J.Natn.Sci.Foundation Sri Lanka 2016 44 (4): 359 - 365
DOI: http://dx.doi.org/10.4038/jnsfsr.v44i4.8018

RESEARCH ARTICLE

Evaluation of single bed and multi bed dried copra on the quality of extracted coconut oil

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Revised: 03 February 2016; Accepted: 17 March 2016

Abstract: Single bed and multi bed drying of copra was evaluated using a hybrid dryer with three compartments. A high percentage (> 75 %) of white copra resulted in single bed drying at low temperatures (< 60 °C), while a comparatively lower percentage (< 22 %) of white copra resulted from multi bed drying. The percentages of white and light brown copra in the bottom, middle and top beds of the multi bed dryer were 85.0 %, 93.8 % and 91.3 %, respectively. A high production rate per unit cross sectional area of 2.06 kg/h could be achieved with multi bed drying as compared to single bed drying (0.90 kg/h at 55 °C and 0.97 kg/h at 60 °C). The specific moisture extraction in multi bed drying was 0.112 kg/kWh as compared to 0.064 kg/kWh at 55 °C and 0.065 kg/kWh at 60 °C in single bed drying. The oil extracted from both white and light brown copra was comparable with the Sri Lanka Standards for virgin coconut oil except the notably higher content of free fatty acids (FFA).

Keywords: Coconut oil, copra, hybrid dryer, multi bed drying.

INTRODUCTION

From ancient times coconut oil has been commonly used as an edible oil in tropical countries. It is mainly used in the food industry and in many non-food applications such as in the production of pharmaceuticals and cosmetics (Sashya *et al*., 2012). The oil can be extracted from either wet or dry coconut kernels and these extraction processes are named dry or wet processes accordingly. Dry processing with mechanical expellers is the most widely used method of extracting oil in many countries (Canapi *et al*., 2005; Krishna *et al*., 2010). In the dry process, the quality of coconut oil is affected by the quality of copra, which is mainly dependent on the method of drying; hot air drying, sun drying or kiln drying. The moisture content of copra needs to be reduced to around 7 % to make good quality copra (Mohanraj & Chandrasekar, 2008a). A high moisture content increases the free fatty acid (FFA) content, decreases oil recovery and causes rancidity in oil. Contamination by aflatoxin is also possible with the high moisture content in copra (Rodrigo *et al*., 1996; Marinaa *et al*., 2009).

Direct contact of copra with smoke and burnt gases in the kiln drying process causes the deposition of polycyclic aromatic hydrocarbons (PAH) on the kernel of the copra (Rodrigo *et al*., 1996; Wijeratne *et al*., 1996). Aflatoxin and PAH in copra can be transferred to coconut oil during the extraction process (Guarte *et al*., 1996). The colour of coconut oil is strongly affected by the colour of copra. The copra becomes brown due to direct contact with smoke during kiln drying and brown copra gives brown coconut oil. In Sri Lanka, the majority of copra is produced by kiln drying and the quality of copra varies with the skill of the operator and with climatic conditions (Rodrigo *et al*., 1996). Indirect hot air drying is a better alternative to kiln drying. It can produce good quality copra since it prevents smoke deposition and the colour of copra is mostly white or light brown (Satter, 2003; Thanaraj *et al*., 2007; Mohanraj & Chandrasekar, 2008b).

Although high temperatures increase the rate of drying, they result in brown copra and also causes case hardening of copra. Case hardening is the formation of a hard outer layer on the coconut kernel, which restricts the passage of moisture from the interior to the surface (Guarte *et al*., 1996). The maximum temperature for drying copra without quality deterioration was found to be in the range of 60 – 70 °C. Thanaraj *et al*. (2004) suggested an optimum temperature of 60 °C, while Mohanraj and Chandrasekar (2008a) reported a maximum drying temperature of 63 °C. Although relative

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humidity and velocity of air also affect the drying rate of copra, the effect is not as considerable as the effect of temperature (Satter, 2001). An air velocity of 0.5 ms^{-1} has been recommended by Guarte *et al*. (1996) for industrial scale copra drying while Mohanraj and Chandrasekar (2008a) reported an optimum velocity of 1.2 ms^{-1}.

