Research Article *Journal of Plantation Crops, 2008, 36 (3): 480-485*

Thin layer drying characteristics of copra and coconut oil

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Abstract

The effect of drying air temperature from 50 to 100° C on dehusked and split coconuts were investigated at constant air velocity of 0.5 m s^{-1} to produce good quality copra and coconut oil (CNO) with shortest drying time. The drying characteristics of copra were significantly affected by the drying temperature, being fastest at highest temperature. Drying time to reach the desired moisture content of 5-6% wet basis was significantly reduced when the temperature of the air-stream was increased from 50 to 90°C but not between 90 and 100°C. As the drying temperature was increased to 80°C, both copra and CNO quality were unaffected. Drying at 100°C caused excessive browning, but left the aroma unaffected. Neither drying temperature nor nut position affected significantly the various quality characteristics of CNO and this was also the case for fatty acid composition. The results suggest that drying temperature of 80°C is optimum for the production of high quality copra and CNO in the shortest drying time of 24h as compared to 85h at 50°C.

Keywords: Drying temperature, copra, coconut oil, free fatty acid, moisture content

Introduction

At present, the copra industry is beset with quality and technical problems that resulted in very low prices of copra-related products in the world market. Quality problems include the contamination by aflatoxins in copra and copra cake, a cancer-causing toxic metabolite produced by the *Aspergillus* sp. group of moulds, specifically *Aspergillus flavus,* the presence of high contents of free fatty acid (FFA) that increases the refining cost and reduces the oil recovery by 1.4 times (Flynn, 1973), and a carcinogenic and mutagenic polycyclic aromatic hydrocarbon (PAH) in (CNO). The aflatoxins and FFA problems are attributed to the high moisture content of copra after drying and during storage, while PAH-related problems are due to direct contamination with smoke during copra drying. Many of these difficulties stemmed from technical problems of inappropriate drying conditions and poor dryer design.

This study investigated the influence of drying temperature on dehusked split coconuts with respect to the drying air stream so that good quality copra and CNO are produced at the shortest drying time. The response by copra to different combinations of time and temperature were investigated.

Materials and Methods

A working laboratory model dryer was developed for the study. This mainly consists of a motor-blower assembly, heating chamber, plenum chamber, drying chamber, sample container and a thermostat as shown in Fig. 1. A centrifugal blower of 1.5 m^3/min. capacity was used to blow the drying air. It was connected with a 0.5 hp electric motor. Manually operated control valve was provided to regulate the air flow through the system at the desired level. The air heating system located between the blower and the plenum chamber, consisted of two heating elements of 1.0 kW each. A thermostat was fixed in the plenum chamber so as to control the temperature of incoming hot air into the drying chamber with an accuracy of ± 2 °C. A mild steel sample container, 340 mm diameter and 200 mm depth, with a 5 mm hole size screen bottom were placed on top of the plenum chamber.

The coconuts used in the study were procured from Central Plantation Crops Research Institute, Kasaragod farm. Only matured and good quality West Coast Tall variety of coconuts were used in the experiments. For each experiment four coconuts were used. The coconuts harvested were of 11 months old. The coconuts used for experiments were not stored prior to drying. Before the

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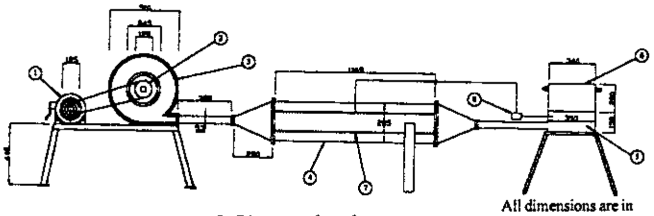
start of drying, the coconut husks were removed and the nuts were split equally into halves in crosswise manner to remove the coconut water. After drying the coconut to 6.25% moisture content, the copra was stored in existing environmental conditions in gunny bags.



1. Motor
2. Step pulley
3. Blower
4. Heating coil drum
5. Plenum chamber
6. Drying chamber
7. Strip heater
8. Thermostat

Fig. 1. Schematic representation of laboratory model copra dryer

Effect of drying air temperature on drying time and quality characteristics of copra and oil

Before conducting any experiment, the experimental set up was allowed to run for 10 minutes untill the desired drying temperature attained equilibrium. The ambient inlet and exhaust hot air temperatures were recorded using an electronic automatic temperature recorder, (Tempsen make, Asian Engineering and Services, Chennai, India) having a range of 0 to 1000 °C. The moisture content of the sample for drying tests was determined using the copra moisture meter developed by Madhavan (1986) which is commercially manufactured and marketed by Kerala Agro Industries Corporation Limited, Kasaragod, model CMM: KP 21 V9. The accuracy of the moisture meter was compared with AOAC (1995) and the moisture readings were found to have an accuracy of ± 0.5 % w.b. The relative humidity was measured using Barigos hygrometer.

