Quality of cocoa beans dried using a direct solar dryer at different loadings

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Abstract: In this study fermented cocoa beans were dried in a direct solar dryer at three levels of loading (20, 30 and 60 kg). Surface mouldiness was found to be heavy in the 60 kg treatment, with beans appearing blackish. All the dried beans were reasonably acceptable in terms of vinegary odour and weak in alcohol odour. Weak odour and 60 kg treatment was rated strong for wet sock odour due to poor drying condition. A significant difference ($P < 0.05$) was found between the 60 kg treatment and the lower loading treatments for pH and titratable acidity. A cut test showed that the lower loading treatments resulted in a higher percentage of brown beans. The 20 kg treatment showed the highest cut test score, which is significantly different ($P < 0.05$) from the 60 kg treatment. Fermentation index also showed a tendency for lower loading treatments to have a higher index. No significant difference ($P > 0.05$) was found among the treatments in terms of cocoa, astringency, bitterness and sourness flavour notes. However, better flavour was observed for beans from the 20 kg treatment. No mouldy off flavour was found in any of the dried beans. Overall quality assessment showed that the 20 kg treatment was able to produce reasonably good-quality beans as compared to other loadings and therefore is recommended for the direct solar dryer.

Keywords: cocoa; drying; solar dryer; Theobroma cacao L., quality

INTRODUCTION

Sun drying is the most popular method used by Malaysian smallholders to dry cocoa beans. However, the main harvesting season usually coincides with the rainy season and the risk of mould development due to prolonged drying is possible. Labour is often needed to attend to the drying process, especially in the event of rain. Hence the direct solar dryer was developed for smallholders because of its simplicity in design and in operation/maintenance, and ability to dry small quantities. It uses direct sunlight to dry cocoa beans placed inside a transparent enclosure. The transparent enclosure also has the advantage of protecting the cocoa beans from unfavourable weather conditions.

Cocoa beans are usually dried as a thin layer of about one or two beans thick under typical tropical weather when using sun drying. Under favourable and sunny conditions, cocoa beans at two to three beans thick can still be dried without any significant loss in quality, but quality loss will be expected under adverse weather conditions. Low-quality beans are not recommended to be made into finished products owing to the presence of off flavours and microbiological contaminations.

Successful attempts have been made by various researchers to dry cocoa beans in solar dryers. In terms of drying rate and bean quality, no significance difference was found between solar and sun drying.1,3 Studies by Bonaparte et al.2 have shown that beans dried at lower loadings tend to have better colour than those dried at higher loadings when using solar drying. However, at higher loading, acidity was lower due to a slower drying rate.

In this study, direct solar dryer prototypes developed for cocoa smallholders were tested in terms of bean loadings. The quality of dried beans produced was assessed to observe the quality changes that might occur at these loadings.

MATERIALS AND METHODS

Experimental design and analyses

Factorial design was used to assess the effect of wet fermented cocoa loading at 20, 30 and 60 kg, using the direct solar dryer prototype at three replications. In each replication drying was conducted concurrently for all the loadings to minimize variations (weather, raw materials etc.) that might occur during trials. The data obtained from the physical and chemical analyses were analysed for one-way ANOVA and Duncan’s Multiple Range Test using SAS statistical software (Version 8, SAS Institute, Cary, NC, USA) at 95% confidence level.

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Contract/grant sponsor: Ministry of Science, Technology and the Environment (Malaysia); contract/grant number: 01-04-07-0804

Published online 2 May 2006; DOI: 10.1002/jsfa.2475

Preparation of fermented cocoa beans
Fresh cocoa beans were extracted from ripe cocoa pods of PBC clones obtained from Sg. Ruan, Pahang, Malaysia, and fermented in wooden boxes (61 × 91.5 × 30.5 cm) for 120 h with turning after every 48 h.

Drying procedure
Drying started from 8 a.m. to 6 p.m. daily. The beans were mixed manually every 2 h for the first day or until superficially dried and every 4 h thereafter until the moisture content of the nib reached 7.5%. Determination of moisture content was done on a wet basis according to Malaysian Standard MS 293.4 Samples were taken every 24 h (200 g) before mixing for analyses.

The solar dryer
The solar dryer prototype consists of two sections, namely the drying platform and the transparent enclosure (Fig. 1). The drying platform was constructed with 1 cm thick plywood measured 153 × 91.5 cm (length × width) and elevated 70 cm above ground level. Holes measuring 1 cm in diameter were drilled and arranged in a 2 cm square pitch at the drying platform. The transparent material used for the enclosure was ultraviolet-stabilized polyethylene film. Apertures measuring 10 × 153 cm were made at the apex, and side apertures measuring 136 × 0.5 cm were made along the wooden planks below the transparent windows to facilitate air movement.