Multi bed drying is a preferred option as a postharvest treatment due to the high recovery of heat energy from hot air. However, maintaining a uniform temperature gradient and drying conditions within the drying chamber is always a challenge. The objective of the present study was to compare single bed drying with multi bed drying of copra, and evaluate the quality of copra and coconut oil under different drying conditions.

METHODOLOGY

Hybrid dryer

A pilot scale hybrid dryer consisting of a solar collector, a biomass stove-heat exchanger unit and a drying chamber was used for the drying experiments (Figure 1). The drying chamber and the heat exchanger were connected through a one (01) horsepower centrifugal blower to provide the necessary air flow to the drying chamber. Air was initially heated in the solar collector before it was passed through the stove-heat exchanger unit. The hot air temperature was controlled with an accuracy of ± 5 °C by incorporating a bypass line to supply ambient air in between the drying chamber and the heat exchanger. Further, a gate valve was fixed at the outlet of the heat exchanger to regulate the air flow rate through the dryer.

Drying chamber

A vertical drying chamber (600 × 600 × 1350 mm) was used to store copra in three compartments as shown in Figure 1. Hot air was allowed to pass from the bottom compartment to the top compartment. The chamber was designed to store around 360 dehusked coconut halves, equally distributed. Drying trays were made out of 25.4 × 25.4 mm iron mesh. Each compartment was provided with a separate door for loading and unloading of materials. A trapezoidal plenum chamber was fixed below the first drying compartment to maintain proper distribution of inlet air. The outlet of the drying chamber was also fitted with a trapezoidal chamber to guide exhaust air out to the exterior. The outer box of the chamber was made of 1 mm thick iron sheets and lined with 25 mm glass wool. The supporting frame was made with L-iron (38.1 × 38.1 mm). Hollow aluminium tubes of diameter 10 mm were inserted through the walls of the chamber to insert temperature probes to measure the temperature in each compartment.

Experimental procedure

Single bed drying

Single bed drying was performed at two different drying temperatures to determine the drying characteristics of copra. In each experiment, exactly 120 dehusked coconut halves of fully matured coconuts were loaded into the lower compartment of the drying chamber. After 24 – 26 hrs of continuous heating, the copra was allowed to cool for 4 hrs in order to avoid case hardening, which

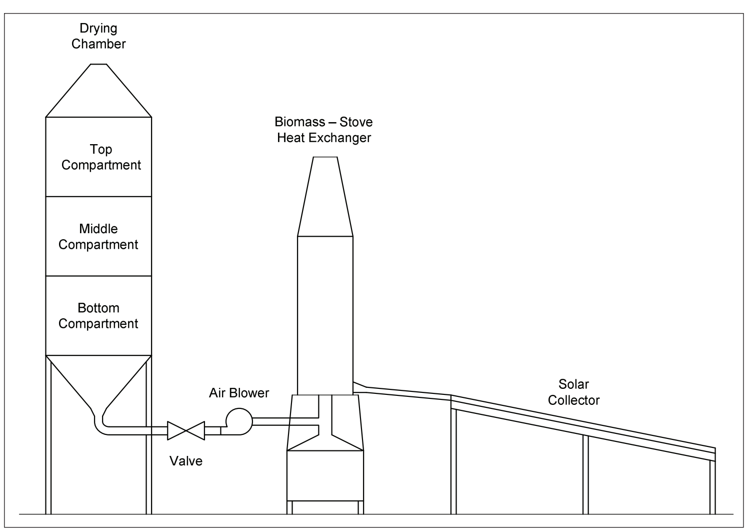

Figure 1: A sketch of solar-biomass hybrid dryer

may have happened during continuous heating. This period of cooling is shown as a discontinuity in Figures 2 and 3. The kernals were scooped out of the shells and drying was continued further without the shells until a constant weight was recorded. Mean bed temperatures of 55 °C and 60 °C were used for the two different trials of the single bed drying by maintaining the heat exchanger outlet temperature in the range of 55 – 60 °C and 60 – 65 °C, respectively.

