Journal of Plantation Crops 13 (2): 78-87 December, 1985

Review Article

COPRA DRYING PROCESS AND EQUIPMENTS

R. T. PATIL
Central Institute of Agricultural Engineering
Nabi Bagh, Berasia Road, Bhopal 462 018, India

Copra is the dried coconut kernel which is used either for edible purposes or crushed in the rotary mills for the extraction of oil. Wet kernel contains about 47 per cent moisture (wet basis) and requires drying to reduce moisture to the level of 6 per cent. Uniform drying under optimum conditions is required to obtain good quality copra. The literature/studies on copra processing parameters and copra dryers developed to get good quality copra are reviewed in this article.

PROCESS

PROCEDURE FOR OBTAINING GOOD QUALITY COPRA

Nathaneal (1962) categorised the factors that would detract from quality and influence the production of off-grades as i) maturity of fruit ii) method of pretreatment iii) drying procedure and iv) precision in kiln design.

Eden (1958) explained some of the precautions to be taken for getting high quality copra from hot air dryers. They are i) avoid overheating ii) avoid overloading which may spoil good copra iii) avoid under loading; open spaces act as rapid exits for the hot air to escape and unless closed these exits keep dryer cold despite constant stocking of the furnace iv) dry copra should be removed immediately v) cool the copra before bagging vi) use the cold air vents vii) avoid smoke leaks and viii) clean frequently the furnace, the ash pit and flue pipes.

HEAT TOLERANCE OF THE COPRA

Samson (1971) studied the heat tolerance of coconut meat. The properties evaluated were browning of colour, Lysine destruction, protein solubility at pH of 2.8 and 10.5 and nitrogen solubility index. It was found that meat could tolerate upto 100°C air temperature and upto 105°C air temperature for 60 min without significant loss of protein solubility. However, marked loss of lysine availability occurs if heated at 120°C.

EFFECT OF TEMPERATURE ON DRYING

The studies on mechanical drying of cup copra by Rajshekharan, Bhatia and Pandalai (1960) in cabinet through draught dryer indicated that at constant parameters of 1.37 M/S air velocity, 26 kg/m^2 loading density and 15% RH i) the drying rate was markedly affected by temperature of drying air; ii) the charring of coconuts at higher temperature occur only at the end of drying and iii) the drying rate tends to minimise below 20% moisture content (db).

Cunade (1977) discussed the procedures for copra preprocessing, processing and postprocessing in Philippines and also found that temperature upto 105°C could be used for drying without charring during early stage of drying when moisture content was high. At 120 cubic ft/min. air flow rate, the drying times at 37.8°C, 60°C, 75°C and 90°C were 38 hr, 20 hr, 9 hr and 8 hr respectively.

EFFECT OF RH ON DRYING

Sill (1965) studied the relationship between rate of drying and relative humidity of drying air. When the copra was dried at 71°C the case-hardening occurred. In this case water was removed faster from surface layer than the diffusion of water from centre to surface. Two methods were suggested to prevent it *viz.*, i) low temperature slow drying, and ii) drying at higher temperature with high humidity of drying air. Since the enthalpy of the air at high relative humidity is more it increases the rate of drying. At 65.5°C temperature of drying air, the optimum relative humidity was found to be 35% for first 12 hours and 20% in the final stage.

Ramaswamy et al. (1970) studied the drying characteristics of cup copra and suggested phased drying at two different temperatures for quicker drying and to get good quality copra.

EFFECT OF SLICING ON DRYING

Brill, Parker and Yates (1917) studied the effect of chips or slicing on drying compared to cup copra in rotary lauver dryer. It was observed that slicing results in uniform drying whereas brim of copra cup dries faster than the central portion, resulting in the rancidity of copra in storage. They described the moisture of copra in three forms *viz.*, surface moisture, central moisture occupied by the spores and interstices and hygroscopic moisture which is absorbed by kernel till equilibrium.