Cut test
This was carried out according to the Malaysian Standard MS 293.4 Three hundred pieces of dried cocoa beans were cut lengthwise through the middle using a penknife. Both halves of each bean were examined visually in full daylight by an experienced cocoa grader according to the cross-sectional colour of the beans, namely fully brown, partly purple-brown, fully purple and slaty, based on a standard colour chart. The percentage count of each colour note was calculated for the cut test score (CTS) as shown below:

\[ CTS = (10 \times \% \text{ fully brown}) + (5 \times \% \text{ partly purple brown}) + (0 \times \% \text{ fully purple and slaty}) \]

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. Three predefined bean samples rated at none, moderately heavy and extremely heavy levels were given as references to the trained panels for comparison during visual assessment.

Odour assessment
The dried cocoa beans were assessed qualitatively for vinegary, alcohol, faecal, rancid, cheesy and wet sock odours at levels such as none, weak, moderately strong, strong and extremely strong. Each level was based on the odour intensity of the dried bean, ranging from none (0%) to extremely strong (100%) at 25% intensity interval. Two predefined samples rated at none and extremely strong levels for each odour were given as references to the trained panels for comparison during odour assessment.

Sensory evaluation of cocoa liquor
Cocoa beans (500 g) were processed using a laboratory winnower and breaker (John Gordon, UK) to obtain the cocoa nibs. The nibs were roasted in an oven (Memmert, Germany) at 140 °C for 35 min and cooled.

Figure 1. Construction drawing of the solar dryer prototype.
Quality of cocoa beans dried using a direct solar dryer

Ground nibs (5 g) were homogenized in 45 mL boiled distilled water. The homogenate was filtered with Whatman No. 4 filter paper and cooled to 20–25 °C. pH was determined using a pH meter (Mettler Toledo, Columbus, OH, USA). This measurement was taken daily in triplicate.

Titratable acidity (TA)
The nib TA was determined according to the AOAC.5 About 25 mL of the aliquot collected for pH determination was titrated drop by drop with 0.1 M NaOH to pH 8.1, determined using a pH meter (Mettler Toledo). This measurement was taken daily in triplicate.

Fermentation index (FI)
This was determined according to the method of Gur’eva and Tservevitinov.6 Ground cocoa nibs (0.5 g) were added to a mixture of methanol and HCl (concentration 37%) at a volume ratio of 97:3 and homogenized. The mixture was left in the cold room (temperature 8 °C) for 16–18 h and filtered using Whatman No. 1 filter paper. The filtrate was collected and the ratio of the absorbance at 460 nm and 530 nm was determined using a UV-visible spectrophotometer (Shimadzu, Japan).

RESULTS AND DISCUSSION

Surface mould of dried beans
Mouldiness on the bean surface was found to be light in the 20 kg loading, moderately heavy in the 30 kg loading and extremely heavy in the 60 kg loading, as rated by majority of the panels (Fig. 2). The none to light level of mouldiness in the 20 kg loading is expected, as drying was conducted in a shorter period (5 days) as compared to the 30 kg (7.5 days) and 60 kg (9.5 days) loading as measured. Mouldiness was highest in the 60 kg loading due to poor drying conditions, which favoured surface mould growth. The beans also appeared blackish on the surface, with a putrid odour detected. It was noted that water vapour condensed within the bed of the beans in the early morning and hence resulted in a longer drying time.

Odour of dried beans
Results of the odour assessment are shown in Table 1. The vinegary odour, which is attributed to acetic acid, was rated much weaker in the 60 kg loading by a majority of the panels as compared to the other loadings. This was due to the longer drying period, which allowed sufficient time for the evaporation of the acetic acid. The rating was mostly between the weak and moderately strong level in the 20 kg loading and between moderately strong and strong level in the 30 kg loading. In terms of alcohol type odour, which is attributed to ethanol, the majority of the panels rated the beans as weak in all the loadings. The ethanol formed evaporated easily during drying, due to the volatile nature of the compound.

In terms of faecal odour, the majority of the panels could not detect this odour from beans of 20 kg and 60 kg loading. The rating was almost distributed equally from none to moderately strong level in the 30 kg loading. This odour is attributed to butyric acid.7 A rather similar trend was also observed for the rancid odour, which is attributed to combination of butyric and isovaleric acids.7 This odour was detected mostly at the weak level and below in the 20 kg and 60 kg loading.

