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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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ESTABLISHMENT OF A COCONUT PROCESSING TECHNOLOGY CONSULTANCY SERVICE UF/RAS/78/049

ASIAN AND PACIFIC COCONUT COMMUNITY

COCONUT PROCESSING TECHNOLOGY INFORMATION DOCUMENTS

PART 1 OF 7

"Coconut Harvesting and Copra Production"*

Based on the work of T. K. G. Ranasinghe
in co-operation with representatives of the coconut processing industry
of the Asian and Pacific Coconut Community and individual international experts

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4th Floor, JAYA BUILDING
Jl. Thamrin 12, Jakarta, Indonesia

Cable : COCOMUN
Mail : P.O. BOX 343

Asian and Pacific Coconut Community

Jakarta — Indonesia

Our Nr :

PREFACE

A valid criticism against the poor performance of many agricultural extension services in coconut producing countries is that the services do not have or know what to "extend". A similar analogy can be applied to a consultancy service on coconut processing technology.

"Registering" coconut processes applied in the APCC countries, may be a simple achievement and considered unimportant, when one views the deluge of impressively formulated and identified objectives and programmes pouring out of international agencies and institutions. The fact is, that the disappointments from two UN Development Decades, could be traced to the failure to execute the basic "Home Work" essential for achieving the ultimate objectives.

UNIDO, which concieved and supervised the execution of this project, rightfully owns the entire credit for an important programme of meaningful benefits to APCC and APCC member countries. UNIDO has provided APCC with a firm basis from which APCC must now build and develop an essential service to those countries and individuals reliant on the coconut for their economic survival.

Godofredo P Reyes Jr
Director

13 June 1980.-

INTRODUCTION

The United Nations Industrial Development Organisation, Vienna, funded and executed this project "Establishment of Coconut Processing Technology Consultancy Service" for the Asian and Pacific Coconut Community based in Jakarta. The project was initiated in 1978 and completed within 18 months.

Coconut Processes, commercial and household, applied in the APCC member countries were documented in individual technology sheets by Consultants for specialised areas and by the Project Manager/Coconut Processing Technologist. Each technology sheet carries a product code, based on the Customs Cooperation Council Nomenclature (CCCN) which has replaced the Brussels Tariff Nomenclature (BTN). This facilitates easy reference to determine import or export duties, freight rates, etc, as well as coding for library systems. Where there are co-products or by-products in a process, only the main product has been taken into consideration for coding.

The immediate objective of the project is to make the technology sheets available to all concerned as a "Consultancy Service" in the framework of technical cooperation among developing countries and others interested in improving the coconut processing discipline.

The technology documented is not only on major commercial processes but also on the hitherto, somewhat neglected, rural and household processes. These processes offer a large scope for further development with appropriate and suitably scaled technology, in order to bring about the commercialisation of new or improved products.

The development of the Coconut Processing Sector through technical cooperation in existing commercial processes and the improvement of rural and household products, could mean higher incomes and better living conditions for several hundred million people living in the coconut areas of the world.

ACKNOWLEDGEMENT

The kind assistance and co-operation rendered by the counterparts, the national collaborating agencies and the excellent services given by the APCC Secretariat are gratefully acknowledged.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

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"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

This document is one of VII parts: -

PART I	COCONUT HARVESTING AND COPRA MANUFACTURE
PART II	COCONUT OIL EXTRACTION
PART III	COCONUT OIL REFINING AND MODIFICATION
PART IV	DESICCATED COCONUT MANUFACTURE
PART V	DOMESTIC COCONUT FOOD PROCESSES
PART VI	COCONUT COIR FIBRE AND PRODUCTS
PART VII	COCONUT SHELL PRODUCTS AND OTHER PROCESSES

These Technology sheets have been prepared by :-

P.C. Catanaoan, UNIDO Consultant on oil extraction

H.B.W. Patterson, UNIDO Consultant on oil refining

P.M. Abaca, UNIDO Consultant on non traditional food

T.K.G. Ranasinghe, UNIDO Project Manager/Coconut Processing Technologist.

1979/1980

Consultancy Service on Coconut Processing Technology

UNIDO/APCC Project UF/RAS/78/049

PART I

COCONUT HARVESTING AND COPRA MANUFACTURE

List of Technology sheets

Product code CCCN 08.01
Technology sheet No. I / 1

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

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"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology Sheet for :- NATURAL FALL COCONUT HARVEST - mainly Pacific

2. Uses of finished product :-

2.1 The naturally fallen nuts being fully mature, make good quality copra. These from selected varieties are used as seednuts.

2.2 The nuts are also suitable for desiccated coconut.

2.3 These coconuts are used for culinary purposes in the Pacific region. The per capita consumption in this region is 300 to 500 nuts per person per year, which is several fold compared to that in Asian member countries.

3. Country of Origin

PAPUA NEW GUINEA, SOLOMON ISLANDS, WESTERN SAMOA

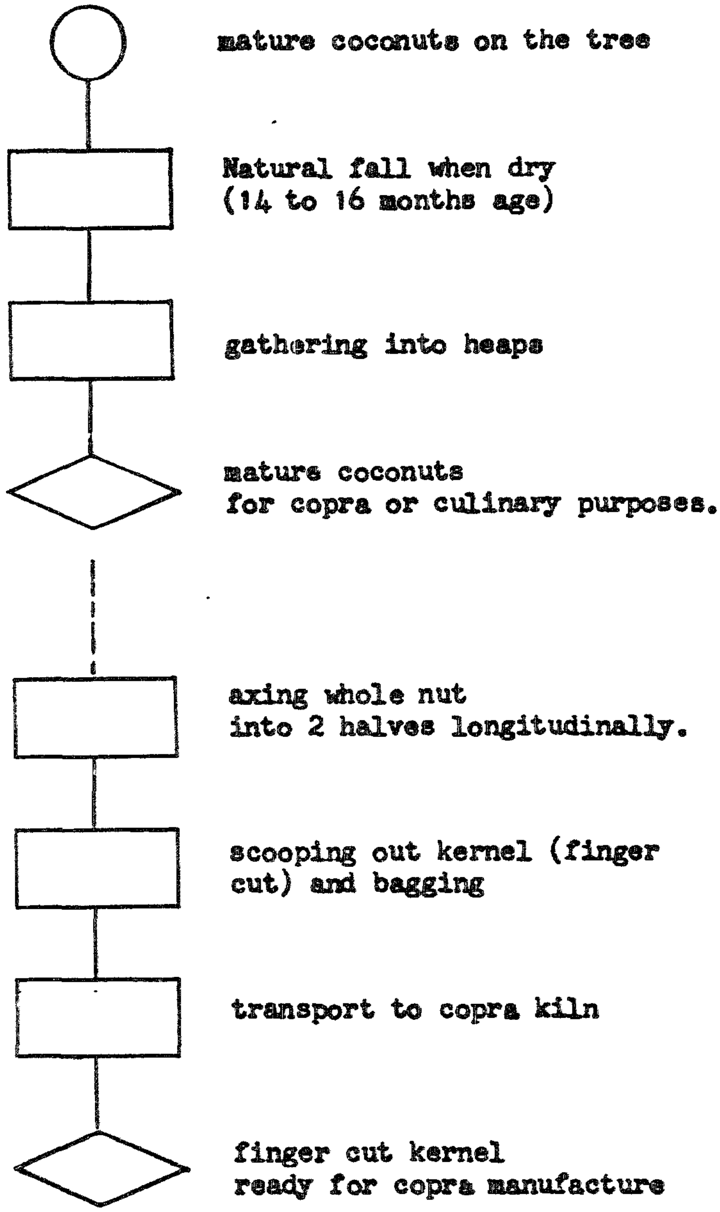
Coconuts are not plucked but allowed to fall naturally in the Pacific region. In some countries like Philippines and Sri Lanka, natural fall harvest is practised only for the very tall trees in large holdings as plucking would be very inconvenient.

4. Equipment or facilities :-

Workers are required for gathering the nuts into heaps, periodically. Where nuts are cut open and kernel scooped out in the field, the same work force is engaged for this on a piece rate basis. In small holdings, the farmer and his family members will carry out the gathering, axing the nuts and scooping out the kernel.

5. <u>Process</u>: -

5.1 Process flow diagram: -



5. 5.2 Description of Process :-

Harvesting coconuts in the Pacific region is by gathering the naturally fallen nuts every 2 to 4 weeks. Under normal circumstances, only fully mature dry nuts of 14 to 16 months age from flowering will fall naturally.

Natural fall harvest ensures that only fully mature nuts are obtained. The exception however is when there is premature nutfall during adverse conditions such as dry weather. Another important advantage is that it is the cheapest method available because no labour is expended in plucking the nuts. There is an important disadvantage in that due to the undergrowth, many nuts are not seen when gathering. Since the nuts are fully ripe, they tend to germinate if not gathered each time. As a result it is common to see about 5% of all nuts have germinated when opened out for copra making.

The group of men engaged for gathering into heaps also axe the nut into two; longitudinally and scoop the kernel to obtain "finger cut" kernel. The same workers bag the copra for collection by trucks. The workers are paid on a piece rate basis. In the case of small holders, the farmer and his family members carryout these functions and either makes his own copra or sell the kernel to another who has a kiln.

In the estate sector of Papua New Guinea, the practice differs depending upon the type of dryer used. Only in the case of Sri Lanka type kilns; the nuts are husked in the field, split open into two along the equator, and packed into bags with the half shell intact. This is transported by truck and the kiln loaded with the half shell intact. Payment for gathering, husking, splitting and bagging is on a piece rate basis.

In the estate sector in Western Samoa, whole nuts are transported to the kiln area, axed in half and kernel scooped. The purpose of transporting the whole nut is because the husk and the shell (intact) are used for fuel.

It is interesting to note that whilst one group of workers is harvesting, another group clears the undergrowth in some other area of the plantation. The two groups rotate their tasks periodically.

Details of preparation of nuts for copra manufacture are dealt with fully in the relevant technology sheets.

5.3 Product flow diagram :-

Not available.

6. Quality of finished product :-

The nuts are fully mature and hence are in the ideal condition for copra manufacture.

7. Source of Information :-

Observation during field visits to member countries in the Pacific region.

Product code : CCCN 08.01
Technology sheet no: I / 2

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"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology Sheet for :- HARVESTING COCONUTS (Small & Large Holdings).

2. Uses of finished product :- For processing into Copra, Desiccated Coconut or consumed as fresh nuts for cooking; and other miscellaneous food items. By product - Husks (in 3 to 4 segments) are mainly used as fuel for copra drying if the farm has a copra dryer. Otherwise they are allowed to perish. Some husks are used for extraction of coir fibre.

3. Country of origin :- PHILIPPINES

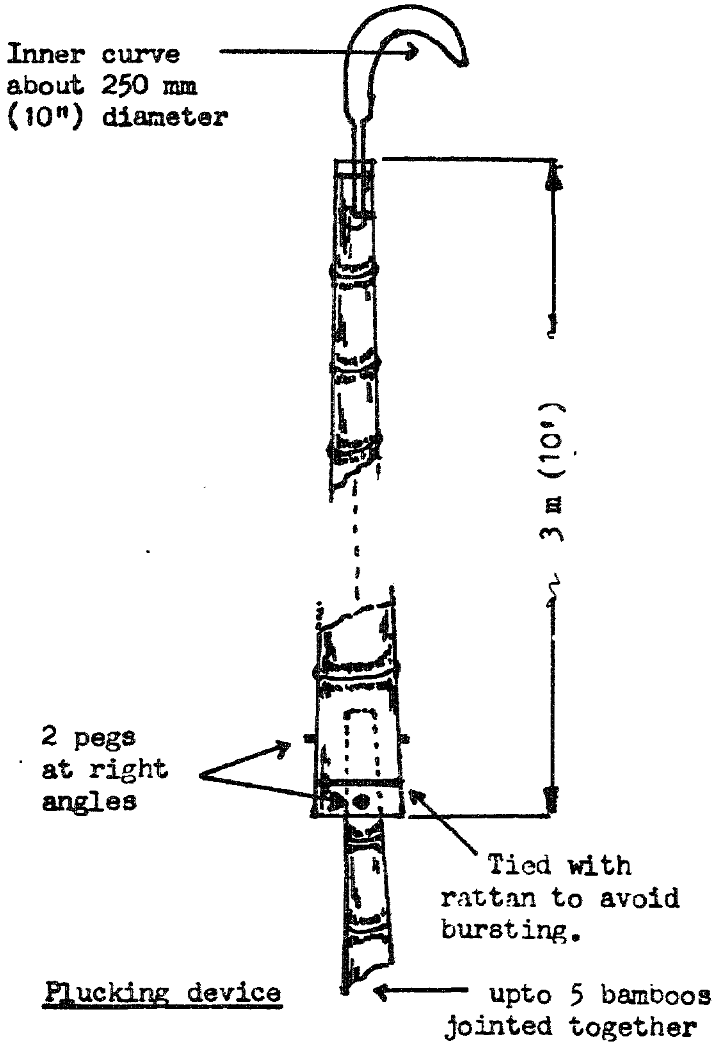
4. Equipment

4.1 Description of equipment: -

Plucking device

Several bamboo poles jointed together and knife attached to uppermost bamboo. The inner curve of knife is about 250 mm diameter which is bigger than a coconut. Each bamboo is about 3 meter long. The joint is made with 2 pegs at right angles. The lower portion of each bamboo is strengthened against burst by tying with rattan. The number of bamboos linked together will depend upon the height of the trees which in turn depends upon the age. Usually not more than 5 bamboos are linked together because beyond that the device cannot be managed. Trees taller than about 15 meter are harvested by professional climbers in small holdings.

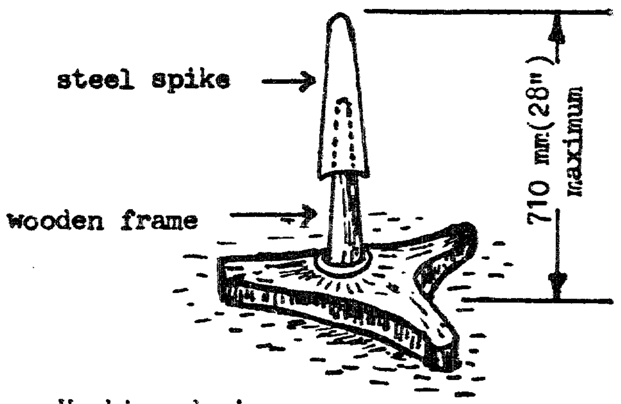
Trees which are climbed have V shaped notches cut onto the coconut trunk to serve as steps in climbing up to the crown. The notches are large enough to accomodate a toe hold. One side of the notch is parallel to the ground. Cutting notches is however injurious to the health of the tree. This practice of climbing is being done away with in most areas. In larger holdings, the nuts from very tall trees are allowed to fall naturally and are collected regularly.



Plucking device

Husking device

This is a wooden horse type device with a verticle spike fastened to it. It has a wooden base frame and thus can be carried from place to place.



Husking device

4.2 Materials for construction

Plucking device

One knife

Five bamboos specially prepared, each 3 meter (10 ft) long.

Pegs for easy assembly and dismantling of joints.

Movable Husking device - Wooden horse with verticle spike

4.3 Cost of equipment

Plucking device

	₱	US$	(1US$ = ₱ 7.42)
Knife	25	3.37	
5 Bamboos (a) 6	30	4.04	
Total	55	7.41	

Husking device

Total cost	₱ 70.00	US$ 9.43

4.4 Capacity

Use of bamboo

A group of 3 men with one plucking bamboo can harvest and gather nuts in an area of 2 Hectare per day of about 10 hours working time. On the basis of 156 trees per Hectare and 5 nuts per tree per harvest (harvesting every 45 days which is 8 times a year), the capacity will be 1560 nuts per group of 3 men.

Payment per 1000 nuts ₱ 10 (US$ 1.35).

Use of human climbers

Group of 3 men with two climbers can pluck the nuts of about 80 trees per day of about 10 hours. On the basis of 5 nuts per tree, the capacity for the group will be 400 nuts (about ½ Hectare).

Payment per 1000 nuts ₱ 25 (US$ 3.37)

Husking

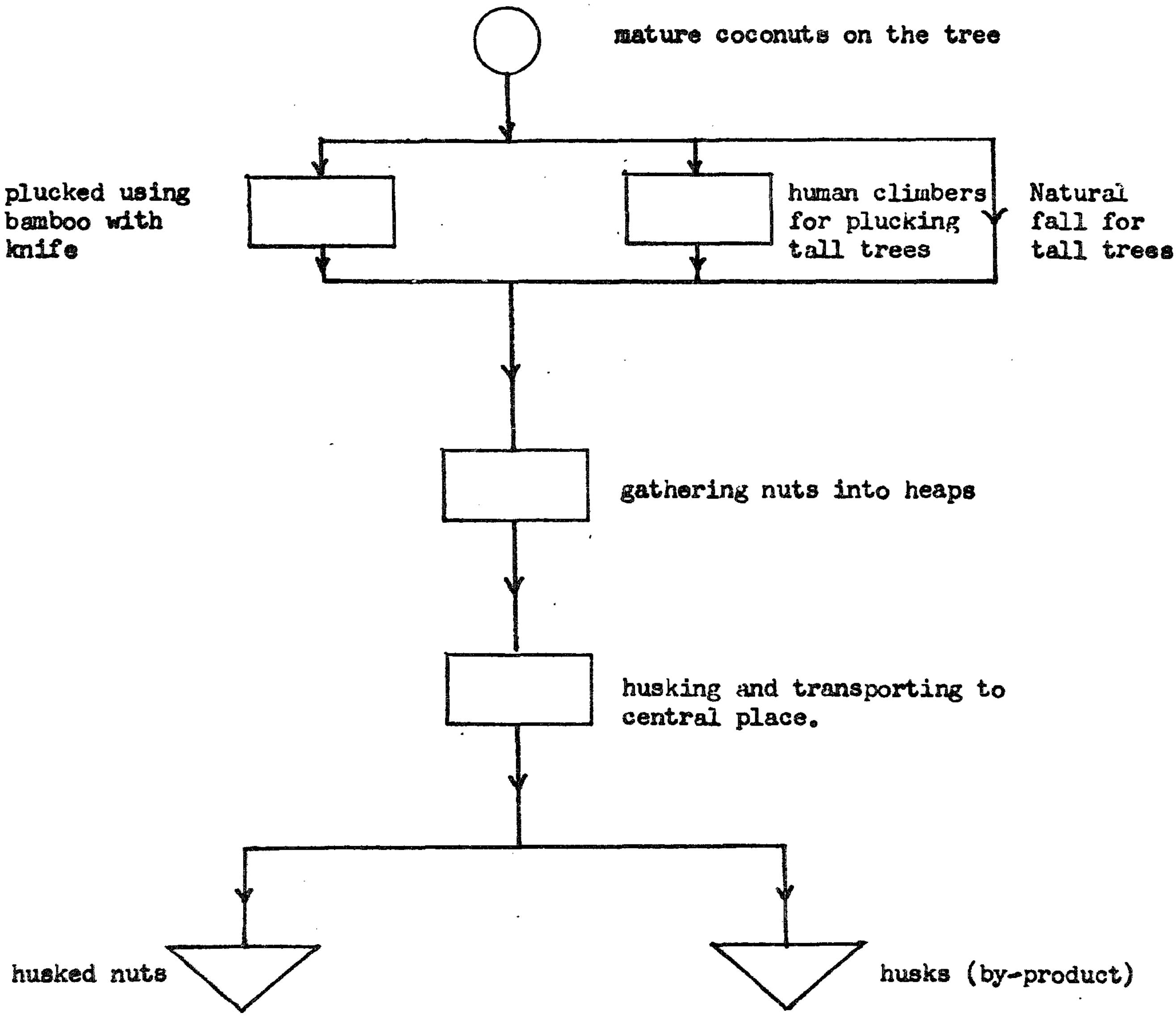
One man using the wooden horse and spike can husk about 1000 nuts per day of 10 working hours.

Payment per 1000 nuts ₱ 10 (US$ 1.35)

Payment for gathering and transporting upto Copra dryer or central point on premises for despatch per 1000 nuts ₱ 10 (US$ 1.35).

5. Process

5.1 Process flow diagram: -



5.2 Description of process: -

The group of 3 men comprise of 1 experienced plucker and 2 helpers who gather and husk the nuts. The knife attached to the bamboo is carefully taken over the nuts and the frond cut with one downward pull bringing the entire bunch down. For each tree, one or two bunches are plucked depending upon maturity of nuts.

The nuts plucked in the Philippines appear to be 10 to 14 months old from polination which is 12 to 16 months old from flowering. The youngest nuts plucked therefore will be just mature or sometimes just under mature. The oldest nuts will be on the verge of falling naturally.

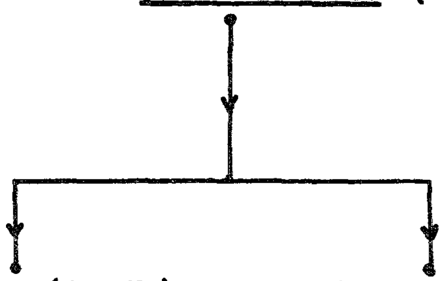
Once the nuts are gathered into small heaps, they are husked using the movable wooden horse and spike. The husks are removed from the nuts in 3 to 4 segments depending upon the size of the nut. The husks are left on the land unless there is a copra dryer in the premises in which case the husks are used as fuel for firing.

The husked nuts are separately transported using a cart to either the copra dryer or to a central point to be sold and despatched for production of Desiccated coconut or as food nuts.

5.3 Product flow diagram

Harvesting : - Not applicable

Husking : - 1000 whole nuts (1200 Kg)



1000 husked nuts (800 Kg) 1000 husks (400 Kg).

6. Quality of finished product

The nuts must be fully mature (ideally 12 months old from polination which is the same as 14 months from flowering). However, in actual practice the age from polination may vary from 10 to 14 months.

There should not be immature nuts or germinated nuts for processing into Copra or Desiccated coconut.

7. Source of information

Investigations during field visit to Davao in Mindanao Island, Philippines.

T.K.G.R 1979.

Product code: CCCN 08.01
Technology sheet no: I / 3

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology Sheet for :- HARVESTING COCONUTS (INDIA)

2. Uses of finished products :-

2.1 The fully mature coconut is used for manufacture of cup copra and desiccated coconut. Nuts from selected varieties are used as seed nuts.

2.2 The nut when plucked at full maturity with drying commenced on the tree (14 to 16 months age) can be used for making edible ball copra if suitably stored without husking.

2.3 Coconut is used for culinary purposes particularly in Kerala State.

2.4 In Kerala husks of coconuts just under mature (10 to 12 months age) are retted to extract white coir fibre. This is an important cottage industry supporting a large population.

3. Country of Origin :-

INDIA - mainly Kerala State followed by Tamil Nadu and Karnataka States.

4. Equipment :-

4.1 Description of equipment :-

4.1.1 Ladder of single bamboo - see figure I. Though bamboo is available in some areas, it is not used as a plucking device but as a ladder to climb the tree.

4.1.2 Sharp curved knife - see figure II and loop for the feet.

4.1.3 Husking device - see fifure III.

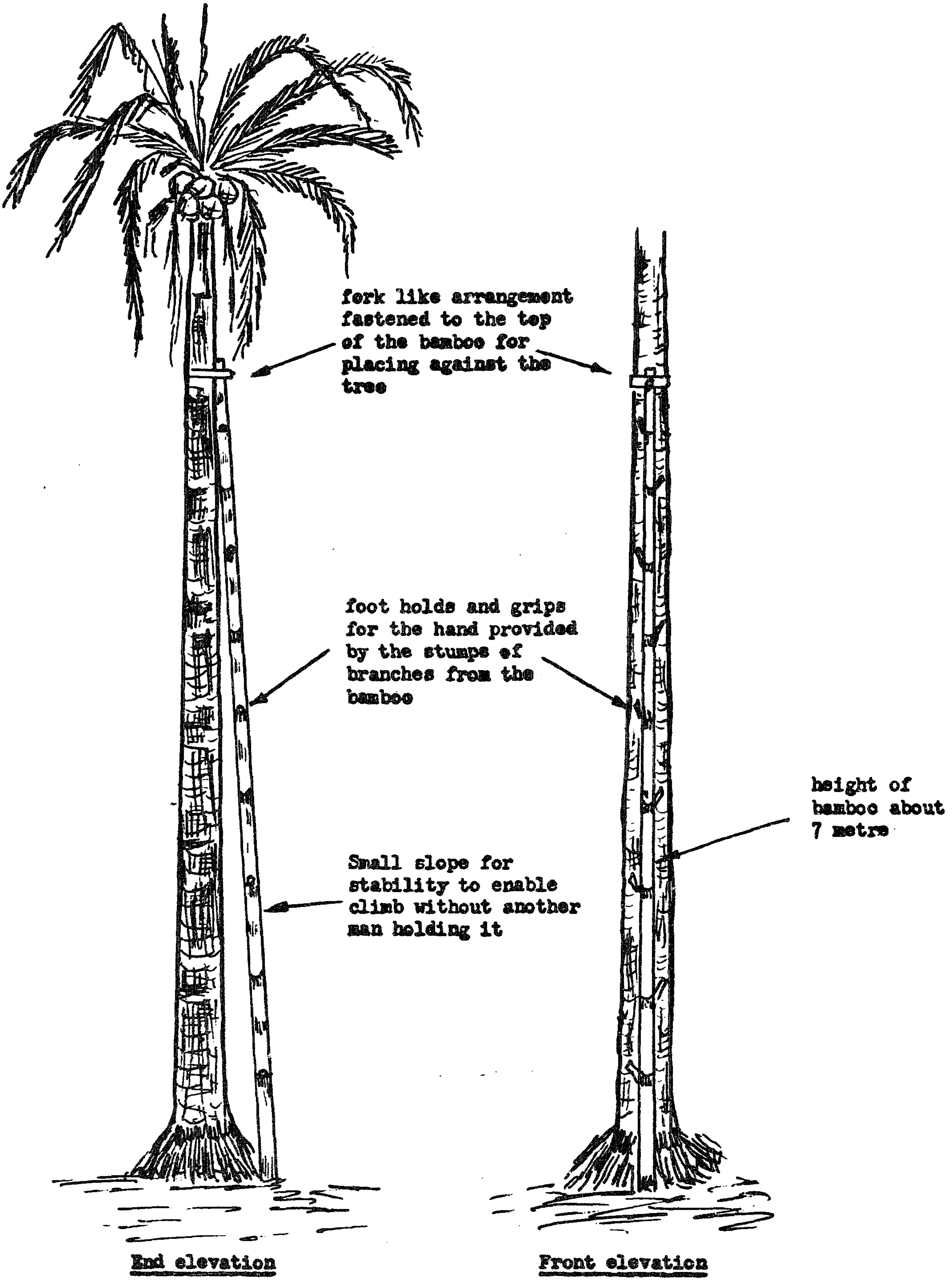


FIGURE I LADDER OF SINGLE BAMBOO

3.

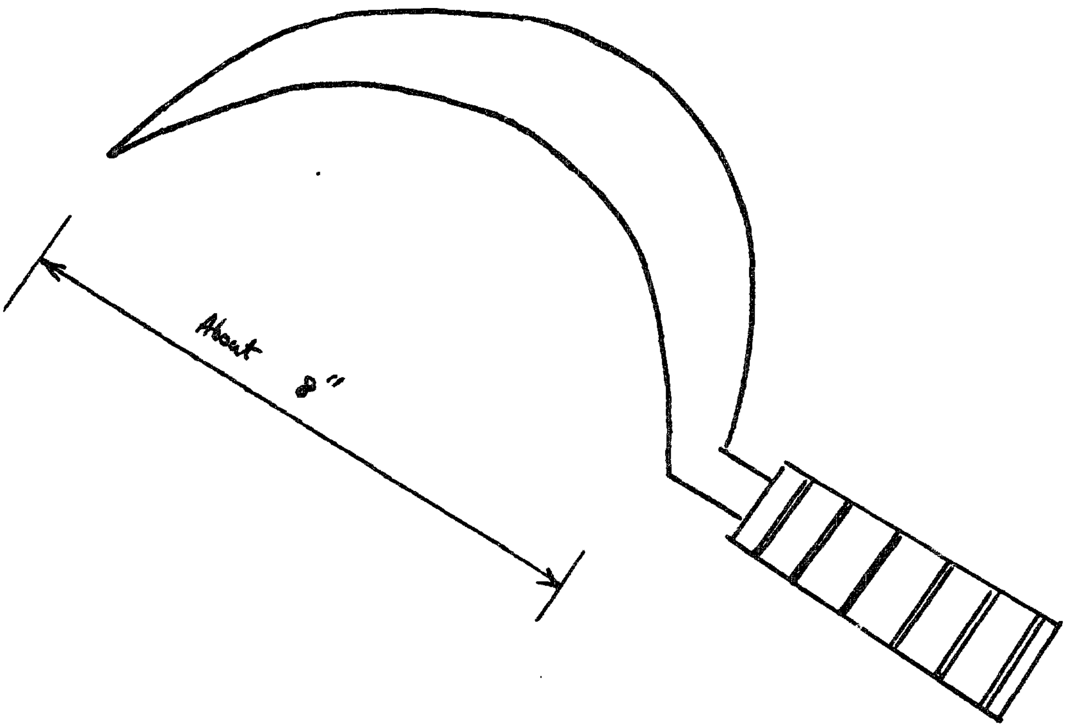


FIGURE II **SHARP KNIFE FOR HARVESTING COCONUTS**

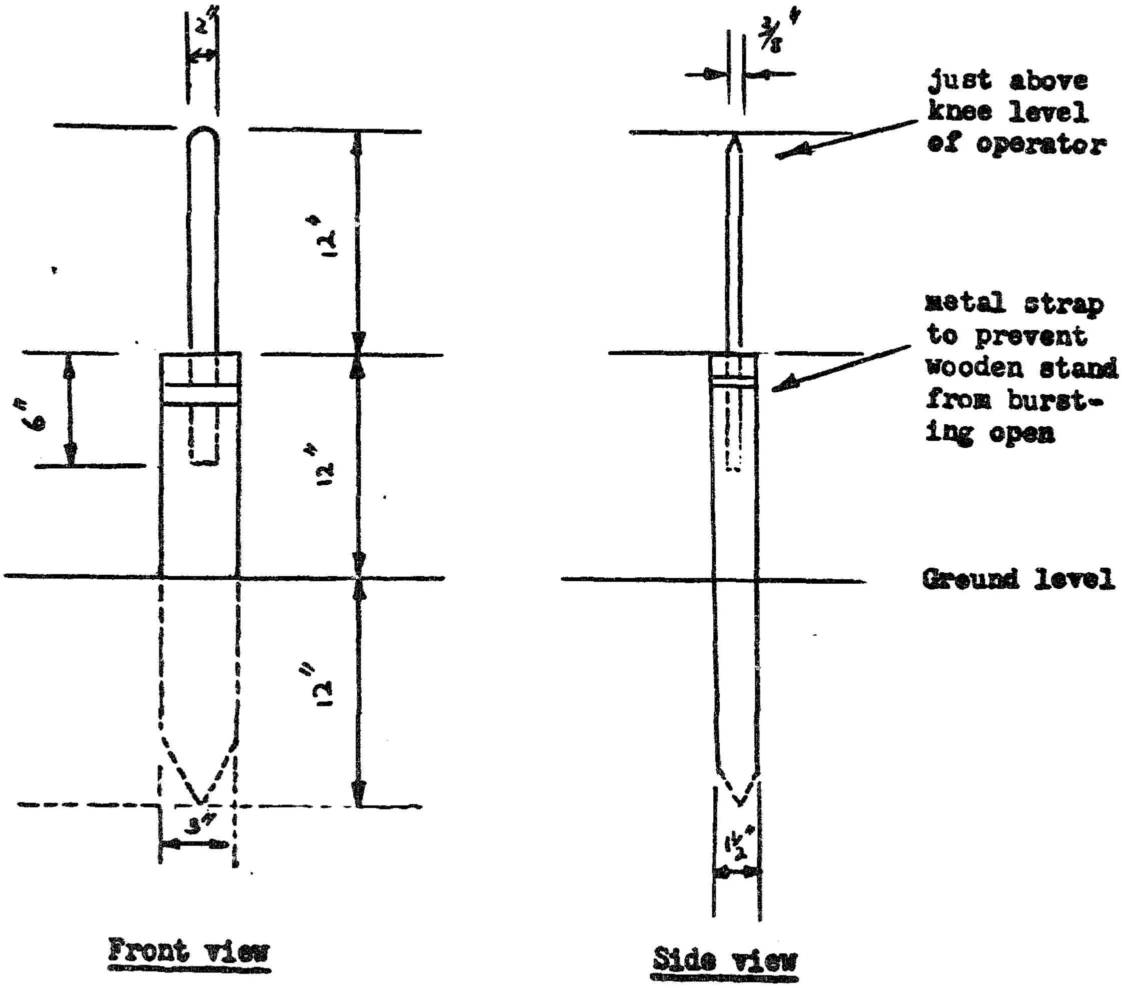


FIGURE III **HUSKING DEVICE**

4.2 Materials for construction :-

Not applicable

4.3 Cost of equipment :-

4.3.1 The bamboo will be about Rs 5/= (US$ = :/61)

4.3.2 The cost of the knife is about Rs 10/= (US$ = 1/22)

4.3.3 The cost of the husking device is Rs 15/= (US$ = 1/83)

4.4 Capacity :-

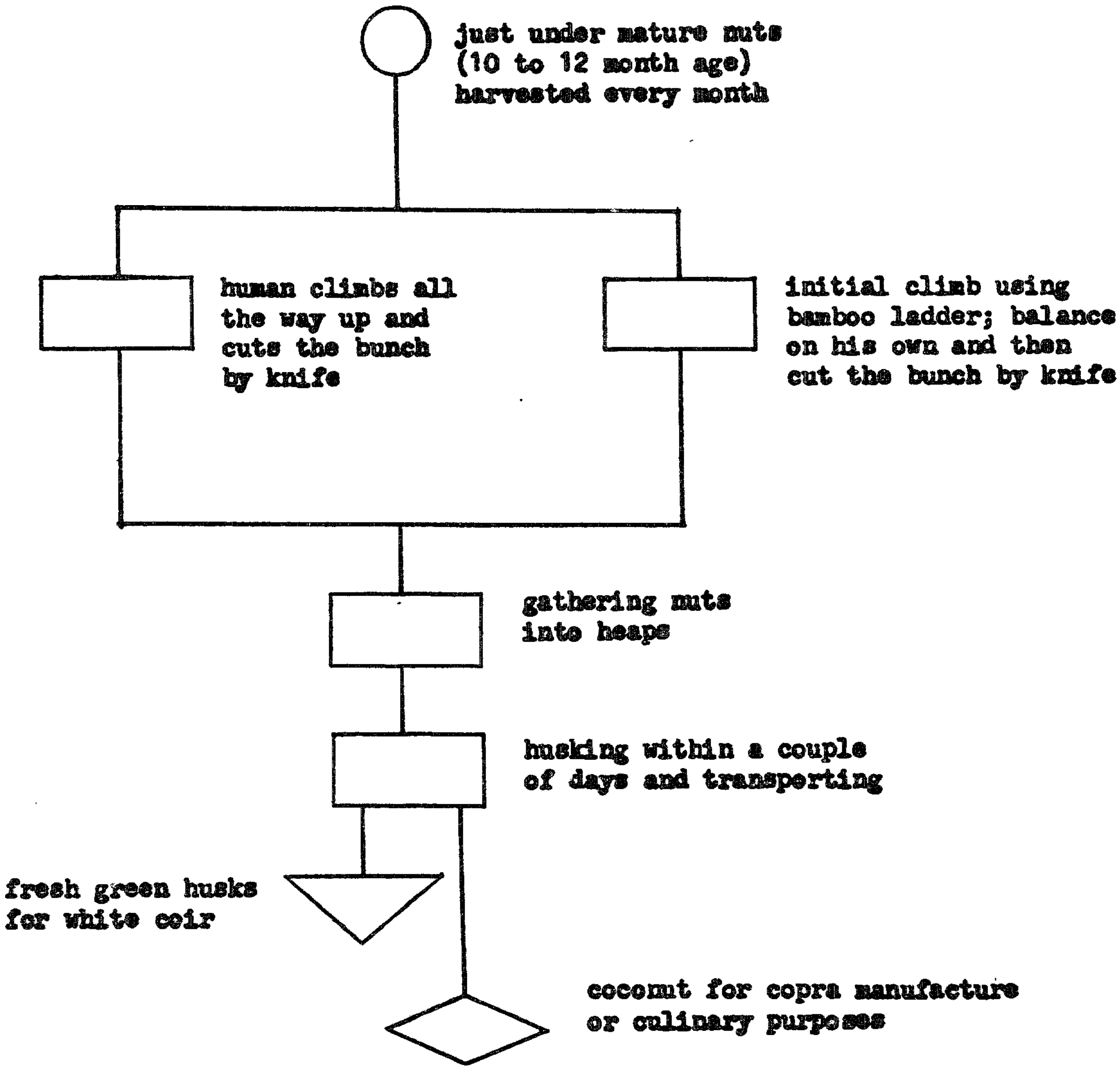
A skilled human climber can harvest about 50 trees in a working day. The harvesting charge for 100 trees varies from Rs.20 to Rs.25 (US$ 2/50 to 3/=). The harvesting in white coir areas is every month whilst other areas it is once in 2 months.

The capacity for husking by a skilled worker is 1500 to 2000 nuts per normal working day. Payment is on piece rate basis and varies between Rs 6/= to 10/= (US$ = /73 to 1/22) per 1000 coconuts depending upon the area.

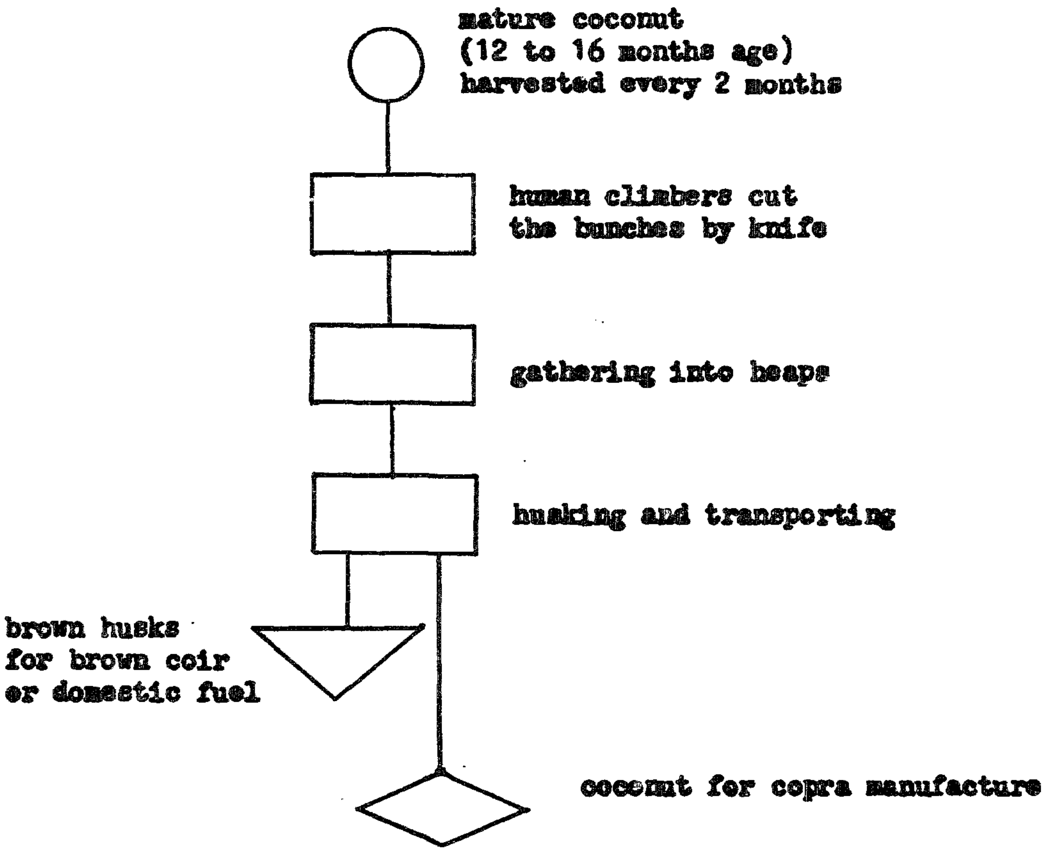
5. **Process : -**

5.1 **Process flow diagrams : -**

System A as in Kerala State



<u>System B as in other States</u>



5.2 Description of process :-

In Kerala State where the white coir industry exists, coconuts just under mature, (10 to 12 months age from flowering) are harvested monthly. Skilled climbers go all the way upto the crown by using a loop round the two feet for gripping them onto the tree trunk. In some areas, a ladder made of a single bamboo is used to climb upto a certain height of the tree and the balance is climbed on his own with the help of the loop for the feet. The footholds and grips for the hand are the stumps left over from the alternating shoots or branches which come off the bamboo. The bamboo has a fork like device fastened at the top to place against the tree. The bamboo is placed with a slope to provide stability for a climber without another man holding it at ground level. Owing to its simplicity and light weight, the bamboo can be easily carried by the climber from tree to tree.

Once at the top of the tree or crown, the selected bunch is cut down by the use of the sharp knife with one strong jolt. The nuts are gathered, put into heaps and husked with the husking device. The nuts go for food nut purposes or for making copra whilst the fresh green husks are retted for white coir.

For centralised copra manufacturing units, the whole nuts are transported by bullock carts, boats (where backwater canals are available) to the central yard. Here dehusking is done, immediately followed by splitting the nuts for copra drying.

In these areas, the maximum lapse of time between harvesting and copra manufacture is about three or four days which is inevitable if the nuts have to be transported to central copra dryers. This does not constitute "seasoning" or crop storage as practised in Sri Lanka. Besides, dryage of the kerbel would be et rimental to obtaining good soft white coir. 'urthermore, nuts just under mature cannot be stored for a few weeks because spoilage will occur.

In the State of Tamil Nadu and Karnataka where retting facilities are not available for white coir, the harvesting system is different to that in Kerala State. Only nuts fully mature 12 to 16 months old are harvested and that too at a frequency of once in two months. This is similar to the practices in Sri Lanka.

Harvesting is done only by human climbers as in Kerala. Although bamboo is available in some areas, for certain reasons of customs etc., the bamboo with a knife is not used for plucking coconuts from the ground. The plucked coconuts are gathered into heaps and transported to central copra making units. Use of coconuts for food nut purposes is not as common as in Kerala.

At these processing units, the coconuts are husked and nuts used for copra. The lapse of one or two weeks between harvesting and husking helps to partly dry the husk of these coconuts which are nearly turning brown as they are fully mature. The temporary storage upto 2 weeks does not season the nuts as well as in Sri Lanka, but causes the husks to dry out to be suitable for extraction of brown coir fibre. Some of the husks are therefore used for making brown fibre as in Sri Lanka by mechanical methods (wet or dry milling process), whilst some husks are used as domestic fuel.

5.3 Process flow diagram :-

Not available

6. Quality of finished products :-

Just under mature coconuts as harvested in the coastal areas of Kerala State are not ideal for copra manufacture. However, fresh green husks of such coconuts are the right quality for extraction of white coir. Such coconuts are suitable for use as food nuts for which there is a heavy demand in these areas.

Fully mature coconuts as harvested in the interior of Kerala State, and in the States of Tamil Nadu and Karnataka give rise to excellent quality copra. In fact those nuts which have commenced drying in the tree itself are suitable for ball copra. The husks from dry brown coconuts are the right quality for extraction of brown coir by mechanical methods (wet or dry milling) as in Sri Lanka.

7. Source of information :-

7.1 Directorate of Coconut Development, Cochin, Kerala, India.

7.2 Observations during visit to coconut areas of India.

Product code : CCCN 08.01
Technology sheet no: I / 4

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for : - HARVESTING COCONUTS USING TRAINED MONKEY (Small holdings).