The first experiment was carried out to determine the effect of drying air temperature on drying characteristics of coconut and to optimize the drying temperature based on drying time, colour, taste, smell, free fatty acid content, peroxide value, acid value, fungal growth and oil content of copra. The oil analysis, free fatty acid, peroxide value and acid value were determined as per Sadasivam and Manickam (1992). Organoleptic evaluation of copra was done by a panel of 10 judges who are actually involved in the copra processing business for colour, taste, smell, and by visual observation for fungal growth. Thin layer drying experiments were conducted at 50, 60, 70, 80, 90 and 100 °C hot air temperatures. Each experiment was replicated three times and the average values were used for analysis. Four coconuts were taken and its initial moisture content was noted. The nuts were kept in the drying chamber in single layer. The split coconut halves were placed in the drying chamber with kernel portion facing the direction of air flow. Drying was carried out with constant air flow rate of 0.5 m/s, the recommended air velocity for industrial drying of coconut (Nampoothiri *et al.*, 1986). All the experiments were conducted in the prevailing atmospheric conditions. From each coconut five moisture content readings were taken and the average was used for all calculations. Removing, taking moisture reading and replacing of the samples took about two minutes.

As the temperature affects the quality of coconut, the temperature of hot air was optimized based on the nine-point scale (on par with nine-point hedonic scale and ISI specification: IS 6273-1971) given to drying time, colour, taste, smell, free fatty content, fungal growth and oil content of copra. The nine-point scale range was fixed based on IS 6273-1971, those reported in literature and thin-layer drying experimental maximum and minimum values of the drying time, colour, taste, smell, free fatty acid content, fungal growth and percent oil content of copra (Table 1).

Score was given to all the coconuts dried at 50, 60, 70, 80, 90 and 100 °C hot air temperatures and the one that scored the highest total value was considered as the optimized one.

Coconut samples were dried at different temperatures to assess the influence of drying temperature on oil output and fatty acid composition of oil. Coconuts were dried at drying air temperatures ranging from 40 to 110 °C with 10 °C interval. In all the treatments, copra was dried to 5-6% moisture content (dry basis). Oil was extracted from copra samples using Soxhlet apparatus.

Table 1. Nine point scales to classify the drying time, smell, taste, colour, oil content and free fatty acid fro coconut dried in thin layer dryer

Drying Time, h	Smell	Taste	Colour	Fungal growth	Oil content, %, d.b	Free fatty acid, %
15-20 (9)	Typical (9)	Typical (9)	White (9)	Not visible (9)	65-70 (9)	< 0.1 (9)
21-25 (7)	Slightly burnt (7)	Slightly burnt (7)	Light Brown (7)	Traces (7)	60-64 (7)	0.1 - 0.2 (7)
26-30 (5)	Burnt (5)	Burnt (5)	Deep brown (5)	Visible (5)	55-59 (5)	0.21 - 0.29 (5)
31-35 (3)	Slightly charred (3)	Slightly charred (3)	Brown (3)	Fully affected (3)	50-54 (3)	0.30 - 0.34 (3)
36-40 (1)	Charred (1)	Charred (1)	Black (1)	Spoiled (1)	<49 (1)	> 0.35 (1)

Values in parenthesis indicate scores

In this solvent extraction method, known amount of copra was crushed in mortar and pestle by adding equal amount of sodium sulphate. Petroleum ether was used as a solvent. The oil content in copra was determined by gravimetric method.

Treatments were compared by follo9wing the ANOVA.

Results and Discussion

Drying characteristics

The moisture content of coconut reduced exponentially as the drying time increased (Fig. 2). The free moisture content available was more in the case of coconut dried at low temperature (50 °C) than the one dried at high temperature (100 °C) at the same drying time. Reduction in moisture content of coconut at any point of time increased with increase in temperature of the drying air from 50 to 100 °C. Similar type of result was quoted by Guarte *et al.* (1996) in the case of coconut in the temperature range of 40 to 100 °C. The drying data indicated that the coconut dried at higher temperature dried at faster rate as compared to the coconut dried at lower temperatures.