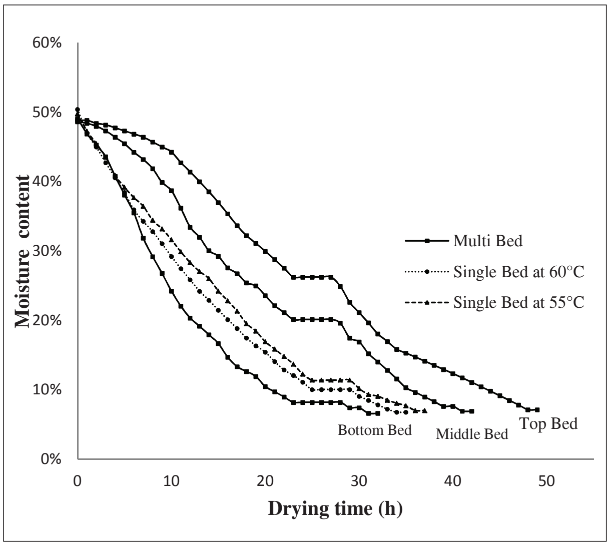

Figure 2: Variation of moisture content with time

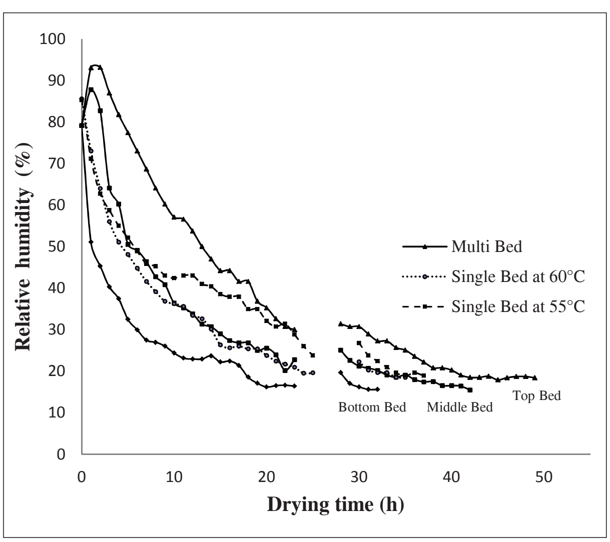

Figure 3: Variation of relative humidity with time

Multi bed drying

Each compartment of the drying chamber was loaded with 120 dehusked coconut halves. The temperature of the top bed was maintained around 50 – 60 °C during drying. Accordingly, the heat exchanger outlet temperature was maintained around 80 – 90 °C in the initial drying stages and around 70 °C in the latter stages. The heating process was stopped for 4 hrs after 23 hrs of drying to avoid case hardening of the copra. This period of cooling is shown as a discontinuity in Figures 2 and 3. The kernels were scooped out from the shells during the cooling period. When the copra in the first compartment reached the preferred moisture content, they were unloaded and the drying process was continued with copra in the other two compartments. Similarly, the copra in the second compartment was unloaded when the desired moisture content was achieved, while keeping the copra in the third compartment for further drying.

Data analysis

Initial moisture content

$$M_i = \left(\frac{W_0 - W_f}{W_0}\right) \times 100 \qquad ...(1)$$

M_i = Moisture content on wet basis
W_0 = Initial weight of the sample
W_f = Final weight of the sample

Instantaneous moisture content

$$M_t = \frac{m_i M_i - (m_i - m_t)}{m_t} \qquad ...(2)$$

m_t = Mass of material at any given time
m_i = Initial mass of material
M_t = Moisture content of material at given time
M_i = Moisture content on wet basis

Mean bed temperature

The bed temperature at a given instant is defined as the average of the inlet and outlet air temperatures of the bed. The mean bed temperature was calculated by averaging bed temperatures throughout the entire drying time, neglecting the first 5 hrs of unsteady state operation.