2. Uses of finished product : - The harvested coconuts are used as food nuts or for processing into copra.

3. Country of origin : - INDONESIA.- Province of West Sumatra
MALAYSIA - East coast of Malaysian Peninsular.
THAILAND - For tall trees only.
See technology sheet for coconut harvesting in the Philippines by use of bamboo poles.
See also technology sheet for crop storage or seasoning of whole nuts in Sri Lanka where-in harvesting practices are given.

4. Equipment/Requirements : -

4.1 Description : - Trained monkey (a particular species) of either sex but the female is stronger and superior.

Working age of female	1 to 25 years.
Working age of male	1 to 20 years.

An experienced man controls the monkey. The monkey is tied and held by a long cord.

4.2 Materials : - Not applicable

4.3 Cost : - Cost of monkey 1 year old Rp.7500 (US $ 12)
Cost of training (1 month duration) Rp.7500 (US $ 12)

The charges for harvesting (without gathering) is one coconut per ten nuts harvested. The price of one whole coconut is Rp. 60 in West Sumatra (Indoneaia).

4.4 Capacity : - One monkey can harvest 50 palms per working day. On the basis of palm density of 150 trees per hectare, this will be $\frac{1}{3}$ hectare per day per monkey.

Assuming each palm yields 7 nuts per harvest, the capacity per monkey per day will be 350 nuts. The payment which is the value of 10% of the nuts will be - Rp 60 x 35 = Rp 2100 (US $ 3.36)

5. Process

5.1 Process flow diagram : - Not applicable.

5.2 Description of the process : - The special species of monkey available in the province of West Sumatra (Indonesia) is the monkey that is trained for harvesting. The same technique is used in the East Coast of West Malaysia. In Thailand this same monkey is used but only for the very tall trees as the bamboo pole is used for trees upto about 15 metre height. It is to be noted that in Thailand, harvesting by bamboo is nut by nut with a knife attached to the bamboo. The reason is probably due to the enormous size of the nut which makes the task more dangerous to the plucker. In the Philippines, and Sri Lanka, the entire bunch is cut at the main stem using the knife attached to the bamboo.

Both sexes of the monkey can be trained. The usual age for training the monkey is when 1 year old. The training takes about 1 month for which the charges are Rp.7500. The cost of a 1 year old monkey is also Rp.7500. Therefore the cost of the monkey after training will be Rp.15,000or US $ 24. There are people available in the coconut areas of West Sumatra who undertake the training.

The working age of the monkey is 1 to 25 years for the female and 1 to 20 years for the male. The female of the species is strong and superior for harvesting. Though a monkey is trained at the age of 1 year, the monkey needs another year to gain experience for optimum performance.

The monkey is tied by a strong light cord and held by the owner who controls the monkey. The man is able to communicate with the monkey by using the words which have been taught to the monkey during training. The monkey is instructed to climb a particular tree and upon reaching the crown, the most mature bunch is harvested nut by nut. The nut is released from the bunch by turning the nut continuously so as to twist the stem attaching the nut. When the nut has been turned by about 4 full rounds, the stem gets severed, and the nut falls down. Once the most mature bunch has been plucked, the man examines the next most mature bunch while standing at the bottom of the tree. If it is not yet ready for harvesting, the monkey is instructed to climb down and the next tree is similarly attended to.

Human climbers harvest nuts in small holdings in Sri Lanka, India, some provinces of the Philippines, some provinces of Indonesia and some provinces of Malaysia. The climber whilst at the crown is able to pick a whole bunch by cutting the main stem with a sharp knife. This makes the operation of releasing the nuts from the palm much faster. However there is a certain amount of risk involved in doing so. Therefore there are often instances of these men preferring to remove nut by nut by turning the nut. There is an interesting variation in India as regards the climbing technique by men. A bamboo is placed like a ladder against the trees which are of medium and greater height. The climber works himself up rapidly along the bamboo which has small foot holds at the stubs left where branches had sprung out. The balance height of the tree is climbed using the usual technique and the nuts harvested.

5.3 <u>Product flow diagram</u> : - Not applicable.

6. Quality of finished product : - Not applicable.

7. Source of information : - Observations during visits to West Sumatra province of Indonesia and other coconut regions of Indonesia, Thailand, Malaysia, Philippines, India and Sri Lanka.

T.K.G.R. 1979.

Product code: CCCN 08.01
Technology sheet no: I / 5

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"
(Project UF/RAS/78/049)

1. Technology sheet for : - CROP STORAGE OR SEASONING OF MATURE WHOLE NUTS AFTER HARVESTING

2. Benefits of technology :

Storage of mature whole nuts after harvesting brings about a seasoning (maturing, drying) of the whole nut. Thereby, coconuts of uniform and good quality can be made available for making copra and desiccated coconut and thus improve the quality of these two products. (Seasoned or dried nuts are not suitable for cooking purposes or food nuts).

For industrial processing, seasoned and dried nuts are easier and faster to dehusk. The husks come off clean. These husks are dry and are suitable for extraction of brown fibre after soaking.

Seasoning also results in easier and faster splitting of the husked nut due to dryage.

The coconut kernel and testa separate easily from the shell due to dryage, thus speeding up deshelling. This gives rise to unbroken half kernels for cup copra and unbroken whole kernels for desiccating.

Seasoning results in a clean dry raw shell free of husk matter which gives high quality charcoal suitable for activation.

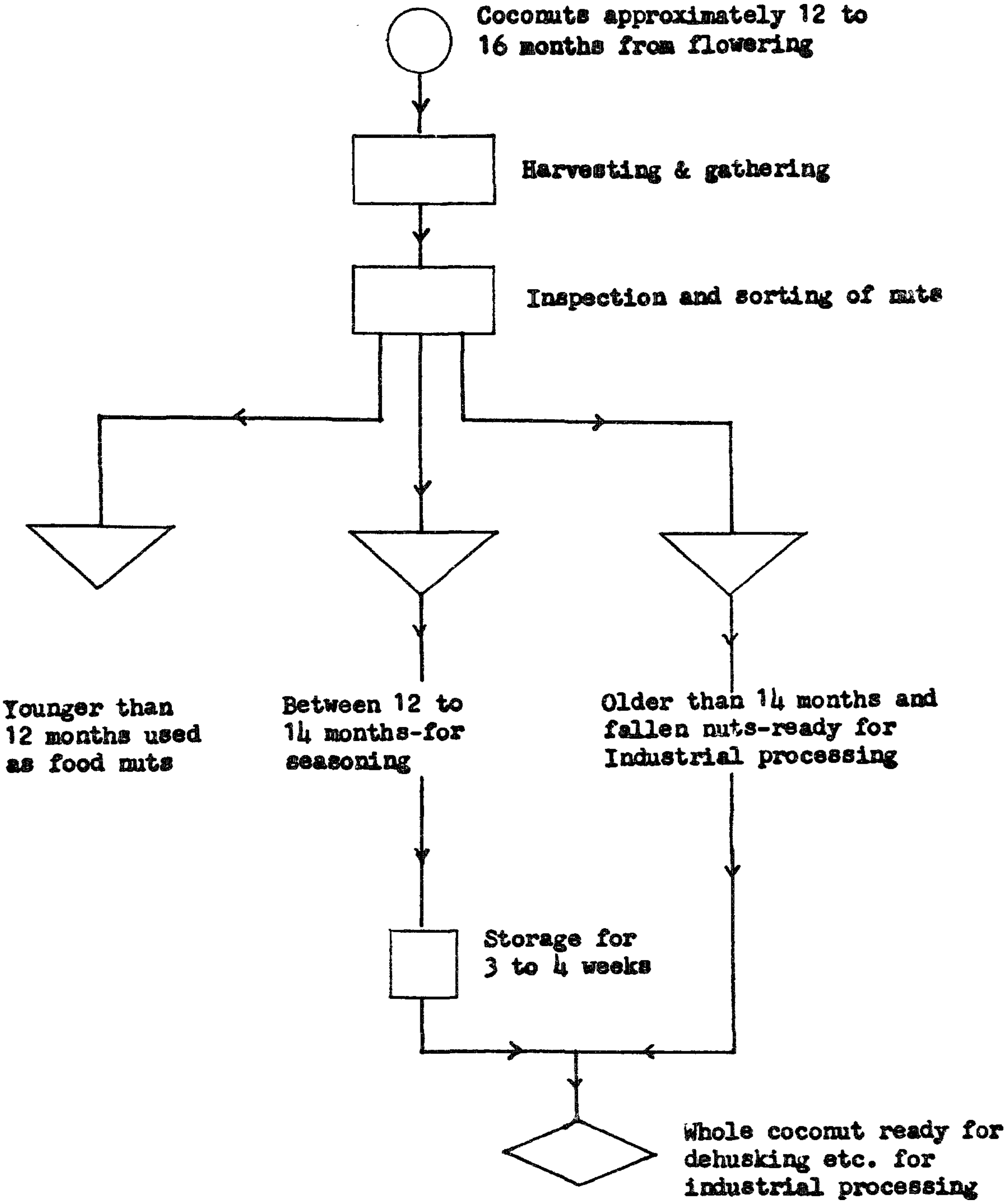
3. Country of origin : - SRI LANKA

Sri Lanka is unique in following this practice of storing coconuts prior to industrial processing.

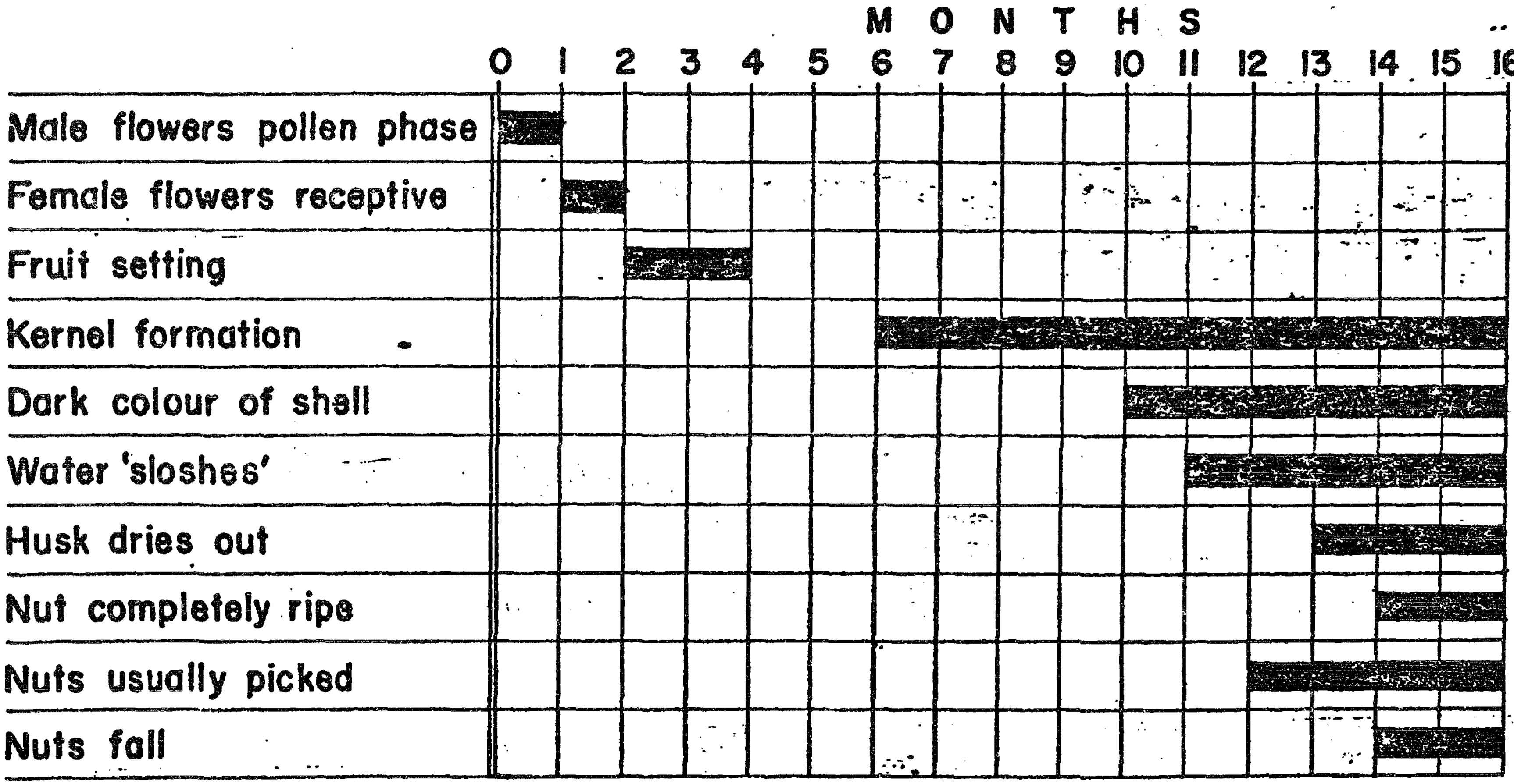
4. Equipment : - Not applicable

5. <u>Process</u>

5.1 Process flow diagram



DEVELOPMENT OF NUT FROM FLOWERING TO HARVEST



Source: COCONUTS by Reginald Child
Longmans , London, 1964

5.2 Description of process

Coconuts are considered mature for industrial processing when they are approximately 12 to 16 months old from flowering. On the basis of polination occurring when the flower is upto 2 months old, mature coconuts would be 10 to 14 months old from the stage of polination. See the chart given in page 3 illustrating the development of the nut from flowering to harvesting. In the practice of harvesting, nuts are picked on the basis of 'maturity' rather than age of nut, but the chart relates the various stages to age from flowering. Judgment based on experience is the means of assessing whether a bunch of coconuts is mature or not.

The following paragraphs give extracts from leaflet no. 27 (1965) issued by the Coconut Research Institute (C.R.I.) now called the Coconut Research Board of Sri Lanka.

5.2.1 Methods of harvesting: -

In some countries, natural nut-fall is the practice. However, this requires the regular monthly collection of the fallen nuts, if loss of copra and spoilage by germination is to be avoided. Furthermore, there is always the risk of crop thefts.

In consequence, it is the custom in Ceylon to cut down two bunches of nuts, once every two months, making six picks a year. Monthly harvesting might be better, but the cost of harvesting and collection would be doubled.

Many years ago, when the reputation of Ceylon copra was very high on the world market, the coconut crop was harvested by climbers who could select the right nuts. The work was slow, costly and exhausting. A skilled climber could only harvest about 20 to 25 palms per day.

This method has given way to harvesting by means of long bamboo poles, fitted with sharp curved knives. This is naturally quicker and cheaper, but less accurate, as it is not easy for the picker to decide which are the correct two bunches to cut down when the palms are tall. Sometimes an unripe bunch gets dislodged from its supporting frond and hangs invitingly, as though ready for harvesting, sometimes unripe bunches are cut down accidentally as the heavy cutting poles are not easy to manage. Sometimes, when the men are working on contract, over harvesting is deliberate. A skilled man can harvest the crop from about 250 palms per day.

The strictest supervision of these picking gangs is essential. It is not always appreciated that green unripe nuts yield much less copra than ripe brown nuts.

The results of an experiment conducted on 200 nuts each of different ripeness from one harvest is given below:

	Average copra per nut	Out-turn nuts per tonne of copra
Green unripe nuts	.42 lb.	5240
Yellowish green nuts	.49 lb.	4490
Ripe brown nuts	.50 lb.	4400
Overall standard for Sri Lanka		4925

5.2.2 Method of Crop Storage

Usually the coconuts are brought into a central depot and stacked. Sometimes, as in the case of a desiccated coconut factory, the heap of nuts covers an extensive area, but the height of the stack is seldom more than three feet. If the fruits are heapd to a greater height, say 6 feet, the work is slowed, the under-lying soil is compressed and the palms suffer. As the heap cannot be ventilated, the interior heats up and the fully ripe nuts begin to germinate.

It is advisable in fact to move the site of storage around the mill area. Since air is excluded from the roots of the palms and as a result of soil compaction, the sheltering palms turn yellow and are inclined to taper off and die.

The number of nuts, so stored, depends; in the case of a desiccated coconut factory, on the price of nuts relative to the selling price of the manufactured product. In the case of the estate, the normal storage period is one month but it may be reduced, if ready money is required or if copra prices are particularly good. On a 1,000 acre estate, there would be a fluctuating stock of about 500,000 nuts.

5.2.3 Purpose of Storage

The purpose of storing nuts is as follows: -

1. It makes it possible to manufacture copra at a uniformly steady rate, irrespective of crop fluctuations.
2. Copra production can be suspended during periods of stormy weather when it is more difficult to make good white copra.
3. Conversely copra production can be speeded up to take advantage of favourable market prices.
4. Nut storage make husking and splitting very much easier.
5. The contained coconut meat hardens and a better quality of copra or desiccated coconut is obtained.

As indicated in section 2, storage also assists in dehusking, deshelling, and utilization of husk and shell.

5.2.4 Storage Trials: -

A trial was conducted at the C.R.I. in order to compare the quality of copra, obtainable from stored and unstored nuts of different degrees of ripeness. The nuts used were graded to three degrees of ripeness and 1,500 nuts were used in each trial. Afterwards the resulting copra was subjected to piece-by-piece examination with the results shown below.

Description of copra	Description of nuts		
Fresh Unstored Nuts:-	Ripe	Near Ripe	Unripe
	%	%	%
Smooth, hard round	9.1	2.9	0.9
Smooth, hard but not round	45.1	24.8	7.0
Rough, hard but not round	28.1	47.8	23.3
Strained, cracked or distorted	8.5	12.4	12.4
Rubbery with testa complete	4.5	6.5	27.1
Rubbery with no skin	Nil	1.3	22.1
Discoloured copra	0.7	2.8	6.3
Over-ripe pieces	0.4	Nil	0.1
Broken copra or empty nuts	3.6	1.5	0.8
Stored Nuts :-			
Smooth, hard round	8.5	5.4	2.2
Smooth, hard but not round	19.8	10.7	8.6
Rough, hard but not round	54.9	64.5	50.2
Strained, cracked or distorted	6.5	9.6	7.3
Rubbery with testa complete	3.9	4.0	20.1
Rubbery with no skin	0.2	1.2	5.7
Discoloured copra	0.2	0.2	0.8
Over-ripe pieces	2.4	0.1	Nil
Broken copra or empty nuts	3.6	4.3	5.1

5.2.5 Conclusions: -

(a) The storage of ripe brown nuts does not improve the quality of the resulting copra, but there is a marked improvement when unripe green nuts are stored thus;

Yield of No. 1 copra	from ripe brown nuts	from unripe green nuts
Without storage	90.8%	43.6%
With storage	89.7%	68.3%

(b) The amount of rubbery copra is reduced by storage for one month

Yield of rubbery copra	from ripe nuts	from near ripe nuts	from unripe green nuts
Without storage	4.5%	7.8%	49.2%
With storage	4.1%	5.2%	25.8%

(c) The yield of No. 1 copra from unstored brown nuts is slightly greater than that from stored near ripe yellow green nuts thus: -

Yield of No. 1 copra	from ripe brown nuts	from yellow green nuts
Without storage	90.8%	87.9%
With storage	89.7%	90.2%

(d) Unripe nuts produce an appreciable percentage of offwhite or discoloured copra or desiccated coconut, if the nuts are not stored before processing.

5.2.6 Recommendations

I. Where a mixed crop is harvested, it is essential to separate the green from the brown nuts, store the former for one month and convert the latter into copra without storage.

II. The harvesting of green unripe nuts must be prevented by more careful supervision.

III. Unripe green nuts should never be bought by millers of desiccated coconut, as the product will be spoiled by yellow-granules.

5.3 Product flow diagram - Not applicable

6. Quality of finished product: -

The quality of the whole nut after seasoning is ideal for industrial processing of the kernel and the by-products as practiced in Sri Lanka.

7. Sources of information: -

1. Coconut Research Board
   Lunuwila
   Sri Lanka
2. Writer's personal observations

T.K.G.R. 1979

Product code: CCCN 12.01 b
Technology sheet no: I / 6

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for : - PRINCIPLES OF COPRA MANUFACTURE

2. Uses of finished product : -

2.1 Edible Copra. Special grades and types are used directly for edible purposes.

2.2 Mill Copra. This is used for milling to extract the oil. Coconut oil has edible uses such as cooking oil, margarines etc. Coconut oil also has industrial uses such as in the manufacture of soap, glycerine, cosmetics, detergents and a whole series of oleo-chemicals. Mill copra is the most important commercial product from the coconut. However, in the densely populated coconut areas the fresh kernel (without drying into copra) is a very important product as it is used as food nuts, thus meeting the fat requirements in the diet of the people.

3. Country of Origin : - Copra is manufactured in all the coconut producing countries for local use or for export.

4. Equipment : - There are several types of dryers (kilns) employed in copra manufacture. However, these fall into four basic methods.

A. Natural drying
B. Direct heat smoke dryers
C. Direct heat smokeless dryers
D. Indirect heat dryers.

See the following technology sheets where further classification has been carried out and full details such as equipment, method of operation etc. have been presented.

Drying Method A

A.1 COPRA MANUFACTURE BY NATURAL DRYING USING DIRECT SUN IN THE OPEN.

A.2 EDIBLE BALL COPRA MANUFACTURE BY NATURAL DRYING WHOLE NUT IN THE SHADE.

Drying Method B

B. COPRA MANUFACTURE BY DIRECT HEAT SMOKE DRYERS USING TRADITIONAL FUEL OTHER THAN COCONUT SHELLS.

Drying Method C

C.1 COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELLS AS FUEL COMBINED WITH PRE-DRYING IN THE SUN.

C.2 COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELLS AS FUEL.

Drying Method D

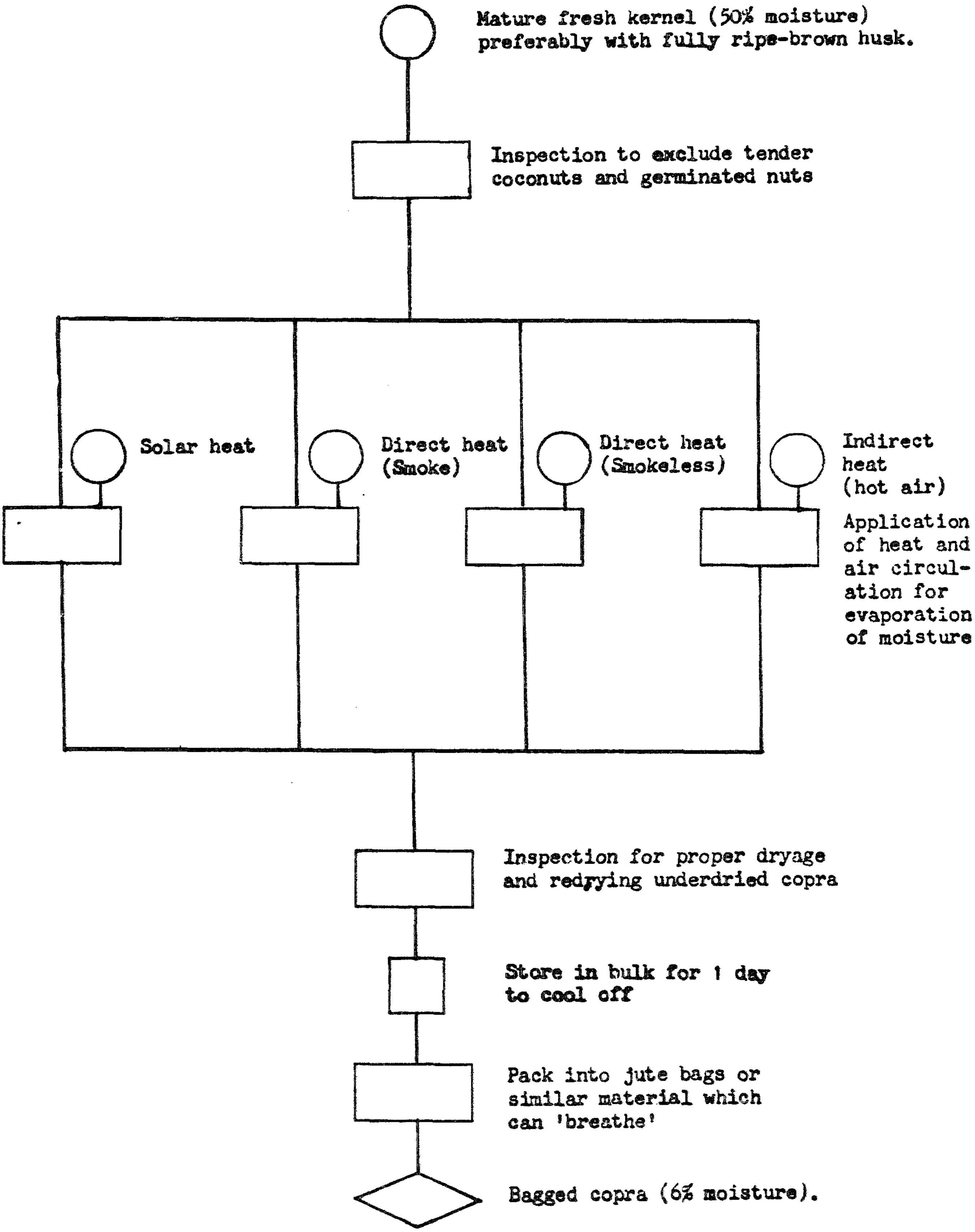
D.1 COPRA MANUFACTURE BY INDIRECT HEAT HOT AIR DRYERS WITH NATURAL DRAFT.

D.2 COPRA MANUFACTURE BY INDIRECT HEAT HOT AIR DRYERS WITH FORCED DRAFT.

In this series of technology sheets, an attempt has been made to separate the direct heat dryers as smoke dryers (using husk, firewood etc) and smokeless dryers (using coconut shells as fuel). Although most publications classify both in the same category, the writer has separated them because whilst the direct smoke affects the quality of copra, the latter gives copra without the adverse effects of direct smoke.

5. **Process**: -

5.1 Process flow diagram: -



5.2 <u>Principles of the process</u>: -

5.2.1 <u>Selection of coconut</u>. For optimum oil yield, fresh kernels of mature nuts only should be used for copra making. A nut is considered mature when it's age is between 12 to 16 months from flowering. If there are nuts 11 months or younger that have been harvested, they should not be used. Immature nuts do not make a noise when shaken because the cavity is completely full of water. When the nut matures some water is lost and thus makes a noise (sloshes) when shaken. Of the mature nuts, those 12 to 14 months old are green or yellow colour whilst, those 14 to 16 months are fully ripe and brown in colour due to husk drying out.

Experience has shown that the fully ripe nuts produce superior quality copra. In Sri Lanka, there is a unique practice in storing the green or yellow mature nuts for about a month to accelerate the drying of the whole nut. This is known as "Seasoning". See technology sheet "Copra Storage or Seasoning of Mature Whole Nuts after Harvesting". The fully ripe nuts are not stored. This is not necessary and furthermore they tend to germinate if they are exposed to the sun and rain. Germinated nuts should not be used for copra manufacture as experience has shown that they are inferior.

In actual practice proper harvesting of mature nuts, elimination of tender and germinated nuts donot happen when small holders themselves make the copra,particularly in the absence of grading and lack of price incentives for good copra. This situation has been aggravated due to many coconut regions having oil milling capacities far in excess of the copra availability. The oil millers are willing to buy copra of any inferior quality when their capacity utilization is only 20 to 30%.

In professionally managed large holdings and copra processing centres where there is free trade of the nut, only coconuts of the right quality are utilized for copra; particularly when there are grading systems and price differentials for good copra. Sri Lanka is one such example.

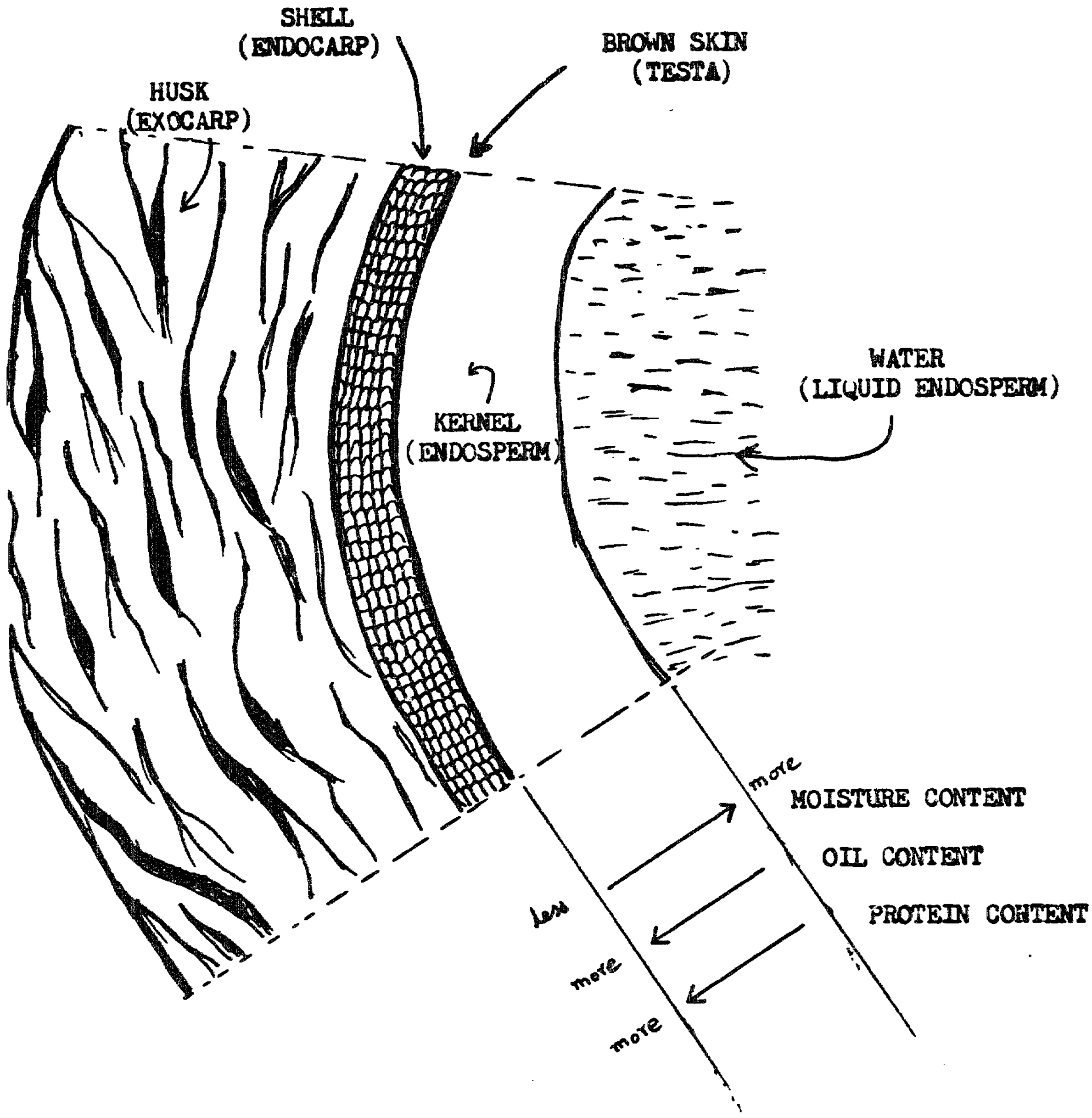
In the Pacific region, nuts are not plucked from the tree but allowed to fall naturally. This system, in addition to low cost of harvesting, has a tremendous advantage in that the nuts are fully mature and have commenced drying out (14 to 16 months age). The exception would ofcourse be in the case of immature nut fall. The natural nut fall has one serious drawback in that during gathering; some nuts may be left for long periods hidden in the undergrowth. Therefore, the incidence of germination is heavy as compared to plucked harvest.

5.2.2 <u>Nature of the kernel</u>: -

The various parts of the whole coconut is illustrated in figure I.

The moisture content is about 50% for wet kernel which has just been split open and water allowed to run out; when the entire kernel complete with testa is considered. However, if the kernel is taken to consist of thin imaginary layers, the layer adjacent to the nut water would have a moisture content well above 50%. The moisture content of the different layers decline gradually towards the testa where it is the lowest.

The kernel contains oil, protein and sugar as the other important constituents. The oil content and the protein content are maximum at the testa and decrease towards the surface in contact with the nut water. The oil content of the wet kernel (with testa) is about 35% and upon dryage to copra, the oil content will be 65 to 70%.



SECTION OF WHOLE COCONUT

FIGURE I

5.2.3 Growth of micro-organisms in the fresh kernel

The high moisture content and the presence of protein and sugar makes the fresh kernel an ideal medium for the growth of bacteria, fungi and moulds. It is therefore liable to deterioration and very susceptible to attack by these organisms, with the development of free fatty acids and rancidity. In order to avoid (or minimise) this deterioration, it is necessary to reduce the moisture content to 6% as fast as is practically possible.

According to "Copra dryers" by G.B. Gregory, V.E. Sills and J.A. Palmer, page 4-Bulletin 32 of the Department of Agriculture, Fiji: -

"It is important to realise that deterioration of fresh coconut meat commences as soon as it is exposed to air, that is immediately the nut is split. When the meat is cut out still more surface becomes exposed and deterioration will proceed more rapidly. The smaller the pieces the greater is the deterioration. Deterioration is increased by the presence of coconut water on the exposed surface of the meat after the nut has been split. A thin film of this sugary water promotes rapid fermentation which is quickly followed by penetration of the surface layers of the meat by invading micro-organisms. If fermentation and the subsequant decaying processes continue for several hours the surface of the meat becomes slimy; this product when dried, presents an unattractive and discoloured appearance".

The care for the kernel therefore commences from the moment the nut is opened. The lapse of time between opening the nut and commencement of drying should be as little as is practical.

In an experiment in Malaysia split nuts were left exposed to the air for varying periods and then subjected to kiln drying. The resulting copra was assessed for quality. The following.

results have been reported in "The practical aspects of copra deterioration" (F.C. Cooke 1937) - Bulletin of the Department of Agriculture, Malaya.

Expt No. 300 nuts per trial	Delay period before drying (hrs)	White Copra (%)	Slightly discoloured or dirty copra (%)	Red to Reddish black copra (%)
1	Nil	82	18	0
2	2	80	20	0
3	4	75	25	0
4	6	70	29	1
5	9	61	35	4
6	12	36	42	22
7	24	10	48	42
8	48	0	17	83

There is a marked decline in white copra and an increase in badly coloured copra with increased exposure to air particularly beyond 4 hours.

In India, Malaysia and Sri Lanka, where the coconuts are opened only in the kiln area, this delay is never allowed to exceed 4 hrs. In many other countries too, the lapse of time is usually within 4 hrs.

According to the experiences in Sri Lanka, the meat of the ripe brown nut (and the seasoned coconut) is hard and firm and has better resistance to the growth of micro-organisms and discolouring.

In the pacific region, ramming of fresh kernel into bags for transport to the dryers sets up conditions ideal for fermentation and spoilage. As little time as possible should therefore be lost between bagging and loading the dryers. This is not always possible with centralized copra processing for kernel transported over long distances by boat etc. As long as cutting the kernel (green copra) in the field and bagging for transport is inevitable, the use of clean bags and shortening the time of transport will minimise spoilage of copra.

According to "Copra processing in rural industries" by F.C. Cooke (FAO 1958), the attack of micro-organisms on coconut meat containing 20 to 50% moisture can be described as follows: -

(1) Penetration of bacteria, sometimes followed by
(2) Yeasts, occassionally, and only of secondary importance;
(3) Penetration of moulds, Aspergillus flabus, with a yellow - green colour,
(4) Penetration of moulds, Aspergillus niger with black colour,
(5) Attack by mould, Rhizopus nigricans, initially with a white colour, later turning from grey to black. (Black colour appearing particularly when coconut meat is kept in airless storage).

The time taken in drying is also important as once deterioration of the copra has started, it may continue until the product is commercially dry. This is especially important in the case of sun drying where the temperature of 30° to 40° C encountered is inadequate to destroy the micro-organisms. In hot; low humidity (60 to 75% relative humidity) areas which are ideally suited for sundrying, this problem is not serious as the activity of the micro-organisms decrease with declining humidity. During artificial drying where temperatures are between 50 and 70° C, all the micro-organisms become inactive.

The extent to which the initial deterioration has set in has a bearing on the keeping qualities of the copra after dryage. This is particularly so if the copra is even slightly underdried. In practice most of the copra produced by small holders (who account for 90% of the worlds copra) has moisture levels of 8 to 12% and sometimes even 15%.

There has been a practice in the past to wash finger cut kernel in fresh clean water to remove the slimy matter. This was carried out by large plantations with centralised processing facilities where the distances and methods involved (inter-island by boat) for transportation caused delays in drying. Sea water was not allowed to come into contact with the kernel. This practice has been done away with due to high costs involved.

In an attempt to improve the quality of Philippine copra, V. Subramanyam, an FAO consultant, introduced a chemical dip pretreatment. This has since become known as the Subramanyam process (1966). The pretreatment involved washing the kernel in a dilute solution of alkali (Sodium Carbonate), or acid (Sulphuric or Hydrochloric acid). The equipment used was very simple - requiring wooden vessels and bamboo or rattan baskets for holding the kernels during the dipping operation. This process however meant an extra cost to the producer. The pretreatment of the kernel as cut pieces or in the half shell is followed by any of the traditional drying methods such as sun or kiln drying. This process which is only a surface action with penetration of less than a millimeter was found to be very effective in preserving the coconut from attack by micro-organisms. It's usefulness was not only in protecting the kernel prior to drying but also in keeping qualities after dryage.

The initial trials with alkaline treatment proved to be encouraging with minimal loss of oil and the quality of expelled oil was excellent (FFA under 0.1%) edible quality. This process has not been put to commercial use due to milling problems when large trials were conducted in the U.S.A. The alkaline treatment resulted in a soapy surface causing slip in the expellers. The acid treatment was supposed to cause corrosion problems with milling equipment.

5.2.4 <u>Equilibrium moisture content of dry copra</u>

Stored copra will gain or loose moisture until it has reached a state of equilibrium with the moisture of the surrounding air. During rainy and humid periods, the copra will gain moisture and when the air is dry, the copra will dry out a little to reach a lower equilibrium level of moisture. The equilibrium moisture level is also affected by the temperature of the air.

Bustrillos and Banzon (1949) determined the equilibrium moisture content of copra at various relative humidities at room temperature (28.5°C) and at 40°C. The results are plotted in figures II and III. It can be seen that at 28.5°C and relative humidity of 85%, the equilibrium moisture content of copra is 4%. This would rise to 5% at 90% relative humidity and 6% at 95% relative humidity.

At moisture levels of 5 to 7%, copra is able to keep well without bacterial and mould action. Perfectly sound dry copra is not attacked to any significant extent by insects (Mcfarlane 1962) unless it is stored for long periods or stored under bad conditions.

Commercially dry copra therefore has a moisture content of 5 to 7%. Some writers treat the level as 7% whilst some consider 6% as the maximum.

When copra is dried in practice, it is common to find moisture levels of 8 or 10% soon after processing. If this copra is properly stored; allowing for breathing out in well ventilated stores, the moisture level will decrease to 5 or 6%.

It is usual to find moisture levels in the region of 3 to 4% for copra received in Europe after shipment. This further dryage is due to lower temperature and lower humidity characteristic of the colder climates.

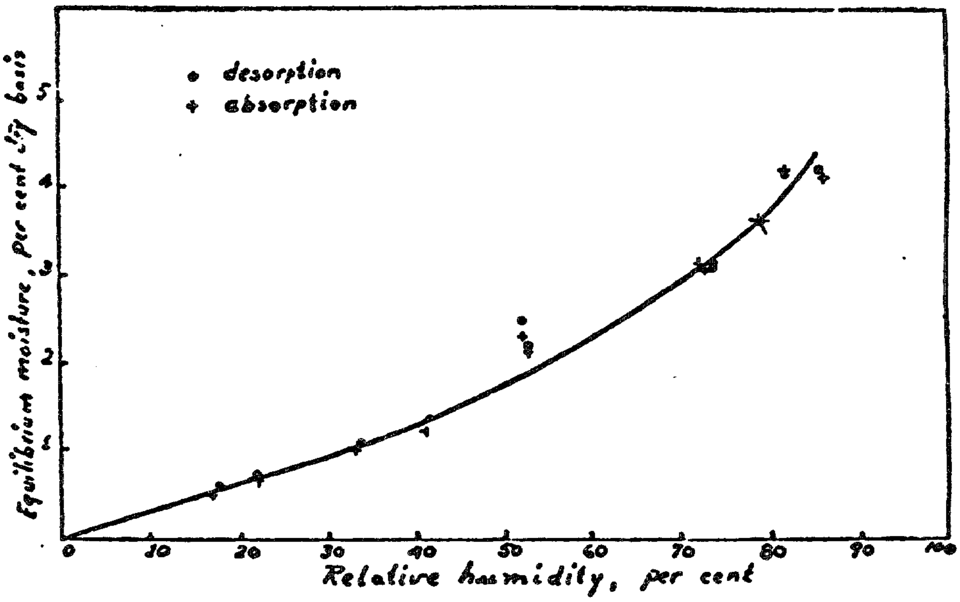


Fig. II Equilibrium curve for copra at room temperature, 28. 5°C ± 3 (Bustrillos and Banzon, 1949).

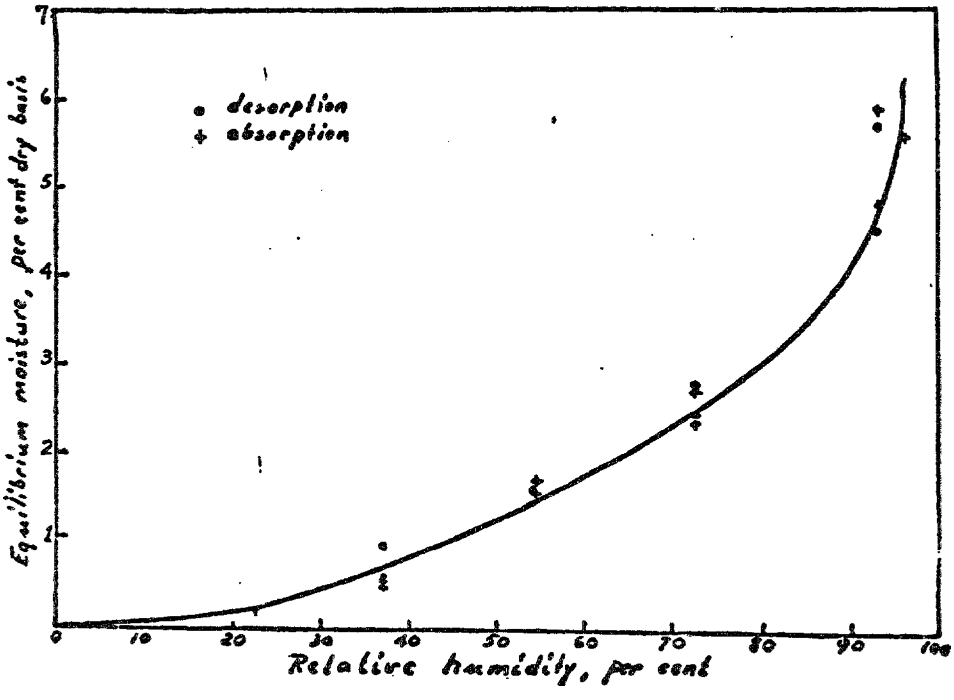


Fig. III Equilibrium moisture curve for copra at 40°C±2 (Bustrillos and Banzon, 1949).

Some copra is poorly dried leaving moisture contents of 10 to 15%. At such high levels deterioration is inevitable even though some dryage may take place due to good storage practices. Further dryage of copra will be retained if the copra is case-hardened or otherwise spoilt. Deterioration of dried copra is presented in section 5.2.10.

Copra with low moisture content burns readily and this ability declines with increase in moisture. The following behaviour for thin slices of copra at various moisture levels is of interest:

less than 7%	-	Burns readily
7 to 10%	-	Flame splutters
10 to 15%	-	Burns with difficulty
more than 15%	-	Does not burn at all.

5.2.5 Scientific phenomena in dryage of kernel

When the nut is split open and water allowed to drain out, the concave surface earlier in contact with the nut water would have some surface water. This will undergo evaporation due to the exposure to air and the rate of loss of moisture is constant. This takes place rapidly in a few minutes. It is common to find that by the time the nuts are loaded onto the dryer, this surface moisture has already evaporated signifying a moisture drop from say 55% to about 50%.

