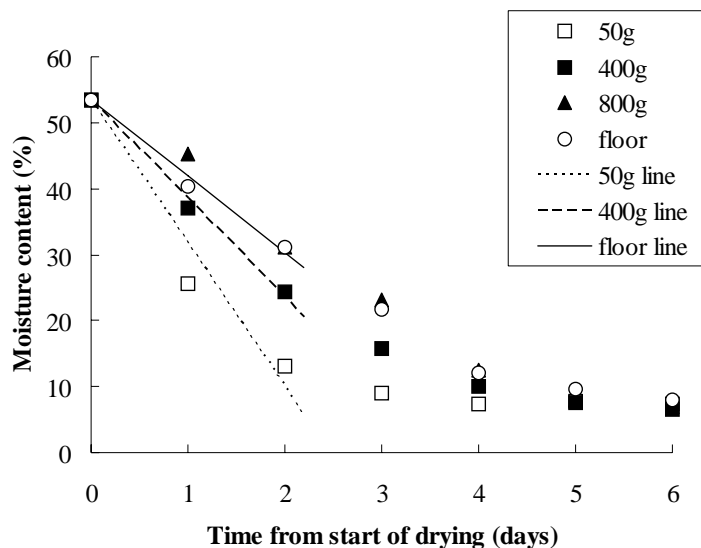
**Figure 2. The change in moisture content with time for the bulk fermentation mass and weighed samples in  $60 \times 60$  cm drying trays on the floor on a cocoa house. Lines were fitted by linear regression of days 0-2 with a fixed intercept of the starting value.**

Significant differences were observed between the drying rates of the heaped and spread samples compared to the floor mass. As seen in Table 1, the 2kg and 3kg spread samples showed the steepest slopes over the first 2 days of drying. Compared to the floor sample, these dried at rates that were 1.7 and 1.6 times faster, respectively. This led to differences of 16.4% and 13.5% between the moisture content of the floor sample and those of the 2kg and 3kg spread samples on day 2, respectively. Drying rates of the 2kg and 3kg heaped samples were much closer to the floor sample (1.3 and 1.1 times faster, respectively). This led to differences of 6.3% and 2.6% between the moisture content of the floor sample and those of the 2kg and 3kg heaped samples on day 2, respectively. Results for the 3kg heaped sample were very similar to the bulk floor sample.

**Table 1. The rate of change of moisture content for cocoa bean samples from day 0-2, given by the slope of regression lines. The treatments compare the bulk floor sample with heaped and spread samples in drying trays.**

Treatment	Slope of line (% per day)	Coefficient of determination	Moisture content on day 2 (%)
Floor	-11.59	0.988	31.0
2kg spread	-20.03	0.992	14.6
3kg spread	-18.33	0.996	17.5
2kg heaped	-14.49	0.9996	24.7
3kg heaped	-12.98	0.990	28.4

Experiment 2b.



**Figure 3. The change in moisture content with time for the bulk fermentation mass and weighed samples in a multi-celled tray on the floor on a cocoa house. Lines were fitted by linear regression of days 0-2 with a fixed intercept of the starting value.**

The final moisture contents for all treatment and the bulk floor samples were also similar moisture (7-8%) by day 6 of experiment 2b. However, clear differences between treatments were observed in the rate of drying during the first two days (Figure 3). Between the start of drying (day 0) and day 2, the decrease in moisture content was approximately linear, and linear regression lines, with a fixed intercept of the initial value, were fitted to the points over this restricted period. Lines for the bulk floor sample, 400 g and 50 g treatments are shown in Figure 3 (the other lines are omitted for the sake of clarity), and the slopes of all the lines are given in Table 2 with the coefficients of determination ( $r^2$ ).

**Table 2. The rate of change of moisture content for cocoa bean samples from day 0-2, given by the slope of regression lines. The treatments compare the bulk floor sample with samples of different sizes in multi-celled drying trays.**

<b>Treatment</b>	<b>Slope of line (% per day)</b>	<b>Coefficient of determination</b>	<b>Moisture content on day 2 (%)</b>
Floor	-11.59	0.988	31.1
50g	-21.73	0.944	13.2
100g	-20.67	0.928	15.1
200g	-19.53	0.982	16.1
400g	-14.99	0.994	24.3
800g	-10.64	0.973	31.1

Clear differences were observed between rate of drying of the floor sample and those for the 50 g, 100 g, 200 g and 400 g samples (they dried 1.9 to 1.3 times faster than the floor sample, Table 2). On the other hand, the 800g sample dried at a similar rate to the floor sample, resulting in almost identical values of moisture content on day 2.

## **Discussion**

These results demonstrate the possibility of large differences between the drying rate for the bulk floor and small samples, especially during the first two days of the drying process. The smaller the bean masses and the thinner the bean layer, the faster the drying rate. Rapid drying rates early in the process are likely to lead to case hardening that would trap acetic acid in the beans (Jinap and Thien, 1994).

The results of Experiment 2a confirm the advantage of arranging the beans in a heap when 2-3 kg samples are being dried. Both the heaped treatments were fairly similar to the bulk floor fermentation mass. It is clear from Figure 2 that, for any sample size, thin bean layers result in drying rates that diverge significantly from that of floor the early in the drying process.

For situations in which small bean samples (<1000g) must be dried, small cells that ensure that the beans are arranged in thick layers would help to achieve optimal drying rates. However, for samples of less than 800g it would be better to avoid the use of small cells.

Experiment one demonstrated that samples in netted bag and placed within the bulk floor fermentation mass dried at a similar rate to the surrounding beans throughout the drying process. This desirable situation would also minimise the disruption of normal activities when drying samples in a commercial estate. The space occupied by the micro-fermentation samples on the house floor would be kept to a minimum, so the use of netted samples instead of drying trays is recommended.

## **References**

Jinap, S. and Thien, J. (1994) Effect of drying on acidity and volatile fatty acids of cocoa beans. *Journal of Science of Food and Agric.* **65**: 67-75.

Mossu, G. (1992) Drying. In: *Cocoa. The Tropical Agriculturalist*. London: Mac Millan. Pages 73-77.