It took 85, 63, 43, 29, 27 and 19 h to dry the coconut from its initial average moisture content of 81.81% d.b. to the final moisture content of 5-6 % d.b. at 50, 60, 70, 80, 90 and 100 °C of hot air temperature, respectively. Guarte *et al.* (1996) reported that the average drying time to reach the 7 % moisture content (w.b.) from the initial range of 45 - 47 % w.b. was 110, 79, 58, 46, 34, 21 and 18 h at drying temperatures of 40, 50, 60, 70, 80, 90 and 100 °C, respectively in thin layer drying experiment. Patil (1985) reported a drying time of 65, 70 and 80 h to dry coconut from the initial moisture content of 86 % d.b. to 6 % d.b. under thin layer drying under the sun on black painted Palmyra mat, jute cloth and coconut floor respectively. He also reported a drying time of 50 h in solar cabinet dryer.

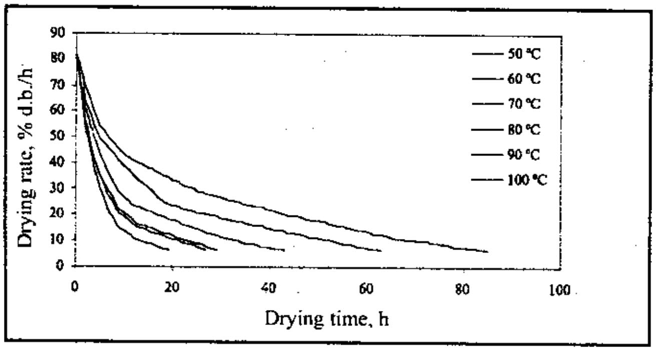


Fig. 2. Effect of drying air temperature on drying time and moisture content of coconut in thin layer drying

The drying characteristics of copra, indicated by the progressive change of moisture content, was significantly affected by the drying temperature. Constant rate of moisture removal during the early stage of drying was not observed as in other studies (Cardenas, 1968; Rajasekharan et al., 1961). In general, moisture removal slowed as the tissue dried out and this is attributed to the shrinkage of the cell structure and low water concentration which may have reduced the water diffusion coefficient, as in the case of scalded potato reported by Fish (1958). Case hardening, the formation of a hard layer on the outer layer of the product that restricts the passage of moisture movement from the interior to the surface, was not observed even at drying temperatures of 80–100°C in contrast to the claim of Child (1964).

Effect of drying air temperature on drying time and drying rate of coconut

The drying rate of coconut was 6.37, 8.94, 12.32, 15.15, 15.15 and 15.15 % d.b. / h in the first hour and 0.88, 1.197, 1.75, 2.60, 2.79 and 4.09 % d.b. / h in the final stage of drying at 50, 60, 70, 80, 90 and 100 °C of hot air temperatures, respectively (Fig. 3). It may be due to the fact that the coconuts were having high moisture content in the order of 80 % d.b. and above in the initial period and was only 6.25 % d.b. in the final stages of drying. From Fig. 3, it is clear that the constant rate period was absent and that for the entire duration, the drying of coconut took place under the falling rate period at all the drying air temperatures. Similar type of results was quoted by (Rachmat *et al.*, 1999) where the drying rate was 2 % w.b. / h at drying temperature of 50 to 60 °C. The constant drying rate period was absent due to variation in the moisture migration from inner to outer surface by kernel which is a biological property of coconut.

The drying rate was more up to an average drying

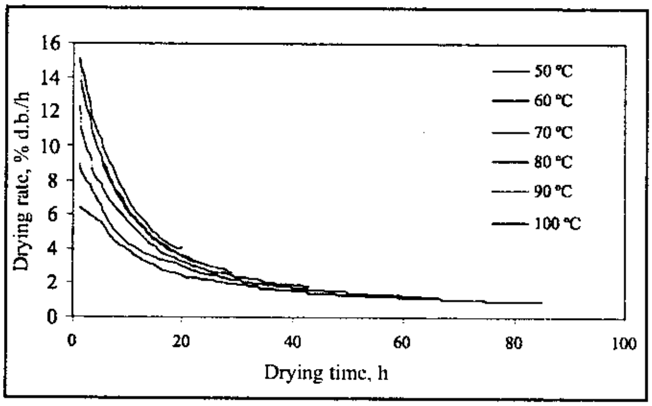


Fig. 3. Effect of drying air temperature on drying time and drying rate of coconut in thin layer drying