The surface would tend to remain moist for a slightly longer period due to the easy movement of water nearby this surface but the rate of evaporation would gradually decrease. This evaporation would last only one to two hours. In the subsequent drying, more moisture within the kernel has to permeate or diffuse and move towards the surface to enable further evaporation. When the copra is nearly dry this movement is extremely slow.

Therefore dryage depends on three fundamental factors:

<u>Firstly</u> The nature of the kernel affecting ability of the moisture to diffuse or move to the surface

<u>Secondly</u> The surface area of the kernel for transfer of moisture to the drying air, and

<u>Thirdly</u> The ability of the air to absorb the moisture being made available from the kernel surfaces.

Let us consider the <u>first</u> factor. Now, as regards the nature of the kernel affecting diffusion of moisture, there is no possibility for improvement of the texture upto the present level of knowledge. However, the processing has to be carried out so as not to damage this ability. Case-hardening is a major cause in retarding dryage of kernel. Case-hardening is brought about when surface evaporation from the tissues of the coconut meat exceeds the rate of moisture diffusion from the interior to the surface. The surface then gets scorched or withered, forming a tough skin which arrests further diffusion of moisture.

It is the practice in kiln drying to lay off firing periodically, particularly overnight. This allows time for moisture within to diffuse towards the artificially dried surfaces. This minimises ill effects such as case-hardening, discoloration, scorching etc.

Increase of temperature of the kernel and the moisture contained within would increase the ability of diffusion to the surface due to the increased vapour pressure. This will be so; as long as the temperature at the kernel surfaces is lower (cooling due to evaporation) than the temperature within the kernel. This is discussed further under section 5.2.8.

The permeability or ability for moisture diffusion through the kernel may vary from kernel to kernel depending upon variety and maturity of the nut. Rajasekharan, et al (1972) obtained shorter drying times for more mature samples.

Besides the nature of the kernel, particle size reduction would assist diffusion of the moisture due to reduced distances of movement and easy access to a surface in contact with the air. Particle size reduction which is the same as surface area increase is discussed below.

The <u>second</u> fundamental factor favouring dryage is increased surface area for transfer of the moisture from the kernel to the air. Increase of surface area through reduction in particle size has various draw backs. This aspect is presented in section 5.2.6 of this technology sheet.

The <u>third</u> factor affecting dryage is the ability of the drying air to absorb the moisture being made available from the kernel surfaces. There are three interrelated parameters which favour this ability: -

(1) lower relative humidity
(2) higher temperature
(3) higher flow rate

Each of these will be discussed in the proceeding sections.

5.2.6 <u>Effect of particle size and surface area on drying</u>

From basic scientific considerations explained above, increase of surface area through particle size reduction would promote both transfer of the moisture from the kernel surface to the air as well as movement of moisture within the kernel to the surface due to reduced distances.

This infact is the case with desiccated coconut where drying down to about 2 or 3% moisture is possible within 20 to 30 minutes.

Though it is not usually possible to cut the meat to small pieces when manufacturing copra in the field, Palmer (1968) and de Vos (1956) have shown that the drying rate is increased with particle size reduction. The comparative drying curves obtained by Palmer for various particle sizes (below 15 g, 50 to 100 g and over 100 g) are illustrated in figure IV. The results

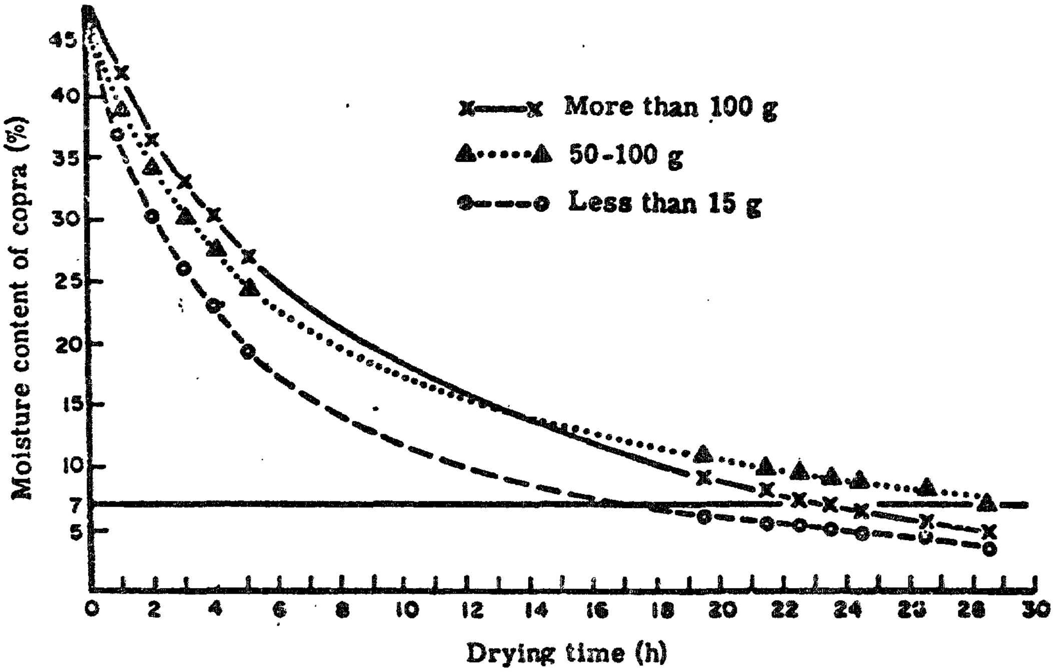


Fig. IV Comparative drying rates for copra pieces of different sizes (Palmer, 1968).

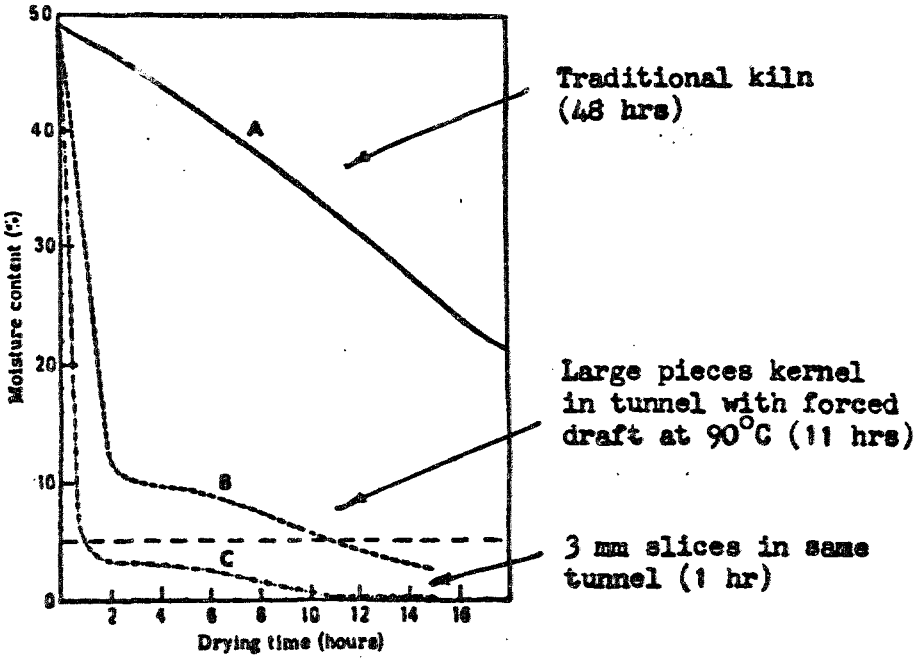


Fig. V Copra drying time curves for different copra sizes (De Vos, 1956).

of the studies conducted by de Vos are shown in figure V. The curve A is for a traditional direct smoke dryer requiring 48 hours for dryage down to 5%. The curve B shows the results obtained for large pieces of kernel dried in a tunnel at 90°C with an air speed of 80 meter per minute. The time required to reduce the moisture to 5% was 11 hours. Curve C shows that dryage to 5% moisture took only 1 hour for kernel cut into thin slices of 3 mm thickness under the same drying conditions as for curve B.

It is reported that the oil pressed from copra dried in this manner has a good taste and flavour, not showing rancidity after 8 months of storage. This method of drying can be used only when unopened nuts are transported directly to the mill as finely cut kernel does not keep and thus cannot be transported over a long distance. There are now mills where coconuts are decorticated, fresh meat dried to copra and the copra milled for oil, all operations being carried out at the same place (B.E. Grimwood, 1975). The oil is of extremely good quality, as there is no opportunity for the deterioration of either meat, or copra during storage.

As regards the traditional methods available for copra manufacture, particle size reduction will not be practical at the farm level, besides the deterioration that would be caused by micro-organisms.

Removal of kernel from the shell results in the exposure of the surface of the testa in addition to the surface exposed before deshelling. However, the nature of the testa is such that it would not help diffusion of water easily. Furthermore, the water content of the kernel is more at the concave surface and very little towards the testa. Removal of the testa would favour drying the kernel but this is detrimental to the operation as the portion richest in oil and protein will be lost. Deshelling therefore does not appear to promot dryage particularly at the initial stage of drying. This has not been established conclusively through research but a recent experiment conducted in the Philippines appears to indicate that there is no difference. In a series of experiments on sun drying using a newly developed dryer, copra with 7% moisture was obtained in 125 hours with deshelling and 124 hours with the shell intact. See "Seminar on copra drying" (page 58) by P.C.A. and P.C.A.R.R. (1978).

It is the practice to carryout initial drying with the shell intact for 2 days in Sri Lanka, India, Malaysia and for 1 day in Thailand. Thereafter, the kernels are deshelled and drying continued. If there is a disadvantage in this it would be if the shell initially retards drying but this probably is not so. The advantages are many. It avoids contamination with sand, breakage of kernels during handling and loading dryers, and facilitates easy deshelling subsequently. This also means that the shells get dried to some extent whereby its performance as a fuel for copra drying is improved.

5.2.7 <u>Effect of relative humidity on drying</u>

Lower relative humidity favours copra drying as the drying air is able to more readily absorb moisture than if it was more humid.

This is an important aspect in the case of sun drying. Conditions ideally suited for sun drying includes the low humidity requirement, without which the resulting copra becomes mouldy and spoilt. Sun drying is carried out in many parts of the world under unfavorable humid conditions producing poor quality copra.

In the use of kilns and dryers, the relative humidity of the ambient air is not a significant factor though decreased humidity is desirable. This is because, in the artificial drying methods; the increased temperatures employed improve the water absorbing properties. In scientific terms, raising of temperature of air reduces the relative humidity. For every increase of 29°F (16.1°C), the water-holding capacity of air is approximately doubled. This means that hot air at, say 160°F (71°C) is able hold just about twice as much water when compared to air at 130°F (55°C). In other words, if there is air at 130°F fully saturated with moisture, upon raising the temperature to 160°F, the air would be only half saturated (50% relative humidity). Thus, this air would now be capable of taking - in more moisture and perform a drying function.

5.2.8 <u>Effect of temperature on drying</u>: -

Increase of temperature favours dryage of the kernel from the several consideration given hereunder: -

(i) Increases moisture holding capacity of the drying air as discussed above,

(ii) Increases ability of the moisture at the kernel surfaces to evaporate,

(iii) Increases ability of the moisture to diffuse towards the surface as mentioned in section 5.2.5

As can be seen, the raising of temperature is a major factor in improvement to drying rates, though this represents a cost factor in processing. Although higher temperatures are favourable to faster drying, there are limits to the temperatures that can be applied to the kernel at various stages without causing damage or otherwise undesirable changes.

Palmer (1968) and Cardenas (1968) have demonstrated that high temperatures increase drying rates and therefore shorten drying time. The results of the studies are illustrated in figures VI and VII. From figure VI, it can be seen that the drying rate becomes very slow after the moisture level comes down to 10%.

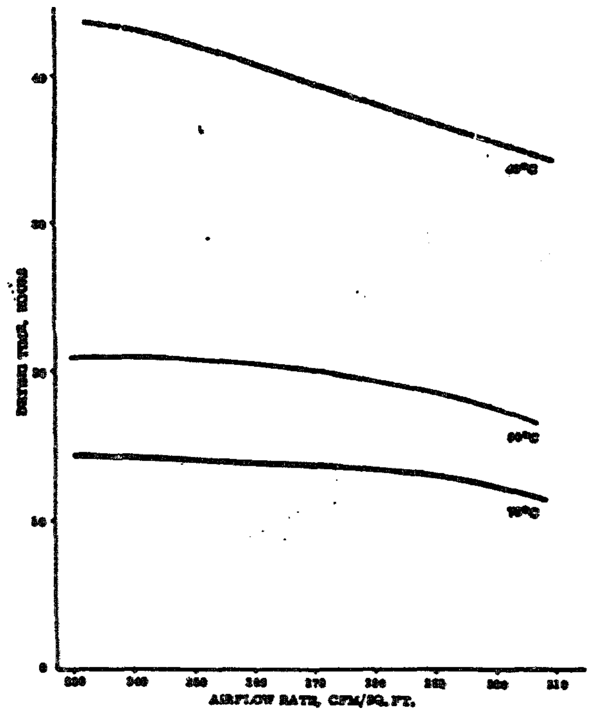


Fig. VII. Effect of temperature on drying time of coconut (Cardenas, 1968).

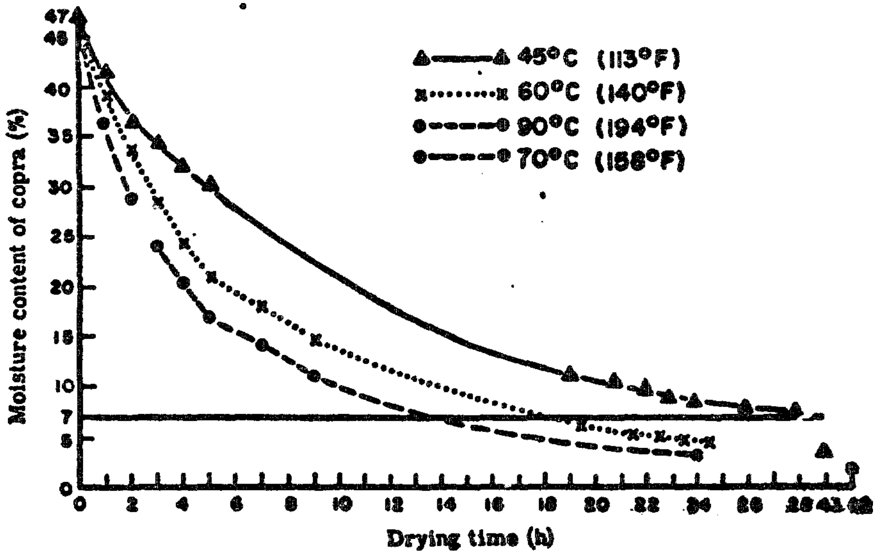


Fig. VI. Drying time for copra at different temperatures (Palmer, 1968).

Cardenas (1968) charred the samples at 70°C towards the end of the 24 hour drying period. Rajasekharan, et al (1961) obtained good results using 70°C for the first 8 hours and completing the drying at 60°C. Lozada and Costales (1977) used temperatures ranging from 90 to 110°C during the first hour of the 5 hour temperature cycles with minimum temperature at 60°C, obtaining quality copra.

From the above results, the following would be safe limits of temperature for drying cycles.

70°C (158°F) - for the initial stages of drying. This would be for about 1 to 2 hrs for forced hot air drying.

60°C (140°F) - for the subsequent stages of drying.

The adverse effects of excessive temperatures can be described as follows: -

Initial stages: - The kernel gets "cooked" or "baked" and results in distortion of the copra cups.

Subsequent stages: - Case-hardening results from the surface being exposed to excessive temperatures at a time when the surface evaporation from the kernel exceeds the rate of moisture diffusion from the interior to the surface. The surface then gets scorched or withered, forming a tough skin which does not permit further diffusion of moisture. This means mould and insect attack.

The other ill effects of excessive temperature are browning, scorching and carbonization of the oil. This means badly coloured oil after expelling. Moreover, the copra cake derived from it may be so badly burned as to be unsuitable even for cattle feed.

5.2.9 Effect of air flow rate on drying

The drying air performs the important function of picking up moisture and flowing away from the copra. Therefore the more air that flows, more moisture that can be picked up; within certain limits. The minimum air flow must be such that the air after picking up moisture by passing through the copra is just under full saturation. From pra ical considerations, an air flow rate above this minimum rate w ld ensure efficient drying. This minimum rate would be high at the beginning and decrease with decreasing availability of moisture.

In the case of sun drying, natural movement of the surrounding air would play a significant role in drying the copra, such as in the case of open air drying of washed clothes on a windy day. Sun drying near the coastal areas is usually aided by adequate breeze. Another aspect of air movement for sun drying in hot areas will be the convection currents going up from the heated surface of the Earth.

In the case of all kiln drying operations and hot air drying with natural draft, the air flow is created by convection currents. For any given temperature of the drying air, therefore, there must be good circulation for the convection currents to carryout effective drying. Good circulation can be promoted by in two ways. Firstly, the design of the kiln with good ventilation. Secondly, facilitate good airflow through the copra bed.

In the second case, the depth of copra would be critical for any given type of arrangement of kernels. For kiln drying with half kernels with shell intact, experience has shown that the maximum depth of bed is about 1 foot or 0.3 m. See technology sheet on "COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELL AS FUEL (Method C 2). In the case of kernels scooped out of the shell, the depth of bed is between 8 inches and 1 foot or 0.2 m and 0.3 m. This is because, here the kernels pack more

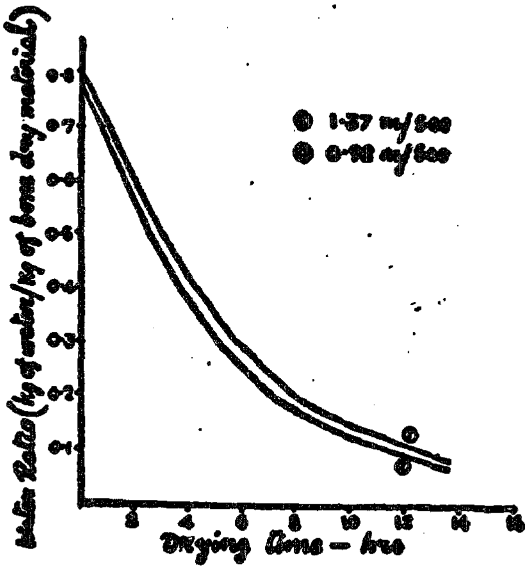


Fig.VIII Drying at various air velocities (Rajasekharan, et al., 1961).

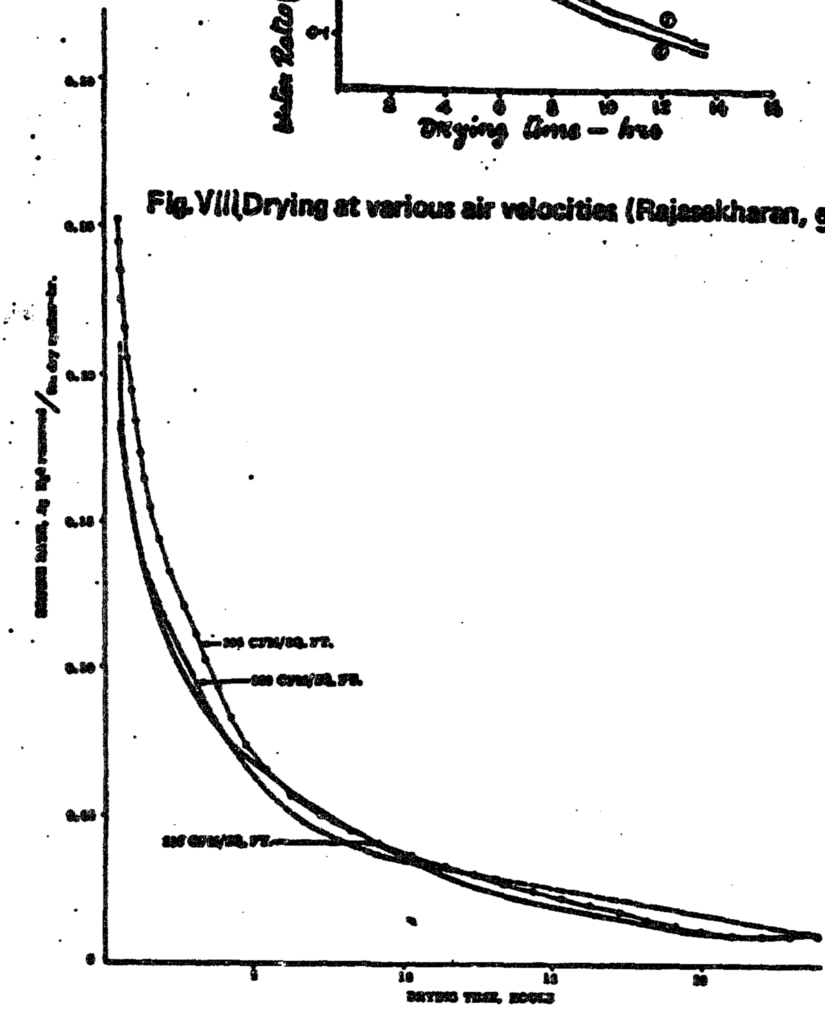


Fig.IX. Effect of air flow rate on drying rate coconut at drying temperature of 55±3°C (Cardenas, 1968).

densely than when in the shell. See technology sheet "COPRA MANUFACTURE BY DIRECT HEAT SMOKE DRYERS (Method B). For finger cut copra, the depth of the bed is 4 to 8 inches or 0.1 to 0.2 m. See technology sheet "COPRA MANUFACTURE BY NATURAL DRAFT HOT AIR (Method D 1)".

Too thick a layer of copra "chokes" the free flow of hot gases hindering the convectional flow. This results in the hot gases impinging on the lowest layer, scorching and casehardening it.

Forced circulation hot air dryers donot have problems in circulation. However as the air flow rate is increased beyond a certain level, there is no corresponding increase in the drying rate because the availability of moisture for dryage would now depend upon the rate of moisture diffusion to the surface.

Results obtained by Rajasekharan, et al (1961) and Cardenas (1968) indicated that air flow rate did not greatly influence the drying time. See figures VIII and IX. From figure VII also, it can be seen that the drying time was hardly improved by altering the air flow rate for any given temperature.

5.2.10 Deterioration of dried copra

According to "Copra processing in rural industries" by F.C. Cooke (FAO 1958).

"The fundamental causes of the deterioration of a shipment of copra are to be found mainly in the country of origin. Careless methods of processing, insufficient drying, the practice of blending poor with good copra before shipment, are factors responsible for subsequent deterioration. The reabsorption of the moisture during damp weather is not serious if the copra is well dried.

The microorganisms causing defects and thus decreasing the quality of the copra can be divided roughly into two groups: -

1. those which attack only the surface of the copra, and
2. those which penetrate deeply into the endosperm (meat).

The microorganisms under 1 do not decrease the quality of the copra to any great extent; those under 2, on the other hand, considerably decrease not only the quality but also the quantity of the copra, as they split the fatty oil into glycerol (glycerine), water, and free fatty acids, the latter sometimes even being further broken down.

In addition, microorganisms encourage the damage caused by insects, particularly mites which have the effect of breaking the meat into pieces and powder, resulting in loss of weight.

Wet coconut meat with a moisture content of 20 to 50 percent is more liable to be attaked by bacteria, which is evidenced by the appearance of yellow and brown-colored layers on the surface of the copra.

Bacteria is most likely to develop in an atmosphere of 80 percent relative humidity and a temperature of about 30°C. (86°F). To avoid such damage, preventative action should be taken immediately in the early stages of processing, as even if left for only four hours after splitting a mucous layer can develop capable of spoiling the copra in about 8 hours. This bacterial attack is dangerous as long as the meat has a moisture content of more than about 20 percent. The split nuts should, therefore, be exposed immediately to full sunlight or be placed in an appropriately heated kiln. Overloading of kilns and insufficient heating should be avoided. The storage and carriage of split nuts or wet meat in bags also promotes such deterioration. The growth of moulds and bacteria during the drying process can be prevented by fumigation with vapors of burned sulphur.

In normal trade practice copra covered with a light white to grey-coloured layer of mould is accepted as normal, and even the green moulds do not do very much harm. Black-coloured copra, however, is judged to be of inferior quality.

When copra is shipped from the coconut growing areas usually nothing can be seen of the moulds as they dry up, and in the case of well dried copra, a very thin layer of mould will become almost completely powdered during the time of transportation. This means that a heavy attack of mould can only be discerned by loss of weight, a certain smell and discoloration and, if subjected to great heat, this smell and discoloration becomes more apparent.

The result of such attacks is coloured and bad smelling oil, which, not being suitable for edible purposes, has to be refined so increasing the cost and limiting its uses. The press cake of highly infected copra is unsuitable for cattlefood so as well as the loss in the value of the oil, there is no profit from the by-product. It can be sold only as an ingredient of mixed fertilizer.

Losses during storage and shipment decreases, and free fatty acid content increases, can be very serious as oil percentage and condition generally change continuously. A few examples are given hereunder: -

CHANGES IN COPRA DURING STORAGE

Sample	Oil Percentage (dry basis)	Moisture (%)	Condition of Copra
	Dry Copra		
Start	67.4	4.5	Clean and white
End of 2 months	68.4	5.4	superficial mould only; colour good
	Undried Copra		
Start	64.4	12.1	Clean and white
End of 2 months	23.5	64.7	slimy, black, mite-ridden; wet and rancid

(F.C. Cooke, W.J. Blackie, C.L. Southall).

LOSS OF COPRA BY DECOMPOSITION DURING STORAGE AND SHIPMENT

Conditions before Shipment	Moisture (%)	Loss of Copra by Decomposition (%)
Well dried copra	6	Less than 0.5
Ordinary dry copra	6 - 8	0.5 - 2.0
Fairly dry copra	8 - 10	over 2.0

(F.C. Cooke, W.J. Blackie, C.L. Southall).

Schematically, the attack of microorganisms can be described as follows: -

A. On coconut meat containing 20 to 50 percent moisture: -

(1) penetration of bacteria, sometimes followed by
(2) yeasts, occasionally, and only of secondary importance;
(3) penetration of moulds, Aspergillus flavus, with a yellow-green colour,
(4) penetration of moulds, Aspergillus niger, with black colour,
(5) attack by mould, Rhizopus nigricans, initially with a white colour, later turning from grey to black. (The last colour appears particularly when coconut meat is kept in airless storage).

B. On copra, containing 12 to 20 percent moisture: -
moulds mentioned under A. (3), (4), (5).

C. On copra, containing 8 to 12 percent moisture: -

(6) moulds of the Glaucus species, only superficial,
(7) penetration of moulds, Aspergillus tamarii,
(8) occasionally, other less important moulds.

D. On copra, containing less than 8 percent moisture: -

(9) Aspergillus cinnamomeus, a cinammon-coloured mould, which is only superficial,

(10) Penicillum gaucum, gree-coloured and superficial,

(11) Aspergillus glaucus species, white to green, occasional and superficial.

Regarding insects reported to attack copra, the following are to be mentioned: -

(a) on kiln processed copra, which has not been subjected to sufficient heat: Carpophilus dimidiatus (known to the trade as the "copra bug").

(b) on well processed copra: mainly Necrobia rufipes, Oryzaephilus (Silvanus) mercator and Tribolium castaneum.

The first is the most prevalent pest encountered on arrival of exported copra. Re-drying, prior to shipment is essential, while fumigation at regular intervals with suplhur dioxide may also be necessary.*

5.3 Product flow diagram: -

When wet kernel with 50% moisture is dried, the yield, depending upon the final moisture content is as follows: -

1880 kg wet kernel 50% moisture

↓

1000 kg dry copra (6% moisture)

1800 kg wet kernel 50% moisture

↓

1000 kg dry copra (10% moisture)

The out-turn of copra based on the national conversion rates for commercially dry copra is given hereunder: -

Country	Nuts required per tonne dry copra
India	6700
Indonesia	4500 (Sulawesi)
Malaysia	5270
Papua New Guinea	5500
Philippines	4500
Solomon Islands	4500
Sri Lanka	4925
Thailand	4450
Trust Territories of the Pacific Islands	4500
Western Samoa	5300

The yield of nuts per hactare is worked on the basis of a ten year average from the Statistical Yearbook (APCC 1979).

Nut production, Area planted and Yield per ha.

Country	Nut Production Annual average 1979 - 1978 (million nuts)	Area Planted Annual average 1969 - 1978 (1000 ha)	Yield (nuts/ha)
India	5,918.5	1,071.0	5,526
Indonesia	6,717.0	2,072.3	3,241
Malaysia	845.5	319.4	2,647
P.N.G.	759.6	249.3	3,047
Philippines	9,268.4	2,307.5	4,017
Sri Lanka	2,319.7	466.0	4,978
Thailand	556.3	365.8	1,521
T.T.P.I.	80.7	29.6	2,726
Solomon Islands	181.0	33.1	5,468
Western Samoa	199.3	32.9	6,058
Total	26,845.0	6,946.1	3,865

6. Quality of finished product: -

Various copra grading practices exist in different coconut regions. In some countries there is no grading and hence the pricing is same irrespective of quality. This is common in regions using direct fired dryers using traditional fuels (other than good shells only).

The Asian & Pacific Coconut Community has prepared a final draft on "Uniform Standard Specification for Copra" (April 1978). There are two grades specified irrespective of the process used for making copra. The various characteristics specified for the two grades are given hereunder.

Characteristic	Grade 1	Grade 2
(1) Moisture contact (percent by weight), Max.	6	8
(2) Oil content (on moisture free basis) percent by weight, Min.	68	66
(3) Free Fatty Acid (% as lauric) percent by weight. Max.	1	3.5
(4) Impurities percent by weight Max.	0.5	1
(5) Immature kernels (wrinkled cups) percent by count. Max.	Nil	5
(6) Mouldy cups, (percent by count) Max.	Nil	4
(7) Charred or black cups (percent by count.) Max.	Nil	5
(8) Broken cups or chips (percent by weight) Max.	Nil passing through 3/8" mesh sieve	Not more than 1 per cent pass-3/8" mesh sieve.
(9) Colour of the expelled oil on 5¼" cell on the Lovibond colour scale expressed as Y" 5R not deeper than	10	12

7. <u>Sources of information</u>: -

7.1 Copra processing in rural industries by F.C. Cooke (FAO 1958), formerly Director, Coconut Research Institute, Ceylon and Department of Agriculture, Malaya.

7.2 Coconut Palm Products by B.E. Grimwood (FAO 1975).

7.3 Proceedings of Seminar on methods of copra drying jointly organized by Philippine Council for Agriculture and Resources Research and Philippine Coconut Authority. (1978)

7.4 Coconut Research Board, Sri Lanka

7.5 Some aspects of copra drying by J.A. Palmer, Malaysia (1968)

7.6 Copra dryers by G.B. Gregory, V.E. Sills, J.A Palmer, Department of Agriculture, Fiji. (1958)

7.7 Contribution from member countries and observations made during visits to member countries of the Asian and Pacific Coconut Community.

T.K.G.R. 1980.

Product Code : CCCN 12.01b
Technology sheet no.: I / 7

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for :- COPRA MANUFACTURE BY NATURAL DRYING USING DIRECT SUN IN THE OPEN (Method A 1).

The method employed by small holders and is suitable in hot and dry coconut regions.

2. Benefits of technology :- The simplest and cheapest method available for copra manufacture. No investment except in some cases a barbecue is used by constructing a cement or concrete floor. No operational costs except labour.

When properly carried out in areas suitable for effective sun drying, edible white copra is obtained. As this is rare, usually mill copra is the resulting product.

3. Country of origin :- This traditional method for small holders is employed in all coconut regions. However in many regions, sun drying is carried out initially for a day or two only and then direct fired kiln dryers are used for final drying.

In India use of sun only is very common during the dry season. The practice of alternatively sun drying during the day and kiln drying at night is found in India. However, during the rainy season, drying is solely by the use of kilns.

Sun drying is common in the Philippines, but some of the copra is found to be of poor quality. This is probably due to sun drying in humid areas.

Copra manufacture solely by sun drying can be effective only in coconut regions with long periods of sunny clear skies, high mid-day temperatures (30 to 35°C in the shade) and low humidity air (60 to 70% relative humidity). This is one extreme of the climatic conditions for coconuts to grow. However, commercial cultivation in such areas is possible due to there being adequate subsoil moisture. The other extreme of climatic conditions are rain or cloudy skies, cooler mid-day temperature (such as 25 to 30°C and very humid air (above 75% relative humidity). In such areas or whenever the weather has changed to these extreme conditions, sun drying becomes ineffective, and meaningless as spoilage takes place. The importance of low humidity (dry air) is not properly understood in many coconut regions. Natural air movement is another factor assisting sun drying.

The writer has observed that the following regions have hot and dry air with predictable long periods of sun which are the ideal conditions for effective sun drying.

INDIA	- Alleppey and similar districts of Kerala State
SRI LANKA	- Chilaw, Puttalam and Kurunegala districts of the North Western Province.
	- Eastern province.
PHILIPPINES	- Cebu Island of the Central Philippines.
MALAYSIA	- North East regions of the Malaysian Peninsular.

There are likely to be numerous other regions where such climatic conditions are met. In regions where very humid air is prevalent most of the time, though sun drying is practiced, it is ineffective and spoilage is common.

4. Equipment :-

4.1 Description of equipment

As already stated, no equipment is required for the process of sun drying in the case of small holders. An open, clean yard is used. Screens of bamboo, or coconut fronds are used to cover the copra at night or when rain suddenly breaks in.

The large scale copra manufacturers usually construct a barbecue (or drying floor) by cementing or concreting a suitable area. This helps in keeping the copra clean during preparation of the nut and the subsequent drying operation. Regular washing and cleaning the floor is recommended.

A barbecue such as the one illustrated in technology sheet 'copra manufacture by direct heat dryers using coconut shells as fuel combined with pre-drying in the sun (C 1)' is 30 feet square. This is found in Sri Lanka.

In Sri Lanka and in some other countries a movable galvanised iron roof is used to cover the floor with the copra at night or when rain breaks in. In this type of arrangement, the steel roof structure is mounted on a set of steel wheels which run on two rails installed on either side of the drying floor. When in use, the roof is moved away to expose the drying floor to the sun.

In India it is common to use a wire or cotton net held by bamboo above the drying floor, to protect the copra against birds.

In coconut regions outside the Community membership, wooden racks or platforms are used for sun drying copra. They are about 4 feet x 2½ feet and sloping to enable effective covering during rain.

4.2 Materials for construction:-

For the drying floor of 30 feet x 30 feet used in Sri Lanka, see the relevant technology sheet.

4.3 Cost of equipment:-

Cost of cemented floor 30 feet x 30 feet in Sri Lanka (1973 prices) Rs. 1,450/= Current prices say Rs. 5000/= (US$ 330).

Cost of movable galvanized iron roof on rails - estimated at current prices - say Rs. 15,000/= (US$ 1,000).

Cost of net of different materials - not available.

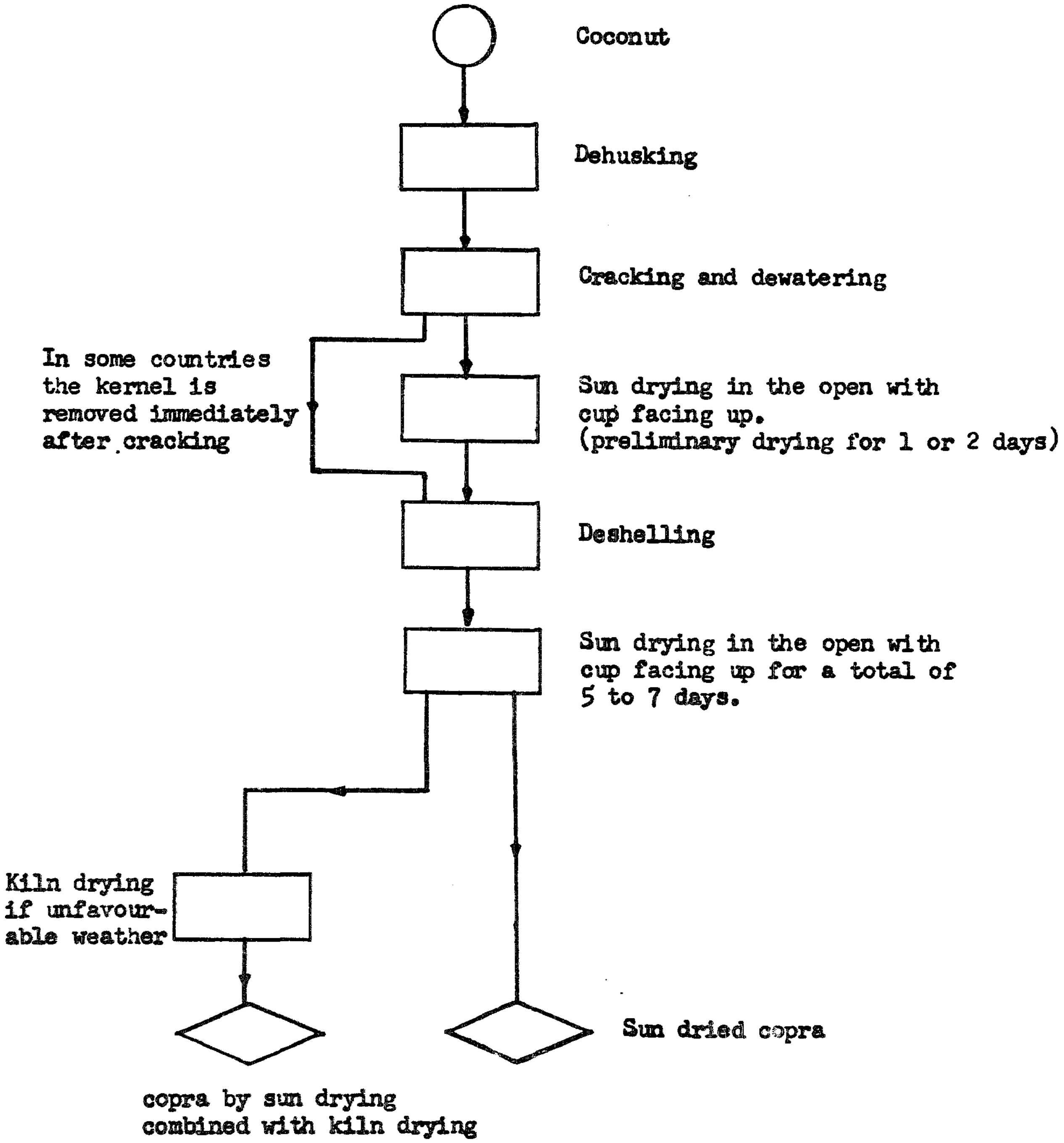
4.4 Capacity:-

The capacity for a floor of 30 feet x 30 feet (900 square feet or 80 square meter) is 3000 nuts per batch which gives 609 kg copra using conversion ratios applicable to Sri Lanka. To handle 3000 nuts two experienced workers would suffice.

The time for one batch is 5 to 7 days drying, depending upon the intensity of the heat.

5. <u>Process:</u> -

5.1 Process flow diagram



5.2 Description of process

Coconuts of differing maturities are used for copra manufacture depending upon the practice existent in the different coconut regions in the member countries.

Special mention must be made of the unique situation in Sri Lanka. Coconuts are harvested only at full maturity and further-more, the coconuts are stored up-to 4 weeks to effect "seasoning". This results indrying out of those mature coconuts which are still green and thus bring about uniformity in the nuts as well as improve the condition of the kernel for processing. This is presented in detail in the technology sheet "Crop storage or seasoning of mature whole nuts after harvesting". The most important advantage of seasoning whole coconuts is in hardening of the kernel and improved resistance to deterioration by bacterial action.

Climatic requirements are already discussed in section 3 of this technology sheet. The importance of climatic conditions for effective sun drying is not properly understood in many coconut regions. Furthermore the most effective climatic factor is low humidity. Natural air movement is another important factor.

The coconuts for copra making are transported to the manufacturing area as whole nuts in the case of India and Sri Lanka. In other countries, the husked nuts are transported. Care has to be taken in the case of husked nuts to process into copra within a few days as spoilage occur. Exposure to direct sun light results in cracking of the husked nut.

Coconuts are husked, cracked open into two halves by striking a heavy knife or iron bar at the "equator" and the water allowed to run out. This is done early in the morning say by

08.00 hours in order to obtain a full day's sun on the first day of drying. This facilitates maximum removal of moisture at the commencement of drying, thus minimizing deterioration. It is also important to dry the kernels as soon as they are opened out. Delay of more than four hours encourages bacterial action and deterioration sets in.

In India, Sri Lanka and Malaysia, the kernels are dried for 2 days in the sun initially with the shell intact. At this stage, the kernels are easily detached from the shell due to the dryage and shrinkage. Thereafter sun drying continued until adequately dry. This means a total of 5 to 7 days depending upon the amount of heat each day from the sun. In Thailand the preliminary drying with the shell is only for 1 day after which deshelling and further drying is carried out. In Indonesia and the Philippines, the kernels are usually removed immediately after cracking and dewatering. This tends to break as well as contaminate the half kernels. Removal of the kernel from the shell and thus exposure of the testa surface does not appear to dry the kernel faster. This is discussed in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

The maximum temperature encountered by the copra when being sun dried in the open is 40°C. This is well below the critical temperature of 70°C above which copra is spoilt by charring. See technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

Sun dried copra gives a final product of 10-15% moisture which is too high to avoid deterioration. However, in certain parts of India and Sri Lanka, the moisture is found to be 8-10% and during storage further reduction to 5 or 6% takes place. In this manner, good quality sun dried copra is produced in these two countries in certain areas where the climate is suitable.

The copra is packed into coir-net bags in India and Sri Lanka - containing about 50 kg each. In other countries, plastic bags, jute bags and bamboo baskets are used to pack copra.

5.3 Product flow diagram:-

On the basis of moisture content of 50% in the kernel when fresh and 10% after sundrying, we have:-

1800 kg wet kernel (50% moisture)

↓

1000 kg copra (10% moisture)

The out-turn of copra is variable from country to country, region to region within a country and dependent on the season. Prolonged dry weather reduces the size of the nut and the kernel and hence require many more nuts per tonne of copra.

The out-turn of copra for the different member countries on the basis of the national conversion rates is given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE"

6. Quality of finished product:-

Various copra grading practices exist in different coconut regions.

The Asian & Pacific Coconut Community has prepared "Uniform Standards Specification for Copra" (Final draft April 1978). There are two grades specified irrespective of the process used for making copra. The characteristics specified for the two grades are given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

As discussed in section 5.2, the moisture content remains high (10 to 15%) in most countries where sun dried copra is produced. In India and Sri Lanka however the moisture level is brought down to 8-10% as the weather conditions are suitable for sun drying.

7. Source of Information:-

Personal observations during field trips to member countries of the Asian and Pacific Coconut Community.

Product Code:- COCN 12.01b
Technology sheet no.: I / 8

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for :- EDIBLE BALL COPRA MANUFACTURE BY NATURAL DRYING WHOLE NUT IN THE SHADE (Method A 2) This is a small scale commercial activity as well as a household activity practiced in hot dry coconut regions.

2. Uses of finished product :- Ball copra has several uses.

2.1 In India, ball copra is consumed by the population in non-coconut growing areas who have a liking towards it's flavor. These are in the states adjoining the coconut areas of South India. The ball copra is breken into small pieces without removal of the testa (brown outer skin) and eaten either as it is or with jaggery (coconut sugar) or cane sugar. The consumption of edible ball copra in India is about 45,000 tonne per year.

2.2 In India, whenever the prices are favourable, ball copra (and edible white cup copra) is converted into desiccated coconut. The colour in this case is off-white or creamy. The testa is first peeled off and the copra disintegrated by machine. This however is not a regular practice and is based on purely economic and marketing considerations. The usual method is by using the fresh kernel such as in the Philippines and Sri Lanka.

2.3 In Sri Lanka, in the rural coconut areas ball copra is consumed occasionally as "sambol" by grating and then mixing with hot peppers.