Del Rosrio (1966) studied the optimum conditions for drying the small pieces of coconut kernel of 3.5 cm × 0.2 cm × 1 cm. The upper temperature limit for drying was found as 70°C, air velocity 16.1 Kmph and relative humidity of 60%.

EFFECT OF LOADING DENSITY ON DRYING

Sill (1965) reported that for drying at 65.5°C temperature and 35% RH for first 12 hours and 20% thereafter the optimum tray load was 12.21 kg/m^2 and it could be raised to 58.6 kg/m^2 without affecting the drying rate.

Rajshekharan et al. (1960) reported minimum loading density in through draught dryer as 26 kg/m^2 and at lower capacities the drying was not efficient due to channelling (non mixing) of hot air whereas there was no significant change though the capacity was doubled.

PROCESS PARAMETERS

Constrears (1965) investigated the degree of dehydration by soaking coconut meat in hypertonic solution. The studies on outward diffusion used fresh coconut meat whereas for inward diffusion sun dried coconut meat for 3–5 days was used. The important variables considered were kind of solute, concentration of solute and the temperature. The outward diffusion (dehydration) increased with concentration and temperature while for inward diffusion, high percentage of increase in weight was achieved with using saturated solution of osmotically active constituents of the cell, together with capillary and imbibition.

Bustrillos and Banzon (1949) determined the important parameter in drying *i.e.*, equilibrium moisture content for copra at different relative humidities, as given in Table I.

Table I. *Equilibrium moisture content values for copra*

Relative humidity	E. M. C. in percentage	
	At room temp. 30°C	At 40°C
10	0.32	0.11
20	0.80	0.23
25	0.80	0.32
30	0.96	0.45
35	1.10	0.60
40	1.30	0.78
45	1.55	0.99
50	1.80	1.21
55	2.05	0.48
60	2.31	1.80
65	2.61	2.09
70	2.95	2.41
75	3.32	2.74
80	3.73	3.13
85	4.30	3.60
90	—	4.76
95	—	6.00

OPEN SUN DRYING OF COPRA

The studies conducted by Coconut Research Institute, Ceylon, (Anonymous, 1966) indicated that under conditions of average temperature of 27.4°C and 7.44 hr of sunshine, the time required for drying was 9 days to reduce the moisture from 46.9% to 6% (wb). It was found that water was more near the centre (wet surface) and least in the testa whereas oil content was highest in testa and least near the wet surface (Table II.) It was also reported that copra obtained from washed nut was superior to unwashed nut (wet meat).

Table II. *Moisture and oil gradient in coconut*

Position	Moisture	Oil	
T	28.4	60.3	T = Testa
RT	31.8	78.5	W = Surface
TR	34.9	72.7	contact with
RW	63.7	49.2	water

Decastro and Coranera (1978) reported that pretreatment of fresh meat with the shell ash prior to air drying proved to be effective in arresting mould growth.

Patil and Nambiar (1982) found that the time required for open sun drying was 9 days on cement floor, to reduce the moisture content from 46% to 6% under the ambient conditions of 31.9–33.0°C temperature and 71–79% RH with daily 6.5–9.7 sunshine hours. It was also observed that substitution of drying surface of mud or cement floor with black painted palmyra mat reduced the drying time to 7 days.

DRYING EQUIPMENTS

DIRECT TYPE DRYERS

Cooke (See Grimwood, 1975) in Malaysia had designed copra kiln suitable for 10 acre plantation having capacity for 100 nuts/batch and fuel required was 100 shells. The net firing time was reported to be 15 hr and total time required for drying was 24 hr. The kiln for 30 acre plantation had capacity of 200 nuts/batch with fuel requirement of 500 shells. The net firing time was 23 hr. and overall time required was 30 hr.