In terms of cheesy odour, most of the panel detected this odour at a weak level from the cocoa beans of 20 kg loading but rated from weak to strong level for those of 30 kg and 60 kg loading. The cheesy odour is attributed

Figure 2. Effect of loading of cocoa beans on the level of surface mould development on dried cocoa beans in the direct solar dryer prototypes.
Table 1. Effect of loading of wet cocoa beans in the direct solar dryer prototypes on the odours of dried cocoa beans

<table>
<thead>
<tr>
<th>Odour</th>
<th>Loading</th>
<th>None</th>
<th>Weak</th>
<th>Moderately strong</th>
<th>Strong</th>
<th>Extremely strong</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegary</td>
<td>20 kg</td>
<td>10</td>
<td>40</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>30 kg</td>
<td>0</td>
<td>10</td>
<td>60</td>
<td>30</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60 kg</td>
<td>0</td>
<td>60</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Alcohol</td>
<td>20 kg</td>
<td>30</td>
<td>60</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>30 kg</td>
<td>10</td>
<td>50</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60 kg</td>
<td>20</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Faecal</td>
<td>20 kg</td>
<td>70</td>
<td>20</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>30 kg</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60 kg</td>
<td>70</td>
<td>20</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Rancid</td>
<td>20 kg</td>
<td>30</td>
<td>60</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>30 kg</td>
<td>20</td>
<td>40</td>
<td>30</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60 kg</td>
<td>50</td>
<td>40</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Cheesy</td>
<td>20 kg</td>
<td>20</td>
<td>60</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>30 kg</td>
<td>10</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60 kg</td>
<td>10</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Wet sock</td>
<td>20 kg</td>
<td>20</td>
<td>40</td>
<td>20</td>
<td>20</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>30 kg</td>
<td>20</td>
<td>40</td>
<td>30</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60 kg</td>
<td>10</td>
<td>30</td>
<td>10</td>
<td>50</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2. Effect of loading on duration of drying using the solar dryer prototype

<table>
<thead>
<tr>
<th>Loading (kg)</th>
<th>Duration of drying (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>5.0a</td>
</tr>
<tr>
<td>30</td>
<td>7.5a,b</td>
</tr>
<tr>
<td>60</td>
<td>9.5b</td>
</tr>
</tbody>
</table>

Mean values having a common letter within the same column are not significantly different according to Duncan’s multiple range test at the 5% level.

Table 3. Effect of loading of wet cocoa beans in the solar dryer prototype on dried cocoa beans pH and titratable acidity

<table>
<thead>
<tr>
<th>Loading (kg)</th>
<th>Before drying</th>
<th>After drying</th>
<th>Before drying</th>
<th>After drying</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>4.64a</td>
<td>5.10a</td>
<td>25.75a</td>
<td>17.80a</td>
</tr>
<tr>
<td>30</td>
<td>4.64a</td>
<td>4.91a</td>
<td>25.75a</td>
<td>18.57a</td>
</tr>
<tr>
<td>60</td>
<td>4.64a</td>
<td>5.39b</td>
<td>25.75a</td>
<td>13.30b</td>
</tr>
</tbody>
</table>

Mean values having a common letter within the same column are not significantly different according to Duncan’s multiple range test at the 5% level.

The pH and titratable acidity of the dried beans are shown in Table 3. The pH of the dried samples ranged from 4.91 to 5.39 with an initial pH of 4.64, showing a significant difference among the treatments ($P < 0.05$). pH was significantly higher in the 60 kg loading than in 20 kg and 30 kg loadings. However, pH was not significantly different between the 20 kg and 30 kg loadings.

A similar trend was observed in the titratable acidity of the dried beans. Average titratable acidity of the dried beans ranged from 13.30 to 18.57 meq NaOH.
100 g, with an initial value of 25.75 meq NaOH 100 g. The 60 kg loading showed significantly lower titratable acidity \((P < 0.05)\) compared to the other loadings. Higher loading generally causes drying to progress more slowly and enables sufficient evaporation and balanced diffusion of the free liquid, which contained dissolved acids, from the testa and from the nib.\(^7\)\(^8\) However, the beans could be over-fermented as putrid ammonia smell was detected due to poor drying conditions.\(^7\)

The acidity of the beans obtained from the 20 kg and 30 kg loadings were also slightly better than those reported by Bonarparte \textit{et al.}\(^2\) for solar dried beans of pH in the range 4.78–4.81 and titratable acidity in the range of 22.38–23.03 meq NaOH 100 g.