2.4 In Sri Lanka ball copra has medicinal uses as practiced in the native herbal medicine systems. Such a use is also likely to be found in India.

2.5 In India ball copra is used for religous and cultural ceremonies symbolising prosperity and well being. The use of the fresh mature coconut is more popular for this in coconut growing areas.

3. Country of origin :-

INDIA :- Mainly in the hot dry coconut areas such as
Mysore State (Tiputur area)
Lakshadweep Islands
Karnataka State
Kerala State

In India ball copra is made both on a commercial scale as well as a household process.

SRI LANKA:- Only occasional household manufacture in rural coconut areas towards the interior. This has become uncommon due to the ready saleability of fresh nuts in the market.

4. Equipment

4.1 Description of equipment

For commercial scale operations in India, "Ball copra stores" are constructed. They are two storeyed brick and mortar buildings, the upper floor and the four sides of the upper section being made of hard timber bars spaced 3 to 4 inches (75 to 100 mm) apart. The upper floor (platform) and the four upper sides are sometimes made of bamboo or arecanut stem wood.

The size of the store varies according to the scale of operation. It is common to find 5 or 6 compartments, each having 12 feet x 12 feet (3.65 m) in plan. The height of the lower and the upper storeys is 6 feet (1.8 m) each. One upper compartment of 12 feet x 12 feet x 6 feet height can hold about 4000 to 5000 nuts. (These are small whole unhusked nuts).

Small scale manufacturers use a wooden platform above the kitchen fire-place just below the roof.

In India and Sri Lanka where ball copra is made as a household process, a few nuts are hung over the kitchen fire-place at the roof level. Sometimes the attic is used.

4.2 Materials for construction

Material requirements for the construction of one compartment 12 ft x 12 ft ball copra store is not available in details. These are however locally available low cost items such as bricks, timber (or bamboo, arecanut stem wood), mortar and thatching for the roof.

4.3 Cost of equipment:-

For one compartment 12 ft x 12 ft the estimated cost is Indian Rs 2300/= (US$ 300)

In small scale commercial manufacture and in household activities, the costs involved are negligible.

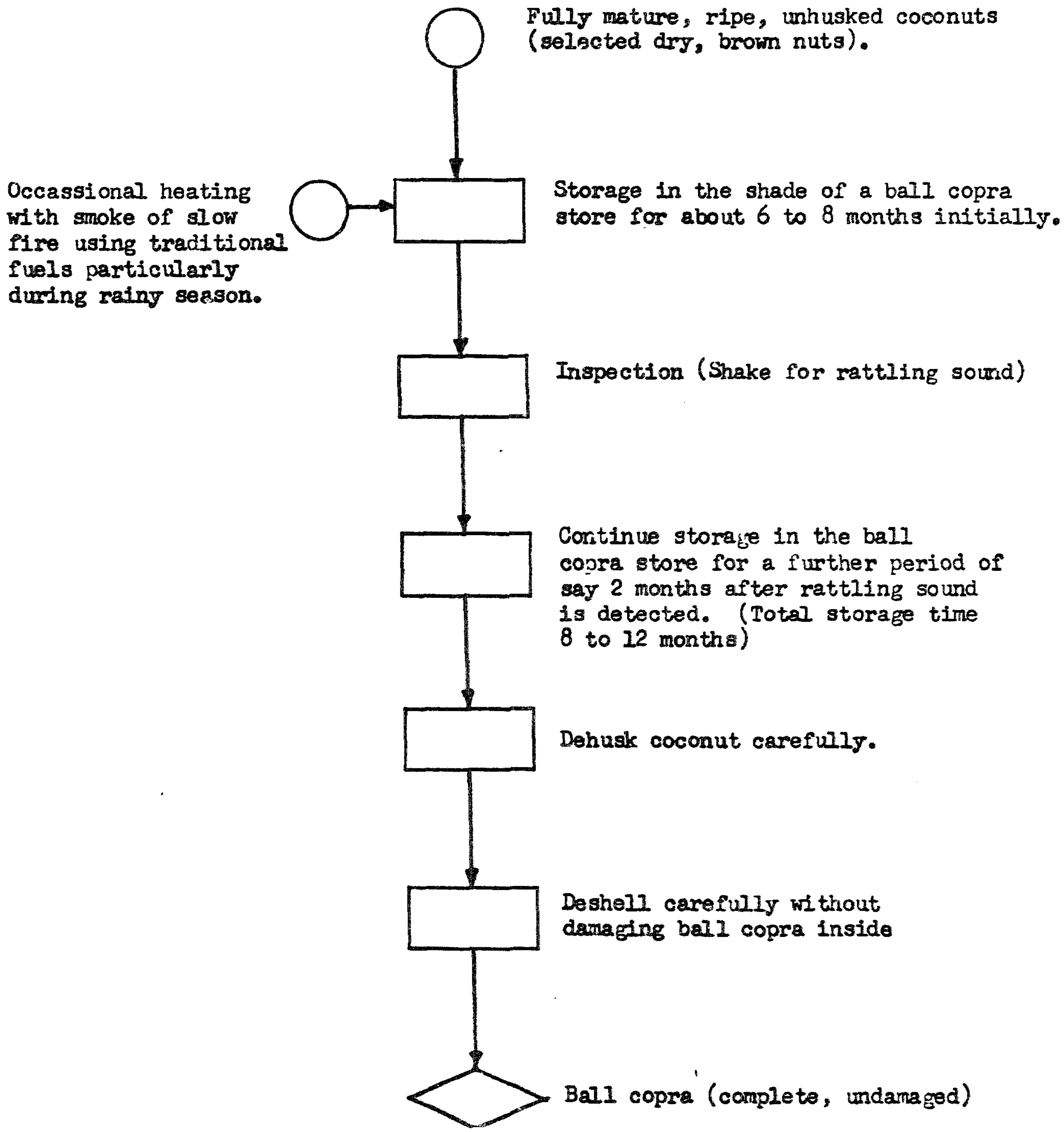
4.4 Capacity

The capacity per compartment of 12 ft x 12 ft x 6 ft upper deck is 4000 to 5000 small unhusked coconuts. One batch will take about 8 to 12 months.

The capacity per batch for a small manufacture will be about 200 to 500 nuts depending upon the size of the platform above the kitchen fire. The time for one batch in this case is however about 6 to 8 months due to the regular hot smoke from the kitchen fire.

5. <u>Process</u>: -

5.1 Process flow diagram: -



5.2 Description of the process:-

For the manufacture of ball copra, only selected nuts are used. The coconuts which are fully mature, ripe and have commenced drying when harvested or nuts which have fallen naturally are used without husking. Such nuts have the outer skin turning to dark brown due to the dryage. A husked coconut cannot keep good for more than a few days as spoilage occurs. Furthermore even unhusked nuts which are not fully mature (green colour) also donot keep as spoilage occurs after one or two months.

Manufacture of ball copra is possible only in relatively hot and dry areas of the coconut regions. This is discussed in section 3 of this technology sheet. When fully mature unhusked nuts are kept for long periods in humid areas or during the rainy season, germination tends to takes place. Ball copra cannot be made if the coconut germinates.

The selected unhusked coconuts are loaded onto the compartments of the ball copra store and allowed to dry naturally for 8 to 12 months.

In all cases the coconuts are placed on an elevated platform. This helps in keeping the coconut from germinating. It is the writers experience to find coconuts lying on the soil having a damp patch on the area of the nut in contact with the soil. Supply of moisture either from the ground or the atmosphere promotes germination. In very humid regions it is not possible to make ball copra due to this reason. In the dry, hot areas where ball copra is made, the rainy season tends to promote germination. Therefore, the coconuts are smoked occassionally by burning a slow fire using traditional fuels on the ground floor. The fuels commonly used are paddy husk, coconut husk, dry leaves or cheap firewood. Smoking the coconuts is also carried out occassionally even during non-rainy periods, to slightly accelerate the process of drying out the coconut. In the case of very small scale operators who have wooden platforms over the kitchen fire-place, there is no problem of germination during the rainy season due to the regular (daily) smoking caused by the daily cooking for the household.

Manufacture of ball copra has also to be in the shade as can be seen from the type of equipment used. Exposure of the fully mature unhusked coconut to direct sun light also promotes germination.

Although the manufacture takes 8 to 12 months, the coconuts have to be inspected to assess the extent of dryage after about 6 months of storage. At this time all the nut water would have dried out causing a shrinkage of the kernel inside. This releases the kernel in a ball shape from the hard coconut shell. The inspection is by shaking each nut. All nuts which have dried out properly would give a rattling sound caused by the loose ball shaped kernel. From this stage, further dryage of about 2 months is necessary.

After a total of 8 to 12 months, the coconuts are carefully dehusked and the coconut shell cracked to remove the ball copra. It is necessary to remove the ball copra without damage during the deshelling operation. Complete, undamaged ball copra keep well and demand ready sale as edible copra in India.

In India, usually very small varieties of coconuts are used for manufacture of ball copra. Verghese et al (1955) have shown that small sized coconuts are best suited for the process. The popular commercial varieties in India are Lakshadweep micro and Triputur (Mysore).

5.3 Product flow diagram:-

No accurate information can be had on the incidence of germination or spoilage of nuts during manufacture. In any event it would depend on the person selecting the coconuts and other criteria such as rain, humidity, effect of the smoke caused by the occassional slow fires etc which are highly arbitrary.

An estimated loss of coconuts is 5%

1000 Mature unhusked coconuts

↓

950 coconuts of ball copra

6. Quality of finished product

The meat of ball copra is soft, sweet and oily. The colour is creamy as compared to bright white colour of the fresh kernel. Ball copra has a distinct odour and flavour.

Accurate recordings of moisture and oil contents are not available. However, the moisture content can be estimated at 2-3% and the oil content about 70%.

7. Source of information:-

Personal observations and investigations during field trip to India.

Product Code: CCCN 12.01 b
Technology Sheet no.: I / 9 to 13

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for :- COPRA MANUFACTURE BY DIRECT HEAT SMOKE DRYERS USING TRADITIONAL FUEL OTHER THAN COCONUT SHELLS. (Method B).

The method adopted by small holders.

2. Benefits of technology :- In the direct heat smoke dryers, the products of combustion come into direct contact with the coconut meat. Hence the copra is of poor quality. The benefits are:-

2.1 Low cost of copra manufacture due to use of traditional fuel.

2.2 Low cost of equipment due to use of traditional construction materials.

2.3 This method does does not need electricity, petroleum based fuels and skilled Technicians.

The following however, are disadvantages of using traditional fuel such as husk and firewood etc.

(i) Smoky odour and flavour. These smoky deposits on the other hand, offer some resistance to mould attack such as in the case of smoked fish or smoked natural rubber sheets.

(ii) Poor quality copra from darkening due to smoking, and scorching from occasional excessive heat at times of ignition of fuel.

(iii) Poor quality copra due to inadequate and irregular drying and case-hardening (10 - to 15% moisture) through lack of proper control. This high moisture content causes deterioration of the copra.

A technical assessment of using traditional fuel such as husk and firewood etc. is given in section 5.2.

3. Country of origin :- Copra manufacture by direct smoke dryers using traditional fuels such as husk, firewood, bamboo, or coconut shell mixed with these fuels is practiced in the following countries of the Coconut Community:-

INDONESIA
PHILIPPINES
THAILAND

Smoke drying with husk and shell is also found in the remote areas of Western Samoa, Solomon Islands and Papua New Guinea. In India, Malaysia and Sri Lanka, the fuel used for direct dryers is coconut shell only without mixing with other traditional fuels, thus giving a better grade of copra. In some parts of the Philippines, Papua New Guinea and Thailand, use of coconut shell only is also practiced.

4. Equipment

4.1 Description of equipment and operation.

4.1.1 Traditional direct smoke dryers used by small holders in Indonesia.

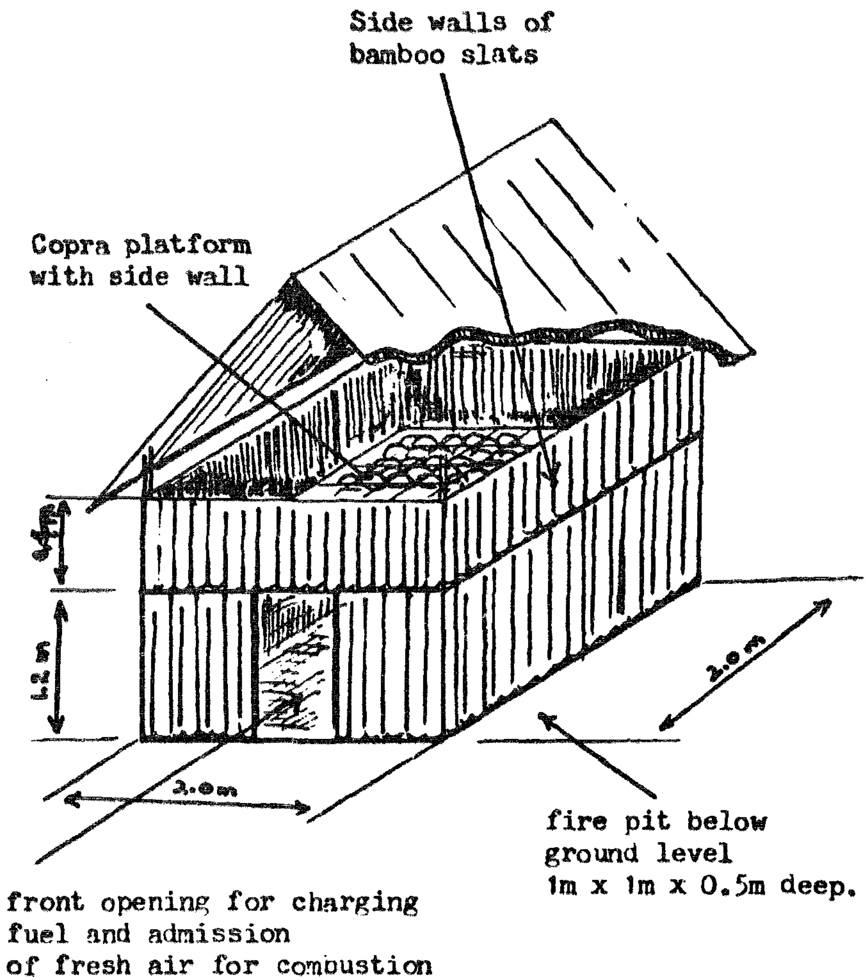
There is no standard design for these kilns. The size and type of material used vary from island to island and province to province.

The basic feature of these kilns is the use of traditional construction material such as local round timber, bamboo, thatching etc. The copra platform has slats placed a few inches apart to permit upward flow of hot smoke and gases. The platform has a short side wall to hold the loaded copra. The larger kilns use old galvanised iron sheets for the roof.

Traditional fuel such as husk, firewood, bamboo or coconut shells mixed with these materials is burned inside a pit about 1 m x 1 m x 0.5 m deep.

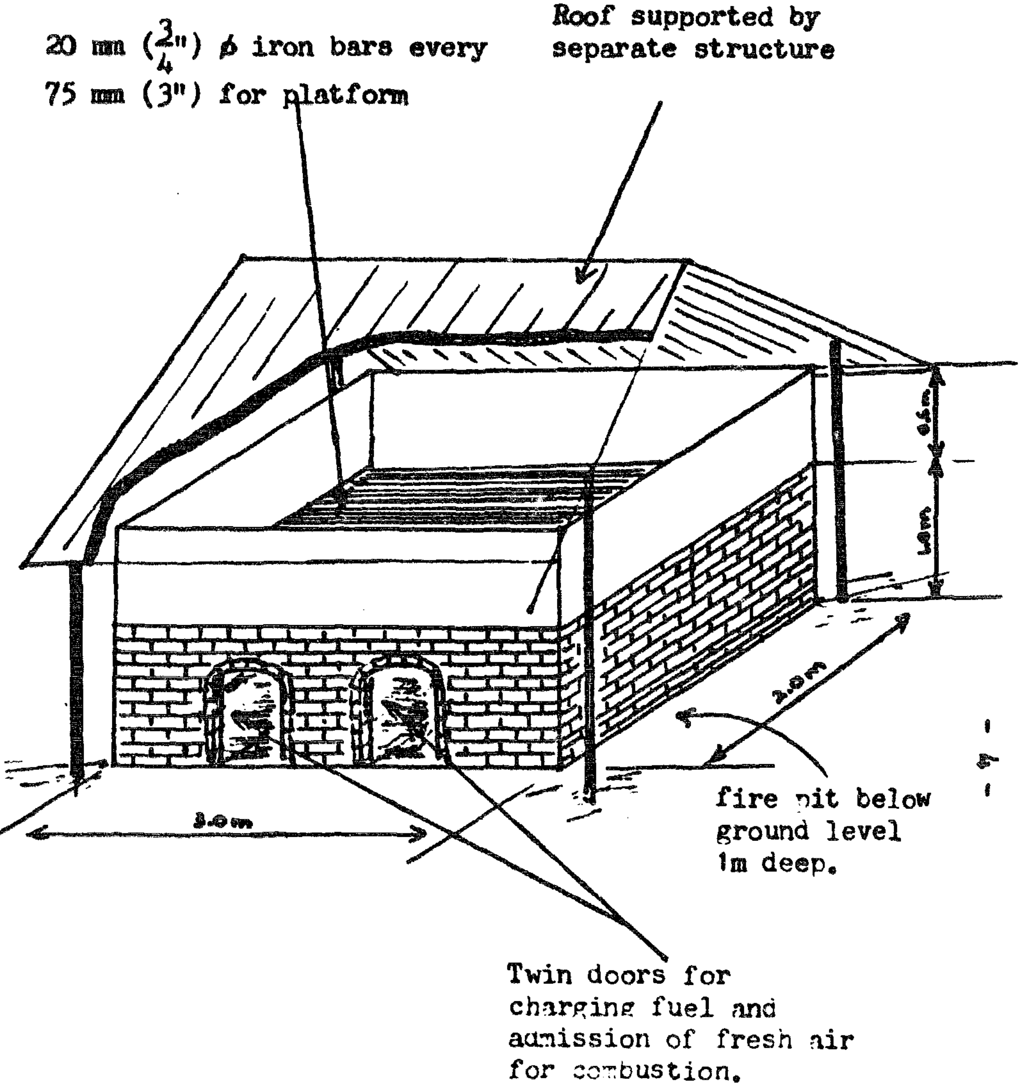
The side walls round the kiln direct the hot smoke and combustion gases upward through the copra placed on the platform. These side walls and roof protect the kiln from disturbances during wind and rain. The front opening provides access for charging fuel as well as admission of fresh air for combustion.

The kiln illustrated in figure I has a 1000 nut (222 kg dry copra) capacity per batch. The platform area is 2 m x 2 m (or 4 m^2). The arrangement of copra is on a random basis and the height of copra loading is 0.3 m (or 1 foot). In Java and Sumatra, the kernels are scooped out of the shell before any drying; whilst in Sulawesi, the deshelling is done only after the drying is over. The cost of the kiln is about Rp. 27,500 (or US$ 44).



1000 nut capacity per batch.
Larger ones upto 2500 nuts

4.1.1 TRADITIONAL DIRECT SMOKE DRYER
USING HUSK, FIREWOOD ETC IN INDONESIA
FIGURE I



3000 nut capacity per
batch.

4.1.2 TRADITIONAL DIRECT SMOKE DRYER
USING HUSK IN THAILAND

FIGURE II

The larger kilns in North Sulawesi have for example a 3 m x 3 m platform (9 m^2) with a capacity of 2250 nuts (500 kg copra per batch when loading copra up to 0.3 m height. The cost is about Rp. 60,000 (or US$ 100). Here the increase in cost is in proportion to the increase in capacity.

The use of husk as fuel is about 67% of the coconuts being dried. Although waste wood is frequently used, estimates of usage are not available. The cycle time for one batch is 2 to 3 days. On the basis of 2 batches per week and 50 working weeks per year, the annual capacity is 100,000 nuts (22.2 tonne copra). On the basis of 3240 nuts yield per ha., this kiln can service 30 ha. The investment per 100 tonne annual dry copra capacity is US$ 200.

4.1.2 Traditional direct smoke dryers used by small holders in Thailand.

There is no standard design for these kilns. The size and type of material used vary from province to province. These kilns use as much as possible of locally available material such as round timber, bamboo, thatching etc.

The kiln illustrated in figure II is the type used in Samui Island of Surathani Province in Southern Thailand.

The copra platform is made of 20 mm (¾") diameter iron bars spaced 75 mm (3") apart and placed on the side walls which are constructed of hollow cement blocks. The timber side wall above the platform is 0.6 m (or 2 ft) high and the copra is loaded upto nearly 0.5 m or 1½ feet which is rather high. The usual arrangement of copra is on a random basis although in some areas, the lowest layer is placed with the cup upwards.

The roof is thatched with 'Nipa' palm leaf and the support structure is made of coconut trunks (verticals) and timber beams.

Husk is commonly used for firing the kiln. The fire pit is underground, being of 0.5 m depth. The side walls have a twin door opening for charging the kiln as well as to admit fresh air for combustion.

The kiln has a 3000 nut (or 857 kg dry copra) capacity per batch. (Coconuts in Thailand are very big compared to other member countries). The coconuts are husked, split in two and loaded with the shell intact. Deshelling after 1 days' drying and reloaded for further drying. The platform area is 3 m x 2 m (6 m^2). The cost of the kiln is about B 5000 (US$ 250).

The use of husk as fuel is about 67% of the coconuts being dried. The cycle time for one batch is 2 to 3 days. On the basis of 2 batches per week and 50 working weeks per year, the annual capacity is 300,000 nuts (85.7 tonne dry copra). On the basis of 1520 nuts yield per ha, this kiln can service 197 ha. Investment cost per 100 tonne annual dry copra capacity is US$ 290.

4.1.3 Sariaya type traditional direct smoke dryer used by small holders in the Philippines.

This dryer is suitable for flat ground where there is no flooding with water and the water table is low such as in Sariaya area of Luzon Province in Northern Philippines. There are two other adaptations of this known as Pagsanjan and Tayabas which are suitable for different local conditions. See sections 4.1.4 and 4.1.5. All these traditional dryers are called 'tapahan' which means "heating grill" in the local language.

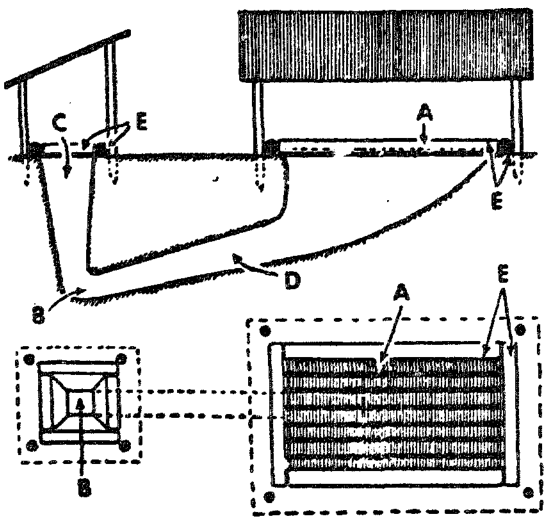
These 'tapahans' are constructed using mostly traditional construction materials. Some variations exist in the use of galvanized iron sheets for roof, stone and cement blocks for side walls, iron bars for the grill etc.

The Sariaya type dryer is illustrated in figure III. There are two pits, one narrow and 3 m deep and the other wider but shallower at 1 m deep. The two pits are inter-connected by a narrow tunnel which slopes at about 20° to the horizontal. The fire-pit or hearth is at the bottom of the narrow pit. The copra grill made usually of woven split bamboo is placed at the ground level, suitably supported by bamboo beams. The grill or platform has timber surrounds. Charging the dryer with a mixture of husk and shell is from the mouth of the narrow pit. Both pits are covered by small roofs to project against the rain.

During combustion, the hot smoke and gases rise up the pit which is wider, thus drawing fresh air from the narrower pit. The gases rise up the grill and come into contact with the copra. The copra is loaded on a random arrangement upto a height of about 0.2 m (or 8 inches). Care has to be taken so as not to overload the grill or else there would be too much resistance to the flow of smoke through the kernels. This will render the dryer ineffective and create problems of scorching of the copra at the bottom layer.

From the nature of the design, it can be seen that the dryer cannot be disturbed by gusts of wind. Another important feature is that the copra loading has to be moderate so as to create and maintain a natural draught. Consequently the rate of combustion becomes fairly regular. This avoids scorching the copra and ensures uniform quality through the depth of the copra layers. However, the overall effect of the direct smoke is to produce poor quality copra.

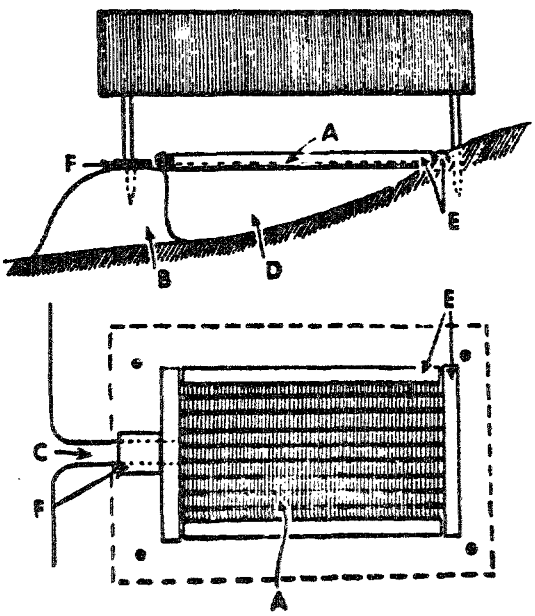
The reason to add husk to the shells is that when shells alone are fired in a pit or a pile, they burn fiercely. Husks keep smouldering for a long period thus damping down the fiercely burning shells.



A. Copra platform
B. Hearth
C. Fire hole
D. Underground flue
E. Timber surrounds

FIGURE III

4.1.3 SARIAYA TYPE TRADITIONAL DIRECT SMOKE DRYER OF PHILIPPINES (COOKE 1936)



A. Copra platform
B. Hearth
C. Fire hole
D. Fire pit
E. Timber surrounds
F. Stone slab or iron plate

FIGURE IV

4.1.4 PAGSANJAN TYPE TRADITIONAL DIRECT SMOKE DRYER OF PHILIPPINES (COOKE 1936)

The kiln is loaded with cups of kernel which have been scooped out of the shell soon after splitting the nut. The usual practice with this type of kiln is to sort out and reload each morning until all the copra is suitably dried. Those cups which are found to be adequately dry are removed from the process. The total operation may take 2 to 3 days for 1 batch.

The capacity of the Sariaya type dryer is about 450 nuts (100 kg copra) for the simple units having a platform area of 2 m^2. Twin type elaborate kilns are sometimes used. The large capacity dryers are however simple units arranged in a battery of three. These have combined capacities upto 4500 nuts (1000 kg copra) per batch. The use of husk is about 67% and a small quantity of shells.

The estimated cost of this small dryer is ₱ 300 (US$ 40). On the basis of 450 nuts per batch, 2 batches per week, and 50 working weeks per year, the annual capacity is 45,000 nuts (10 tonne copra). On the basis of 4020 nuts yield per ha., this kiln can service 11 ha. Investment cost per 100 tonne annual dry copra capacity US$ 400.

4.1.4 Pagsanjan type traditional direct smoke dryer used by smallholders in the Philippines.

This dryer is a modification of the Sariaya type for adaptation for sloping or hilly coconut areas, such as in Pagsanjan area of Laguna Province of the Northern Philippines. It is illustrated in figure IV. A ditch is dug along the slope to form a 'flue' and at the lowest point, it serves as a firepit or hearth. As seen in the illustration, a portion of the ditch is covered with stone and filled up with earth so as to form a cavity. The platform is constructed out of bamboo slats, and surrounded by coconut trunks. A roof is built using traditional materials. Sometimes, old galvanized iron sheets are used for the roof.

A mixture of husk and shell is placed in the ditch outside the dryer and set fire. The smoke and gases travel up the ditch under the stone covering and move upwards through the bamboo slats and the copra.

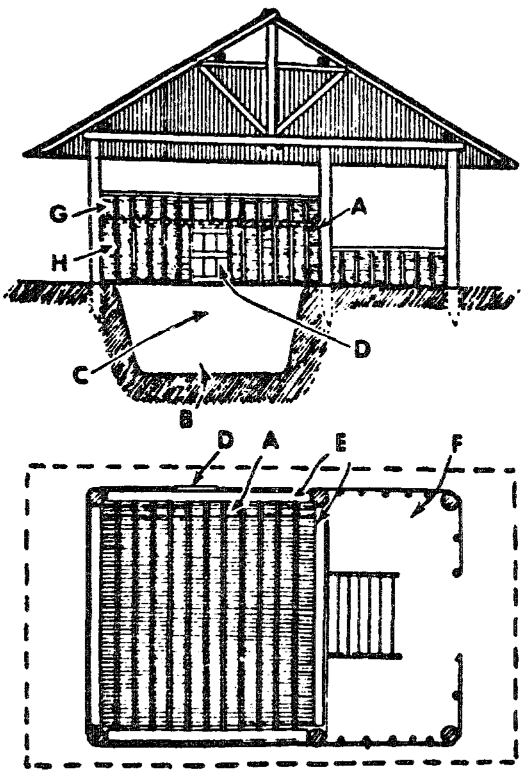
The loading of copra is on a random arrangement. The height of loading is limited to about 0.2 m (or 8 inches) which is 3 or 4 layers of nuts. The cups of kernels are scooped out of the shell soon after splitting the nuts in half.

The capacity of the dryer is 1000 to 1250 nuts say 1125 nuts (250 kg copra) per batch. The grill area is about 5 m^2. The cycle time per batch is 2 to 3 days. Fuel usage is about 67% husk and a small quantity of shells. The estimated cost of this dryer is ₱ 600 (US$ 80).

On the basis of 1125 nuts per batch, 2 batches per week and 50 working weeks per year, the annual capacity is 112,500 nuts (25 tonne dry copra). On the basis of 4020 nuts yield per ha, this kiln can service 30 ha. Investment cost per 100 tonne annual dry copra capacity is US$ 320.

4.1.5 Tayabas type traditional direct smoke dryers used by smallholders in the Philippines.

The dryer is suitable for flat ground with high water table and sandy areas, such as the Tayabas area of Luzon Province of the Northern Philippines. The Sariaya type has a limitation in that the underground flues and pits go down as much as 3 m making it unsuitable in low laying areas due to the water problem, particularly during the wet season.



A. Copra platform
B. Hearth
C. Fire pit
D. Door to fire pit
E. Timber surrounds
F. Bagging shelter and shell storage
G. Windshields for copra
H. Windshields for fire pit

4.1.5 TAYABAS TYPE TRADITIONAL DIRECT SMOKE DRYER OF PHILIPPINES (COOKE 1936)

FIGURE. V

The Tayabas dryer is illustrated in figure V. In this dryer, the fire-pit of about 1 m deep is directly under the grill or platform. The platform is constructed about 1 m above ground level and is supported by the 4 vertical posts which also support the roof. In order to direct the hot smoke and gases, side walls of woven split bamboo is used. The side walls extend upto 0.3 m above the platform. The side walls protect the dryer from disturbances during gusts of wind. The platform is about 10 m^2 in area.

The husks are spread evenly in the fire-pit and set fire. The usage of husk in about 67% of the nuts being processed. The cycle time is 2 to 3 days. The kernels are scooped out of the shell before drying is commenced.

The capacity of the dryer is about 3000 nuts (or 666 kg dry copra) per batch. The estimated cost is about ₱ 2000 (US$ 270).

On the basis of 3000 nuts per batch, 2 batches per week and 50 working weeks per year, the annual capacity is 300,000 nuts (66.6 tonne dry copra). On the basis of 4020 nuts yield per ha, this kiln can service 75 ha. Investment cost per 100 tonne annual dry copra capacity is US$ 400.

4.2 **Materials for construction:-**

Traditional materials such as locally available timber, bamboo in various forms, roof thatching made of Nipa and coconut palm leaves, rattan etc. are used for these types of kilns. Sometimes coconut trunks, Arecanut palm stems are used as timber. There are also many areas using iron bars for the grill or platform, galvanized iron sheets for the roof and cement blocks or bricks for side walls.

4.3 **Summary of design features of the traditional direct smoke dryers: -**

Type of dryer	Batch Capacity (nuts)	Platform area (m^2)	Density of nuts per m^2	Height of platform above fire pit (m)	Height of copra load (m)	Approximate fuel usage if without sundrying
Traditional dryer (Indonesia)	1000 (larger ones upto 2500)	4	250	2	0.3	67% husks and or firewood
Traditional dryer (Thailand)	3000	6	500	2	0.5	67% husks
Sariaya dryer (Philippines)	450	2	225	3	0.2	67% husks and some shells
Pagsanjan (Philippines)	1125	5	225	2	0.2	67% husks and some shells
Tayabas dryer (Philippines)	3000	10	300	2	0.3	67% husks

4.4 Summary of operational features: -

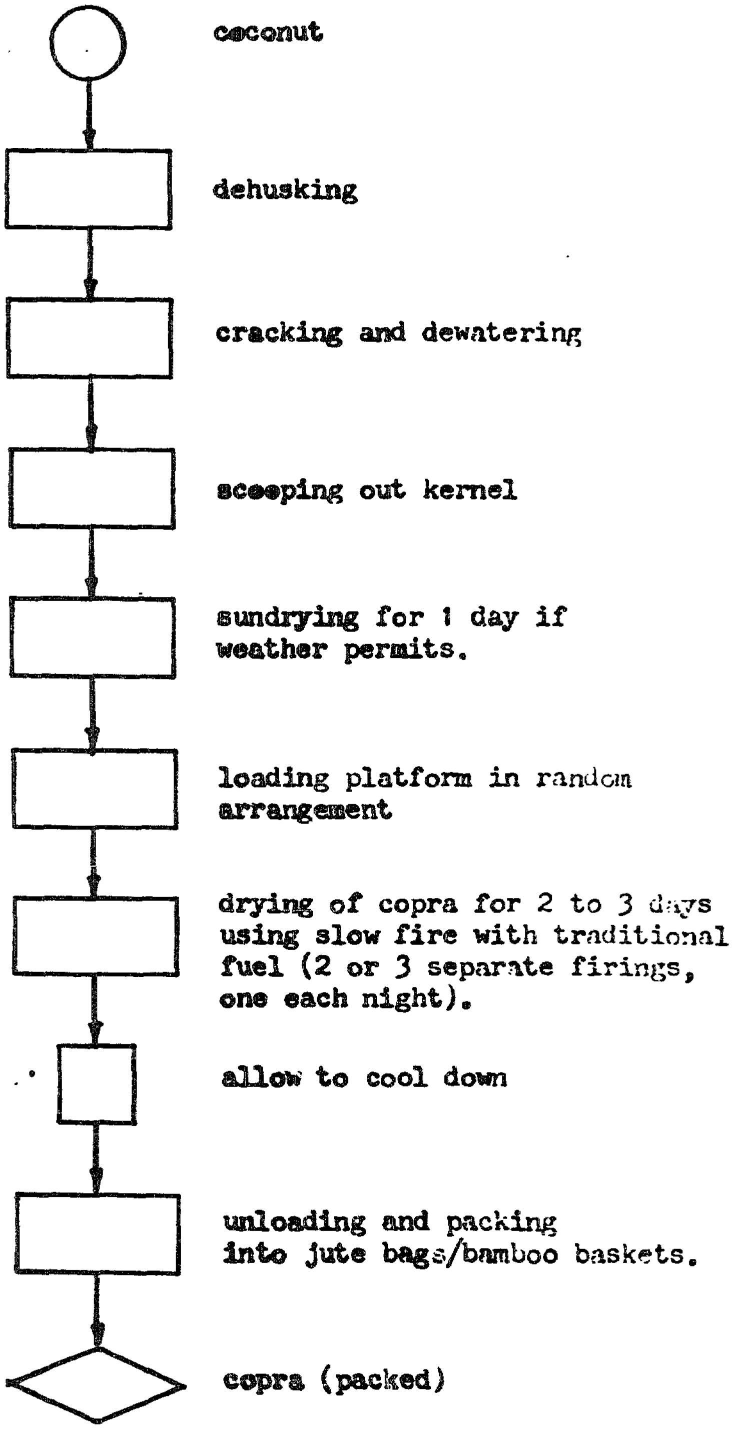
Type of dryer	Pre drying in the sun	Arrangement of nuts when loading platform	Removal of shells	Rotation of copra (turning)	Number of firings
Traditional dryer (Indonesia)	Usually one day	random	No regular pattern	None	2 to 3
Traditional dryer (Thailand)	Usually one day	bottom layer face upwards	After one day's drying	After one day	2 to 3
Sariaya dryer (Philippines)	Usually one day	random	before drying	Usually daily, during inspection	2 to 3
Pagsanjan dryer (Philippines)	Usually one day	random	before drying	Not regular	2 to 3
Tayabas dryer (Philippines)	Usually one day	random	before drying	Not regular	2 to 3

4.5 **Cost and capacity of direct smoke dryers: -**

Type of dryer	Capacity equivalent in land area (ha)	Batch Capacity (Nuts)	Batch Capacity (Kg copra)	Batch time (days)	Cost (US$)	Investment Cost per 100 tonne annual dry Copra capacity (US$)
Traditional dryer (Indonesia)	30	1000	222	2 to 3	100	200
Traditional dryer (Thailand)	197	3000	857	2 to 3	250	290
Sariaya dryer (Philippines)	11	450	100	2 to 3	40	400
Pagsanjan dryer (Philippines)	30	1125	250	2 to 3	80	320
Tayabas dryer (Philippines)	75	3000	666	2 to 3	270	400

5. **Process: -**

5.1 Process flow diagram: -



5.2 Depreciation of process: -

The traditional direct smoke dryers are used by small-holders. There are traditional dryers simpler than the five types presented in this technology sheet. They are the open platform type (without roof and side walls) and the platform and roof type without any side walls. These two very elementary designs are found in certain coconut areas outside the Coconut Community. These driers produce very poor quality copra because of the effect of gusts of wind which create irregular and excessive heat. The five direct smoke dryers in this technology sheet have some protection from wind and rain by way of side walls and roofs.

Coconuts harvested for copra manufacture have different levels of maturity depending upon the customs prevailant in various coconut regions. The fact that nuts of inadequate maturity are used is a major cause for production of poor quality copra. Germinated nuts also give poor copra.

The nuts are transported to the copra kiln by the small-holders and husked. In some areas, the nuts are husked at each point they are gathered and then transported to the kiln. In this case, the husks are transported separately if they are to be used as fuel. The husked nuts are cracked open and water allowed to run out.

In some areas, the kernel is forced out of the shell and then subjected to drying, whilst in other areas, the kernel is removed after about a days drying. The latter practice is superior as firstly, the kernels are easier to remove and thus donot break, and secondly, the kernels with shells intact can withstand mechanical damage during loading. The shell also offers protection from contact with earth and sand.

In some areas, when the weather is favourable, an initial day's sun drying is made use of but it is effective only if the humidity is low. The practice results in improving the quality of copra as initial drying with the mild heat of the sun avoids case hardening. An equally important advantage is that the copra is whiter. This is because, by the time the kernel is subjected to smoke drying, the kernel is already partially dry. If the fresh, wet kernel is subjected to smoke drying straightaway, colouring occurs due to the smoke easily adhering to the wet, slimy surface.

The kernels are loaded onto the platform in a random arrangement. In very few areas kernels are arranged upwards for the bottom layer. This practice helps in avoiding the bottom layer getting case-hardened, coloured and scorched.

The kiln is charged with fuel such as cheap firewood, husk and even bamboo. These are spread evenly in the fire-pit before setting on fire. Shells only are not used because a pile of shell would burn very fiercely and thus burn the copra, unless shells are added one by one which is laborious and needs constant attention. Hence some shells are used by mixing with the husks. The correct method of using shells is not known. See technology sheet on "COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELL AS FUEL" (Method C. 2).

Fuels such as husks and firewood give low heat compared to coconut shells. Husks are of low density and contain much moisture, particularly when they are fresh and green. The type of firewood available in coconut areas is of low to medium density timber which also contain a fair amount of moisture. When such materials are set on fire they keep smouldering (burn without flame) for long periods like in a cigarette. The thick smoke is due to moisture and vapours from pyroligneous liquors and wood tar. In these circumstances the heat emanating is low due to partial combustion. After considerable time, the husks and firewood ignite throwing up flames and hot gases. This causes excessive heat resulting in scorching and case-hardening. There is also the risk of the dryer itself catching fire if the flames are high enough to set fire to the copra bed.

Although low heat is desirable for the process, the smoke coming into contact with the copra colours it thus spoiling the quality. The smoke deposits impqrt an undesirable odour and flavour to the copra and the oil extracted from it subsequently. This disadvantage far outweighs the small benefit introduced by the smoke deposits in resistance to mould attack such as in the case of smoked fish or smoked natural rubber sheets.

Dry mature coconut shells are very dense and comparable to high density timber (hardwood). These have low moisture levels. For example coconut shells have about 12% moisture which comes down to 6 or 8% when dried in open air or in the copra kiln when intact with the kernel. When set on fire, after a very brief period of initial smouldering, the material ignites and flames are seen. When flames are present there is complete combustion, burning all the products of thermal decomposition in the material. The wood tar which is responsible for the colouring also burns without coming into contact with the copra.

The use of dry coconut shells in piles or thick layers spread in a fire-pit gives excessive heat though the smoke is clean. The technique of using coconut shells arranged in a chain one locked into another or "nested" is not known in many coconut regions in the world. In Sri Lanka, India and Malaysia this technique is used extensively. When the shells are ignited at one end of the chain, the fire moves slowly from one shell to another like a fuse. Thus, the rate of heat given out is controlled.

The process of drying copra in the smoke dryers takes 2 to 3 days. This firing is done in 2 or 3 nights. When suitably dry, the copra is unloaded and packed into jute bags, bamboo baskets etc. and sold to copra buyers.

5.3 Product flow diagram

The resultant copra has 10 to 15% moisture. On tthe basis of a final moisture content of 10% and original moisture content of 50% we have: -

1800 kg wet kernel (50% moisture)

↓

1000 kg copra (10% moisture)

The out-turn of copra is variable from country to country, region to region within a country and also dependant upon the season. Prolonged dry weather reduces the size of the nut, it's kernel and hence many more nuts are required to make a tonne of copra.

The out-turn of copra for the different member countries on the basis of the national conversion rates is given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

6. Quality of finished product: -

Various copra grading practices exist in different coconut regions.

The Asian and Pacific Coconut Community has prepared "Uniform Standard Specifications for Copra" (Final draft - April 1978). There are two grades specified irrespective of the process used for making copra. The characteristics specified for the two grades are given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

As discussed in section 5.2, the copra is coloured brown due to the use of direct smoke kilns which is a major quality deficiency of the method used.

The moisture content usually found for this copra is 10 to 15% which is another major deficiency in the copra. This however is due to inadequate drying or sometimes if the copra is case-hardened, no further dryage is possible. In any event, copra of 10 - 15% moisture is saleable in the countries where this direct smoke dryers are used due to lack of proper enforcement of grading and pricing.

This is a matter of trading practices in such areas. Such copra has to be further dried by the oil millers prior to processing.

7. <u>Source of information:</u> -

7.1 Review and techno-economic evaluation of various copra production methods applied in the A.P.C.C. region by Mr. M. Varnakulasingam, and J. Camacho (UNIDO/APCC 1978).

7.2 Copra processing in rural industries by F.C. Cooke (FAO 1958) formerly Director Coconut Research Institute of Ceylon and Dept. of Agriculture of Malaysia.

7.3 Personal observations during field visits to member countries of the Coconut Community.

7.4 Statistical Yearbook on Coconut - APCC 1979. The average nut production per ha. per year to determine the capacities of kilns on hectarage basis was calculated on a ten year average (1969 to 1978) of nut production and area planted as per tables 5 and 6 in the yearbook.

T.K.G.R. - 1980.-

Product code: CCCN 12.01 b
Technology sheet no: I / 14

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN AND PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for : - COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELLS AS FUEL COMBINED WITH PRE-DRYING IN THE SUN (Method C 1).