Frederic (1950) reported a simple Ceylon copra kiln having a fire pit, copra grill and a corrugated iron roof with a covered verandah. The total capacity was 10,000 nuts/year. The depth of copra was maintained maximum 30cm. The copra loaded in the kiln after one day of sundrying. The drying process required 5 days with 8 to 9 firings of double row of shells.

Menon (1968) described the Pearson patented copra kiln having iron structure for drying chamber of 6×6×30m with 24×2.1m verandah. There were four compartments with a central chimney with heating from two furnaces located at either side of the chamber. The total capacity per year was 20000 nuts. Series of control doors were fitted on the sides and bottom of the chamber to control the temperature of the hot gas.

Verghese and Thomas (1952) had modified and adopted 10 acre Malaysian copra kiln to suit Indian conditions. The kiln consisted drying chamber, grill, fire tunnel, fire container, heat spreader and inspection door. The fuel used was shells or spathe. The temperature was maintained at 53–60°C. Heating was done during day time with overnight tempering. The heating time was reported to be 22.5 hr.

Mansoor Mohd (1973) reported a hot air dryer constructed out of cheap materials. The drying time required was 64 hr. and total capacity was about 7 tonnes of copra.

The dryer designed by Dr. Ibarra Guz of Philippines was reported to be suitable for big plantations (Anonymous, 1973). The fuel was coconut shell, charcoal or diesel oil. The copra produced with charcoal was reported to be cleaner and whiter, whereas diesel oil fuel deteriorated the quality of copra. The copra dryer had three sections *viz.*, drying chamber, blower and valve. The capacity of drying chamber was 1000 nuts. The nuts were dried at 82°C for 12–16 hr.

Saiz (1971) compared kiln dryer and oil fired forced hot air dryer and reported that the time required in the latter type dryer was 24 hr compared to 3–4 days in the former, with ease of operation and less labour requirement. Experience in Papua New Guinea showed that these factors result in production of a better quality copra at lower cost than was possible with the kiln dryer.

The early smoke dryers were known as tapahan dryers in Philippines. They were further improved to obtain quality copra (Anonymous, 1962). The improved versions were known as De vapor and tapat.

INDIRECT TYPE COPRA DRYERS

The chula copra dryer was developed by M/s Tyneside Foundry & Engg, Co. Ltd. England (Anonymous, 1959) which consisted of an air heater with furnace and power driven fan and a drying chamber. The damper and ash trap was provided in the chimney. The maximum capacity of drying chamber was 1000 nuts and after shell removal the capacity could be doubled. Drying time required was 17 hr. On an average 28633 half shells, 2425 kg of firewood or 2830 petioles were required as fuel to make 1 tonne of copra. In this dryer, temperature control was found to be difficult to attain when husks were used.

Millan and Barrau (1959) described the tunnel type (Atahiti Kiln) French hot air dryer, which accommodated end to end three trolleys on iron rails. Each trolley could hold seven rows of trays. The main hot air flue was slopping pipe under the concrete slab supporting the trolleys. At the end of the kiln remote from the furnace the flue rose to floor level, where it was connected to two parallel return pipes running on either side of rails. These pipes were opened into chimney on either side of the kiln at the furnace end. At the same end at floor level, the openings for intake of fresh air were provided and hot damp air was expelled through chimney in the roof at the other end of the kiln. The kiln capacity was 1200 nuts/day. Each fixing required about 300-400 husks. The dryer was reported to produce 60-70 tonnes of copra during 250 days of operation. Total tray area was 104 m^2 with each tray carrying 64.6 kg kernel.

Le Gall and Dercle (1960) reported kukum type tagabe hot air dryer. The capacity was 300-400 kg lbs of fresh kernel and drying time was reported as 48 hr.

The tongo hot air dryer (Anonymous, 1968) used old oil drums for furnace. The drying chamber had three compartments with nine racks each. The drying capacity was 1600 nuts/batch. The predrying with shells was done in open sun for two days and kernel without shell were dried in the dryer for another 2 days. Thereafter open drying was adopted for 2-3 days.

