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 was also detected for the faecal, rancid and cheesy odours. The 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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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:

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

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

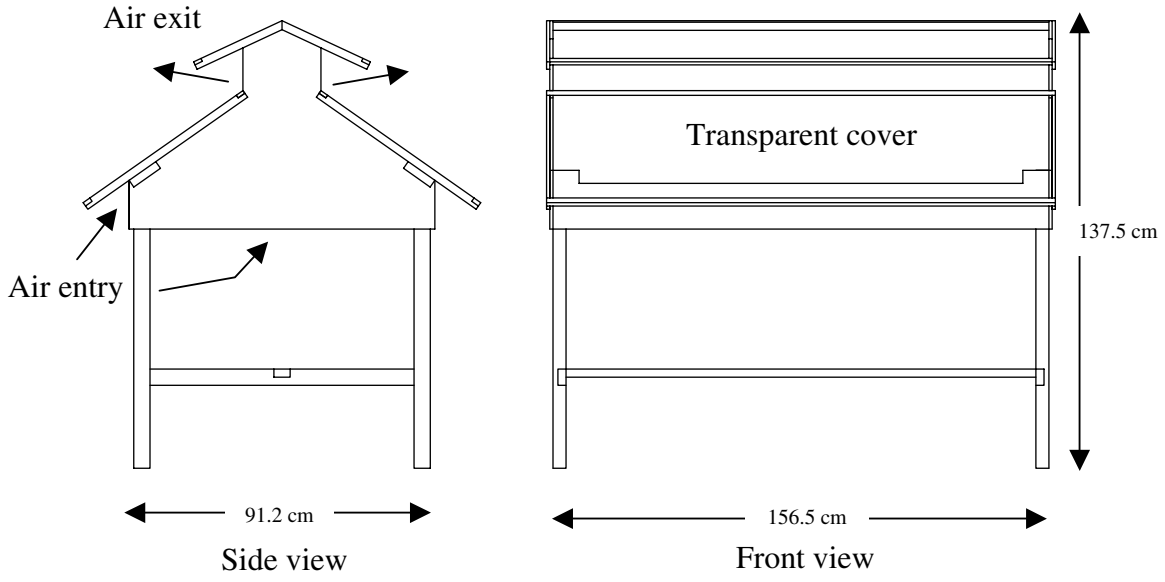

Figure 1. Construction drawing of the solar dryer prototype.

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at room temperature. The roasted nibs were then ground in a laboratory mortar and pestle mill (Pascal Engineering, UK) for 3 h to obtain the cocoa liquor. Ghanaian cocoa liquor was used as reference. The sensory evaluation was conducted by 10 trained panels from the Malaysian Cocoa Board.

pH

The nib pH was determined according to the AOAC.[5] 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 Tserevitinov.[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

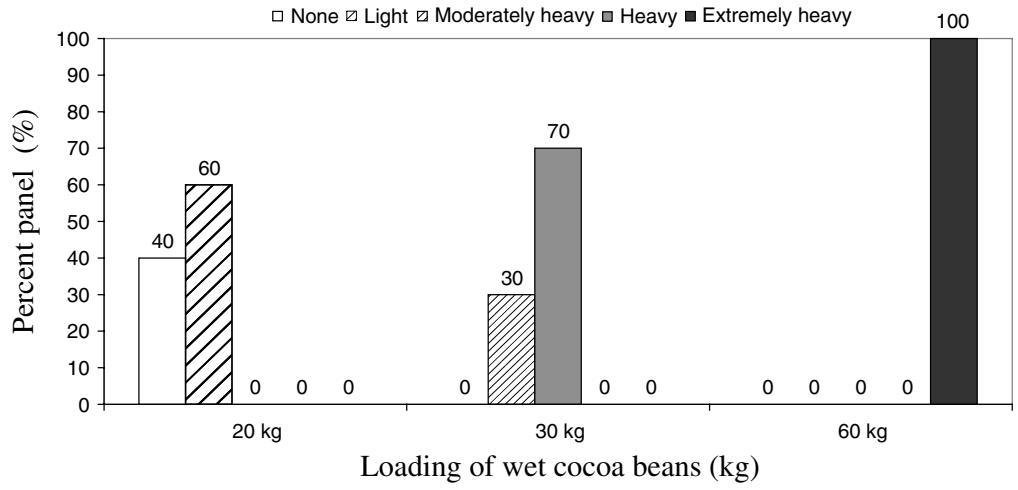

Figure 2. Effect of loading of cocoa beans on the level of surface mould development on dried cocoa beans in the direct solar dryer prototypes.