Specific moisture extraction rate (SMER)

Specific moisture extraction rate (SMER) is the amount of water evaporated per unit of energy

$$SMER = \frac{m_l}{P_{bl} + W \times C} \quad ...(3)$$

m_l = Amount of water evaporated during the drying process
P_{bl} = Amount of energy consumed by the blower
W = Amount of biomass fuel used
C = Calorific value of the particular biomass

Grading of copra

The quality of copra was graded by mainly considering the colour, oil content and the presence of low grade copra. Low grade copra includes scorched copra, slimy copra and mouldy copra.

Analysis of oil content and physicochemical properties

Oil extraction

Oil was extracted using an industrial-scale mini expeller. Five-kilogram samples were randomly selected from each grade of copra for extracting oil. The copra was cut into small pieces of about 1 – 2 cm using a crusher and heated up to 60 °C before being fed to the expeller.

Oil content

A Soxhelt extractor was used to determine the oil content of each copra sample. Scraped copra samples of 10 g from each grade of copra were used in the Soxhlet unit where 300 mL of hexane was used as the solvent.

Physicochemical properties of oil

The free fatty acid (FFA) content, iodine value, saponification value, refractive index, relative density, colour and moisture content of coconut oil samples were tested.

Table 1: Comparison of the results of single bed and multi bed drying of copra

Experiment	Mean bed temperature (°C)	Drying time (hours)	Moisture content (% wet basis)		Production of copra (kg)	Rate of production of copra (kg/h m^2)
			Initial	Final		
Single bed at 55 °C	55	37	49.81	7.00	12.06	0.90
Single bed at 60 °C	60	35	50.41	6.75	12.24	0.97
Multi bed - bottom	73	32	49.13	6.60	11.94	
Multi bed - middle	66	42	48.62	6.91	12.11	2.06 [a]
Multi bed - top	59	49	48.82	7.11	12.37	

[a] Rate of production for multi bed dryer

RESULTS AND DISCUSSION

Comparison of single bed and multi bed drying

The results indicate that the final moisture contents of copra from both single bed and multi bed drying were about 7 % (wet basis) (Table 1). In multi bed drying, the moisture that evaporated from the bottom bed passes through the middle and top beds and notably affects the performance. As a result, the drying time and the final moisture content were significantly high in the top bed (49 hours and 7.11 %) and the middle bed (42 hours and 6.91 %) as compared to the bottom bed (32 hours and 6.60 %). This effect of moisture migration from the bottom to the top bed is depicted in Figures 2 and 3. The initial high rate of drying (Figure 2) in the bottom bed of the multi bed dryer and in the single bed dryer is attributed to the removal of surface moisture. Figure 3 depicts that the relative humidity of hot air at the middle and top beds is notably higher than that of the bottom bed during the first 10 hours of drying. This result suggests an alternative option for loading copra into the multi bed dryer, which is to initially load only the bottom bed, loading the middle bed after 5 hours and loading the top bed after 10 hours.

Table 1 indicates that the drying time of the top bed during multi bed drying operating at 59 °C was significantly high as compared to single bed drying operating at a relatively low temperature of 55 °C. A similar comparison can be made for the drying times of the middle bed operating at 66 °C and the single bed operating at a relatively low temperature of 60 °C. This is mainly attributed to moisture migration from the bottom beds to the top beds in multi bed drying. As a result, the relative humidity of air increases considerably (Figure 3) and the moisture extraction rate decreases at the top beds.