Tumaneng et al. (1970) described the construction and testing of ordinary hot air copra dryer. In this dryer, fuel was burnt in the drum heat exchanger. The hot air produced rises by convection into an indirectly heated drying chamber above the furnace. The drying efficiency of the indirectly heated drying chamber was evaluated using three different piling schemes of the half nuts. Coconut husk or shell was utilized as fuel. Highest drying efficiency was obtained with half nuts in the first layer facing down and in the second layer, they were piled slanting at about 60° with the concave side facing down to one direction. The coconut husk is as good a fuel as the shells. Drying was also found to be more easily controlled with the use of husk than with shells.

De castro (1976) reported the performance of kukum hot air dryer developed in Philippines. He suggested the drying process in two or three stages for moisture to travel to the surface. This increased the efficiency of drying and minimised the scorching. The use of knotted jute sacks covering on copra was found suitable for efficient drying and heat distribution on drying platform. This dryer was further improved to accommodate maximum of 2000 nuts by increasing the total height to 45 cm compared to 1000 nuts/batch capacity earlier.

Masuhit and Domingo (1978) developed the integrated charcoal kiln and indirect dryer which could be operated simultaneously utilizing the heat generated from the kiln. The dryer had drying tray which facilitated even drying of coconut meat or any other material and the kiln was having a metal lid which facilitated the loading of material to be charcoal and also serves as heat exchanger of the dryer.

Cruz (1978) also developed an integrated system of copra drying and charcoal manufacture. In this process, product gases from the charcoaling process supplied part of heat required in drying process. Recirculation of an average 60% of hot exhaust air from copra dryer resulted in considerable fuel saving. Fifty per cent of the shell from a lot to be dried was required to supply the heat for drying.

Fanguin (1979) reported a copra oven designed by the IRHO and installed on the Grand Devin Plantation in the Ivory Coast. It was natural draught hot air dryer fueled by coconut husks. It was operated by two persons and the output was 1100 kg copra/day of operation. The total drying capacity was reported to be 1.5 million nuts/year in 300 working days.