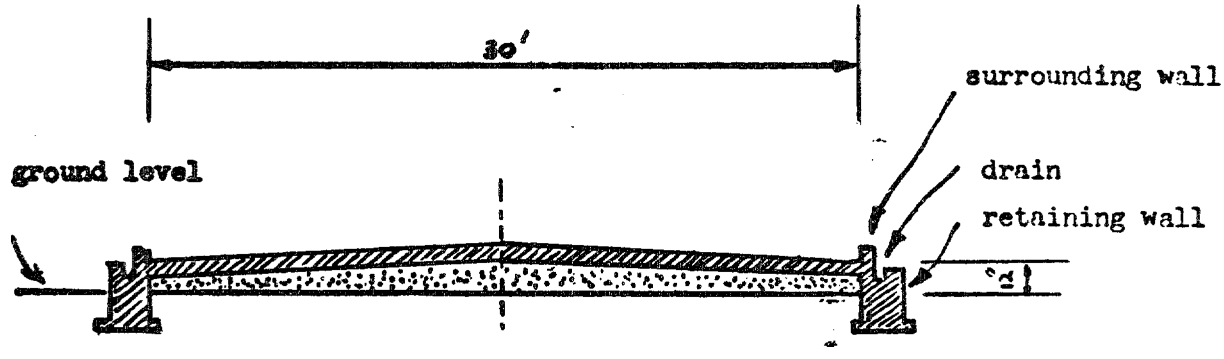
2. Benefits of Technology : -

The copra manufactured by this method is of good quality. The main features are; the use of "seasoned" coconuts, predrying in the sun combined with direct heat smokeless drying.

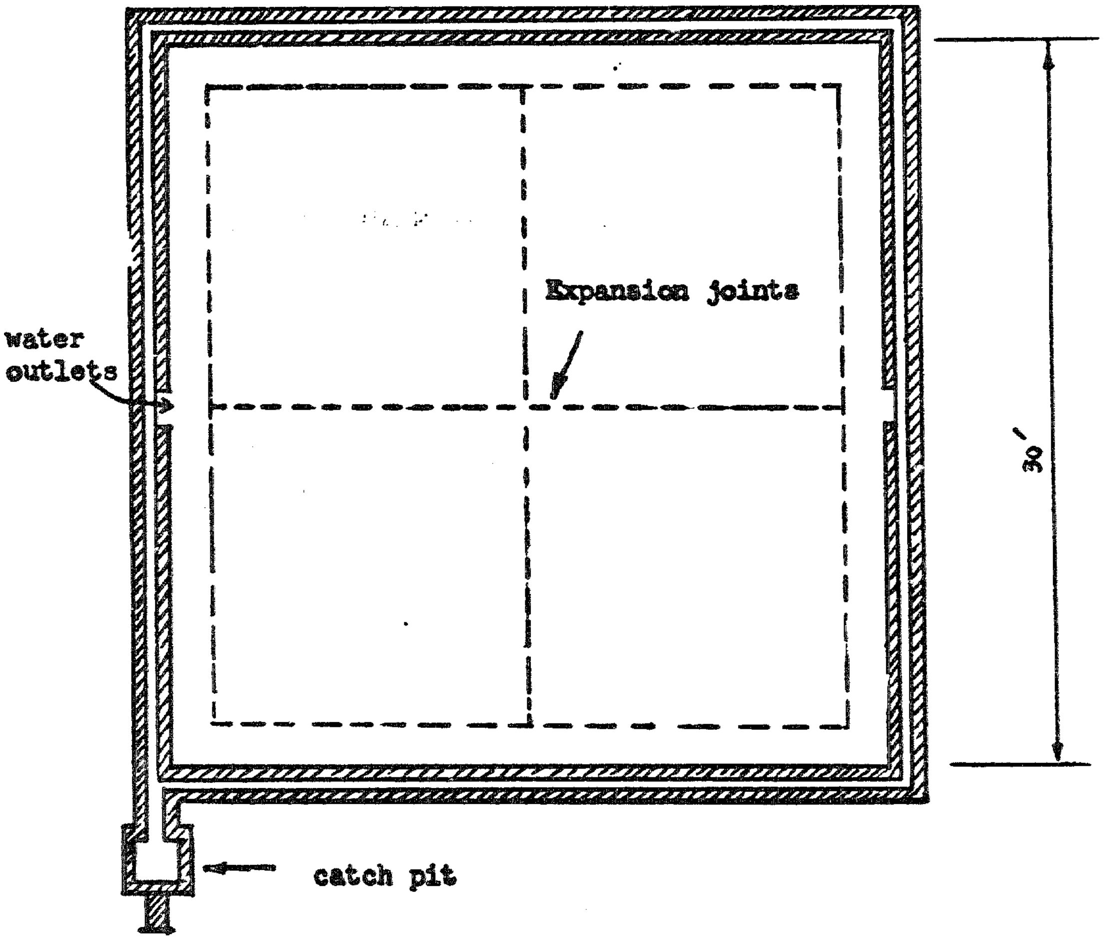
3. Country of origin : -

Sri Lanka is the only country employing this technology with "seasoned" coconuts

Use of coconut shells as fuel with or without pre-drying in the sun is also practiced in India, Malaysia, Philippines, Papua New Guinea but the nuts are not seasoned as in Sri Lanka. The inevitable lapse



Sectional elevation



Plan

FIGURE I BARBECUE FOR SRI LANKA KILN

of one to seven days between harvesting and copra manufacture does not result in "seasoning".

4. Equipment

4.1 Description of equipment: -

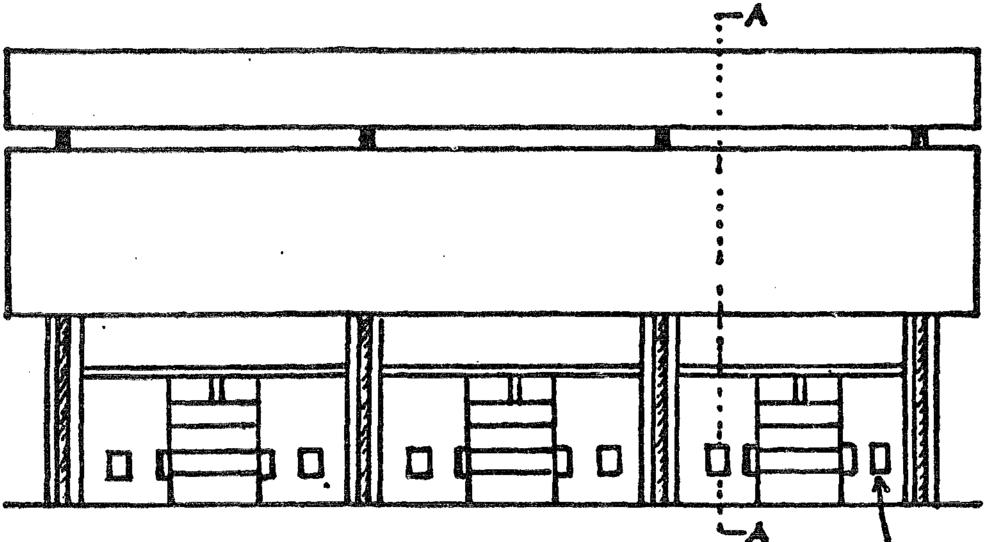
4.1.1 The Barbecue. This is a specially constructed cemented floor and is part of the Ceylon Copra Kiln. The split nuts before going into the Kiln are spread out for one day's pre-drying in the sun.

The details given hereunder have been extracted from leaflet No. 20(1973) issued by the Coconut Research Board of Sri Lanka.

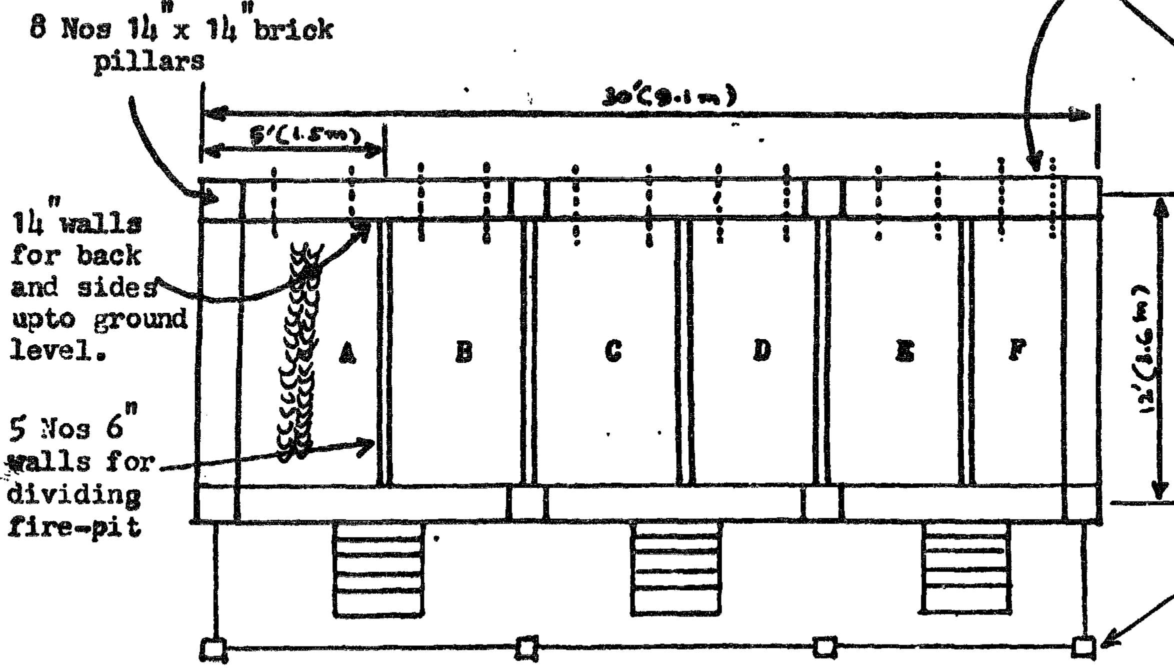
A sketch of a barbecue is given in figure I. The normal width of the barbecue is 30 feet. The length varies according to the size of the kiln and the maximum quantity of nuts intended to be split per day. For smaller kilns the length of the barbecue is normally the same the length of the kiln and is situated in front of same. For this kiln, the length is 30 feet.

The arrangement of retaining wall, drain, surrounding wall etc. are shown in the sketch. The top of the wearing surface at centre is 16 inches above ground level and the edges 12 inches above ground level. Water flows along the sloped surface to the openings shown on either side and enter the drain which leads the water away from the barbecue through a catch pit for disposal.

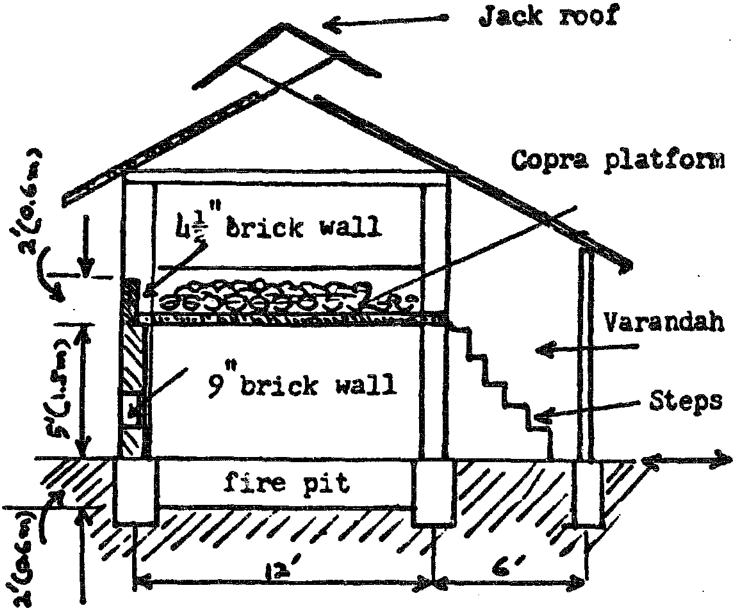
On determination of the length of the barbecue the foundation is marked on the ground with a width of 30ft. internally. Trenches for foundation are cut along the edge of the area thus marked. The depth and width of the foundation depends on the soil at site. An average depth of 18" and width of 18" are sufficient for hard soil. An 18" wide wall is built



Front elevation



Ground plan



Sectional end elevation

Ventilation windows 6" x 12" every 2 ft at 1 ft above-ground level on the back wall

4 Nos 9" x 9" brick pillars for varandah

STANDARD SRI LANKA COPRA KILN

FIGURE II

above the foundation up to a height of 6" above ground level. Retaining wall and surrounding wall 4½" wide each are constructed above the 18" wall on either side of same; leaving room at the centre to form the drain. The drain should be sloped to carry water and is 6" deep at the end where the catch pit is to be situated. The enclosure thus constructed is filled with earth in 3" layers up to the height shown in sketch. The earth must be wetted with water while filling and well rammed. It is sloped from the centre to the two edges, the height at centre being 4" above the edges. The surface of the barbecue is laid above the consolidated filling and may be made with concrete 4" thick, or brick-paved 3" thick and cement-rendered, or rubble-paved and cement-rendered depending on availability and economical purchase of these materials at a given site. It is preferable to use rubble (granite blocks) and even the side walls may be constructed with rubble if available locally. The top wearing surface should be finished rough with cement sand mortar 1:3 and should be at least 1" thick in case of brick or rubble paving. Expansion joints are laid as shown in sketch and should be filled with bitumen. A 4" wide layer of cement and sand 1:4 should be laid below the expansion joints before paving to prevent coconut water seeping through and fermenting under the paving. The edges of the drain and floor are rounded off for smooth flow of water.

4.1.2 <u>The standard Sri Lanka Copra kiln:</u> -

The details given hereunder have been based on leaflet No. 15 (1968) issued by the Coconut Research Board of Sri Lanka.

The Ceylon Kiln is a simple structure, consisting essentially of a fire pit, a copra grill or platform, a corrugated iron roof, fitted with a jack roof and a covered working verandah. There can be minor variations in design and size to suit different conditions and individual requirements. It is also possible to effect economies, by using locally available materials such as unfired mud bricks, round timber, coconut trunks, wooden slats, cadjan roof, etc.

The kiln illustrated in fig. II has a total capacity of 10,000 nuts allowing a daily intake of 2,500 nuts. Smaller kilns to suit individual needs can be built on the same principle.

EXACAVATION: A fire pit measuring 30 feet x 12 feet x 2 feet deep should be marked out and excavated. If the bottom is loose and sandy, about 7 cubes of gravel should be spread evenly and then well rammed to provide a firm foundation for the walls which should be built up to a height of 2 feet, i.e., up to ground level.

WALLS: For the first 2 feet the walls are 14 inches thick. Thereafter the thickness is reduced to 9 inches up to the copra platform. Above this it is further reduced to 4½ inches, so providing the ledge to support the platform.

The two gable-end walls are built up to a height of 7½ feet and the back wall to a height of 7 feet above ground level, but the front wall does not reach above ground level.

The walls are strengthened by 14-inch. pillars, which also support the roof. The fire pit is divided into six compartments by five 6-inch walls, similarly supported by pillars.

VENTILATION: Holes are provided in the two gable walls and the back wall and the front of each section of fire pit is open. The ventilation holes are 6 inch x 12 inch and are set 2 feet apart, one foot above ground level.

Ample ventilation is provided above the copra platform. Humid air can escape via the jack roof, under the eaves and from the gable ends.

VERANDAH: The four pillars supporting the roof are 9 inches x 9 inches. The verandah should be paved with bricks, cemented in position so as to provide a firm floor.

ROOF: The timber for the main uprights should be well-seasoned jak and for the beams well-seasoned coconut rafters. The rafters should be laid 2 feet apart and the reepers 3 feet apart.

A corrugated iron roof is generally to be preferred to a cadjan roof, because it does not require frequent renewal, but a cadjan roof allows free ventilation, keeps the kiln warmer at night and so prevents sooty drops of condensed water falling down on the copra.

THE PLATFORM OR GRILL: Well-matured Arecanut trees should be selected for making the platform. They should be split into slats about 1½ inches broad, placed length-wise across the dividing walls with their ends resting in the 2-inch ledges of the side walls. Slightly broader slats should be placed across these longitudinal slats and secured together with galvanised wire in order to keep the platform firmly in position.

A Halmilla log or a strong flat plank one-foot width, should be laid along the outer edge of the platform to prevent the copra from falling off.

DRAINS: To lead away the rain water falling from the roof, a drain must be provided.

4.2 Materials and labour for construction: -

4.2.1 For the barbecue: -

Material : -

9500 nos. bricks	at 60/-	570.00	
4½ cubes river sand	at 18/-	81.00	
28 bags Portland cement	at 12/-	336.00	
1 gl. bitumen (or plastic asphalt A)	at 2/-	2.00	989.00

Labour: -

3.6 cubes 18" brickwork in cement mortar 1:4	at 30/-	78.00
1.5 sqrs., 4½" brickwork as above at 20/-		30.00
10.6 cubes filling underfloor in 3" layers watered and well rammed	at 7/-	74.20

9.0 sqrs. 3" brick-paved and cement-rendered floor	at 18/-	162.00	
125.0 L.ft. plastering and forming drain	at 50/-	62.50	
Contingencies for clearing site, cutting foundation etc.		54.30	461.00
Cost of material			989.00
Cost of labour			461.00
Total cost (1973 prices)		Rs	1,450.00

4.2.2 For the Standard Sri Lanka Copra Kiln

Materials: -

Bricks	12,000
Cement	20 bags
Sand	2 cubes
Gravel	11 cubes
Clay	15 cart loads
Lime	50 bushels

Timber: -

Wall plates and ridge plates	33'x3"x5"	4 pieces
Ridge plates for jack roof	33'x2"x3"	3 pieces
Cross beams	14'x4"x5"	4 pieces
King posts	3'x3"x3"	4 pieces
King posts for jack roof	1½'x3"x2"	4 pieces
Coconut rafters	8' long	16 pieces
Coconut rafters	14' long	16 pieces
Reepers	2' x 1"	455 feet
Zinc sheets 24 w.g. cwt.	8' long	16 pieces
24 w.g. cwt.	9' long	16 pieces
24 w.g. cwt.	7' long	16 pieces
Galvanised ridging		33 feet
Clips		200

Platform: -

1 Halmilla log or 1 heavy plank, 1 foot width	30 feet long
Arecanut trees for slats	10 trees
Galvanised wire, 1/16 inch. gauge	10 lb

Labour: - Details not available

4.3 Cost of construction: -

4.3.1 The barbecue

Materials	989/=
Labour	461/=
Total cost (1973 prices)	1450/=

Estimated costs in 1979 = Rs. 5000/= (US$ 320)
1 US$ = Rs. 15/60

4.3.2 The Standard Sri Lanka Copra Kiln: -

Total Cost of construction Rs. 25,000/= (US$ 1600)
1 US$ = Rs. 15/60

4.4 Capacity

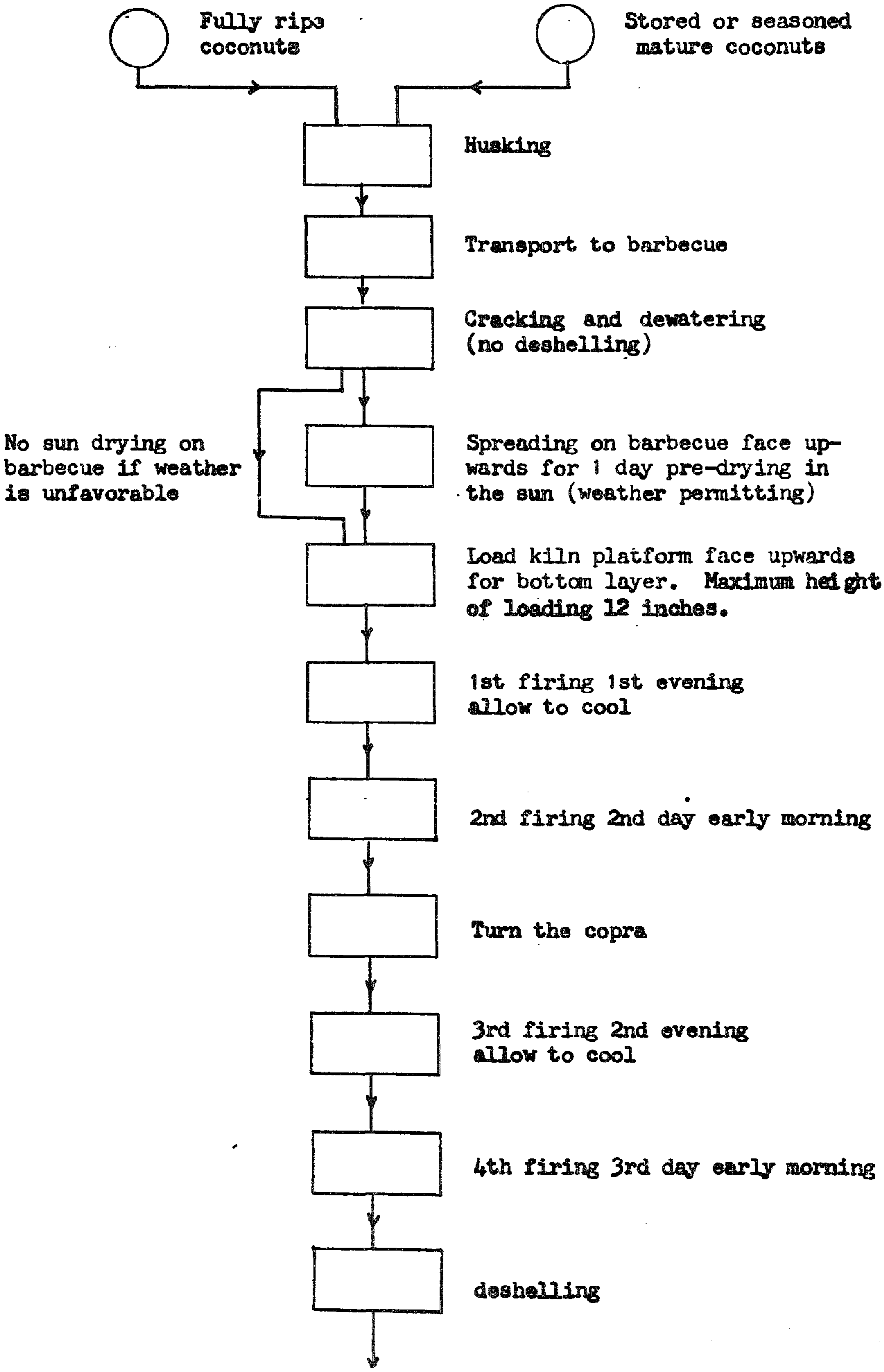
Capacity of barbecue per day	3000 nuts
Capacity of standard kiln per day	2500 nuts

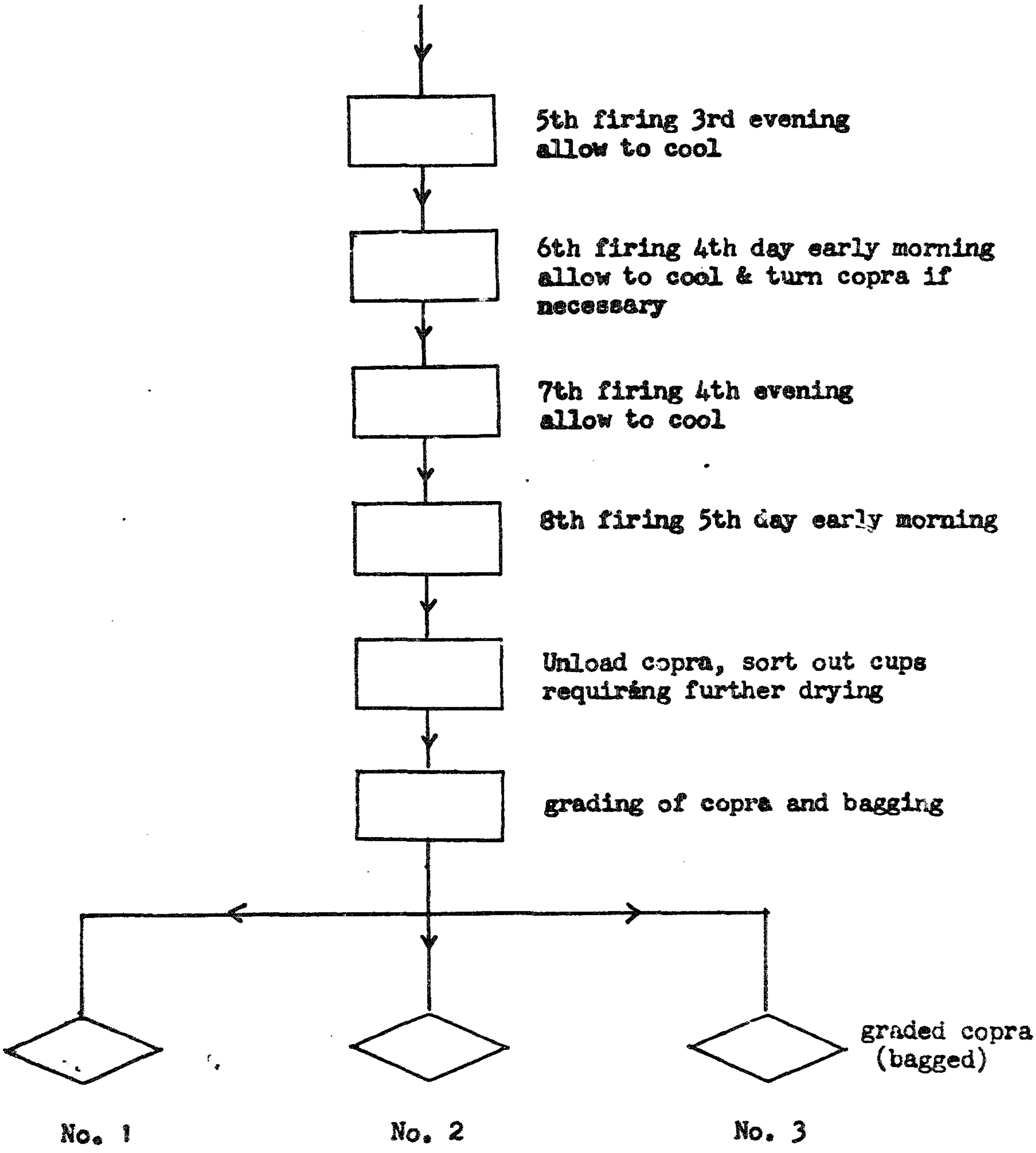
The kiln is worked on the basis of a daily intake of 2500, each batch lasting 4 days. It is possible to work 6 or even 7 days a week depending upon availability of nuts. For the purpose of determining the annual capacity, let us take 10,000 nuts per week, 50 working weeks per year.

Annual capacity is 500,000 nuts (100 tonne copra).

5. Process : -

5.1 **Process flow diagram : -**




5th firing 3rd evening
allow to cool
6th firing 4th day early morning
allow to cool & turn copra if
necessary
7th firing 4th evening
allow to cool
8th firing 5th day early morning
Unload copra, sort out cups
requiring further drying
grading of copra and bagging
graded copra
(bagged)
No. 1
No. 2
No. 3

5.2 Description of process: -

5.2.1 Dehusking & sun drying

The whole nuts which are heaped close to the central copra manufacturing unit are dehusked in the yard. The dehusked nuts are brought to the barbecue where they are cracked and water allowed to run out to the drain. The split nuts (without deshelling) are spread evenly with the face upwards on the barbecue. The pre-drying in the sun for a few hours during the first day helps the "wet" kernel (About 50% moisture) to initially dry out (About 25 to 30% moisture) without any artificial heat action. This promotes a lesser incidence of grade 2 and 3 copra subsequently.

5.2.2 Kiln drying

In the late afternoon on the 1st day, the split halves are loaded onto the kiln platform (or grill). The bottom most layer is placed face upwards so that the shell acts as a shield where the hot gases first imping on the nuts. Other layers are arranged at random upto a total depth of 12 inches (0.3 m). If good white copra is required, the other layers are placed face downwards. The shells (left from previous batches) are arranged in the fire pit in parallel double rows. The shells are arranged in a special manner each shell being fitted into the next or "nested" so that when the row is ignited at one end, the fire moves slowly from one shell to another like a fuse. Thus the rate of heat given out is controlled. The copra drying process needs eight firings over about four days. Deshelling is done on the 3rd day after the 4th firing.

The method of operating the kiln is given below: -

1st Day

Early morning	Split the nuts
7.00 a.m. to 4.30 p.m.	Sun-drying if possible
5.00 p.m. to 10.30 p.m.	Load chambers A and B and 1st firing, 2 double rows of shells per chamber.
10.30 p.m.	Allow to cool.

2nd Day

2.00 a.m. to 7.00 a.m.	2nd firing, 1 double row of shells per chamber.
4.00 p.m.	Turn the copra
5.00 p.m. to 10.00 p.m.	3rd firing, 1 double row of shells per chamber.
10.00 p.m.	Allow to cool. (On the second day chambers C and D are loaded with new kernels and fired).

3rd Day

2.00 a.m. to 7.00 a.m.	4th firing, 1 double row of shells per chamber.
4.00 p.m.	Remove shells and rearrange in chamber A only; chamber B is now empty. The rearrangement gives a second rotation for the kernels.
5.00 p.m. to 10.00 p.m.	5th firing, 1 double row of shells
10.00 p.m.	Allow to cool. (On the third day, chambers E & F are loaded with new kernels and fired).

4th Day

2.00 a.m. to 7.00 a.m.	6th firing, 1 double row of shells
4.00 p.m.	Turn the copra if necessary
5.00 p.m. to 10.00 p.m.	7th firing, 1 double row of shells
10.00 p.m.	Allow to cool (On the fourth day, chamber B is loaded with kernels from C and D after deshelling. Hence chambers C and D are loaded with new kernels).

5th Day

2.00 a.m. to 7.00 a.m.	8th firing, a short double row according to requirements.
5.00 p.m.	Remove the copra and return any undried for further drying.

The usage of shells is 50% with one day's predrying in the sun. This can be reduced to 30% with longer predrying in the sun. With no predrying, the shell usage is about 67%.

In the Sri Lanka kiln, the drying temperature is maintained at about 55°C (131°F) producing good quality copra. Higher usages of shell (say 100%) would reflect forcing the pace of drying by using too many rows of shells and higher drying temperatures resulting in mild discoloration of the copra due to oxidation of the oil.

5.2.3 Copra Grading: After the copra has been cured it is sorted into following grades: -

No. 1 copra
No. 2 copra
No. 3 copra

This sorting must be done very carefully otherwise serious penalties may be imposed by the buyers.

5.2.4 Grades: -

No. 1 copra: The pieces are hard, smooth, crisp and uniformly greyish white: they break cleanly and with a snap exposing a sharp straight edge with a uniform pearly lustre, indicating uniform drying to below six per cent.

No. 2 copra:
(1) Distorted copra from under-ripe nuts.
(2) Thin and broken copra from over-ripe nuts.
(3) Scorched, burnt or off-coloured copra.

No. 3 copra: (1) All copra of kalati stage, i.e., rubbery or immature copra

(2) All kernels of decayed nuts.

5.2.5 An analysis of causes of deterioration or spoilage of copra applicable to Sri Lanka is given hereunder as per leaflet No. 25 (1970) issued by the Coconut Research Board.

Cause	Effect	Importance
A. Careless Harvesting		
(1) Under-ripe nuts (Kalati)	Thin, torn, distorted, corrugated rubbery pieces	Major
(2) Over-ripe nuts	Thin, broken, sometimes discoloured pieces of high oil content	Generally Minor
(3) Slipshod collection	Black, rotten coconut meat, owing to "eye-rot"	Generally Minor
B. Careless pre-treatment		
(4) Husking and splitting on sand or in a muddy yard or bagging of cut meat	Adherence of dirt and pieces of husk or fibre	Generally Minor
(5) Uncovered heaps of husked nuts exposed to hot sun	Severe cracking causing serious sliming if left over-night	Major
(6) Careless splitting	Broken pieces and "smalls"	Minor

(7)	Delay after splitting before heat applying	Development of gummy slime and dirt adhesion	Major
(8)	Rain on split nuts	Developing of gummy 'slime' discoloration and 'pitting'	Occasional
(9)	Coconut water left to dry up in split halves	Development of gummy slime colour and dirt adhesion	Major

C. Careless Manufacture

(10)	Over-loading	Production of scorched, "stewed" and slimy copra. Drying irregular	Major
(11)	Excessively long delays between fires	Moisture condensation with "pitting" and sliming	Major
(12)	Use of broken and dirty shells as fuel	Smoky pieces	Minor
(13)	Use of shells of irregular diameter for chains	Smoky pieces	Major
(14)	Use of damp shells, wood, husks or combustible rubbish	Very smoky pieces	Major
(15)	Shell lines too close to kiln walls	Case-hardening scorching and distorting of pieces	Major

(16)	Over-firing (early)	"Case-hardening" and distortion of pieces and irregular drying	Major
(17)	Over-firing (later)	(a) Superficial scorching	Minor
		(b) Internal discoloration	Major
		(c) Carbonization with loss of oil	Major
(18)	Shell lines too far	Slimy copra mid-way between fires	Major
(19)	Under-drying with subsequent continued neglect to dry	(8 to 18% moisture) Heavy development of superficial moulds	Major
		(10 to 15% moisture) Decomposition of surface tissue, with penetrating moulds and insect.	Major
	(over 15% moisture)	General decomposition with heavy mould and slime growth	Serious

D. Faulty Kilns

(20)	Too open (with heavy wind)	Both scorching and sliming and smoke due to disturbance of fires	Major
(21)	Too closed, (inadequate exit for air)	Copra stewed, slimy and oversmoked	Major
(22)	Inadequate firepit ventilation (with overloading)	Both scorching and sliming excessive smoke and irregular drying	Major
(23)	Damp firepit	Slow drying and smoky copra due to smoky and uncertain fires	Occasional

E.	Careless Storage and Transport		
(24)	Rain or seawater on copra in bags	Heavy mould and insect attack	Major
(25)	Storage in damp godown	Mould and Heavy insect attack	Common
(26)	Wet and dry copra in contact	Mould and insect attack	Common
F.	Unavoidable Causes		
(27)	Prolonged storage of superior copra	Superficial moulds and surface discoloration through oxidation	Minor
(28)	Imperfect "meat" development in nuts (defective nuts)	Rubbery and often discoloured thin ragged copra	Minor

5.3 Product flow diagram: -

1880 Kg wet kernel from 4925 nuts (50% moisture)

↓

Sun dried (About 25 to 30% moisture)

↓

1000 Kg copra (6% moisture)

6. Quality of finished product: -

Whilst Sri Lanka has her own method of grading copra, the following is the uniform standards for copra as proposed by the Asian & Pacific Coconut Community (Final draft April 1978).

Characteristic	Grade 1	Grade 2
a. Moisture content (percent by weight), Max.	6	8
b. Oil content (on moisture free basis) percent by weight, Min.	68	66
c. Free Fatty Acid (as lauric) percent by weight. Max.	1	3.5
d. Impurities percent by weight. Max.	0.5	1
e. Immature kernels (wrinkled cups) percent by count. Max.	Nil	5
f. Mouldy cups, (percent by count) Max.	Nil	4
g. Charred or black cups (percent by count) Max.	Nil	5
h. Broken cups or chips (percent by weight) Max.	Nil passing through 3/8" mesh sieve	Not more than 1 percent passing 3/8" mesh sieve.
i. Colour of the expelled oil on $5\frac{1}{4}$" cell on the Lovibond colour scale expressed as Y" 5R not deeper than	10	12

7. Sources of information

1. Asian and Pacific Coconut Community, Jakarta
2. Coconut Research Board, Sri Lanka
3. Writers personal observations

T.K.G.R. 1979.

Product Code; CCCN 12.01 b
Technology sheet No. 1/15 to 25

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for : - COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELL AS FUEL (Method C 2).

Usual method used by large copra manufacturers and small-holders in Sri Lanka, India and Malaysia. This method has been adopted in some parts of the Philippines and Papua New Guinea from the 1960 s. This has also been just introduced to Western Samoa and the Solomon Islands.

2. Benefits of technology : - In the direct heat smokeless dryers, although the products of combustion come into contact with the kernel, no smoky odour, flavour or colour is imparted due to the nature of the smokeless gases. The benefits of these dryers are: -

2.1 The quality of copra is better than that manufactured by using direct heat smoke dryers with husk and firewood as fuel. Use of dry coconut shells suitably arranged gives smokeless heat with regular and controlled heat.

2.2 Although the quality is nearly as good as that made using indirect heat dryers, the cost of processing is low due to the efficiency of the direct heat method and due to use of readily available shell as fuel.

2.3 Although good quality copra is obtained, there is no need for electricity, petroleum based fuel and skilled technicians.

3. Country of origin: -

SRI LANKA. In Sri Lanka copra is manufactured mainly by centralised processors. This is possible due to the existence of free trade in coconuts. Copra manufacturers purchase nuts either directly from small holders or through contractors. Large holders usually make their own copra and is known as estate copra.

Good quality copra is produced by using fully nature, "seasoned" coconuts with 1 day's pre-drying in the sun and then kiln drying with coconut shells. The kernels are kiln dried whilst still intact with the shell for 2 days before ejecting the kernel for further dryage. Initial arrangement of kernels on the platform is methodical and not random. This combined system for copra manufacture is unique for Sri Lanka.

INDIA AND MALAYSIA also use these dryers with shells and is usually predried in the sun if the weather permits.

PHILIPPINES, THAILAND AND PAPUA NEW GUINEA have started to use these dryers with shells in some areas from the 1960 s. A new dryer has been developed recently at, University of the Philippines, Los Banos, Laguna (Philippines). This dryer has not yet been put into commercial operations and the technology is not yet published. This dryer is also of the direct heat smoke-less type but uses coconut husk charcoal as fuel.

WESTERN SAMOA AND SOLOMON ISLANDS have just introduced these direct heat smokeless dryers from 1979.

4. Equipment : -

4.1 Description of equipment and operation : -

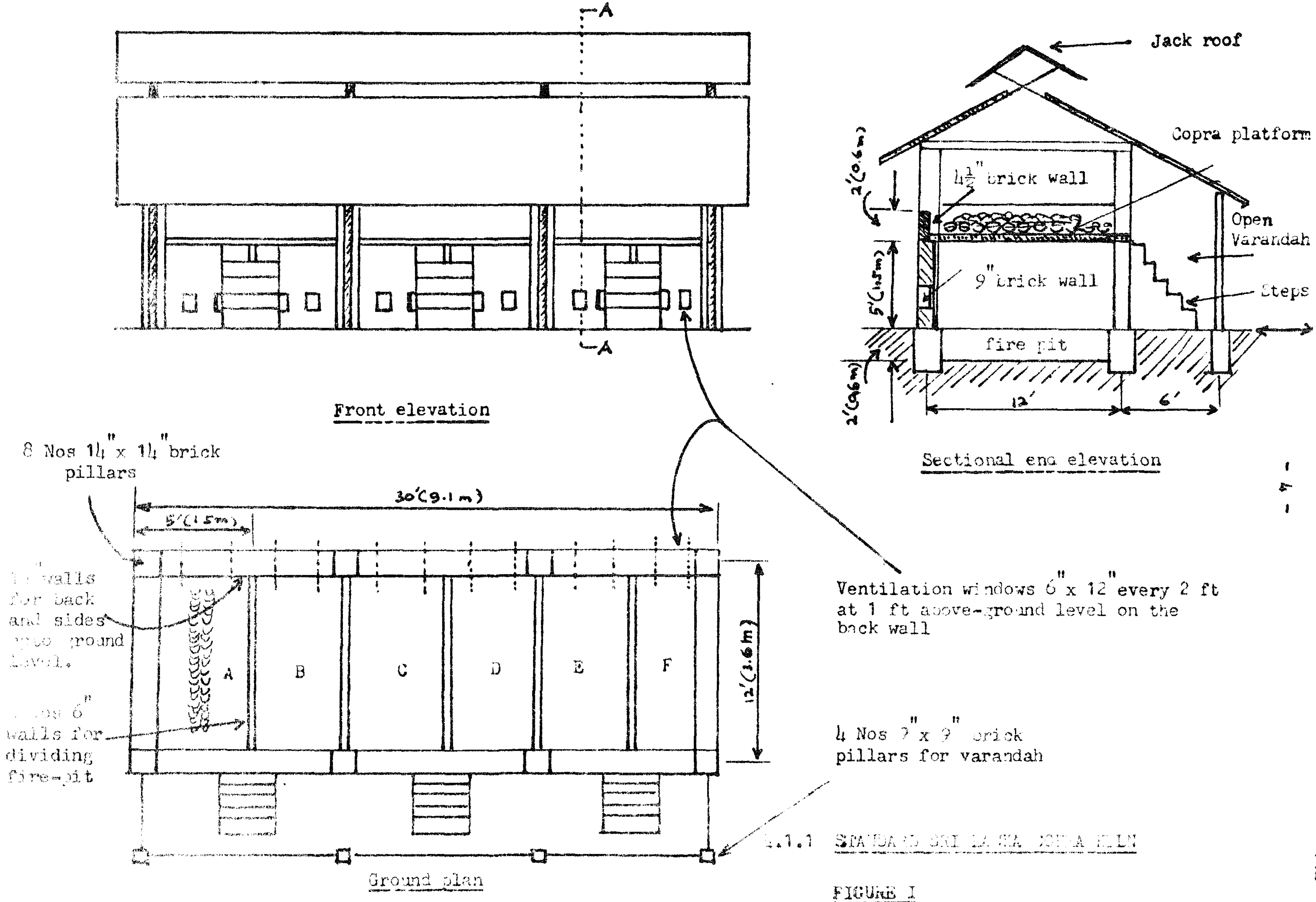
4.1.1 Sri Lanka standard copra kiln.

Similar kilns are used in Malaysia and India, probably introduced by the British planters during the early part of this century.

The kiln shown in figure I comprises of a battery of three simple units, each unit 12 ft x 10 ft being divided into two fire chambers. This type of kiln is used in estates and by central processors. The kiln can be doubled in length for doubling the capacity.

The kiln is a simple structure, consisting essentially of a fire pit, a copra grill or platform, a corrugated iron roof fitted with a jack roof and a covered varandah. There can be minor variations in design and size to suit different conditions and individual requirements. It is also possible to effect economies by using locally available materials such as unfired mud bricks, round timber, coconut trunks, wooden slats, cadjan roof (plaited coconut leaves) etc.

A cemented drying floor (or barbecue) 30 ft wide is constructed adjascent to the kiln in front. The length of the barbecue is the length of the kiln which in this case is 30 ft. This is very useful in keeping the kernels clean during preparation of the nuts and the day's sun drying.



4.1.1 STANDARD SRI LANKA COPRA KILN

FIGURE I

The kiln is fired using dry coconut shells from the previous batch of copra. The shells are arranged in rows ("nested") and ignited at one end. The fire moves slowly (about 2 feet per hour) from one shell to another like a fuse thus giving out controlled heat.

The operation of the kiln is as follows.

1st day

Early morning	Split 2500 nuts
7.00 am to 4.30 pm	Sun-drying if possible
5.00 pm to 10.30 pm	Load chambers A and B and 1st firing, 2 double rows of shells per chamber
10.30 pm	Allow to cool.

2nd day

2.00 am to 7.00 am	2nd firing, 1 double row of shells per chamber
4.00 pm	Turn the copra
5.00 pm to 10.00 pm	3rd firing, 1 double row of shells per chamber
10.00 pm	Allow to cool. (On the second day chambers C and D are loaded with new kernels and fired).

3rd day

2.00 am to 7.00 am	4th firing, 1 double row of shells per chamber
4.00 pm	Remove shells and rearrange all the kernels in chamber A only. Chamber B is now empty. The rearrangement gives a second rotation for the kernels.

5.00 pm to 10.00 pm	5th firing, 1 double row of shells
10.00 pm	Allow to cool (On the third day, chambers E & F are loaded with new kernels and fired).