Table 1. Effect of loading of wet cocoa beans in the direct solar dryer prototypes on the odours of dried cocoa beans

		Percent panels (%)					
Odour	Loading	None	Weak	Moderately strong	Strong	Extremely strong	Total
Vinegary	20 kg	10	40	50	0	0	100
	30 kg	0	10	60	30	0	100
	60 kg	0	60	10	20	10	100
Alcohol	20 kg	30	60	0	10	0	100
	30 kg	10	50	20	20	0	100
	60 kg	20	80	0	0	0	100
Faecal	20 kg	70	20	10	0	0	100
	30 kg	30	30	40	0	0	100
	60 kg	70	20	10	0	0	100
Rancid	20 kg	30	60	0	10	0	100
	30 kg	20	40	30	10	0	100
	60 kg	50	40	0	10	0	100
Cheesy	20 kg	20	60	20	0	0	100
	30 kg	10	40	30	20	0	100
	60 kg	10	40	30	20	0	100
Wet sock	20 kg	20	40	20	20	0	100
	30 kg	20	40	30	10	0	100
	60 kg	10	30	10	50	0	100

to the combination of propionic and isovaleric acids. The concentration of propionic acids would generally reduce as drying progresses.[7]

In terms of wet sock odour, which is attributed to isobutyric acid, the rating was distributed between the none and strong levels in all treatments. However, the 60 kg loading was rated at the stronger level due to the poor condition of drying at a thicker layer. A higher concentration of isobutyric acid has been reported for shade-dried beans, which dried under poor conditions, as opposed to sun-dried beans.[7]

Drying curve

The drying curves of the solar dryers at different loadings, from three replications, are shown in Fig. 3. Initial nib moisture content was in the region 39.5–41.6%; drying to less than 7.5% must be achieved for commercial trading. Figure 3 shows that drying rate was slowest in the 60 kg loading, followed by the 30 kg and 20 kg loadings. Statistical analyses (Table 2) showed that there was a significant difference ($P < 0.05$) between the drying durations of the 20 kg and 60 kg loadings. No significant difference was observed between the drying durations of the 20 kg and 30 kg loadings. Duration of drying was extended by 50% and 90% in 30 kg and 60 kg loadings, respectively, with reference to the 20 kg loading. In order to reduce the risk of deterioration due to prolonged drying, a shorter drying duration is more suitable to smallholders because of the small harvesting quantity.

pH and titratable acidity

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

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

Loading (kg)	Duration of drying (days)
20	5.0a
30	7.5a,b
60	9.5b

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

	pH		Titratable acidity (meq NaOH 100^{-1} g)	
Loading (kg)	Before drying	After drying	Before drying	After drying
20	4.64a	5.10a	25.75a	17.80a
30	4.64a	4.91a	25.75a	18.57a
60	4.64a	5.39b	25.75a	13.30b

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.

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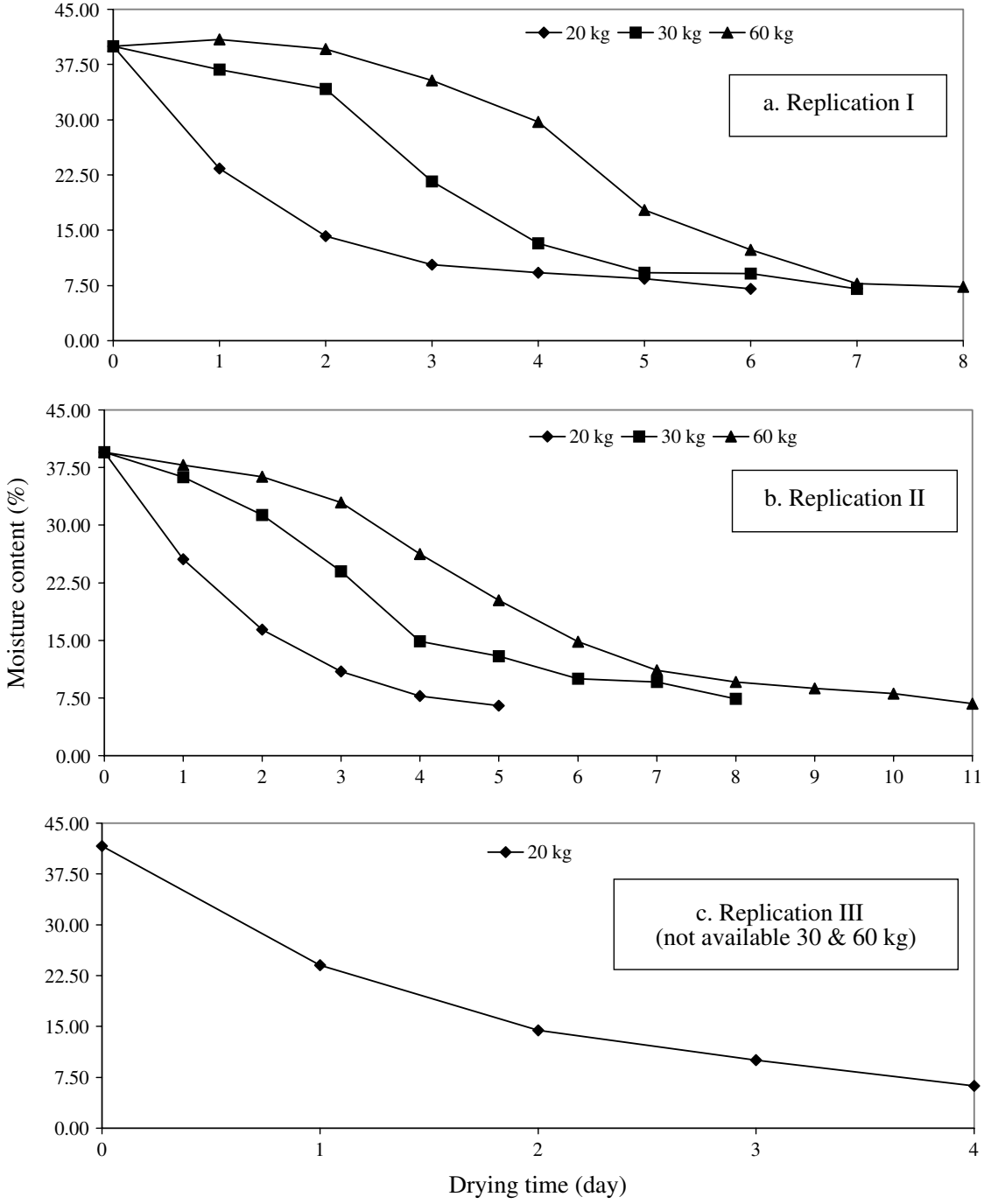