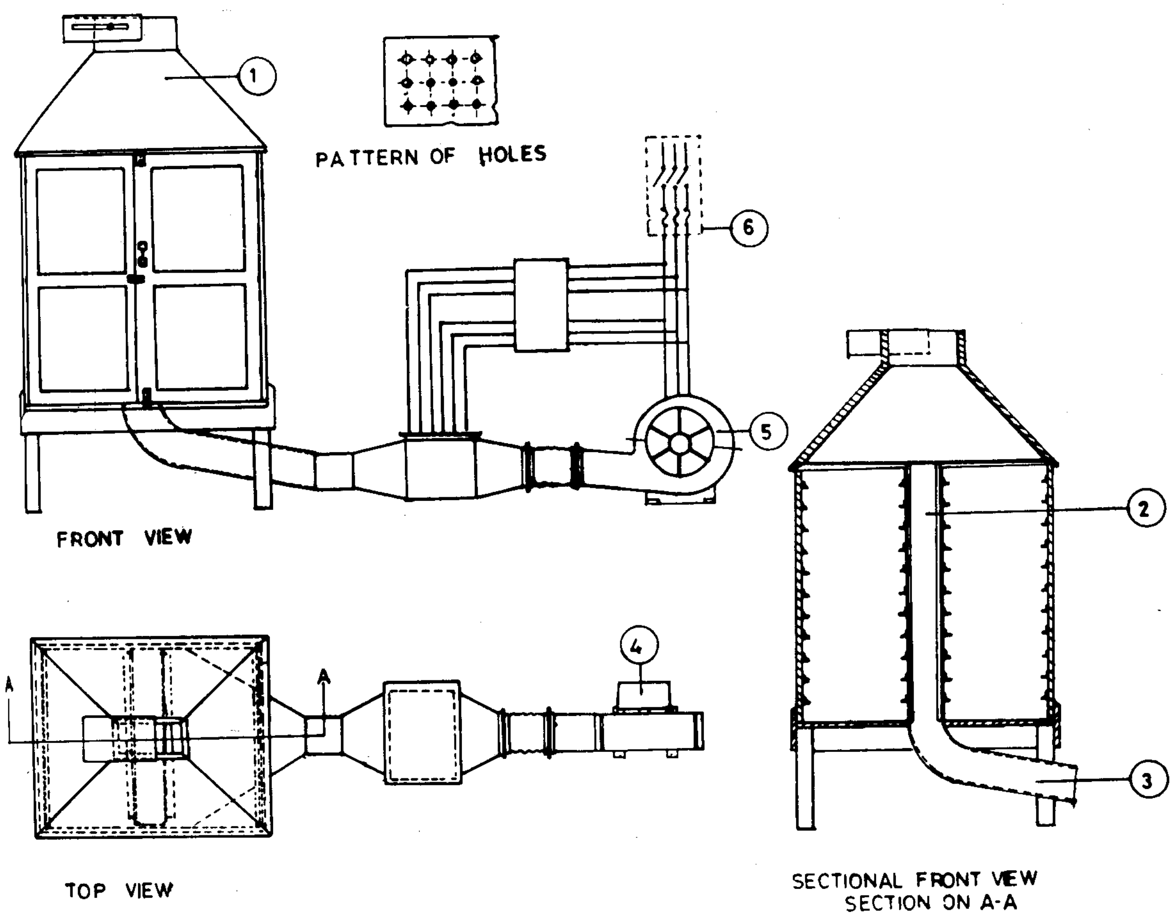
Patil (1984a) reported a small and easily transportable dryer with processing capacity of 400 nuts. The dryer was relatively cheap (Rs. 1600/-) and functions with all sorts of agricultural wastes as husk, shells etc. The dryer was fabricated from angle iron, GI sheet and AC sheets. The components of the dryer were drying chamber, plenum chamber, burning cum heat exchanging unit and a chimney with butterfly valves. The rate of combustion and air temperature could be controlled by the valves. The drying time required was about 40 hours. The same dryer could be successfully used for drying other crops also.

Patil and Singh (1984) reported a tray type (mixed flow) mechanical dryer for obtaining good quality copra even during rainy season (Fig. 1). Electrical energy was used for heating. The dryer was fabricated from wood, GI sheet, Asbestos rope etc. It has drying chamber, air distribution unit, plenum chamber, heating unit and blower. Drying chamber accommodated air distribution unit in the centre with copra trays on its both sides. The air was blown by 1.5 hp motor operated blower on 8 kw heaters. The hot air was then circulated through the material on the trays. The capacity of the dryer was 1000 nuts/batch and drying time required at 60°C temperature was 30 hours.

SOLAR DRYERS FOR COPRA

Boulder (1980) reported a small copra dryer of 200 nuts capacity. The dryer was built with wood and bamboo

Fig. 1. Tray type mechanical copra dryer



1. Drying chamber, 2. Air distribution unit, 3. Plenum chamber, 4. Motor, 5. Blower, 6. Control panel

racks. The plastic was used for covering the roof. The copra was dried in this dryer after 15 hr of open sundrying. The another dryer of tent type with PVC roof could produce excellent quality copra by sundrying even in rainy season.

Patil (1984b) developed two types of solar dryers for drying copra. The low cost polythelene solar dryer made of 10 mm MS bar frame and 200 gauge double layered transparent cover with perforations for air circulation reduced the drying time from nine days to six days with increased capacity of 50% compared to open sundrying. The second dryer was of cabinet type made from jack wood frame. The drying surface was 22 gauge corrugated GI sheet painted in black, with coir fibre insulation below it. The drying chamber was made of 3mm window glass on sides and 3 mm acrylic plastic on the top. The reflectors of 24 gauge aluminium foil were provided from 3 sides and castor wheels facilitated the movement of the dryer for constant suntracking and transportation to short distances. The drying time was reduced to four days in the dryer compared to nine days on concrete floor even at double the spreading density compared to open sun drying.