<u>4th day</u>

2.00 am to 7.00 am	6th firing, 1 double row of shells.
4.00 pm	Turn the copra if necessary.
5.00 pm to 10.00 pm	7th firing, 1 double row of shells.
10.00 pm	Allow to cool. (On the fourth day, chamber B is loaded with kernels from C and D after deshelling. Hence chambers C and D are loaded with new kernels).

<u>5th day</u>

2.00 am to 7.00 am	8th firing, a short double row according to requirements.
5.00 pm	Remove the copra and return any undried for further drying

The usage of shells is 50% with one day's pre-drying in the sun. This can be reduced to 30% with longer predrying in the sun. With no predrying, the shell usage is about 67%.

In the Sri Lanka kiln, the drying temperature is maintained at about 55°C (131°F) producing good quality copra. Higher usages of shell (say 100%) would reflect forcing the pace of drying by using too many rows of shells and higher drying temperatures resulting in mild discoloration of the copra due to oxidation of the oil.

For full details of construction and operation of the copra kiln and the barbecue see technology sheet "COPRA MANUFACTURE BY DIRECT HEAT SMOKELESS DRYERS USING COCONUT SHELLS AS FUEL COMBINED WITH PRE-DRYING IN THE SUN (Method C 1)".

The area of the platform is 360 square feet (32.7 m^2) and the height above fire-pit is 7 ft (2.1 m). Total capacity is 10,000 nuts (2030 kg copra) per batch of 4 days. When loading the kiln with new kernels, the kernels are arranged with the bottom layer facing up. The height of loading is never allowed to exceed 1 ft. The kiln is operated on the basis of a daily intake of 2500 nuts. The barbecue has a capacity to prepare and sun dry upto 3000 nuts per day.

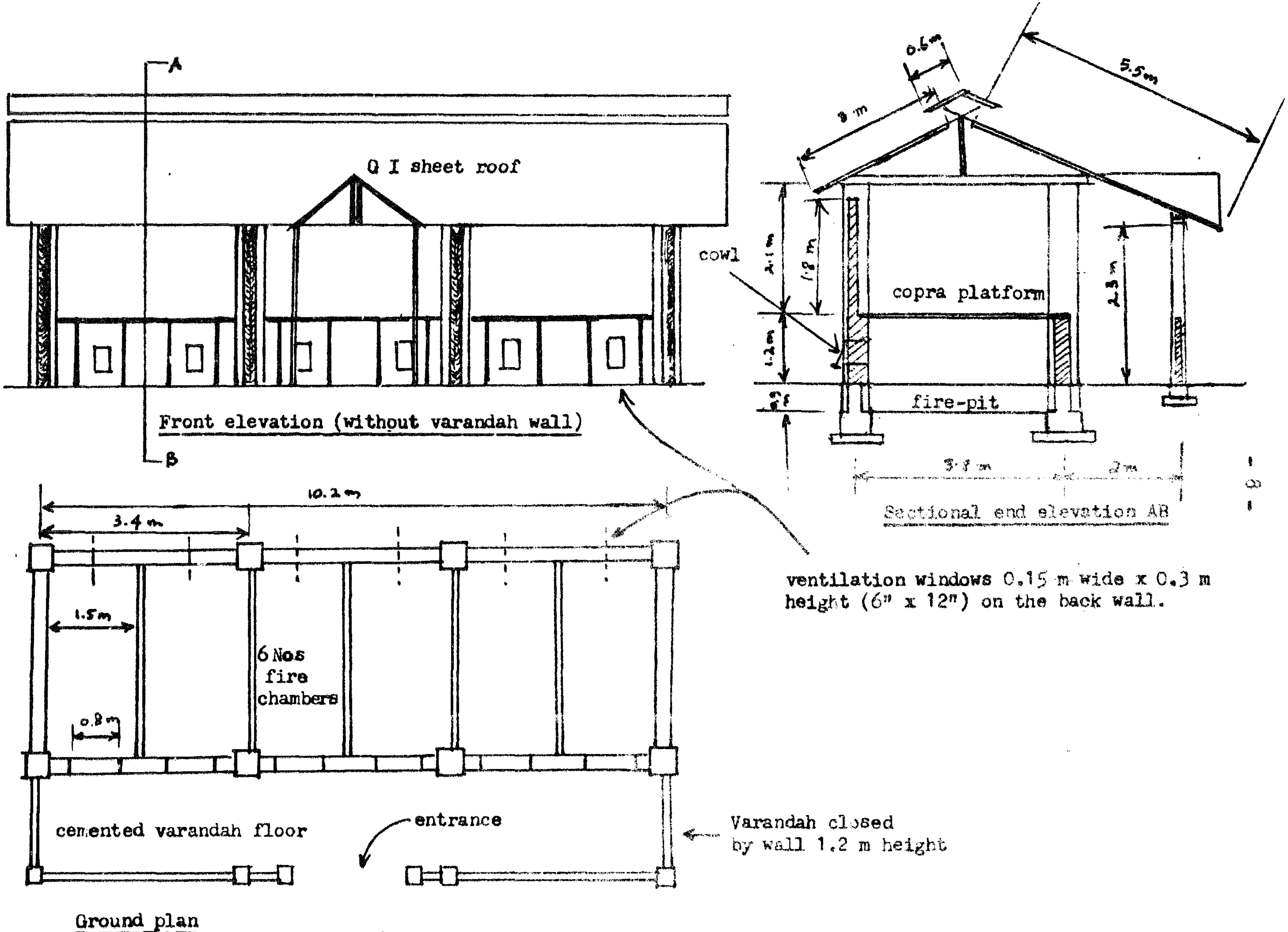
The present cost of the kiln is Rs 25,000 (US$ 1600). The estimated cost of the barbecue is Rs 5000/- (US$ 320). The total cost is Rs 30,000/- or US$ 1920.

On the basis of 10,000 nuts per week and 50 working weeks per year, the capacity per annum will be 500,000 nuts or 100 tonne. This kiln can cater to 100 ha (220 acres) on the basis of an average of yield of 5000 nuts per ha (2275 per acre). The investment per 100 tonne copra capacity per year is US$ 1920.

Some refinements to the design and the use of standard construction materials was introduced by the Coconut Research Board, Sri Lanka in 1972. There is however, no basic change to the design and operation of the standard kiln. This improved kiln is presented in section 4.1.2.

4.1.2 Improved Sri Lanka copra kiln.

This improved version of the standard Sri Lanka kiln was introduced by the Coconut Research Board in 1972. The design and operation is basically the same. The dimensions are nearly the same and the capacity is identical. Improvements have been effected in a deeper fire pit, lower copra



4.1.2 IMPROVED SRI LANKA COPRA KILN (TRIPLE UNIT)

FIGURE II

platform (eliminating the need for steps) and superior draft control through a partly covered front wall for the fire chamber as well as the varandah having a surrounding wall. The number of ventilating window at the rear wall have been reduced to half the number. The rear wall is constructed upto 1.8 m above the copra platform.

The kiln illustrated in figure II is a triple unit having six fire chambers. This facilitates a daily intake of 2500 nuts although the total holding capacity is 10,000 nuts.

An identical kiln has been installed in Western Samoa in 1979 and is now in operation.

The bill of quantities for construction and the 1972 prices applicable to Sri Lanka are given hereunder: -

Improved Sri Lanka. Copra kiln

Bill of quantities for triple unit (6 fire chambers)

Item	Description	Unit	Quantity	Rate Rs.	Amount Rs. c.
(1)	Allow for clearing site, removing trees etc.	-	Item	-	75.00
(2)	Earthwork-excavations in pit	Cubes	41.2	10.00	142.00
(3)	Earthwork-excavations in foundation	"	4.9	10.00	49.00
(4)	6" thick R.C.C.(1:2:4)(1") in foundation reinforced with 1 layer B.R.C. No.8.	"	2.0	500.00	1,000.00
(5)	Brickwork in Ct. Mtr. 1:4 in 18" foundation	"	1.4	275.00	385.00
(6)	-do-in 13½" foundations.	"	1.4	275.00	385.00
(7)	-do-in 13½" x 13½" pillars in superstructure.	"	1.5	290.00	435.00

(8)	-do-in 9" x 9" pillars in superstructure	"	0.3	290.00	87.00
(9)	-do-in 13½" walls in superstructure	"	4.2	275.00	1,155.00
(10)	-do-in 9" walls in superstructure	"	1.6	275.00	440.00
(11)	-do-in 4½ " walls in superstructure	sqq.	3.2	100.00	320.00
(12)	-do-in 4½" walls in fire-pit partitions	"	4.2	100.00	420.00
(13)	Earth-filling under floors in 3" layers well-rammed	Cubes	1.0	12.00	12.00
(14)	D.P.C. in Ct. Mtr. 1:3 blended with tar and sand	Sqq.	1.2	40.00	48.00
(15)	G.I. Sheet roof fixed complete as per detail	"	12.8	225.00	2,880.00
(16)	3" brick-paved cement rendered floor finished rough	"	2.0	100.00	200.00
(17)	External plastering in Ct. lime mortar 1:2:7 finished	"	10.0	40.00	400.00
(18)	Mature arecanut reepers fixed to form copra deck	"	3.9	10.00	390.00
(19)	9" x 12" R.C.C. 1:2:4(¾") in lintol reinforced with 4 Nos.½" M.S. rods and ¼" stirrups at 9" centres including G.I. pipe rail to carry sliding shutters	I.ft.	34.6	8.00	276.80
(20)	Weld mesh shutters on rear wall fixed complete	S.ft.	40.0	3.00	120.00
(21)	Weld Mesh fixed on 4" x 2" frames complete	S.ft.	57.0	2.50	392.50
(22)	Doors 3" x 4" Jak frames and 1" Jak sashes inclusive of door furniture	S.ft.	30.0	10.00	300.00
(23)	Cowls fixed as per detail		6.0	5.00	30.00
(24)	Sliding shutters out of G.I. Sheets on 1" x 3" Jak frames fixed complete with fittings as per detail	S.ft.	72.0	6.00	432.00
(25)	6" x 2" Near R.C.C. beams to Support Copra deck.	L.ft.	33.0	2.50	82.50
(26)	White washing and painting		Item		143.20
			Total		10,600.00

The total cost (1972 prices)	Rs	10,600/=
Estimated prices (1980)	Rs	35,000/=
	(US$	2250/=)
Cost of barbecue (1980)	Rs	5,000/=
	(US$	320/=)

Total cost Rs 40,000/= (US$ 2600).

As in the case of the standard kiln, a barbecue 30 ft (9.1 m) wide is constructed along the length of the kiln which in this case is 10.2 m. The nuts are prepared here and sun dried (with the kernel intact) for one whole day if the weather permits.

The firing using coconut shells is the same as for the standard kiln.

The area of the platform is 38.8 m^2 and the height [illegible] -pit is 2.1 m. Total capacity is 10,000 nuts (2030 kg copra) per batch of 4 days. When loading the kiln for the first time, the bottom layer is arranged face upwards and the rest at random. The height of loading is not more than 1 foot. The kiln is operated on the basis of a daily intake of 2500 nuts. The barbecue has a capacity to prepare and sun dry upto 3000 nuts per day.

The cost of the kiln (1980 prices) with the barbecue is Rs 40,000/= (US$ 2600).

4.1.3 Sri Lanka small-holders kiln (Cooke type): -

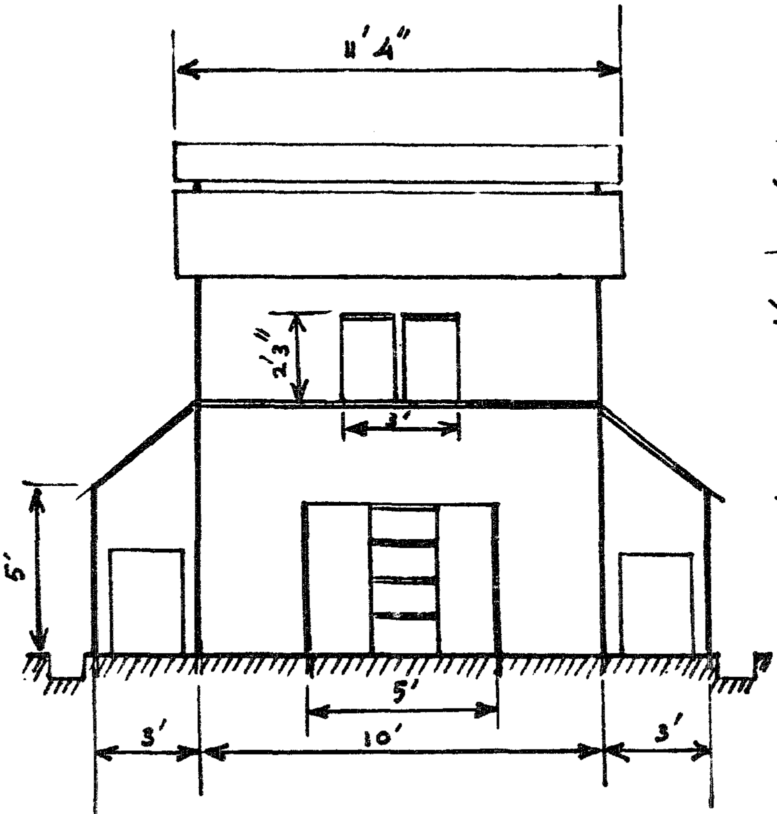
This is suitable for small holdings upto 66 acres (30 hectare) or for decentralised production on large estates, thus eliminating the need for transporting to a central yard.

This kiln illustrated in figure iii is an improvised version of the Sri Lanka standard copra kiln, but of reduced capacity. It produces better quality copra in half the time (2½ days) without unduly forcing the drying process, which could cause case-hardened or scorched copra. This refined design is almost identical to the Malaysian 30 acre kiln (see section 4.1.5).

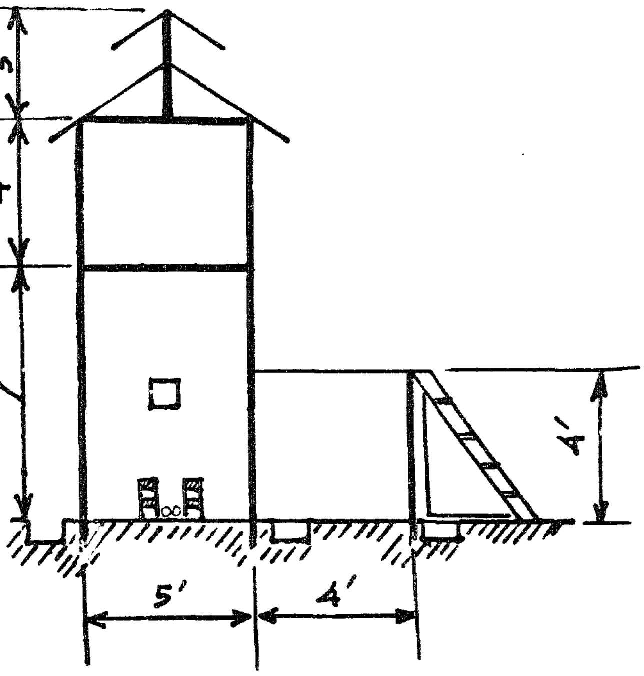
The design is based on the travelling cone of heat given by a 12 ft long double row of nested coconut shells. The rate of movement of the fire is about 2 ft per hour.

When the copra grill is 7 feet above the fire-pit the cone of hot gases is 5 ft in diameter, thus determining the width of the copra grill and the kiln itself. The length of the grill is therefore 10 ft, fire-pit 12 ft and overall length of the kiln 16 ft.

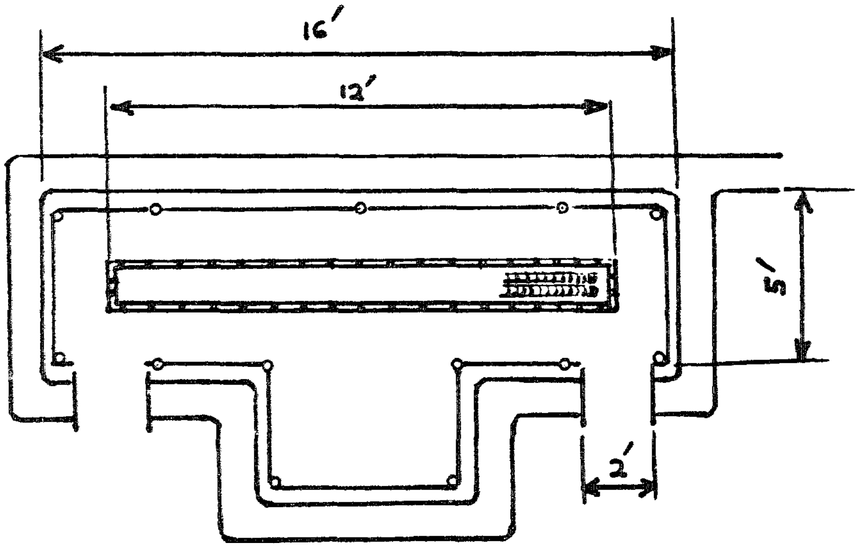
A heat spreader consisting of a piece of flat galvanized iron 1 ft 8 inches x 10 ft is nailed to the underside of the grill directly above the area of the fire-pit to prevent overheating the copra. The roof of the two wings is protected from sparks by two flat sheets of galvanized iron on the underside. Although the kiln uses much traditional construction materials which are inflammable, there is no risk of fire due to the design. Furthermore, the conditions inside the kiln are not affected by gusts of wind.



Front elevation



Sectional end elevation



Plan

4.1.3 SRI LANKA SMALL HOLDERS COPRA KILN
(COOKE TYPE)

FIGURE III

The use of cadjan (plaited coconut leaves) for the walls is preferred to galvanized iron sheet or brickwork because it allows admission of air evenly into the fire-pit without any disturbance associated with ventilation holes. This material also keeps the air inside warm so that no moisture condensation or chilling occur on cold nights as is the case with galvanized iron. When hot humid air is chilled, undesirable convection currents throw the cold moisture - laden air back onto the copra, which becomes chilled by the deposit of cold condensed water.

The kiln is cheap to build because most of the construction materials such as hardwood poles, coconut rafters, split areca palm, plaited coconut leaves, coir string, and old bricks - are available in rural areas.

The shells used as fuel should be those of mature nuts, dry and free of husk. The fuel should be sorted into large and small shells in order to avoid interlocking which occurs when a small shell enters the cavity of a larger one, resulting in a period of undesirable smoking and smouldering. The line of shells should be loose, to allow free ventilation and prompt ignition of a preheated shell. The large shells should provide the first fire. The shells are laid in the serrated brick hearth in a parallel double row. When the chain is first lit, to avoid any excessive production of smoke, it is desirable to ignite some shells outside the kiln and bring them in as soon as they are burning fiercely. The fire-pit doors should thereafter be kept closed to prevent any disturbance of the fires.

It has also been found that 1500 nuts which have been previously sun dried for about eight hours can be dried with eight double fires, allowing two hours' rest between fires.

In rainy weather the coconut halves have to be put straight on the kiln, and the drying should be started with two fires, one at each end, separated by a temporary wall in the middle. An extra day's drying is also necessary - that is, twelve fires in all; however, initial sun drying reduces fuel consumption by 30 percent.

Even whiter copra can be obtained by burning a one inch layer of coconut charcoal in the hearth. In such a case, the length of charcoal layer will be 12 ft and when ignited at one end, takes fifteen hours to burn away and gives radiant heat without smoke. About 113 kg of charcoal is required to dry 1500 nuts. With careful burning this amount of charcoal can be obtained from the shells of 2500 nuts, but the purchase of additional charcoal is justified only if a premium is obtained for the white copra produced.

The usage of shells is 50% with a day's pre-drying in the sun. The kernels with the shells intact are loaded on to the platform initially in a methodical manner. The lowest layer is placed face upwards and the rest downwards upto a maximum height of 0.3 m. After two firings, the kernels are ejected from the shells, and rearranged at random ensuring turning of the copra from the top layers to the bottom. In order to facilitate these operations, a separate working platform and ladder are provided as shown in the illustration.

The area of the copra grill is 50 sq ft (4.5 m^2). The capacity is 1500 nuts per batch lasting 2.5 days.

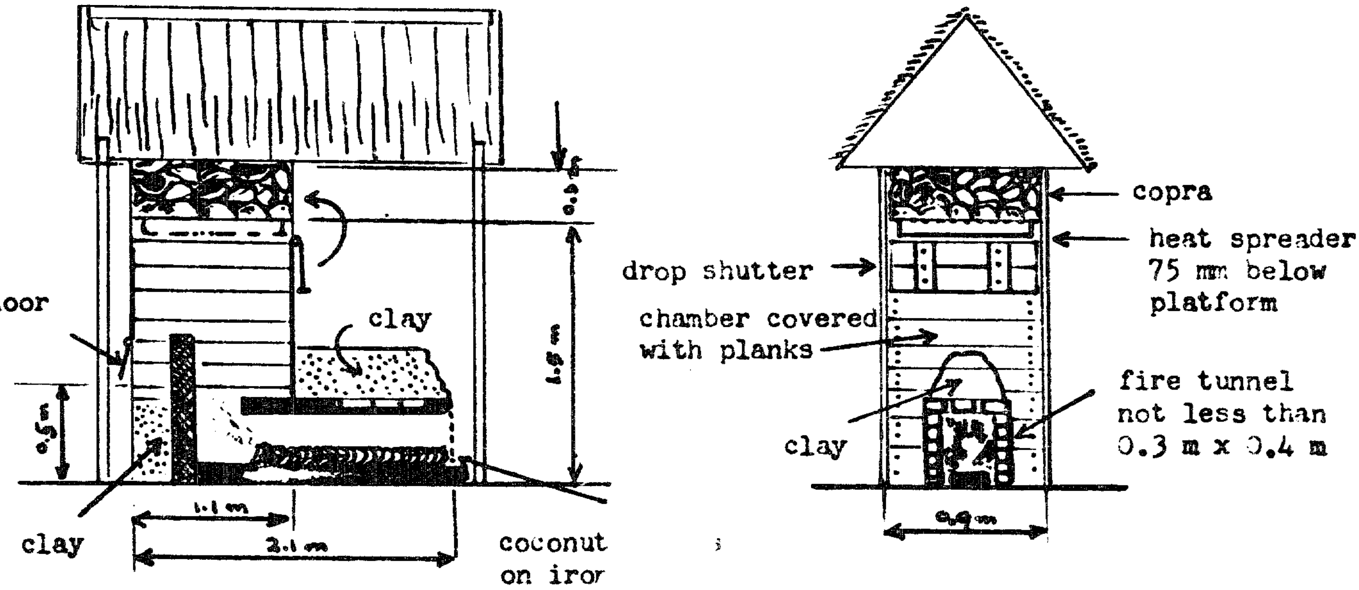
On the basis of 2 batches of 1500 nuts per week and 50 working weeks per year, the annual capacity is 150,000 nuts (30 tonne of copra). For an average nut production of 4980 per ha per year, this kiln can service 30 ha (66 acre).

4.1.4 Miniature Malaysian kiln - Cooke type for 4 ha (10 acre)

This miniature kiln, designed in Malaysia for small holdings upto 4 ha, to dry 100 coconuts and yield crisp, white undistorted and uniformly dry copra in fifteen hours.

The kiln illustrated in figure IV has overall dimensions 2.1 m x 0.9 m and sheltered with an attap roof (thatched with palm leaves). The copra platform itself occupies half this rectangular space and is constructed out of evenly spaced "nibong" (nipa) palm slats at a height of 1.5 m above ground level. The platform is located inside a wooden chamber whose height reaches 0.3 m above the level of the platform. The top of the chamber is open and 0.3 m below the eaves to permit exit of moisture laden air. About 75 mm below the platform is a heat spreader made of sheet iron with perforations and held horizontally by wire. The front of the chamber has a drop shutter for loading the kiln as well as for inspection and cleaning the heat spreader.

A tunnel leading into the base of the chamber forms the hearth, in which a single chain of coconut shells is burnt continuously. The fire tunnel consists of two walls of loose brick laid along the ground leading into the base of the chamber. These walls, each six bricks high, are laid 0.3 m apart and a sheet iron cover 1.8 m x 0.5 m is place on top of the bricks. The sheet iron in covered with rammed clay



Half sectional front elevation

End elevation

4.1.4 MINIATURE MALAYSIAN KILN

COOKE TYPE

FIGURE IV

to avoid loss of heat. The portion of the brick walls outside the chamber is arranged with serration to admit air for combustion. The base of the chamber is filled to a height of 0.5 m with rammed clay leaving a hole in the centre which is lined with loose bricks. The hot gases emerge from this hole and move upwards whilst fresh air is drawn into the tunnel from outside. There is a flap door at the rear of the chamber above the clay filling to facilitate inspection and cleaning the clay base.

A kiln will last for over two years if proper maintenance is carried out such as by applying preservative to the timber. The attap roof however needs replacement after 1 year.

To operate the kiln, clean, dry coconut shells of uniform size are interlocked or "nested" loosely and laid in a single line on a sheet iron tray. This tray, 1.5 m x 0.2 m is drawn out of the tunnel for placing the shells and igniting. The shells are placed with the hollow (concave) surface facing the chamber and it is this same end that is ignited. Use of a little kerosene or scrap rubber aids prompt ignition. Once lit properly, the tray is moved into the fire tunnel. Since the burning end of the line of shells is innermost and against the draft of fresh air, the flames are directed away from the shell next in line for ignition. Thus, the rate of combustion and heat given out is regular and slow. If the other end of the line of shells was ignited, the flames would have rapidly ignited the shells next in line, causing heavy output of heat, thus spoiling the copra and possibly destroying the kiln. The sectional area of the tunnel is of importance for smooth operation. If the cross section is much smaller than 0.3 m x 0.4 m, the speed of the draft is too excessive for the fire, resulting in difficulty in maintaining the flames and thus creating smoke.

When the first line of shells is completely burnt, the tray is withdrawn for reloading with the second line of shells. At the end of the second firing, the copra is turned over. A further 3 firings (5 in all) are lit in succession to dry the copra adequately. The copra is dried throughout with the shells intact, and ejected only at the end of the fifth firing.

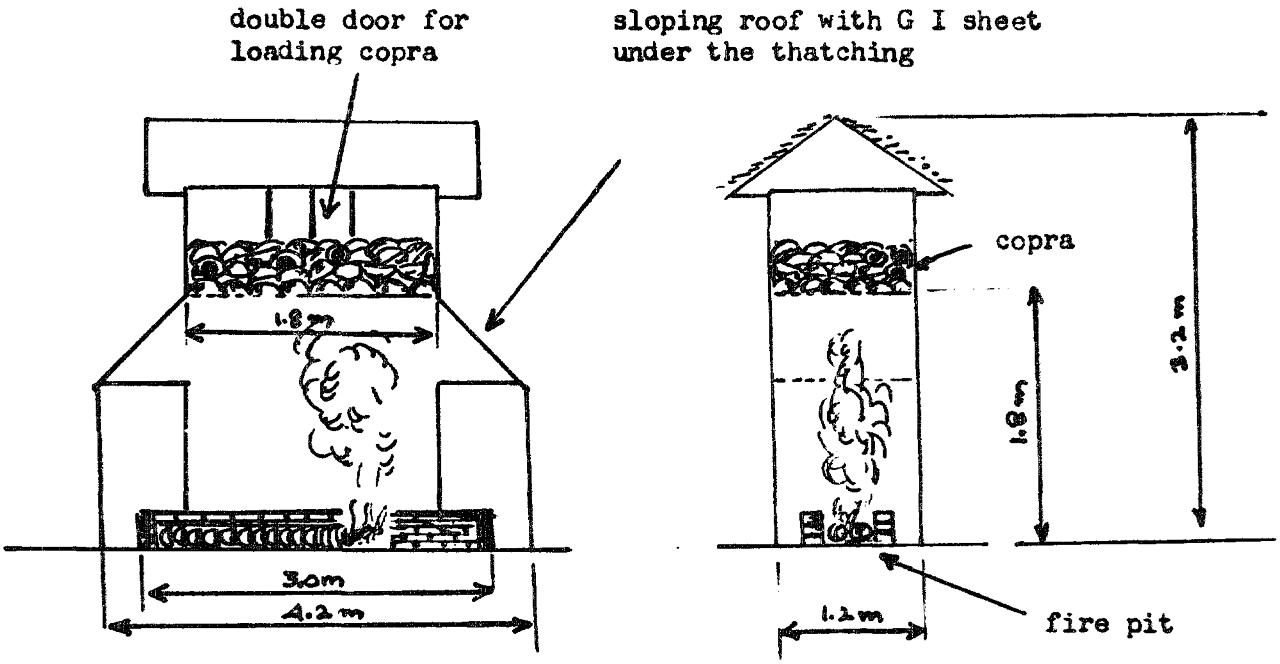
A line of shells 1.5 m long is made up of 40 halves and burns for 3 hours. For the five firings, 200 halves (shells of 100 whole coconuts) are consumed in a total time of about 15 hours. The fuel usage is therefore 100% of the shell supply. A batch can be conveniently processed each day.

The platform area is 1 m^2, height of loading is 0.2 m and the arrangement of kernels is at random throughout the process. On the basis of 100 nuts per batch and only 100 working days per annum, 10,000 nuts (1950 kg copra) could be processed per annum. If the average nut production is 2650 nuts per ha, this represents the output from 4 ha per year. For small holdings it is economical for two holders to own and share one kiln. In such instance, the capacity can be doubled by working for 200 days a year.

4.1.5 Malaysian copra kiln (Cooke type) for 14 ha (30 acre)

This kiln illustrated in figure V is suitable for coconut lands upto 30 acre in extent. It's superior design and operation produces good quality copra in reduced time.

The drying platform 1.8 m x 1.2 m made of evenly spaced "nibong" (nipa) palm slats and cheap wirenetting is located



Front elevation

Sectional end elevation

4.1.5 MALAYSIAN COPRA KILN

COOKE TYPE

FIGURE V

1.8 m above ground level. The simple attap roof (thatched with palm leaves) extends upto a height of 3.2 m. The portion of the kiln below the platform is longer; being 4.2 m so as to accomodate a fire-pit of 3 m length. In this manner, the fire-pit extends by 0.6 m from each end beyond the length of the copra platform. There are two doors on either side facilitating easy replacement of shell at one end when shells are burning at the other end. The upper compartment has a small double door arrangement for loading and unloading the copra. The entire kiln and the doors are covered on the sides with wooden planks (well dried before installation). The wooden planks are fastened upto a height of 0.2 m below the eaves of the roof permitting exit of moisture laden air. The admission of fresh air for combustion is through filtration between the planks at the lower region of the kiln. Large gaps are avoided between the planks as strong gusts of wind would disturb the slow fire, tending to over-heat the copra.

The two sloping roofs of the extended fire pit have galvanized iron sheets as fire protection. These sheets are covered on top with thatching to prevent heat losses. The thatching should not be placed in contact with the galvanized iron sheets as it will crumble due to the heat.

Despite the combustible nature of the construction materials, the fire risk is low. If the timber is suitably treated with preservatives, a kiln life of over 2 years can be anticipated. Most kilns have been found to last several years.

The fire-pit is made of two rows of loose bricks placed with serrations. A single row of clean, dry coconut shells loosely nested, laid over a length of 2.4 m is fired each time. If the kernels have not had a day's pre-drying in the sun, the first firing is with a double row and thereafter single rows are used. To prevent undue smouldering and smoking, ignition of a few shells outside the kiln initially is recommended. Once a line of shells has been ignited, it requires no further attention. A single row of shells 2.4 m long usually comprises of 70 halves, requiring 4 hours for burning. A double row would comprise of 150 halves requiring only 3½ hours for burning due to the higher intensity of heat rapidly igniting the shells next in line.

For kernels that have been predried in the sun for a day, the shell consumption is 560 halves (280 whole shells) per 400 nuts being processed. That is 70%. Without any sun drying, 80% of the shell supply is consumed. If the kiln is used with reduced capacity - say 250 nuts per batch the shell usage goes upto 100%. In this instance the copra quality is improved due to lower height of copra load on the platform (say only 0.1 m). When the load of copra is decreased, the hot gases escape faster through the copra reducing discoloration.

The kiln platform area is 2.1 m^2, height of copra load 0.2 m. The kernels are dried throughout with the shells intact. The copra arrangement is random except for the top layer which is arranged face down. After two firings, the copra is turned for top layers to come down but the rearrangement is at random. A total of 6 firings is carried out to dry the copra adequately. Allowing for intervals between fires and for a full night's rest for the operator, dry copra without previous sun drying can be obtained in a total of 30 hours.

On the basis of 400 nuts per batch, 2 batches per week and 50 working weeks per annum, the annual capacity is 40,000 nuts (7.6 tonne of copra). For a productivity of 2650 nuts per ha per year, the kiln can service 30 acres (14 ha).

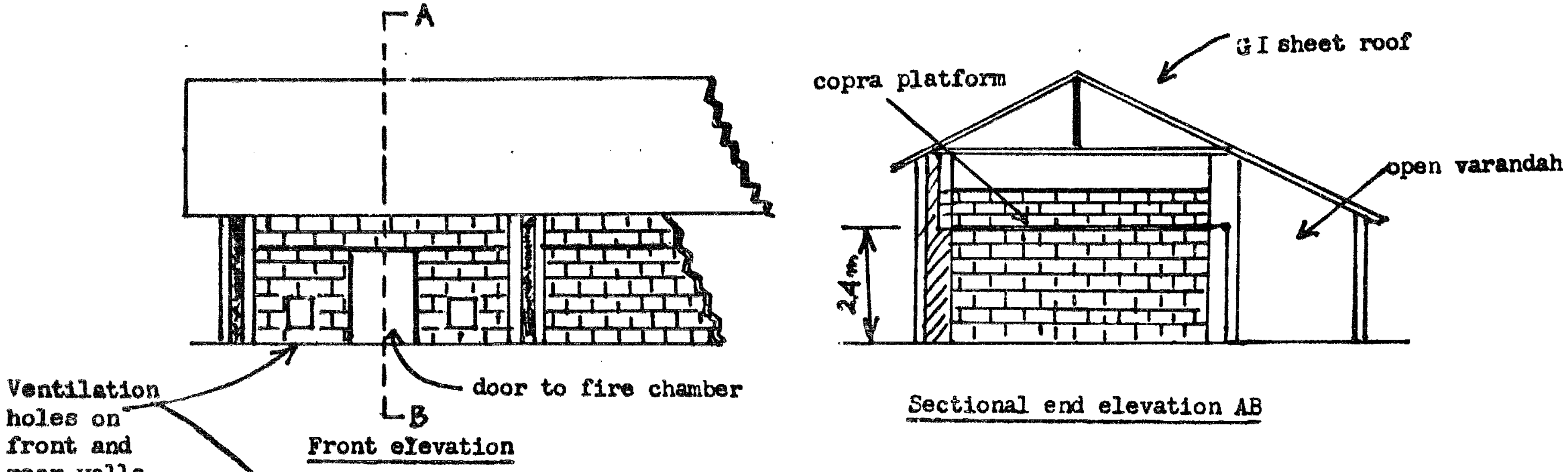
4.1.6 Malaysian version of Sri Lanka copra kiln

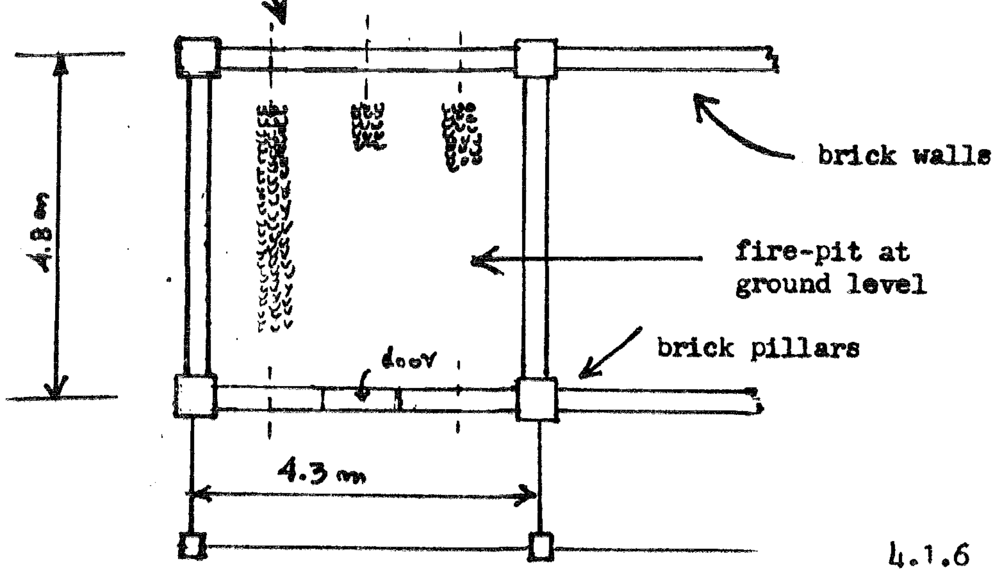
For centralised copra processing and estates in Malaysia, a version of the Sri Lanka copra kiln is utilized. These are also multiple type, the number of units depending upon the total capacity required.

The type of kiln shown in figure VI is installed at the copra processing centre of the Federal Agricultural Marketing Authority. (F.A.M.A.) in Sabak Bernam District, Selangor. A single unit of 4000 nut capacity is 4.8 x 4.3 m in plan with the copra platform 2.4 m above ground level. The kiln is constructed with bricks and cement motar, the walls rising 0.3 m above the platform for holding the copra. The fire-pit is at ground level.

A cemented drying floor is constructed adjascent to the kiln for preparation of the nuts and sundrying if weather permits.

Dry coconut shells from the previous batch are arranged in 3 separate lines, each line consisting of a triple row of nested shells. There are 6 such firings for completing the process. This means 6 firings of 9 rows of shells in 3 days for each unit kiln holding 4000 nuts. The practice in Sri Lanka is; first firing 4 rows and seven more firings of 2 rows per unit kiln (2 fire chambers) over 4 days for 2500 nuts; reflecting a less intensive heat application spread over a longer period.





Plan

4.1.6 MALAYSIAN VERSION OF SRI LANKA KILN

FIGURE VI

The operating procedure is as follows: -

1st day	early morning	split the nuts
	daytime	sun dry
	2 pm to 7 pm	1st firing 3 triple rows of shells
2nd day	previous midnight to 5 am	2nd firing 3 triple rows
	midday	Turn the copra - top layer to bottom and vice versa.
	2 pm to 7 pm	3rd firing - 3 triple rows
3rd day	previous midnight to 5 am	4th firing - 3 triple rows
	2 pm to 7 pm	5th firing - 3 triple rows
4th day	previous midnight to 5 am	6th firing - 3 triple rows
	midday	Unload kiln, deshell, cool for one day and then pack.

The shell consumption varies from 80 to 100% of the coconuts being processed.

Each single unit of the kiln has a platform area of 20.6 m^2, height above the fire-pit being 2.4 m. The kernels are dried throughout with the shells intact. The arrangement of copra on the platform is random and the height of load is about 0.2 m and never allowed to exceed 0.3 m. A total of 6 firings is carried out and a batch takes 3 days.

The present cost of each unit of the kiln is estimated at M$ 2500 (US$ 1140).

On the basis of 4000 nuts per batch per unit kiln, one batch per week and 50 working weeks per year, the annual capacity is 200,000 nuts (38 tonne copra). This unit can cater to 75 ha based on a yield of 2650 coconuts per ha per annum. The investment cost per 100 tonne annual copra capacity is US$ 3000.

4.1.7 Indian version of miniature Malaysian kiln (Verghese & Thomes 1952)

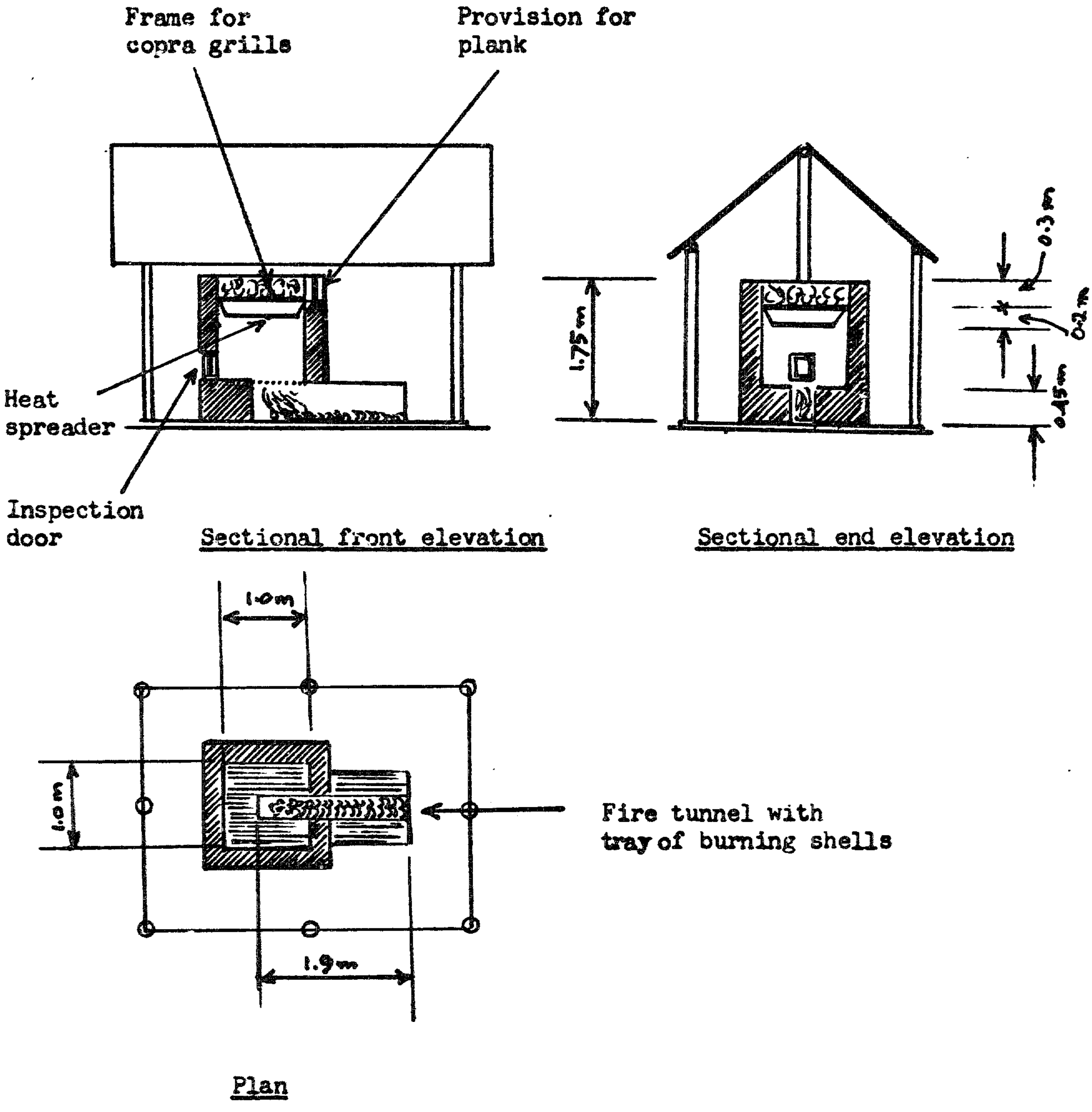
This kiln is constructed on the principle of the miniature kiln of Malaysia where the technique of operation is that of the Sri Lanka kiln.

The kiln illustrated in figure VII has a drying chamber made of suitable earth with internal dimensions of 1.0 m x 1.0 m and 1.75 m height. The walls are 0.23 m (9 inch) wide and the front wall is short by 0.3 m for provision of a wooden plank. The wooden plank is removed for loading and unloading the kiln. An inspection door is provided on the rear wall. The earth used for the chamber is well worked red soil which is the material used commonly for village buildings. This soil is however mixed with adequate amounts of sand so as to prevent cracking due to heat.

The entire chamber is suitably protected from rain by means of a roof thatched with plaited coconut leaves. The roof is supported by a simple bamboo structure and 8 Nos posts.

Four wooden blocks are fixed at the four corners internally in level with the front wall for holding a wooden frame. This is the support for the 4 grills made of woven bamboo slats. Each grill is loaded with 100 coconut halves and placed one over the other, the lower-most resting on the wooden frame. A perforated sheet iron; suspended by iron wire from the wooden blocks and held horizontally 0.5 m below the grill serves as a heat spreader.