time of 14 h in the case of samples dried at higher temperatures and the phenomena was quite opposite after that time. The reason may be that at higher drying air temperatures, more moisture was removed in shorter time and the free moisture available in coconut was less at latter stages. Less moisture was lost in the initial drying periods of coconut dried at lower drying air temperature compared to the one dried at higher temperatures. Hence, the free moisture available in coconut dried at lower temperatures was more compared to the one dried at higher temperature which resulted in longer time for drying with drying rate gradually decreasing. Also in the initial stages of drying, the moisture content at the surface of the material which is in a condition of free moisture was easy to evaporate while at the last stages of drying, the drying rate is reduced because water availability is less and capillary forces from the inner to the surface parts of the copra may be lower. This condition resulted in lesser water evaporation from the surface. Similar results have been reported by Rajashekaran *et al.* (1961) and Xiaoren (1989). They reported that in the initial stages of drying the rate of moisture movement from the interior of the coconut meat to the surface was sufficiently high to maintain the surface in a completely wetted condition. Moisture movement is known to be dependent on diffusion and capillary flow.

Effect of drying air temperature on quality characteristics of copra

The effect of drying air temperature from 40 to 110 °C on quality characteristics of copra and oil content was explored. It was found that per cent oil content has no significant difference among the treatments. The average oil content (%) varied between 60.3 to 63.9 % d.b. (Table 2). Statistical analysis of quality characteristics of coconut oil at various drying air temperature revealed that there is no significant difference in saponification number whereas there was significant difference at 1% level for free fatty acid, acid value and peroxide value. The mean saponification numbers were within the ranges given by Kaufmann and Thieme (1956) and Banzon *et al.* (1977). Based on the FFA content, the coconut oil extracted from different samples obtained during drying experiments were of good quality (Varnakulasingam, 1974). Rajashekaran *et al.* (1961) reported similar results stating that drying air temperature at drying air temperature range of 55-70 °C has no significant difference on oil content.

The analysis of variance of oil content of samples dried in thin layer drying is presented in Table 3. There was no significant difference in oil content with respect to drying air temperatures within the temperatures range studied. That the drying air temperature is significantly different for FFA, PV, and AV, the values are well within the range prescribed. In case of oil content and saponification values no significant difference among different drying air temperatures was noticed. Hence it can be fairly concluded that drying air temperature up to 80 °C does not have any effect on oil content.

Table 2. Duncan's Multiple Range Test for grouping of drying air temperatures based on quality characteristics

Temperature, °C	Oil content%, d.b.	Free fatty acids (lauric acid equivalent), %	Acid Value, (mg. KOH /g)	Peroxide Value, Milli.eq. peroxide/ kg	Saponification number, (mg. KOH/g)
30	61.7 ^{a}	0.404 ^{d}	0.32 ^{c}	0.422 ^{b}	254.0 ^{a}
40	62.6 ^{a}	0.314 ^{c}	0.31 ^{c}	0.378 ^{a}	253.6 ^{a}
50	60.3 ^{a}	0.173 ^{b}	0.24 ^{ab}	0.423 ^{b}	252.5 ^{a}
60	63.9 ^{a}	0.122 ^{ab}	0.24 ^{ab}	0.424 ^{b}	253.6 ^{a}
70	62.9 ^{a}	0.140 ^{ab}	0.22 ^{ab}	0.428 ^{b}	252.2 ^{a}
80	62.1 ^{a}	0.142 ^{ab}	0.28 ^{bc}	0.430 ^{b}	254.2 ^{a}
90	62.8 ^{a}	0.154 ^{ab}	0.24 ^{ab}	0.430 ^{b}	255.8 ^{a}
100	62.9 ^{a}	0.116 ^{ab}	0.19 ^{a}	0.432 ^{b}	254.0 ^{a}
110	61.9 ^{a}	0.143 ^{ab}	0.20 ^{a}	0.477 ^{c}	254.5 ^{a}
120	60.5 ^{a}	0.160 ^{ab}	0.24 ^{ab}	0.464 ^{c}	252.6 ^{a}

**Treatment means with the same letters are not significantly different at DMRT 1% level*

Table 3. Summary ANOVA showing the mean sums of squares (MS) of different quality characteristics of oil