CONCLUSION

It was found from the review that open sundrying takes quite a long time of 7-9 days during which period copra is exposed to the atmospheric conditions resulting in spoilage. To get good quality copra, maturity of fruit and method of pretreatment are equally important as that of drying procedure and kiln design. The precautions which are essential irrespective of type of dryer to get good quality copra, are described by Eden (1958) as i) avoid over heating, ii) avoid over or under loading, iii) remove copra soon after drying and iv) cooling of copra before bagging. The frequent cleaning of furnace ash pit and flue pipe is also important to get efficient dryer operation. The basic studies as that of heat tolerance of coconut meat, effect of temperature and RH on the drying have been studied by many workers. The effect of loading density on drying has been studied by Sill (1956) and also by Rajshekharan et al. (1960). The studies on outward and inward diffusion characteristics were reported by Constrears (1965) whereas equilibrium moisture content was determined by Bustrillos and Banzon (1949). There are three types of dryers reported *viz.*, direct type, indirect type and solar dryers.

The direct type dryers mainly made use of agricultural waste as fuel. In many cases this drying was resorted to in unfavourable weather conditions in combination with open drying. The oil fired dryers also have been reported to be used for copra drying (Saiz, 1971).

The efforts on development of indirect type dryer than the direct type were more as the quality of copra obtained was superior. The development of the dryers was mostly location specific *i.e.*, making use locally available materials and considering socio-economic status of the users.

The coconut growing countries are tropical where plentiful supply of solar energy is available. Hence the conventional practice is of open sundrying which has got its own disadvantages and dependent on the vagaries of the nature. To make use of this energy more effectively, the use of solar dryers is essential. On the use of solar dryers very little work is available (Boulder, 1980, Patil, 1984b). But the dryers reported were of small capacity and hence cost of dryer may be prohibitive. Since coconut is harvested throughout the year and open sundrying is commonly followed, there is a scope to develop the centralised large capacity solar dryer to dry copra and the same drying facility could be used for other crops also.

REFERENCES

ANONYMOUS, 1959. Village copra kiln. *Coconut Bull.* 13(2): 45-50.

ANONYMOUS, 1962. Quality production of copra. *Agril. Ind. life* (Philippines) 24(6): 23-30.

ANONYMOUS, 1966. Report of the Chemist. *Ceylon Coconut Quart.* 17: 97-109.

ANONYMOUS, 1968. Home made hot air dryers of Tonga help make worlds best copra. *Coconut Bull.* 17(1): 3-9.

ANONYMOUS, 1973. A copra dryer for the Central. *Philippine Farmers. J.* 15(9): 15.

BRILL, H. C., PARKER, H. O. and YATES, 1917. Regarding copra drying. *Philippine J. of Sci.* 12: 95-110.

BUSTRILLOS, A. D. and JULLIAN BANZON, 1949. The equilibrium moisture of copra at various relative humidities. *The Philippine Agriculturist.* 33(2): 77.

BOULDER, J. M. 1980. Description of a small copra dryer. In *F. A. O. Tech. Work. Party on Coconut Prod. Prot. and Processing.* P. L./ C. N. P., 61/21 : 3 p.

CONSTREARS, E. M. 1965. Diffusion studies in coconut meat, U. P. C. A. College, Laguna B. S. Thesis, 15 p. Unpublished.

CUNADE I. S. 1977. Copra processing P. C. A. A. R. Devas Res. Centre, Rep. Devas City, 15 P. Unpublished.

CRUZ, H. E. 1978. An integrated system of copra drying and charcoal production, In *The Proceedings of Seminar on Methods of Copra drying.* P. C. A., Diliman Quezon City, Mar 26, pp. 77-92.