The base of the drying chamber is filled upto 0.45 m with the earth mixture, leaving provision for a fire tunnel as shown in the diagram. The tunnel 0.3 m width x 1.9 m length



4.1.7 INDIAN VERSION OF MINIATURE MALAYSIAN KILN

(Verghese and Thomas 1952)

FIGURE VII

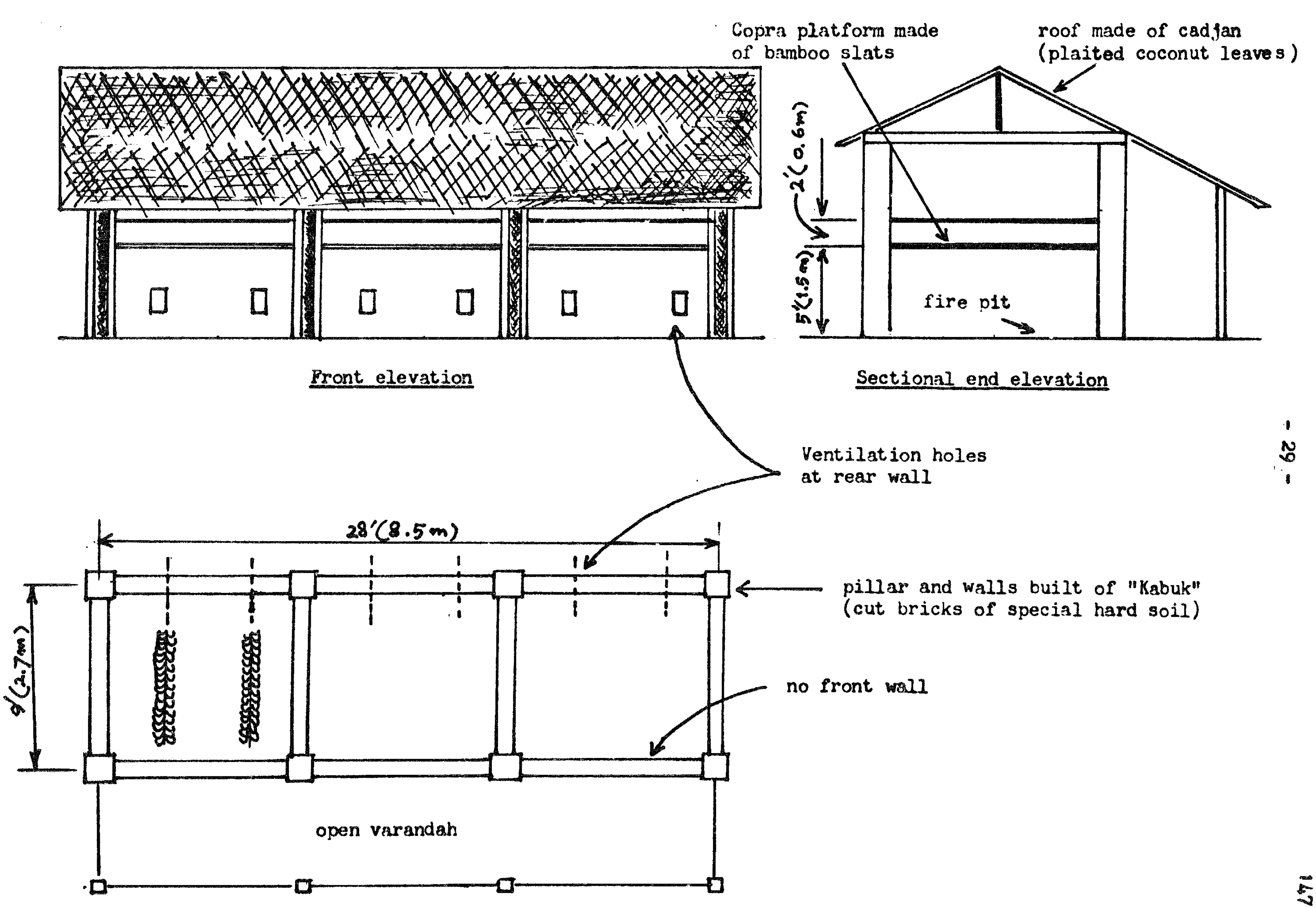
begins 0.38 m from the rear wall and continues 0.9 m beyond the front wall. A sheet iron tray 1.8 m x 0.25 m and 0.1 m deep is loaded with a double row of nested coconut shell halves with the hollow (concave) surface towards the chamber. The end nearest the chamber is ignited and the tray moved into the tunnel. The portion of the fire tunnel which is outside the chamber is covered with a thick sheet iron when the kiln is working. It is to be noted that in India the shells are rather small compared with shells in the nearby countries. Hence the use of a double row of shells will not be excessive. The estimated shell consumption is 100%. However due to regular sun drying the shell consumption is very much less.

The platform of the kiln has an area of 1 m^2 and the capacity is 200 coconuts (30 kg copra) evenly spread on the four grills. The actual batch time is 34 hours which is 2 days for practical purposes. On the basis of 200 nuts batch, 2 batches per week and 50 working weeks per year, the annual capacity will be 20,000 nuts (3 tonne copra). On the basis of an average nut production of 5530 per ha, the kiln can service 4 ha (10 acres) of coconut land.

4.1.8 Indian version of Sri Lanka copra kiln: -

For central copra processing and large holdings, a version of the Sri Lanka copra kiln is utilized. These are also multiple type, the number of units depending upon the total capacity required.

The type of kiln shown in figure VIII is a triple unit installed at Parurthaluk off Cochin in Kerala State. The capacity is 10,000 nuts per batch. The copra platform made



4.1.8 INDIAN VERSION OF SRI LANKA COPRA KILN
(TRIPLE UNIT)

FIGURE VIII

of arecanut palm slats is 28 ft x 9 ft. The height of the platform is 5 ft above ground level. The fire-pit is at ground level. The kiln is constructed out of Kabuk blocks which are blocks cut out of a special variety of hard soil commonly found in India (and Sri Lanka). There are small ventilation holes on the rear wall. The rear and two side walls are constructed 2 ft above the level of the copra platform. There is no front wall. The kiln has an open varandah. The roof is of cadjan (plaited coconut leaves) and the roof structure out of timber. The cadjan roof needs replacement every year and the arecanut palm slat platform every two years.

A cemented drying floor is constructed in front of the kiln for purposes of preparing the nuts and sun-drying. A large nylon net supported by bamboo stilts at a height of about 7 feet offers protection from birds, particularly crows who attack the kernels. Sun drying is carried out every morning with kiln drying in the night.

The following materials and prices are estimated for the construction of the kiln: -

<u>Item</u>	<u>Estimated Cost</u> (Indian Rs)
Kabuk - 4000 blocks	2000/=
Timber for roof structure	2000/=
Lime and sand	400/=
Cadjans for roof	100/=
Arecanut palm stems for platform	500/=
Labour	1000/=
Total	Rs 6000/=
	(US$ 750/-)

It is interesting to note that transport of coconut for the processing centre is by country boat using narrow water-ways. In this particular location, the water-ways run dry during low tide. So, transport is during high tide. The boats commonly used are 40 ft (12 m) long and maximum width 5 ft (1.5 m) and these cost about Rs 5000/= (US$ 625). Two men riding the boat, move it by pushing with bamboo poles.

Dry coconut shells from the previous batch are arranged in triple rows for the first night. This triple row arrangement is special in that two rows are first nested and placed adjascent to each other and the third row comprising of the smallest shells; is nested and placed on top of these two rows. There are two triple rows for each kiln unit for the first firing and thereafter two double rows.

The operating procedure is as follows.

1st day	early morning	split the nuts
	daytime	sun dry
	4 pm to 10 pm	1st firing with two triple rows
2nd day	morning	remove shells
	daytime	sun dry
	4 pm to 10 pm	2nd firing with two double rows
3rd day	daytime	sun dry
	4 pm to 10 pm	3rd firing with two double rows
4th day	daytime	sun dry
	evening	packing

The technique of alternatively sun drying during the day and kiln drying by night in this manner is unique. This however is labour intensive and will be suitable only where labour is very cheap. Such a system of alternatively sun drying will also require special types of climate where there is plenty of sun combined with dry air. There is a large saving of fuel. Coconut shell consumption is only 15% during the summer where plenty of sundrying is possible. During the rainy season, the consumption is 50%.

The area of the platform is 252 sq ft (23.4 m^2). The height above fire-pit is 5 ft (1.5m). The height of copra load is about 1 ft (0.3 m). Removal of shell is done only after one full day's sun drying and the first firing. The arrangement of kernels is face upwards for the first firing only.

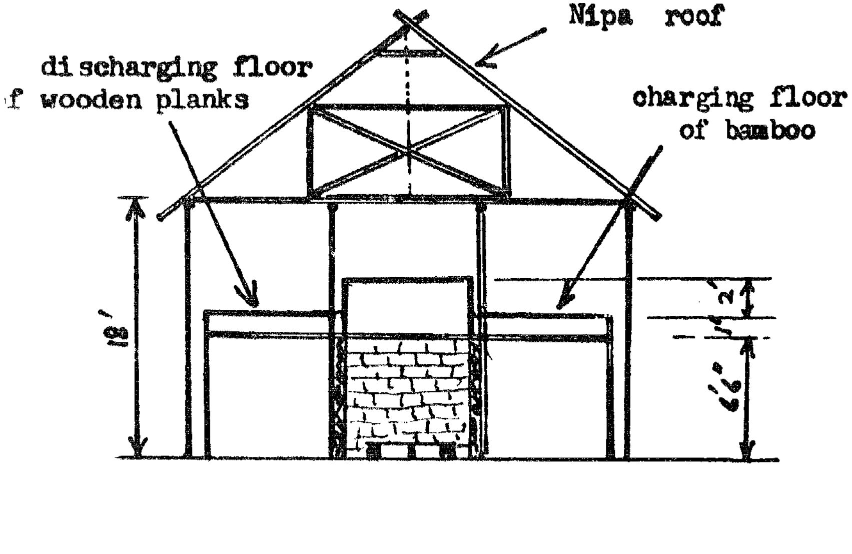
The capacity per batch for the triple unit is 10,000 nuts (1500 kg of copra) lasting 4 days. The cost of the kiln is Indian Rs 6000/= (US$ 750).

On the basis of 10,000 nuts per batch each week, 50 working weeks per year, the annual capacity is 500,000 nuts (75 tonne of copra). For an average yield of 5530 nuts per ha per year, this kiln can service the nut production from 90 ha. The investment cost per 100 tonne annual copra capacity is US$ 1000.

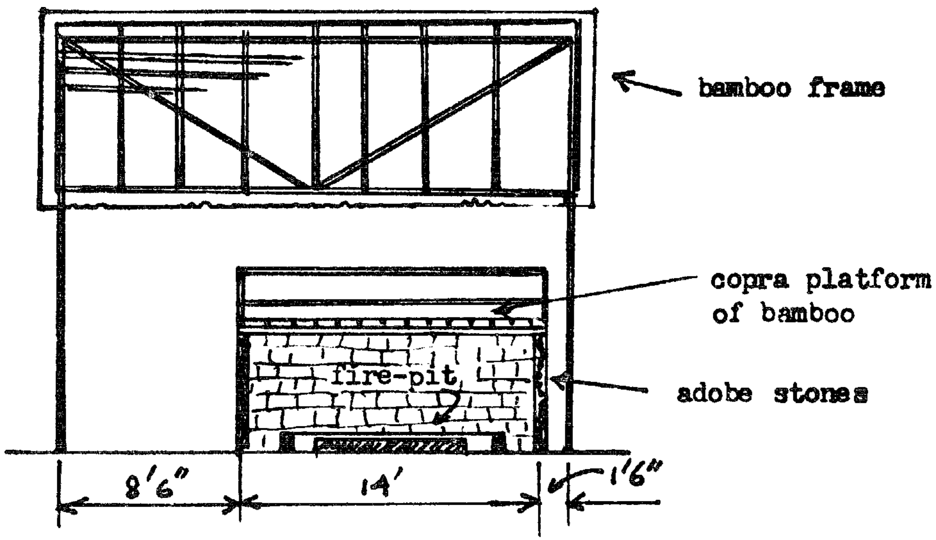
4.1.9 Improved Tayabas Dryer (Tapat) of the Philippines

This is an improved version of the traditional copra dryer found in Tayabas area of Luzon Province of Northern Philippines. The traditional dryer is presented in section 4.1.5 of the technology sheet "COPRA MANUFACTURE BY DIRECT HEAT SMOKE DRYERS USING TRADITIONAL FUEL OTHER THAN COCONUT SHELLS (Method B)".

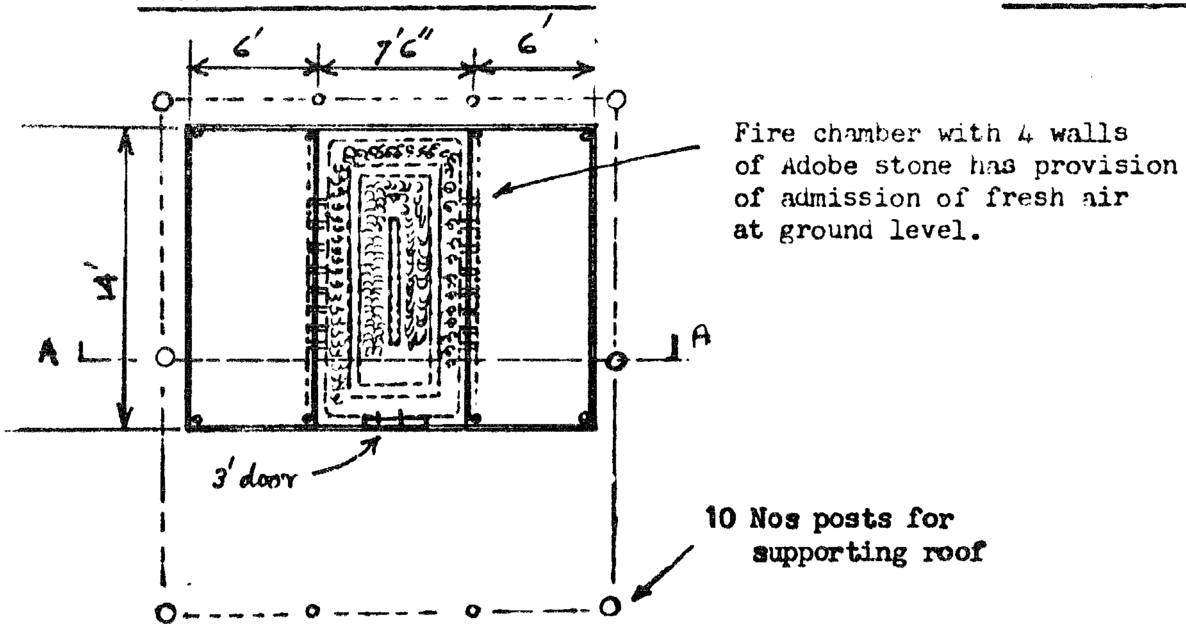
The use of husk as fuel for drying copra has been practiced from the early days in the Philippines. In 1956,



Sectional front elevation A-A



Half sectional end elevation



Plan

4.1.9 IMPROVED TAYABAS DRYER (TAPAT)
OF PHILIPPINES

FIGURE IX

the Philippine Coconut Administration (now known as Philippine Coconut Authority) developed copra dryers by modification of the traditional ones and adapting them to use coconut shells in nested rows. The improved Tayabas dryer shown in figure IX is one such development. It is the "Tapat" type meaning that the heated grill is directly above the fire, in the local language. The improvements compared to the traditional one are mainly: -

(i) use of shell instead of husk,
(ii) fire-pit at ground level instead of underground.
(iii) copra grill and working floors elevated instead of at ground level.
(iv) refinements to construction materials used.

As in the case of the traditional dryer, the improved dryer is suitable for low lying, sandy areas since the high water table will not create problems.

The bill of materials for the kiln of 2000 nuts capacity is given hereunder: -

Item	Specification	Quantity (pcs)
Wooden posts	3" x 3" x 19 ft	6
Wooden beams	2" x 6" x 16 ft	4
Wooden joists	2" x 3" x 14 ft	18
Wooden joists	2" x 3" x 18 ft	18
Studs	2" x 2" x 16 ft	8
Studs	2" x 2" x 14 ft	4
Studs	2" x 2" x 8 ft	4
Door clamp head	2" x 4" x 6 ft	3
Flooring planks	1" x 6" x 6 ft	14
Bricks	2" x 4" x 8"	630
Nipa shingles		1300
Bamboos	4" ø	110

Rattan for tying shingles	$\frac{1}{8}$" ø x 12 ft long	700
Rattan for tying trusses	$\frac{1}{4}$" ø x 12 ft long	300
Adobe stones		320
Cement	bags	4
Sand	cubic yards	2
Machine bolts	$\frac{5}{8}$" ø x 6"	12
Cut washers	for $\frac{5}{8}$" ø bolts	12
Nails	3"	5 kg
Nails	1½"	10 kg

The operating procedure is as follows: -

Load the dehusked nuts on to the charging platform and split to drain the water out. Arrange the kernels with shell intact on the platform. The lowest layer must have face upwards, thereafter load at random and finally the top layer with face downwards. Arrange two double rows of strung coconut shells from the previous batch in the fire-pit and ignite one end of each double row. Note that since the shell usage is 50%, those half shells with the "eyes" are pierced and a string passed through them to form a row. After seven hours of heating with the first firing, new coconut shells shall be arranged in two single rows. The batch will take 2 days practically. The degree of dryness of the copra may be determined by a whitish line which develops along the cross section of the meat as it is dried. Unload the copra onto the discharging platform and eject the kernel from the shell with a scoop. The copra is inspected and underdried ones returned to the next batch but arranged on the top layer. The copra that is adequately dry is chopped and stored preferably unbagged.

The copra platform is 105 sq ft (9.8 m^2) and at a height of 6 ft 6 in (2 m) above the fire-pit. The height of copra load is about 8" (0.2 m).

The present cost of the kiln is about ₱ 5000 (US$ 671). Batch capacity is 2000 nuts or 444 kg copra.

On the basis of 2000 nuts per batch of 2 days, 2 batches per week and 50 working weeks per year, the annual capacity will be 200,000 nuts or 44.4 tonne copra. For an average nut production of 2650 per ha per year, the kiln can cater to the nut production from 75 ha. The investment cost per 100 tonne annual dry copra capacity is US$ 1500.

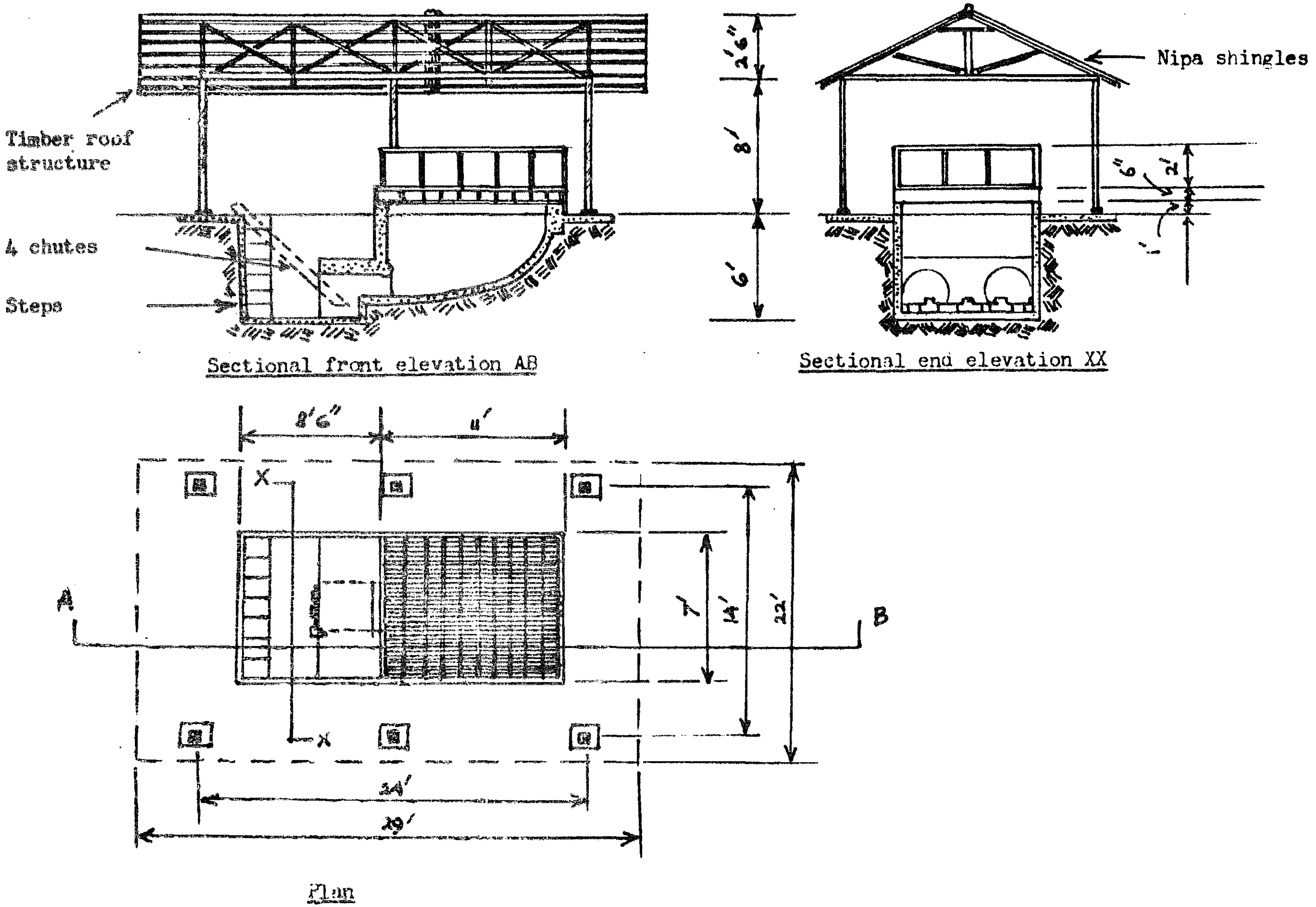
4.1.10 De Vapor improved dryer of the Philippines.

As in the case of the improved Tayabas dryer (4.1.9), this kiln is another improvement developed by the Philippine Coconut Administration in 1956 with a view to utilizing coconut shells instead of the traditional husks.

The design of this kiln illustrated in figure X is actually a further improvement as given in "Coconut Processing" by R.G. Emata (U.C.A.P, 1971). It is basically like the Sariaya type traditional dryer (see section 4.1.3 of technology sheet "COPRA MANUFACTURE BY DIRECT HEAT SMOKE DRYERS USING TRADITIONAL FUEL OTHER THAN COCONUT SHELL (Method B)". The location of such kilns must be on flat ground without flooding, such as in the Sariaya area of Luzon Province of the Northern Philippines.

The illustration gives a single unit kiln but these can be constructed in a battery of several single units or several twin units.

There is a wide choice of materials available for construction. The bill of materials given hereunder is for the simplest type using hollow cement blocks and Nipa shingles: -



4.1.10 DE VAPOR IMPROVED DRYER OF PHILIPPINES

FIGURE X

De Vapor improved dryer (2000 nuts)

Bill of materials

(using cement hollow blocks and Nipa shingles)

Item	Specification	Quantity for dryer	Quantity for shed
Cement	94 ##	17 bags	5 bags
Sand		1.5 cu.m.	1 cu.m.
Gravel		1.5 cu.m.	2 cu.m.
C.H. Blocks	6" x 8" x 16"	267 pcs	
Common wire nails	1½"	1 kg	1 kg
C.W. nails	2"	1 kg	
C.W. "	3"	1 kg	1 kg
C.W. "	4"	1 kg	4 kg
W.I. post straps	$\frac{1}{4}$" x 1$\frac{1}{4}$" x 22"		12 kg
Machine bolts	½" ø x 8"		8 pcs.
" "	½" ø x 6"		12 pcs.
Plain G.I sheets	GA ## 26 - 36" x 8'		4 pcs.
Steel bars	3/8" ø x 20'	18 pcs.	
G.I. wire	## 16	1 kg	
G.I. grates	6½" x 11½"	4 pcs.	
Posts (yacal)	5" x 5" x 8'		6 pcs.
Apitong (class 2 timber):-			
Girts	2" x 5" x 12'		8 pcs.
Bottom chords	2" x 4" x 16'		10 pcs.
Top chords	2" x 4" x 12'		10 pcs.
Web members	2" x 3" x 10'		2 pcs.
" "	2" x 3" x 12'		6 pcs.
Purlins	2" x 3" x 12'		20 pcs.
"	2" x 3" x 8'		10 pcs.
Collar plates	2" x 4" x 12'		4 pcs.
Cleats	2" x 2" x 12'		4 pcs.
Facia board	1" x 10" x 12'		4 pcs.
" "	1" x 10" x 10'		4 pcs.
" "	1" x 10" x 8'		2 pcs.
Cross bracings	2" x 3" x 12'		6 pcs.
Sidings	1" x 10" x 10'	4 pcs.	
"	1" x 10" x 12'	2 pcs.	
Top & bot. plates	2" x 4" x 12'	6 pcs.	
Floor joist	2" x 4" x 14'	6 pcs.	
Form lumbers	1" x 6" x 12'	20 pcs.	
" "	2" x 2" x 12'	11 pcs.	
Bamboo	4" ø	5 pcs.	5 pcs.
Nipa shingles	42" long		500 pcs.
Rattan strips	long size		1 bundle

The operating procedure is as follows: -

Split the nuts, drain the water and arrange on copra platform with face upwards for bottom layer. Thereafter arrange at random and finally, the top layer should have face downwards. Firing should commence within 4 hours of opening the nuts to avoid spoilage. Arrange the coconut shells in the 4 chutes with concave side downwards and start fire at the bottom. After the first 8 hours of continuous firing, allow to cool and scoop the kernel out of the shell. Rearrangement of kernels will be at random. Now, fire only one chute for each of the two tunnels. The total effective heating time is 16 hours, the full batch taking practically 2 days. The degree of dryness of the meat can be determined by a whitish line which develops along the cross-section of the meat as it is dried. Discharge the copra and store preferably unbagged.

It is important to clean the floor area below the platform regularly as fibre and dry copra pieces will accumulate. This presents a fire hazard.

The copra platform is 77 sq ft (7.1 m^2) and at a height of 6 ft (1.8 m) above the fire place. The height of copra load is 1 ft (0.3 m).

The present cost of the kiln is about ₱ 7000 (US$ 940). Batch capacity is 2000 nuts or 444 kg copra.

On the basis of 2000 nuts per batch of 2 days, 2 batches per week and 50 working weeks per year, the annual capacity is 200,000 nuts or 44.4 tonne copra. For a nut productivity of 2650 per year per ha, the kiln can service 75 ha.

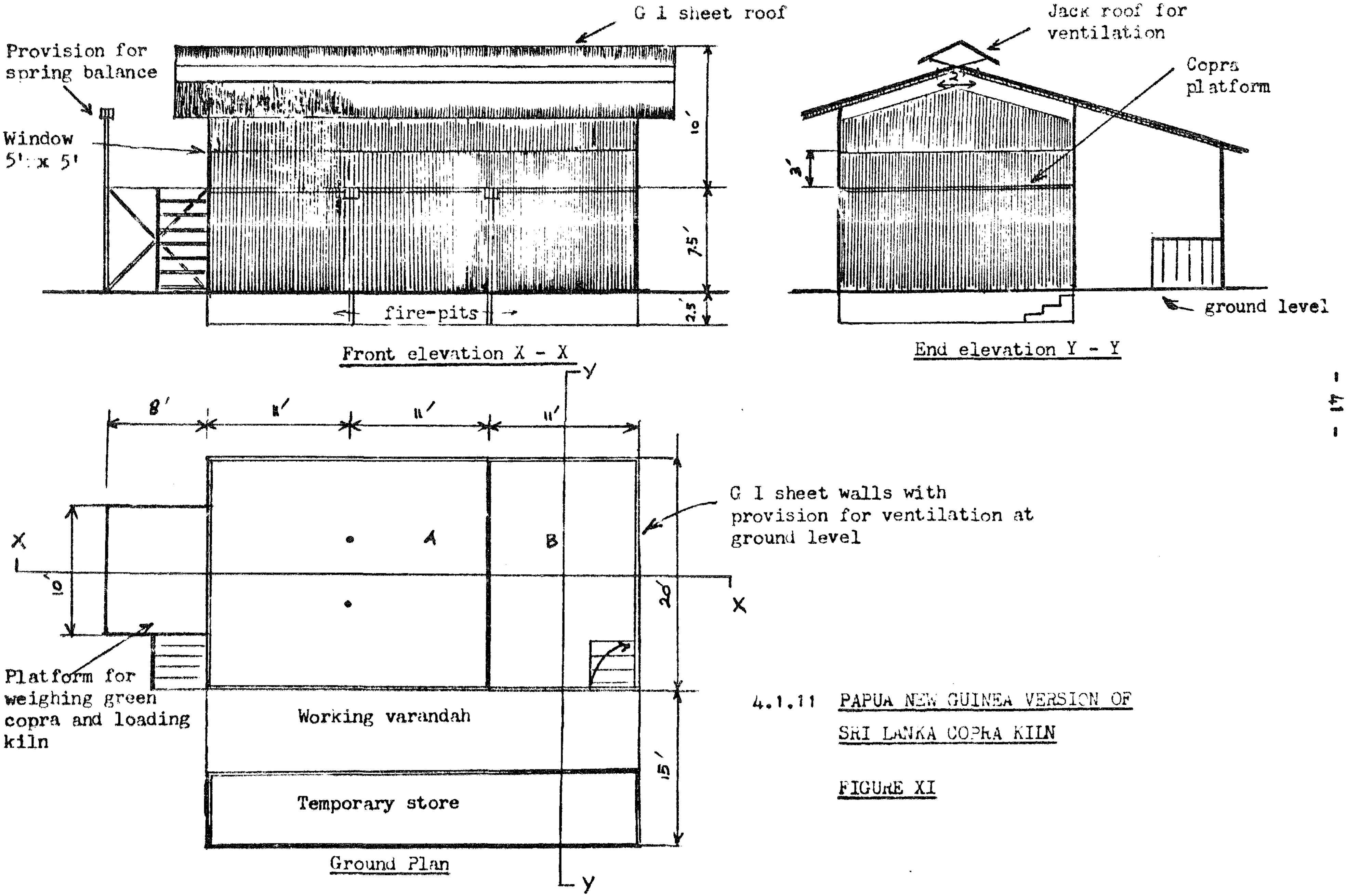
4.1.11 Papua New Guinea version of Sri Lanka Kiln: -

These kilns have been introduced to PNG in the 1960s by the private sector owned large plantations. These kilns are located on a decentralized basis. Each subdivision of about 100 hactare (220 acres) in the plantation is served by one of these kilns. The resulting copra is graded under the category of "hot air dried" copra.

A similar but multiple unit kiln has been recently introduced for centralised copra processing in the private sector large plantations of Solomon Islands.

The kiln illustrated in figure XI comprises of two copra platforms of differing sizes with a fire chamber beneath each platform. The larger bed 'A' is 22 ft x 20 ft and the smaller one 'B' 11 ft x 20 ft positioned adjascent to each other. The firepit is 2½ ft below ground level and the copra platform 7½ ft above ground level. The copra platform has horizontal wooden beams and a welded wire mesh with 3 inch x 1½ inch holes. Wooden boards 1 inch thick are placed round the platform upto 3 ft height to hold the copra. The copra platform has central supports of 3 inch diameter galvanized iron pipe as shown in the figure.

The main structure has 6 inch x 2 inch vertical timber posts which support the copra platform and the roof. The side walls and roof are of corrugated galvanized iron sheets. Whilst new sheets are used for the roof, the side walls can manage with second hand sheets. The obvious choice of brick and cement mortar for side walls is not being used due to the absence of mud fired bricks in PNG. The use of hollow cement blocks is contemplated for new kilns. At the bottom



4.1.11 PAPUA NEW GUINEA VERSION OF SRI LANKA COPRA KILN

FIGURE XI

of the side walls, provision is made for admission of fresh air for combustion of the fuel. In the case of some kilns, the provision for this appeared to be inadequate. The side walls are constructed upto roof level. Ventilation or exhaust of moisture laden air is only through the jack roof provided at the top.

A working varandah and a temporary store is provided adjascent to the kiln. An outside platform elevated to the level of the copra platform serves to receive and weigh green copra, and then loading the kiln. The kiln has a 5 ft x 5 ft window adjascent to this open platform to enable load the copra bed.

The cost of each kiln unit is about K. 3000 - 1980 prices. This is US$ 4,200. (1 K = 1.4 US$).

A group of men who are assigned for harvesting coconuts, gather the naturally fallen nuts, husk and split the nuts in two and pack into jute bags. The half kernels are packed with the shell intact and the kernels facing down to facilitate complete draining of the nut water. Open trucks or open trailors with tractors haul these bags from the plantation to the kiln area. The bags are weighed and each worker's effort is recorded against the number indicated in the bag. A bag weighs upto 170 lb. and a minimum of 5 bags is expected from each worker. The splitting of nuts commences around 8 or 9 in the morning and by 12 noon; all the kernels are transported, and made ready for firing in the kilns.

The fresh kernels with the shell intact are loaded on to the larger platform 'A' upto a height not exceeding 15 inches (0.4 m). This platform under ideal conditions can hold 72 bags, which at an average weight of 75 kg (165 lb) will be 5400 kg. Since the weight of fresh kernel is about twice that of the shells, this represents 3600 kg of fresh kernel (at 50% moisture). When dried down to 6% moisture, this would be reduced to about 2000 kg. Since the conversion factor for Papua New Guinea is 4750 nuts per tonne, each kiln unit can process 9500 nuts every two days. If it is necessary to process 9500 nuts (72 bags) daily, a twin kiln unit or two single kilns have to be installed.

The kiln is fired using dry coconut shells obtained from the previous batch of copra. The shells are nested and arranged in double rows. Alternative double rows are arranged with the hollow (concave) surface facing the same direction. This means that when the rows are ignited two consecutive rows would have the fire moving in opposite directions thus giving out well distributed heat to the copra. The writer observed that the temperature inside the fire chamber to be hotter (60° C) than the kilns operated in Sri Lanka. Furthermore, there have been cases where kilns have caught fire.

The operation of the kiln is as follows: -

1st day

morning	Load kernels with shell intact onto platform A and arrange nested coconut shells in the fire pit.
12 noon to 8 p.m.	1st firing - 7 double rows of shells
9 pm to 5 a.m.	2nd firing - 7 double rows of shells

2nd day

8 am to 4 p.m.	3rd firing - 7 double rows of shells

4 pm to 6 pm	Allow to cool
6 pm to 8 pm	Transfer all copra to platform 'B' (which also ensures rotation of the copra)
9 pm to 6 am	4th firing - 4 double rows of shells.

3rd day

8 am to 4 pm	5th firing - 4 double rows of shells.
4 pm to 8 pm	Allow to cool
8 pm	Unload copra,(Fresh kernels for next batch loaded commencing morning as per 1st day).

4th day

8 am	Deshell kernels. Pack copra into bags. Store shells for use as fuel.

The total area of the platforms A and B is 660 sq. ft. (61.3 m^2) but the area A where fresh kernels are loaded is 440 sq. ft. (40.9 m^2). The density of nuts (when wet) on platform A is 232 per m^2.

The capacity of the kiln is 9500 nuts (5400 kg green copra with shell intact or 2000 kg dry copra) every 2 days. The total manufacturing time is however 3 days. When loading the kiln with green copra, the arrangement is at random. The height of the loading is not allowed to exceed 15 inches (0.4 m). The shell consumption is 100% of the nuts being processed.

The present cost of the kiln is K 3000 (US$ 4,200).

On the basis of 9500 nuts per batch of 2 days, 2 batches per week and 50 working weeks per year, the annual capacity is 950,000 nuts or 540 tonne green copra with shell intact (as weighed at receiving) or 200 tonne dry copra. The investment costs on the basis of 100 tonne dry copra per year will be US$ 2100.

Taking a yield of 3050 nuts per hactare per year; this kiln can service 311 ha or 685 acres. In actual practice however, each subdivision (about 100 ha) of the plantation has such a kiln installed.

4.2 Materials for construction: -

Traditional materials such as locally available timber, bamboo in various forms, roof thatching of Nipa and Coconut palm leaves, rattan, bricks, stones etc are used for these kilns. Sometimes arecanut palm stems and coconut trunks are used. Thus, the costs are kept quite low. Use of galvanized iron sheets for the roof, cement works and such other material tend to increase costs. Bills of quantities where available have been given in the respective sections.

4.3 Summary of design features of the direct heat smokeless dryers:-

Type of dryer	Batch capacity (nuts)	Platform area (m^2)	Density of nuts per m^2	Height of platform above fire-pit (m)	Height of copra load (m)	Approx fuel usage without sundrying
Standard Sri Lanka Copra kiln (Triple unit)	10,000	32.7	230	2.1	0.3	67% shells (50% with 1 day sun drying)
Improved Sri Lanka Copra kiln (Triple unit)	10,000	38.8	200	2.1	0.3	67% shells (50% with 1 day sun drying)
Small holders kiln Cooke type (Sri Lanka)	1,500	4.5	330	2.1	0.3	67% shells
Miniature Malaysian kiln Cooke type	100	1.0	100	1.5	0.2	100% shells
Malaysian Copra kiln Cooke type	400	2.1	200	1.8	0.2	80% shells
Malaysian version of Sri Lanka kiln (Single unit)	4,000	20.6	200	2.4	0.2	80 to 100% shells
Indian version of miniature Malaysian kiln Cooke type	200	1.0	200	1.5	0.3 (with slats)	100% shells (estimated)
Indian version of Sri Lanka copra kiln (Triple unit)	10,000	23.4	430	1.5	0.3	50% shells (15% with sundrying alternatively)
Improved Tayabas dryer (Philippines)	2,000	9.8	200	2.0	0.2	50% shells
De Vapor improved dryer (Philippines)	2,000	7.1	280	1.8	0.3	50% shells
Papua New Guinea version of Sri Lanka copra kiln	9,500	61.3	230 (wet kernels)	3.0	0.4	100% shells

4.4 Summary of operational features:-

Type of dryer	Pre-drying in the sun	Arrangement of nuts when loading platform	Removal of shells	Rotation of copra (turning)	Number of firings
Standard Sri Lanka Copra kiln (Triple unit)	regularly one day	initially lowest layer face upwards	After 4 firings	After 2 firings	8
Improved Sri Lanka Copra kiln (Triple unit)	regularly one day	Initially lowest layer face upwards	After 4 firings	After 2 firings	8
Small holders kiln Cooke type (Sri Lanka)	regularly one day	Initially lowest layer face upwards	After 2 firings	After 2 firings	8
Miniature Malaysian kiln Cooke type	Usually one day	Random	After complete drying	no rotation	5
Malaysian Copra kiln Cooke type	Usually one day	Random except top layer face downwards	After complete drying	After 2 firings	6
Malaysian version of Sri Lanka kiln (Single unit)	Usually one day	Random	After complete drying	After 2 firings	6
Indian version of Miniature Malaysian kiln Cooke type	Regularly one day or more	N.A.	N.A.	N.A.	N.A.
Indian version of Sri Lanka Copra kiln (Triple unit)	Regularly each day alternatively	Face upwards lowest layer first firing only	After 1 day sun drying&1 firing	Before each firing due loading unloading each day	3 firings combined with sun drying
Improved Tayabas dryer (Philippines)	No	Lowest layer upwards top layer downwards	After complete drying	no rotation	(24 hours)
De Vapor Improved dryer (Philippines)	No	Lowest layer upwards top layer downwards	After 8 hr initial firing	After 8 hr initial firing	(16 hours)
Papua New Guinea version of Sri Lanka copra kiln	No	Random	After complete drying	After 3 firings	5

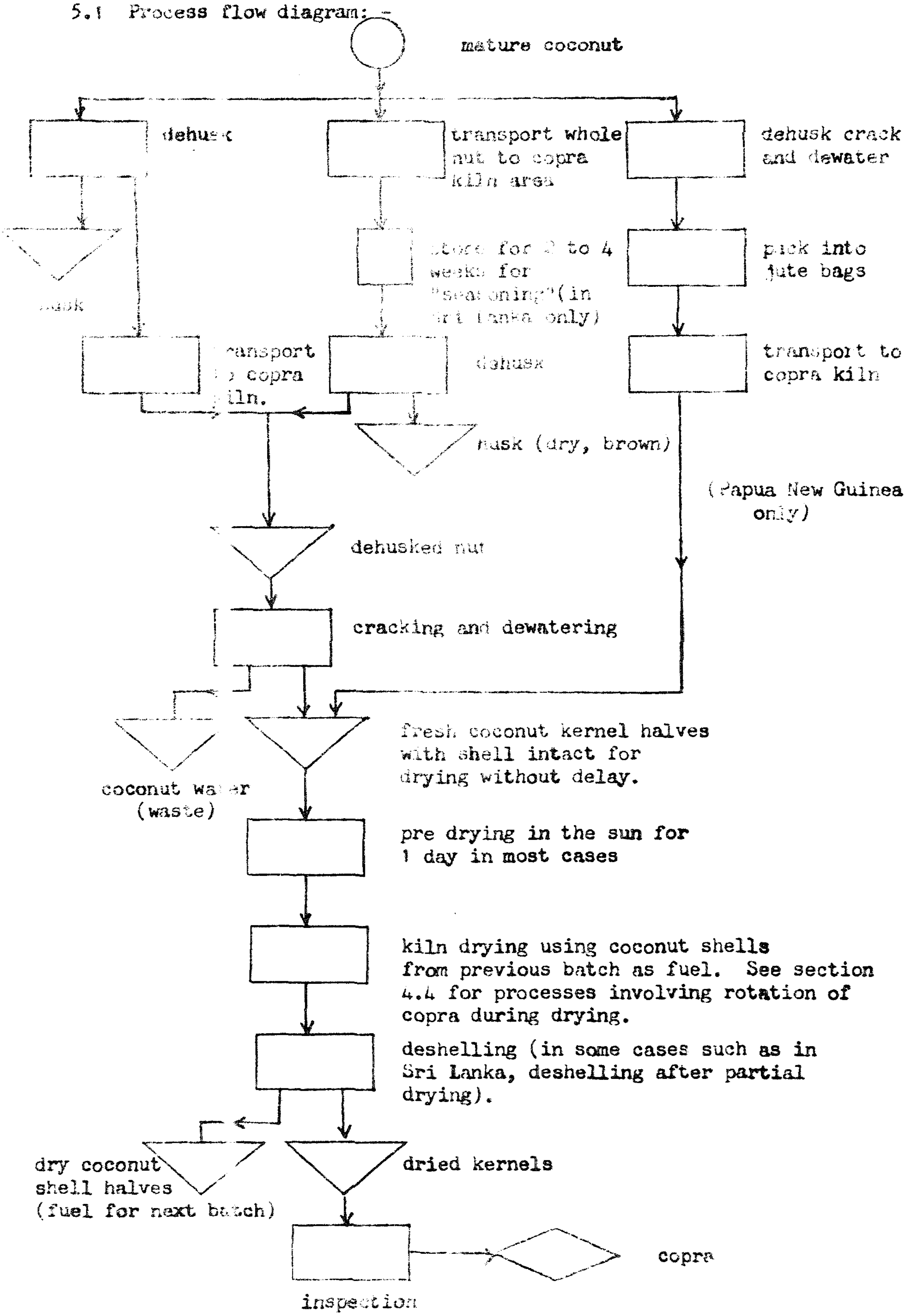
4.5 Cost and Capacity of direct heat smokeless dryers:-

Type of dryer	Capacity equivalent in land area (ha)	Batch Capacity (nuts)	Batch Capacity dry copra (kg)	Batch time (days)	Cost (US$)	Investment cost per 100 tonne annual copra capacity (US$)
Standard Sri Lanka Copra kiln (Triple unit)	100	10,000	2000	4	1920 (includes barbecue)	1920
Improved Sri Lanka Copra kiln (Triple unit)	100	10,000	2000	4	2600 (includes barbecue)	2600
Small holders kiln Cooke type (Sri Lanka)	30	1,500	300	2.5	N.A.	N.A.
Miniature Malaysian kiln Cooke type	4	100	19	1	N.A.	N.A.
Malaysian Copra kiln Cooke type	14	400	76	2	N.A.	N.A.
Malaysian version of Sri Lanka kiln (Single unit)	75	4,000	760	3	1140	3000
Indian version of miniature Malaysian kiln Cooke type	4	200	30	2	N.A.	N.A.
Indian version of Sri Lanka Copra kiln (Triple unit)	90	10,000	1500	4	750	1000
Improved Tayabas dryer (Philippines)	75	2,000	444	2	671	1500
De Vapor Improved dryer (Philippines)	75	2,000	444	2	940	2100
Papua New Guinea version of Sri Lanka copra kiln	311 (100 actual)	9,500	2000	3	4200	2100

* N.A. Information not available

5. Process: -

5.1 Process flow diagram: -



5.2 Description of process: -

The use of coconut shells as fuel for direct fired kilns is practical by small holders as well as centralised copra processors including coconut estates.