Sources of variation	df	Oil content %, d.b.	Free fatty acid, %	Acid Value, mg KOH/g	Peroxide Value, milli.eq. peroxide/ kg.	Saponification number, mg KOH/g
Drying Temperature	9	5.941	0.045**	0.009**	0.004**	5.680
Error	40	4.570	0.001	0.002	0.001	2.763

***Significant at 1%*

Table 4. Grouping quality characteristics of copra as affected by drying air temperature in thin layer drying

Temperature	Smell*			Taste*		Colour (Human eyes)*					Fungal growth*		Quality*	
°C	Typical	Burnt	Charred	Typical	Burnt	White	Light brown	Brown	Dark brown	Black	Not visible	Visible	Desired	Not desired
30	5			5		5						5		5
40	5			5		5					3	2	3	2
50	5			5		5					5		5	
60	5			5		5					5		5	
70	5			5		5					5		5	
80	5			5			5				5		5	
90	5				5			5			5			5
100		5			5			3	2		5			5
110		5			5				5		5			5
120		4	1		5					5	5			5
Chi-square statistic	57.14**			50.00**		183.93**					40.03**		45.16**	

** Numerical values in columns indicates number of samples ** Significant at 1%.*

From Table 4. it is clear that taste of copra were not affected by drying air temperature up to 80 °C. Smell was not affected up to 90 °C where as colour slightly dulled at 80 °C and was brown at 90 °C, dark brown at 100 to 110 °C and black at 120 °C. Similar results were reported by Guarte *et al.* (1996) for colour of copra in thin layer drying of coconut. Copra dried at 30 to 40 °C was affected by fungal growth. The browning of copra at high temperature is mainly attributed the Millard reaction. Since pale white to light brown copra is traded commercially and there has been no report on loss of copra quality even at light brown colour. From this it can be deduced that based on sensory qualities of colour, smell and taste, copra can be dried up to 80 °C without loosing its quality. Thus sun drying has to be restricted to those months when the temperature is above 33 °C.

Optimization of drying air parameters

The drying air parameters of coconut was optimized based on the drying time, smell, taste, colour, fungal growth, oil and free fatty acid content. The scores obtained at each drying air temperature are presented in Table 5 based on scores given to quality attributes (Table 1). Though the coconut dried at 100 °C gave a good score of 9 for drying time, it gave a poor score of 3 for colour and 6 for smell, taste and colour FFA and oil content. It gave a very poor score of 1 for drying time. The coconuts dried at 80 °C scored a total of 53 points, the highest score where as the coconuts dried at 90 and 100 °C scored 49 points. Hence based on the above parameters 80 °C drying air temperature can be adjudged as optimum. The coconut dried at 80 °C was light brown in colour which fetches equally good price in the whole sale market.

Copra quality

The smell and taste of copra was not affected by either drying temperature or position of halved nuts. Except at 80°C, colour was the same for both positions for each temperature. Colour changed as temperature increased from 80 to 100°C, but no charring occurred throughout the drying period, a finding which is in contrast to that of Cardenas (1968). The browning of copra at high temperatures is mainly attributed to the Maillard reaction. Since pale white to light brown copra

Table 5. Scores obtained for dried copra (dried at different temperatures) based on drying time, smell, taste, colour, oil content, and free fatty acid

Drying air temperature, °C	Score							Total score
	Drying Time	Smell	Taste	Colour	Fungal growth	Oil content	Free fatty acid	
50	1	9	9	9	9	7	7	51
60	1	9	9	9	9	7	7	51
70	1	9	9	9	9	7	7	51
80	5	9	9	7	9	7	7	53
90	5	9	7	5	9	7	7	49
100	9	7	7	3	9	7	7	49

is traded commercially and there has been no reported loss of copra quality even at a light brown colour, it can be deduced that based on the sensory qualities of colour, smell and taste, copra can be dried up to 90^{0}C without losing quality.

Conclusion

Drying temperature of 80^{0}C is found to be optimum to produce high quality copra and coconut oil at the least drying time and therefore arrangement of the halves on the dryer in actual field drying can be eliminated to save labour.

Acknowledgements

I acknowledge the help rendered by Dr. K. Muralidharan, Sr. Scientist in statistical analysis of data and Dr. C. Pallinisway, Sr. Scientist for helping in preparing the graphs.

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