A high production rate per unit cross sectional area of 2.06 kg/h could be achieved for multi bed drying compared to single bed drying (0.90 kg/h at 55 °C and 0.97 kg/h at 60 °C). Specific moisture extraction rate (SMER) was found to be 0.112 kg/kWh for multi bed drying as compared to 0.064 kg/kWh and 0.065 kg/kWh for single bed drying at 55 °C and 60 °C, respectively. The relatively high SMER value for multi bed drying may be attributed to the higher usage of sensible heat of hot air as compared to single bed drying. This is reflected in the high rate of production per unit energy for multi bed drying (0.0305 kg/MJ) as compared to that of single bed drying (0.0171 kg/MJ and 0.00176 kg/MJ at 55 °C and 60 °C, respectively).

Quality of copra and coconut oil

Copra produced from hot air drying in both single bed and multi bed drying were free from case hardened, scorched and mouldy copra. Maintaining uniform temperature profiles within the drying chamber of the multi bed dryer was found to be difficult. Therefore, a quality variation among the copra dried in the three different beds was unavoidable. Consequently, three types of copra were obtained and they were categorised according to the colour as white copra, light brown copra and brown copra. Table 2 shows the relative percentages of each type of copra obtained as well as the copra obtained from traditional kiln drying for comparison.

Table 2: Effect of single bed and multi bed drying on the quality of copra

Experiment	Mean bed temperature (°C)	White copra (%)	Light brown copra (%)	Brown copra (%)	Other copra (%)	Oil content (percentage by weight)
Single bed at 55 °C	55	82.00	16.40	0	1.60	60.18
Single bed at 60 °C	60	76.00	23.17	0	0.83	60.44
Multi bed - bottom	73	10.32	74.68	13.33	1.67	60.33
Multi bed - middle	66	13.33	80.46	4.16	2.15	59.25
Multi bed - top	59	42.33	49	2	6.67	59.43
Kiln drying		0	0	97.8	2.2	60.59

The percentages of white copra produced at mean bed temperatures 55 °C and 60 °C of single bed drying were 82 % and 76 %, respectively. The remaining copra in these two experiments were light brown in colour. Thanaraj *et al*. (2007) were also able to produce white copra with a percentage slightly above 70 %, at a drying temperature around 60 °C in their research using a solar–biomass hybrid rotary copra dryer.

In multi bed drying, the percentage of white copra found in the bottom, middle and top beds were 10.32 %, 13.33 % and 42.33 %, respectively. These values are significantly lower than the values for single bed drying. Notably low production of white copra in the bottom bed during multi bed drying may be attributed to significantly high bed temperatures (Figure 4). On the other hand, the mean bed temperature of the top bed in multi bed drying was comparable to that of the mean bed temperature during single bed drying at 55 °C, but the production of white copra was significantly low in the top bed. This may be attributed to the considerably higher drying time (49 hours) in the top bed during multi bed drying than that of single bed drying at a comparable temperature (35 hours). This result indicates that high temperature is not the only factor responsible for the change of copra colour to brown, but the time of drying also plays a contributing role. Although the amount of white copra was low, the majority of copra (more than 90 %) from multi bed drying was light brown or pale yellow in colour. In contrast, more than 97 % of copra produced in conventional kiln drying was found to be dark brown in colour.