Figure 3. Effect of loading on moisture content profile using the solar dryer prototype.

100^{-1} g, with an initial value of 25.75 meq NaOH 100^{-1} 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 *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^{-1} 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 *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)

	Cocoa bean surface colour (%)					
Loading (kg)	Slaty	Purple	Purple/brown	Brown	CTS	FI
20	1.14a	7.21a	13.20a	77.65a	842.53a	1.33a
30	1.00a,b	17.67a,b	21.33a	54.34a,b	673.30a,b	1.05a
60	0.00b	27.67b	26.00a	49.34b	600.00b	1.07a

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.

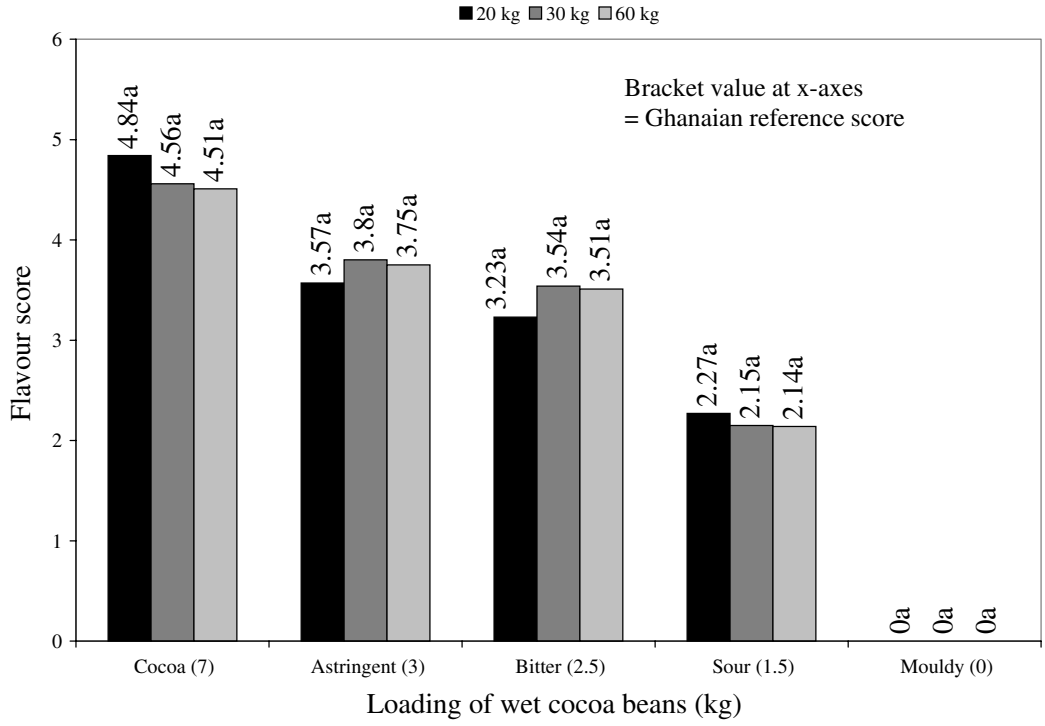

Figure 4. Effect of loading of wet cocoa beans in the direct solar dryer prototype on the sensory evaluation of cocoa liquors obtained from dried cocoa beans. Mean values having a common letter within the same flavour note are not significantly different according to Duncan's multiple range test at the 5% level.

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

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sufficiently dried, are badly fermented and stored under unfavourable conditions.[10] 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.

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