DEL ROSRIO, A. G. 1966. Studies on rate of drying of coconut endosperm. U. P. L. B. College Laguna. B. S. Thesis, 35 p. Unpublished.

DE CASTRO, M. M. 1976. A preliminary report on the performance of the Kukum hot air copra dryer, A paper presented at the Technology Seminar PCA - ARB BPI Feb. 26, p. 8.

DE CASTRO, M. M. and CORANERA, M. C. 1978. Comparative studies on the various methods of copra making and development of alternate technique, P. C. A. - A. R. B. Devas Res. Centre Annual Rept. P - 7 - 8, Unpublished.

EDEN, D. R. A. 1958. High quality copra from hot air dryers. *Q. Bull. S. P. C.* 8: 67.

FREDERIC, W. D. 1950. The Ceylon copra kiln. *The Ceylon Cocon. Quart.* 1(3): 21.

FANGUIN, J. 1979. The copra oven at Grand-Drevin, Ivory Coast, *Oleagineaux.* 34(5): 249-252.

GRIMWOOD, B. E. 1975. *Coconut Palm Products.* F. A. O. of U. N. Rome: p. 261.

LE GALL, H. and DERCLE, P. 1960. The Tagabe hot air copra dryer. *Q. Bull. S. P. C.* 10(3): 32-39.

MENON, A. K. 1968. Kiln drying of copra, *Indian Central Cocon. Committee Bull.* Vol. 2(4): 53-59.

MILLAN, D. R. and BARRAU, J. 1959. Hot air dryer for French planters. *Q. Bull. S. P. C.*, April.

MANSUR MOHD, 1973. Copra drying with hot air. LPTI Pamphlet No. 15-6. pp. 1-15.

MASUHIT, T. A. and DOMINGO, D. S. 1978. Integrated charcoal kiln and indirect dryer. *NSBD Technology J.* 3(3): 83-86.

NATHANEAL, W. R. N. 1962. Copra manufacture and how to reduce off grades. *Ceylon Coconut Plant. Review.* 2(3): 13-16.

PATIL, R. T. and NAMBIAR, C. K. B. 1982. Sun drying of copra *J. Plant. Crops.* 10(1): 26-32.

PATIL, R. T. 1984a. Small holders copra dryer using agricultural waste as fuel. *Oleagineaux.* 38(10): 561-562.

PATIL, R. T. 1984b. Design and development of solar copra dryers. *Agricultural Mechnization in Asia, Africa and Latin America.* 15(2): 59-62.

PATIL, R. T. and SINGH JASWANT, 1984. Development of an improved tray type mechanical copra dryer. *Oleagineaux.* 31(1): 31-37.

RAJSHEKHARAN, N., BHATIA, D. S. and PANDALAI, K. M. 1960. *Cocon. J.* 14(1): 71-80.

RAMASWAMY, et al. 1970. Studies on drying characteristics of coconut kernel. *Indian Chem. Engrs. Trans.* 10(4): 165-168.

SILL, V. E. 1965. Copra drying experiments. Relationship between rate of drying and relative humidity. *Fiji Agri. J.* 1(27): 99-101.

SAMSON, A. 1971. Heat treatment of coconut meat. *J. Sci. Food Agri.* 22(6) : 312-316.

SAIZ, A. G. 1971. Advantages of controlled forced hot air drying of copra. In *Cocoa and Coconuts in Malaysia.* pp. 219-232.

TUMANENG, A. A., DE REAL, E. A., ADVERSARIO, A. S., ISSAC, C. C. and CABALAN, E. V. 1970. Design, construction and testing of an ordinary hot air copra dryer prototype. *Researche.* 6(3) : 43-59.

VARGHESE, E. J. and THOMAS, P. K. 1952. Copra kiln for small coconut plantations. *Indian Cocon. J.* 6(1) : 19-28.