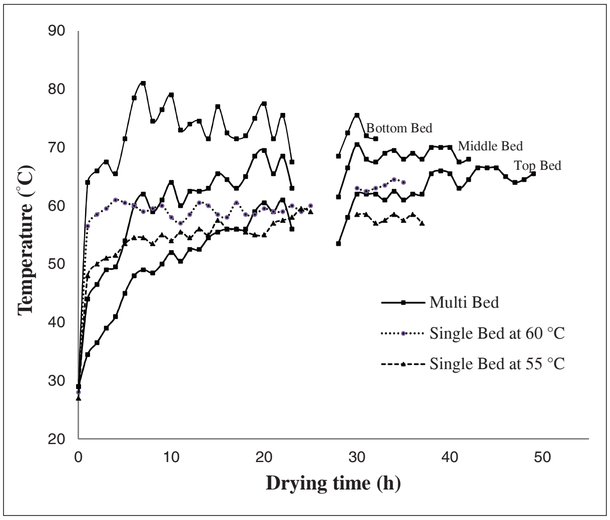

Figure 4: Variation of bed temperature with time

The oil content of copra produced in both single bed and multi bed drying was found to be almost the same with a value around 60 % by mass. Comparison of the physicochemical properties of oil extracted from each type of copra with SLS 313 standards is shown in Table 3. Coconut oil extracted from white and light brown copra was very similar to virgin coconut oil in appearance and in quality except for the content of free fatty acids. Conventionally, virgin coconut oil is extracted using wet coconut without testa (Krishna *et al*., 2010). In the present study, the oil was mechanically extracted from dry coconut without removing the testa. Removal of testa from the kernel is a labour intensive operation, and hence, this method is advantageous. However, the presence of testa and high temperature during the operation might have increased the FFA content. Further, traditional kiln drying was unable to produce white or light brown copra, while the colour of the extracted oil from kiln dried copra was pale yellow.

Table 3: Comparison of oil quality with SLS standards

Characteristic	Virgin coconut oil (SLS)	White coconut oil (SLS)	Coconut oil (SLS)	Oil from white copra	Oil from light brown copra	Oil from brown copra
Colour (25 mm cell on the Lovibond colour scale expressed in Y + 5R)	1	4	5	0.8	1	3.1
Relative density at 30 °C	0.915 – 0.920	0.915 – 0.920	0.915 – 0.920	0.919	0.919	0.918
Refractive index at 40 °C	1.4480 – 1.4492	1.4480 – 1.4492	1.4480 – 1.4492	1.4489	1.4490	1.4490
Moisture and other matter volatile at 105 °C, max.	0.5	0.4	0.4	0.34	0.37	0.38
Free fatty acids as lauric acid percentage by mass	0.2 (max.)	0.8 (max.)	0.8 (max.)	0.71	0.63	0.68
Iodine value	6.0 – 11.0	7.5 – 11.0	7.5 – 11.0	8.53	7.99	8.65
Saponification value	255 (min)	248 – 264	248 – 264	252	255	258

CONCLUSION

The amount of white copra that can be obtained is mainly dependent on the drying temperature. In single bed drying, the production of brown copra could be minimised by maintaining the drying temperature below 70 °C. Low quality copra such as scorched copra was not observed using this process.

The SMER value was considerably higher (0.112 kg/kWh) in multi bed drying than in single bed drying (0.064 kg/kWh) and the rate of production of copra per unit cross sectional area for multi bed drying was 2.06 kg/h, which is almost double the rate reported in single bed drying (0.97 kg/h). The main drawback of multi bed drying is the difficulty in maintaining comparable temperature profiles in the three beds. Therefore, a quality variation among the copra dried in the three different beds was unavoidable. More specifically, the production of brown copra was high in the bottom bed where the mean bed temperature was more than 70 °C. Although the production of white copra was comparatively low in multi bed drying, the percentage of white and light brown copra was found to be more than 90 %.

Coconut oil, which is very similar to virgin coconut oil in appearance and physicochemical properties (according to SLS standards) could be extracted from both white and light brown copra. Further, this colourless oil was extracted without removing the thick brown skin of the kernel (pairing), the removal of which involves labour. However, the free fatty acid content was significantly higher than the specification for virgin coconut oil (0.2 max). This may be mostly attributable to the pairing and the heating of copra. Therefore, future research may be focused on improving this process to achieve a low FFA content in the extracted oil. Further, high temperature oil extraction in the presence of metal surfaces may yield polycyclic aromatic hydrocarbons (PAH), and therefore, special care must be given to use water cooling at the point of expulsion from the expeller.

Acknowledgement

The authors are grateful to the testing facilities and the support given by the staff of the Coconut Development Authority, Sri Lanka.

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