**Cut test score and fermentation index**

Overall evaluation of the bean surface colour (Table 4) showed that the 20 kg loading yielded the lowest percentage of purple colour (7.21%) but the highest percentage of brown colour (77.65%) and vice versa. The cut test scores showed that beans from the 20 kg loading obtained the highest score (CTS = 842.53) and was significantly different \((P < 0.05)\) from the 60 kg loading (CTS = 600). The score obtained from the 20 kg loading was also better than those reported by Bonarparte \textit{et al.}\(^2\) for cocoa drying using direct...
Table 4. Effect of loading of wet cocoa beans in the solar dryer prototype on dried cocoa bean surface colour, cut test score (CTS) and fermentation Index (FI)

<table>
<thead>
<tr>
<th>Loading (kg)</th>
<th>Slaty</th>
<th>Purple</th>
<th>Purple/brown</th>
<th>Brown</th>
<th>CTS</th>
<th>FI</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.14a</td>
<td>7.21a</td>
<td>13.20a</td>
<td>77.65a</td>
<td>842.53a</td>
<td>1.33a</td>
</tr>
<tr>
<td>30</td>
<td>1.00a,b</td>
<td>17.67a,b</td>
<td>21.33a</td>
<td>54.34a,b</td>
<td>673.30a,b</td>
<td>1.05a</td>
</tr>
<tr>
<td>60</td>
<td>0.00b</td>
<td>27.67b</td>
<td>26.00a</td>
<td>49.34b</td>
<td>600.00b</td>
<td>1.07a</td>
</tr>
</tbody>
</table>

Mean values having a common letter within the same column are not significantly different according to Duncan’s multiple range test at the 5% level.

Solar dryer (CTS = 576.8) and indirect solar dryer (CTS = 590.3). This showed that at lower loading the beans were better aerated and sufficient oxygen ensured better activity of the polyphenol oxidase.9

FI values were obtained in the range 1.05–1.33 (Table 4). In general, fully fermented beans have an FI value greater than 1, which indicates that the beans were fully fermented.6 No significant difference was found (P > 0.05) among the treatments based on the FI values. However, the values obtained showed a tendency for the lowest loading (20 kg) to have a higher FI value (1.33) and vice versa. This is consistent with the results obtained from the cut test scores.

Sensory evaluation of cocoa liquor

Results of the sensory evaluation of cocoa liquor using a Ghanaian reference sample is shown in Fig. 4.

In terms of cocoa flavour, no significant difference (P > 0.05) was found among the treatments. However, results indicated the tendency for the sensory panels to award a higher score for the 20 kg loading as compared to the 60 kg loading. This is consistent with the highest cut test score and FI recorded in the 20 kg loading treatment. No significant difference was found (P < 0.05) among the treatments in terms of bitterness. However, results showed the tendency for the sensory panels to award a lower, and hence better, score for the 20 kg loading as compared to the 60 kg loading. This is due to better oxidation of the polyphenol by the polyphenol oxidase at the lower loading.

Astringency scores among the treatments followed a similar trend to bitterness. No significant difference was found (P < 0.05) among the treatments but the samples were quite comparable to the Ghanaian reference. There is a tendency for the sensory panel to award a lower, and hence better, score for the 20 kg loading as opposed to the 60 kg loading. This agrees well with the bitterness scores of the samples.

In terms of sourness, no significant difference was found (P < 0.05) among the treatments. The sensory panels detected no mouldy off flavour among the samples. Mouldiness occurs when beans are not

Figure 4. Effect of loading of wet cocoa beans in the direct solar dryer prototype on the sensory evaluation of cocoa liquors obtained from dried cocoa beans. Mean values having a common letter within the same flavour note are not significantly different according to Duncan’s multiple range test at the 5% level.
sufficiently dried, are badly fermented and stored under unfavourable conditions. During the trials, the beans were properly fermented and were sufficiently dried below 7.5% moisture content. Although external mouldiness on the bean surface was observed during drying, especially in the 60 kg loading, this is restricted to the external surface, while the nib is free from this contamination.

CONCLUSION
Overall results indicated that loading of 20 kg fermented cocoa beans is recommended for the solar dryer prototype. At this quantity, the duration of drying was shorter and this reduces the risk of putrefactive development in the beans due to adverse weather. The dried beans had a good appearance and odour and were extremely light in surface mould. This will serve as good quality indicators for cocoa buyers when sourcing for cocoa beans from smallholders. The high cut test score and fermentation index resulted in beans with acceptable flavours as assessed in liquor sensory evaluation.

ACKNOWLEDGEMENT
This research project was funded by the IRPA Research Grant (project no. 01-04-07-0804) from the Ministry of Science, Technology and the Environment.

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