Coconuts harvested for copra manufacture have different levels of maturity depending upon the customs prevailant in various coconut regions. In many regions nuts are harvested before full maturity and used for copra making. This is a major cause for production of poor quality copra. Germinated nuts also result in poor copra.

In Sri Lanka coconuts are harvested at full maturity and furthermore, those nuts which have not commenced drying are stored with the husk for 2 to 4 weeks for "seasoning". See technology sheet "CROP STORAGE OR SEASONING OF MATURE WHOLE NUTS AFTER HARVESTING". This is a major factor resulting in the production of good quality copra.

In other countries the coconuts are dehusked in the farm and the nuts transported to the kiln.

The dehusked nuts are cracked or split in half and the water allowed to run out. Whereever a cemented platform is available, this pretreatment can be carried out without contaminating the coconut kernels. In most cases, the coconuts are sun dried for a whole day provided that the weather permits. However, sun drying is useful only if the air has low relative humidity (dry air).

The kernels with the shell intact are loaded onto the copra platform. Depending upon the practices prevailant in different regions, the kernels may be arranged methodically. In some cases the bottom layer is placed with kernel facing upwards.

and in some the upper layer facing downwards. Section 4.4 gives details of arrangements of kernels for different processes in this technology sheet.

The kiln is fired using coconut shells from the previous batch. These shell halves are quite dry as they have been subjected to drying along with the kernels in the dryer. The smoke is quite clean due to the nature of the coconut shell which is comparable to dry hardwood. The existence of a flame through-out the firing ensures complete combustion which is a major cause in giving out a clean smoke, thus avoiding discoloration of the kernel. The nesting of half shells and ignition as described in section 4.1 ensures regular and controlled heat for drying the kernels to give good quality copra.

In some cases, the copra is rotated so that the bottom layers and the top layers interchange giving rise to uniformly dried copra.

It is the practice in Sri Lanka to eject the kernel from the shell after partial drying and then subject the meat only for further drying. However, there are cases presented in this technology sheet where the ejection of the kernel from the shell is only after complete drying.

The dried meat is inspected after cooling. Those not quite dry are dried further by placing on the top layer with a new batch. The operator knows through experience whether the copra is adequately dry. The best guide is the crispness and the nature of the section when a copra cup is broken for testing.

The dried copra is usually stored in bulk for sometime to ensure thorough cooling. Grading and sorting of copra is carried out in some countries before bagging.

5.3 Product flow diagram: -

The copra, if properly dried using coconut shells as described in this technology sheet; should have a moisture content of around 6%. On the basis of a moisture content of 50% in the fresh kernel, the product flow diagram will be: -

1880 kg wet kernel (50% moisture)

↓

1000 kg dry copra (6% moisture)

The out-turn of copra for different member countries on the basis of the national conversion rates is given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

6. Quality of finished product: -

Various copra grading practices exist in different coconut regions.

The Asian and Pacific Coconut Community has prepared "Uniform Standards Specification for Copra" (Final draft April 1978). There are two grades specified irrespective of the process used for making copra. The characteristics specified for the two grades are given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

As discussed in section 5.2, the use of coconut shell as fuel though direct fired, results in copra of good quality and is far superior to that produced using direct fired smoke kilns using husks etc. The copra is nearly as good as that produced using indirect dryers.

7. <u>Source of information</u>: -

7.1 Review and techno-economic evaluation of various copra production methods applied in the APCC region by M. Varnakulasingam and J. Camacho (UNIDO/APCC 1978).

7.2 Copra processing in rural industries by F.C. Cooke (FAO 1958) formerly Director Coconut Research Institute of Ceylon and Department of Agriculture of Malaya.

7.3 Personal observations during field visits to member countries of the Coconut Community.

7.4 Statistical Year book on Coconuts: - APCC 1979. The average nut production per ha per year to determine the capacities of kilns on hectarage basis was calculated on a ten year average (1969 to 1978) of nut production and area planted as per tables 5 and 6 in the yearbook.

Product code: CCCN 12.01 b
Technology sheet no: - I / 26

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for :- COPRA MANUFACTURE BY INDIRECT HEAT DRYERS WITH NATURAL DRAFT HOT AIR (Method D 1)

This method gives good quality copra.

2. Benefits of technology:-

Indirect heat dryers produce high quality white copra by heating the coconut meat indirectly. The products of combustion donot come into contact with the coconut meat. Instead, the hot combusted gases heat clean air through a heat exchanger without mixing with the air. The hot air comes into contact with the coconut meat drying it. Indirect heat dryers are also called "hot air" dryers.

Indirect heat dryers can be of two types - those using natural draft for circulation of the hot air and those using a forced draft for the hot air. For indirect dryers using forced draft, see technology sheet "COPRA MANUFACTURE BY INDIRECT HEAT DRYERS WITH FORCED DRAFT HOT AIR (Method D 2)."

The benefits of using indirect heat dryers with natural draft hot air are as follows: -

2.1 Any type of fuel can be used:- husks, fronds, shells or firewood. Hence cost of fuel is within suitable limits.

2.2 Excellent quality white copra can be produced provided that the dryer is operated properly. There is no discoloration of the copra due to deposits of pyroligneous matter from smoke such as in the direct heat smoke dryers. This however will not hold true if the heat exchanger has leaks.

2.3 Edible grade copra is possible if proper pretreatment of the kernel is ensured to avoid contamination and deterioration prior to drying.

2.4 Due to the excellent quality copra, deterioration during storage and shipment can be minimized. This means minimal loss of oil during storage as well as better quality oil when expelled.

The following are the disadvantages of using this type of dryer.

(a) Higher usage of fuel compared to direct dryers, depending upon the heat transferred to the hot air.

(b) High cost of maintenance due to need for replacement of the tunnel with second hand drums which are expensive compared to incomes in coconut areas.

3. Country of origin :-

The simple dryers using second hand 44 gallon petroleum drums for the flue appear to have been introduced to the Pacific region during the 1950s. The use of these drums were originally for drying cocoa and these have been adopted for drying copra subsequently. The countries using these dryers are: -

WESTERN SAMOA
SOLOMON ISLANDS
PAPUA NEW GUINEA
PHILIPPINES

Similar dryers have been in use in the following countries - Tonga, Fiji & Comoro Islands which are not members of the Coconut Community.

The large capacity copra dryers presented in the latter part of this technology sheet have been in use for considerable time. Both 'Chula' type and 'Pearson' type were developed in England. The Chula dryers were commercially manufactured commencing 1923.

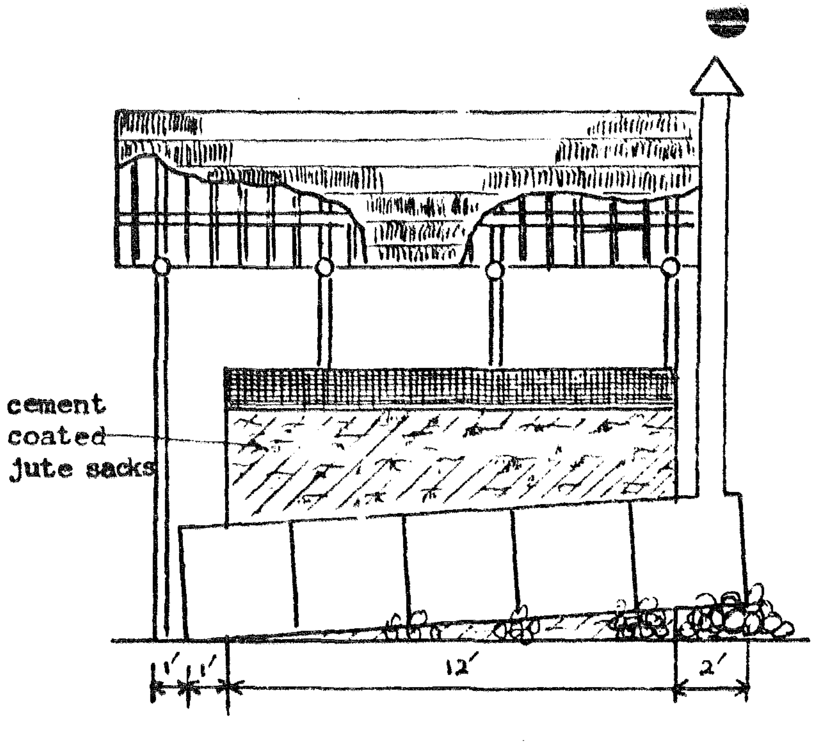
4. Equipment: -

4.1 Description of equipment and operation

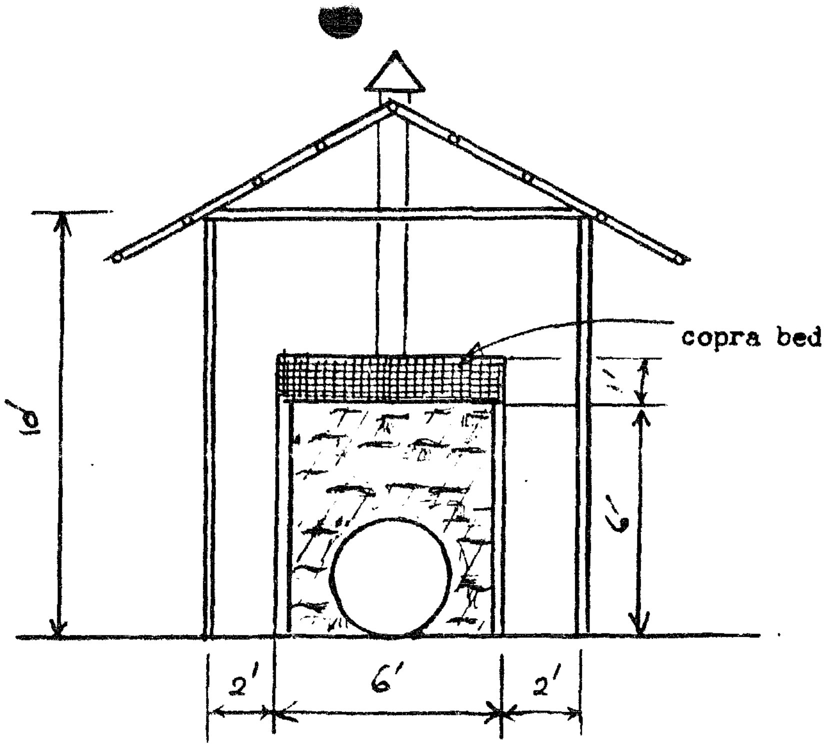
4.1.1 "WESTEC" village copra dryer of Western Samoa.
The Western Samoa Trust Estates Corporation (owned by the government) adapted the village cocoa dryer to dry copra in the 1950s. This is used extensively, by the small holders except in very remote areas where the traditional smoke dryers or sun drying is carried out.

Investigations during field visit to Papua New Guinea revealed that very similar copra dryers adapted from cocoa dryers were introduced to large estates in New Britain and New Ireland in the 1950s. These are now widely used in Papua New Guinea and are responsible for about 40% of the copra production.

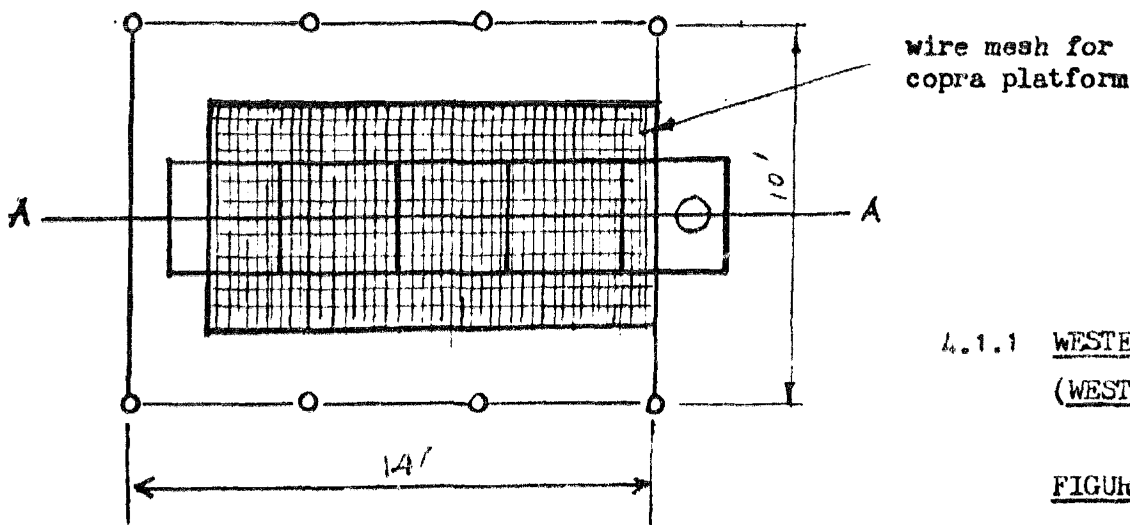
The dryer shown in figure I consists of a flue made of 5 second hand 44 gallon petroleum drums connected to a chimney 6 inch diameter x 14 feet height. The 5 drums are connected to each other by means of soft steel straps



Sectional front elevation A - A



End elevation



Plan without roof

4.1.1 WESTEC VILLAGE COPRA DRYER
(WESTERN SAMOA)

FIGURE I

without leakage of air. The drums are installed with a small incline upwards towards the chimney to facilitate flow of combustion gases.

A wooden structure is constructed to hold the 12 ft x 6 ft platform on which the kernels are loaded. The platform made of cocoa wire (BSS ½ inch wire mesh) is about 6 ft above the ground level. The platform has a 1 inch thick wooden board 12 inch wide placed vertically round it to protect the kernels from falling. The hot air chamber is enclosed with old jute bags which have been soaked in dilute cement grout to make them fire proof. A gap of 2 or 3 inches above the ground level must be kept to admit fresh air for circulation.

The dryer is suitably sheltered by a shed made of timber structure and corrugated galvanized iron sheets for the roof. It is convenient to construct the kiln within reasonable distance from the farmers house to facilitate easy supervision.

The requirements of materials for the construction of the dryer is given hereunder:-

Timber for the shed:-

Posts	3" x 3" x 12 ft long	8 units
Rafters	2" x 4" x 14 ft long	10
Tiebeams	2" x 3" x 14 ft long	4
Bracings	2" x 3" x 14 ft long	4
Purlins	2" x 3" x 16 ft long	6
Standers	2" x 6" x 10 ft long	4
Plates on top	2" x 3" x 2 ft long	2

Timber for the drying chamber

Posts	2" x 3" x 12 ft long	7 units	
Plates	2" x 3" x 10 ft long	2	
Cross pieces	2" x 3" x 12 ft long	10	
Floor joints	2" x 4" x 7 ft long	16	
Board	1" x 12" x 12 ft long	2	) for side walls
Board	1" x 12" x 6 ft long	2	) of copra bed.)

Miscellaneous items

Second hand 44 gallon petroleum drums	5 units
Wire mesh BSS ½ inch, 3 ft wide,	28 feet
Corrugated G.I roofing sheets 7 ft long	18 units
Ridge capping 8 ft long	2 units
Nails 4 inch	6 lb
Nails 3 inch	6 lb
Roofing nails	5 lb
Flat heads 1½ inch	3 lb
Staples ¾ inch	3 lb
Cement	3 bags
Jute sacks - second hand	20 units
Iron straps for joining drums	4 straps
Chimney 6 inch diameter	14 ft height

The platform area is 72 sq.ft (6.7 m^2), with a capacity of 2000 nuts per batch. The cost of the kiln is about WS$ 300/- (US$ 350/-) - 1980 prices. This cost can be reduced considerably if bush timber is used. The drums need replacement every six months whilst the timber structure and the shed etc would last nearly 10 years. The annual maintenance cost is about WS$ 45 (US$ 52/50). The replacement of empty drums appear to be difficult today with limited availability and rising costs. Deterioration of the drums is aggravated due to the intermittent usage rather than regular use.

Harvest of coconut in Western Samoa is by gathering naturally fallen nuts periodically (every 2 to 4 weeks). The nuts are axed in the field by the small holders, and kernel scooped out with a metal device to obtain "finger cut" green copra. This is packed into baskets woven from traditional local material and transported to copra traders. The traders purchase the finger cut kernel and manufacture copra. One man, in an 8 hour working day can gather about 350 nuts in the field, axe in half, scoop the kernel (about 250 lbs), pack and transport same. This is done in two lots of 125 lbs, each at the end of a half day's work. The kernel is carried like a " pingo" with two baskets tied to the two ends of a pole which rests on the shoulder in the middle. This work is done by members of the farmer's family and not by paid labour. An assigned value for a day's work of this nature may be about W.S.$ 3.00 (US$ 3.50). Those nuts used for food purposes are gathered in the field, husked and then transported without splitting open. This is now the practice for the coconut cream plant. The desiccated coconut factory which used to operate in the early 1970's also used to purchase husked nuts.

If the farmer has a reasonable sized coconut land, he may have his own copra dryer. In this case the whole coconuts are carried to the drier and the axing into half and scooping the kernel is carried out besides the dryer. There are also copra traders who purchase the kernel and dry it.

The 'finger cut' kernels are loaded onto the platform to a depth not exceeding 8 inches (0.2 m). The open end of the flue tunnel is fired using husks with the shells intact. A copra trader would use firewood as he purchases kernel only from the farmers. Good clean air heated by the hot flue tunnel, rises through the kernels drying it. The combusted gases and smoke travel through the flue tunnel and escape via the chimney.

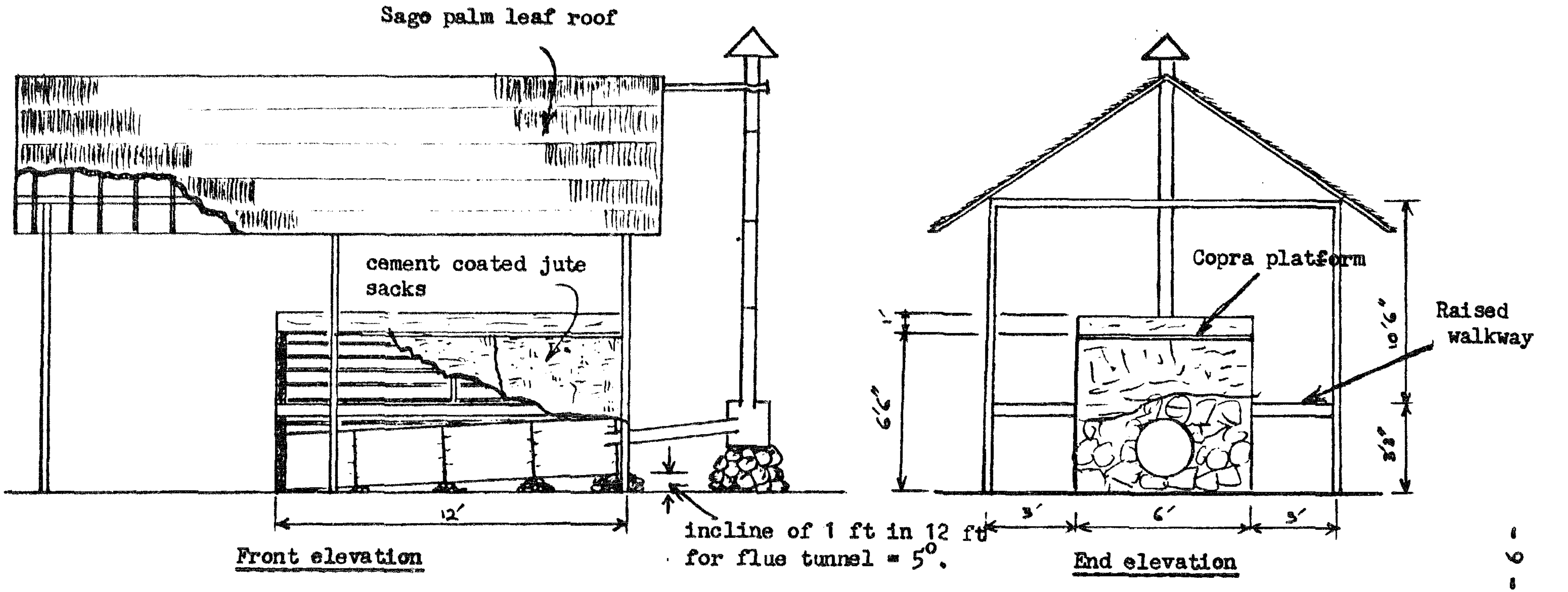
Firing the dryer is carried out through 2 evenings, each firing lasting about 12 hours. Only one man is needed to operate this dryer. The capacity of the dryer is 1500 lbs (680 kg) of fresh kernel which corresponds to 50% wet kernels from 2000 whole nuts. The yield is about 375 kg of dry copra (5% moisture). The fuel consumption is 67% of husks with shells intact.

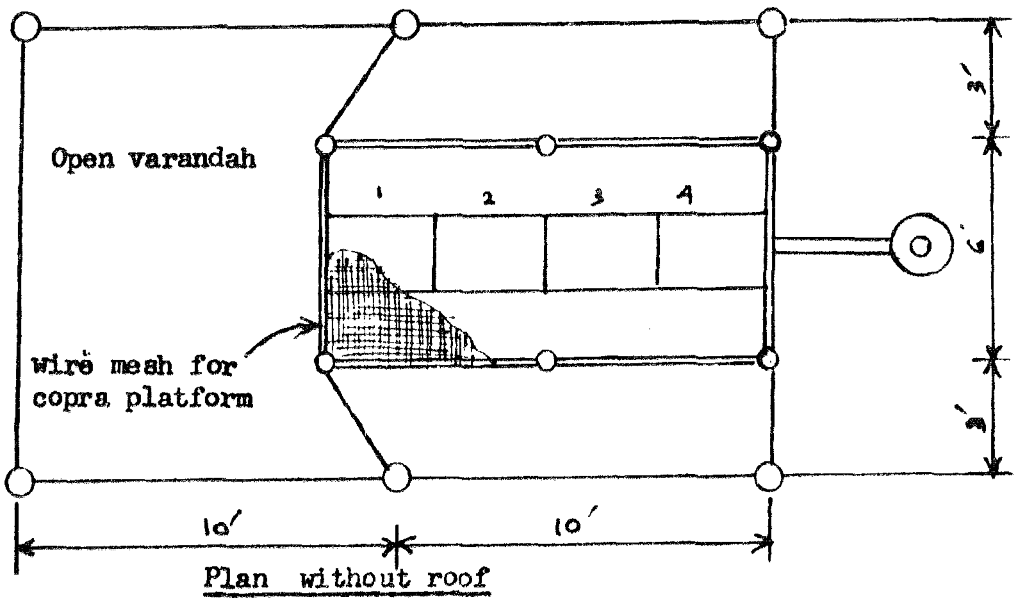
On the basis of 2000 nuts per batch (lasting two days), two batches a week, and 50 working weeks per year, the annual capacity would be 200,000 nuts (37.5 tonne dry copra). On the basis of 6000 nuts yield per ha per year, this dryer can service 33 ha of coconut land. This capacity however is never utilized because the dryers hardly work even once a week; depending upon the availability of nuts. Besides, the people are otherwise occupied in subsistence farming and fishing. The investment costs for dryers per 100 tonne dry copra capacity per year is US$ 933.

4.1.2 "KUKUM" copra dryer of Solomon Islands.

This is a dryer developed by the Department of Agriculture in the 1950s. This was adapted from the WESTEC village copra dryer detailed above. The installation and development work was carried out in Kukum within the municipality of the capital city Honiara. Hence the name of the dryer.

The Kukum dryer as developed in the 1950s had it's flue made of four empty petroleum drums installed below ground level. The first drum which was lagged internally with concrete, projected outside the drying chamber and served as a firebox. There was a baffle plate above the second drum to spread the heat. The last drum was connected to a chimney. The drying





4.1.2 KUKUM DRYER (SOLOMON ISLANDS)

FIGURE II

platform was 2 feet above ground level and this suitably protected by a roof made of traditional materials. A full report of this kukum dryer appears in the South Pacific Commission's Quarterly Bulletin for July 1956.

The kukum dryer now installed by the small holders and co-operatives is much simpler. This dryer is extensively used in the Solomon Islands, being responsible for about 50% of copra produced (Some estates use Chula forced draft dryers).

The figure II illustrates the kukum dryer commonly installed at present, as per the pamplet issued by the Ministry of Agriculture and Lands called "Building a copra dryer". The dryer comprises of a flue made of 4 empty petroleum drums placed on stones at ground level with an incline of 1 ft in 12 ft of flue which is about 5^{o}. A six inch diameter chimney 6 ft long is connected to the closed end of the drums and this in turn connected to a vertical chimney of the same size but 12 ft height.

The copra platform is 12 ft x 6 ft and located 6 ft 6 in above ground level. On either side of the platform is a 3 ft wide raised walkway 3 ft 3" above ground level. The platform has wooden members to support the weight of the copra. A wire mesh of BSS $\frac{1}{4}$" or 1/8" size is placedon the wooden framework of the platform. Wooden boards 1" x 12" are placed round the four sides of the platform to protect the copra from falling off. The chamber is covered with cement coated second hand jute sacks which are nailed onto strips of wood round the four walls. A gap of 3 inches above the ground level is necessary for admission of fresh air for circulation.

The dryer is suitably protected with a roof and structure made of traditional materials. Although a roof of 24 ft x 24 ft in plan with a jack roof is recommended the small holders appear to manage with a simple roof of 12 ft x 20 ft. Besides, several dryers had the drums placed horizontally on the ground giving rise to faulty operation where the products of combustion and smoke came out directly without going through the flue. This smoke appeared to come into contact with the kernels, affecting it's quality. The importance of a slight slope for the drums is not well understood by the farmers. Too much of an incline on the other would push the hot gases rapidly, reducing the efficiency of heat exchange. A further problem encountered is that many farmers have done away with the chimney arrangement. This again leads to contamination of the kernels with smoke. The following information is given in the pamphlet: -

Where to build

- Sheltered from high winds
- Dry ground
- Near to road or wharf

Sharing the dryer

- Sharing the dryer will mean continuous use because the drums rust when idle. (This has been solved in some areas by the introduction co-operative managed dryers which can be hired out by farmers).

Materials for construction and costs (SI$)

- 4 units second hand petroleum drums	à 2.00	12.00
- 6 x 3 foot galvanized iron chimney section of 6 inch diameter		21.00
- 2 bags cement	à 6.50	13.00
- 10 second hand jute bags	à 0.20	2.00
- 25 ft of BSS ¼" wire mesh of standard width 3 ft	à 1.16	34.00

- Some nails and plain wire	3.00
- 4 Boards 1" x 12" timber 36 ft	15.00
- Timber and leaf panels (no value)	-
- Labour (no value)	-
Cost of materials (purchased)	100.00
Cost of bush timber and leaf panels (assigned value)	25.00
Cost of labour (assigned value)	25.00
Total cost of dryer SI$	**150.00**
	(US$ 180/-)

The platform area is 72 sq ft (6.7 m^2) with a capacity of 1000 nuts per batch. The total cost of the dryer (1980 prices) as given above is US$ 180. The drums need replacement every six months whilst the timber structure may last several years. The thatched palm leaf roof is replaced every year but this does not incurr costs like the drums. The annual maintenance cost is about SI$ 37/50 (or US$ 45). The replacement of drums which are corroded appear to be difficult today with the limited availability and rising costs. Due to lack of continuous use of the drum, the corrosion is aggravated.

Larger capacity dryers are installed by using twin, triple or multiple flue arrangements with a large common platform.

Harvest of coconut in Solomon Islands is by gathering naturally fallen nuts periodically - say every 2 to 4 weeks. The kernels therefore are fully mature. There appears to be an incidence of about 5% germinated nuts. The nuts are transported to the kiln, axed and kernels scooped out to give 'finger cut' green copra. Some times the nuts are axed in the field and kernels scooped out. The green copra is then transported to a dryer in which case the husk and shell left in the field is later collected as domestic fuel. This is the case of cooperative operated dryers where cheap firewood is used along with some husk and shell. However, in most cases the fuel used is the husk intact with the shell.

The finger cut kernels are loaded onto the platform usually within 4 hours of opening the nut. The depth of kernels does not exceed about 4 inches (0.1 m) which is 2 layers. The open end of the flue tunnel is fired with husks intact with shell. Infact, the firing should be commenced in the morning before the kernels arrive for loading. This will minimize exposure of the kernels between opening the nut and commencement of dryage.

The operation of the dryer is carried out as follows:-

1st day	10.00 am	heat the dryer with a low fire
	11.00 am	load the dryer
	noon to 8 pm	fire the dryer
	8 pm	Allow to cool overnight
2nd day	10.00 am	turn the copra for uniform dryage
	11.00 am to 7pm	fire the dryer
	7.00 pm	allow to cool overnight
3rd day	10.00 am	Unload and pack the copra

Only one man is needed to operate this dryer. The capacity of the dryer is 750 lb (340 kg) of fresh kernel which is the meat from 1000 nuts. The yield is about 188 kg of dry copra. The fuel consumption is about 67% of the husk with shell intact.

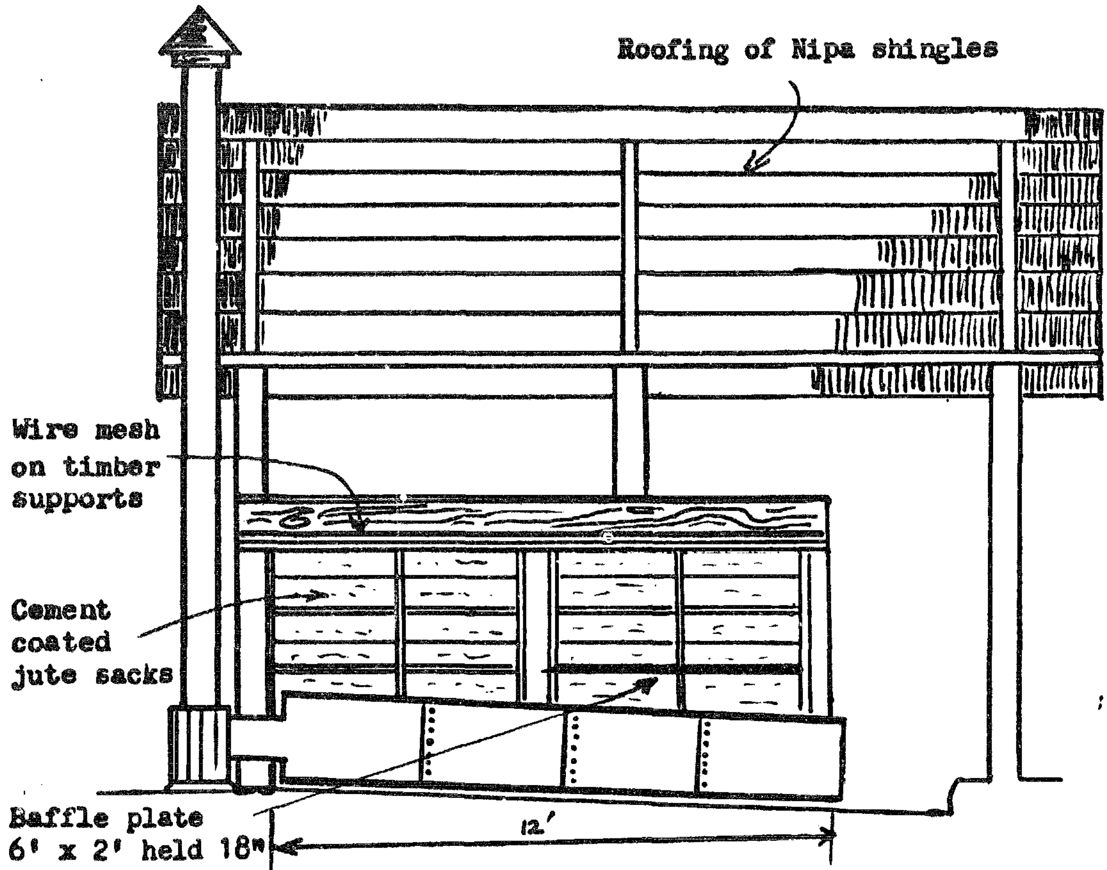
On the basis of 1000 nuts per batch (lasting 2 days), two batches per week and 50 working weeks per year, the annual capacity is 100,000 nuts (18.8 tonne dry copra). On the basis of 5500 nuts yield per ha per year, this dryer can service 18 ha of coconut land. This capacity however is never utilized as in the case of Western Samoa. The dryer is hardly worked even once a week depending upon the availability of nuts. Furthermore, the people are otherwise occupied in subsistence farming and fishing etc. The investment costs for dryers per 100 tonne dry copra capacity per year is US$ 957.

4.1.3 Philippine version of kukum dryer: -

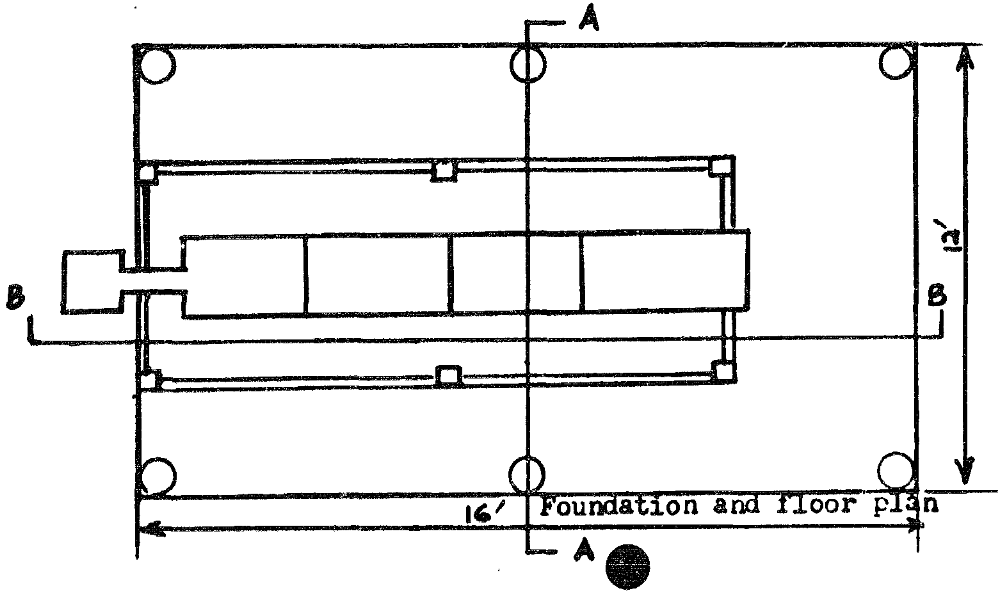
A kukum dryer was installed in December 1974 for further development and testing purposes at the Philippine Coconut Authority - Agricultural Research Branch (PCA - ARB), Bago Oshiro, Davao City in Southern Philippines.

The figure III illustrates the dryer developed as at 1978 which has since been recommended to farmers. The following construction details of the dryer (and results of some trials conducted) appear in the proceedings published on the seminar on "METHODS OF COPRA DRYING" jointly organised by Philippine Council for Agriculture and Resources Research and the Philippine Coconut Authority (April, 1978)

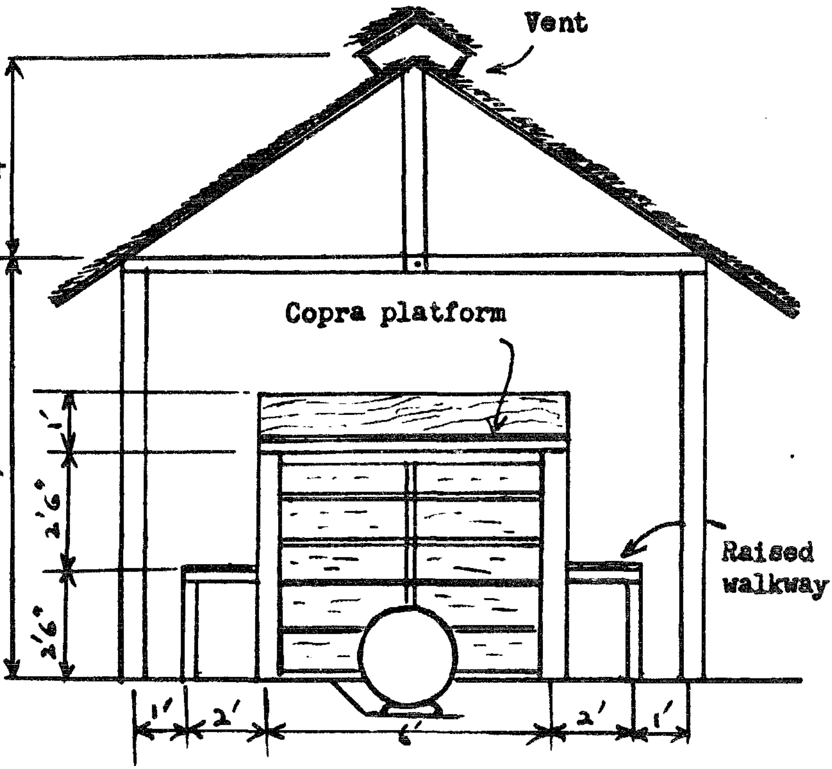
- The flue or fire tunnel - it is composed of 4 empty drums (44 gal. capacity) interconnected with a 1 inch overlap by the use of rivets. The end portion of the last drum has a 6 inch diameter opening at the center from where the chimney flue is connected horizontally.



Sectional front elevation B - B



Foundation and floor plan



Sectional end elevation A - A

6 posts (mature
coconut trunks).

4.1.3 PHILIPPINE VERSION OF KUKUM DRYER

FIGURE III

- Soot trap and chimney - The soot trap is made of a standard size kerosene can with a 6 inch diameter hole at the center top portion and another hole of the same diameter on the side of the can. The chimney is composed of 4 fragmented portions plain G. I. sheet of 3 ft long, 6 inch diameter which are joined end-to-end with an overlap. At the top most portion is the chimney "hat".

- Heating chamber - The proper heating chamber is 12 ft long, 6 ft wide and 5 ft high. The side walls are made of jute sack materials soaked in a cement and fire sand mixture with 1:1 ratio. The base portion of the front and rear side of the dryer is composed of 3 and 2 layers of 6 inch thick hollow cement blocks, respectively. An air-inlet 2 inches above ground level is provided along the longitudinal sides of the drying chamber.

- Drying platform - The dimension of the drying platform is 12 ft long x 6 ft wide x 1 ft high. The flooring is made of ½ inch diameter hole poultry wire with bamboo slats enforcement.

- Baffle plate - The baffle plate measuring 6 ft long x 2 ft wide of plain G.I. sheet is located inside the heating chamber and installed 18 inches above the first drum. It is provided to reduce the production of scorched copra.

- Inspection door - An inspection door is provided to facilitate cleaning and repair as the case may be inside the drying chamber. It measures 3 ft 8 inch high, and 1 ft 6 inch wide. It is located at the rear side of the heating chamber and situated between the concentrate base portion and drying platform.

- Stair - The stair is 12 ft long, 1½ ft wide and 2 ft high. It is provided along the longitudinal sides of the drying chamber.

- Jute sack covering - Knitted jute sacks covering is provided on the drying platform just after the arrangement of the split nuts.

- Shed - The dryer is protected from the rain by a roof made of corrugated G.I. sheet; 24 ft long, 16 ft wide and 14 ft high. A jack roof is provided on top to permit the dispersal of moisture-laden hot air.

The pamplet issued by the PCA - ARB has the following guide lines on construction of the dryer: -

- The dryer generally to be erected on fairly elevated land where water does not stagnate during floods and rain.

- The sidings of the drying platform may be increased from 1 ft to 1½ ft to increase the capacity from 1000 nuts upto 2000 nuts.

- The dryer can be modified to some extent to suit varying local conditions and easily available traditional construction materials.

The list of materials for construction is given hereunder.

	For dryer	For shed
Posts - 8" x 12' mature coconut trunks or any other poles		6 pcs.
- 4" x 4" x 8' Yacal	6 pcs.	
Plates - 2" x 4" x 6' Apitong	3 pcs.	
- 2" x 4" x 12' Apitong		3 pcs.
Girts - 2" x 4" x 12' Apitong	2 pcs	
- 2" x 4" x 16' Apitong		2 pcs.
Roofing - 42" long nipa shingles		384 pcs.
- 4"ϕ bamboo		5 pcs.
- Long size rattan		4 bundles

Floor joists	- 2" x 3" x 6' Apitong	10 pcs.
Side board	- 1" x 12" x 12' Apitong	2 pcs.
	- 1" x 12" x 6' Apitong	2 pcs.
Studdings	- 4" ∅ Bamboo	3 pcs.
Flooring	- 4" ∅ Bamboo	4 pcs.
Stair: Posts	- 4" ∅ x 4' round poles	6 pcs.
Joists	- 2" x 3" x 16' Apitong	1 pcs.
Floor	- 2" x 4" x 12' Apitong	8 pcs.
Rafter and cross bracing for top roof	- 2" x 3" x 12' Apitong	4 pcs.
Rafter	- 2" x 3" x 10' Apitong	6 pcs.
Purlins	- 2" x 2" x 10' Lauan	32 pcs.
Bottom chord	- 2" x 3" x 12' Apitong	3 pcs.
King posts	- 2" x 3" x 12' Apitong	1 pc.
Cross bracing	- 2" x 3" x 12' Apitong	1 pc.
Chimney	- # 26 x 8' Plain G.I. Sheets	3 pcs
Rivets (aluminium)	- 3/16" ∅	$\frac{1}{4}$ kg
Gasoline drum	- 2'∅ x 3'	4 pcs.
Cement		4 bags
Jute sacks	- 25 gantas capacity (16 of these for covering copra bed on top)	50 pcs
Common wire nails	- 4" long	1 kg
	3" long	1 kg
	2" long	1 kg
	1½" long	$\frac{1}{2}$ kg
Form lumber	- 1" x 10" x 12' long	3 pcs.

<u>Note:</u> Apitong means class 2 timber

The estimated cost of the dryer is ₱ 5000
or US$ 675

The area of the platform is 72 sq ft (6.7 m^2) with a capacity of 1000 nuts per batch. The cost of the dryer as given above is US$ 675. Replacement of the drums will be every months and the nipa shingles for the roof every year. The timber structure should last several years. The annual maintenance cost is around US$ 150.

The following operating procedure is set out in the pamphlet issued by PCA - ARB.

- Nut preparation:-

  Husk fully mature nuts only

  Split dehusked nuts into 2 (along the equator) and let the water run out properly.

  Arrange the split nut halves on the platform with the two bottom layers facing up and the rest facing down in a "brick formation".

  Cover the entire top portion of the drying platform with jute bags (copra sacks).

- Firing the dryer

  Start firing immediately after covering the platform with jute bags.

  Use readily available, inexpensive or less valuable fuel such as coconut husk, coconut shell or firewood.

  After 8 hours of continuous firing, say from 10.00 am to 6.00 pm, allow to cool overnight.

  Deshell the meat and reload thus ensuring rotation of the copra.

  The second firing is carried out as before say 10.00 am to 6.00 pm and the copra allowed to dry overnight.

  The copra is unloaded the next morning.

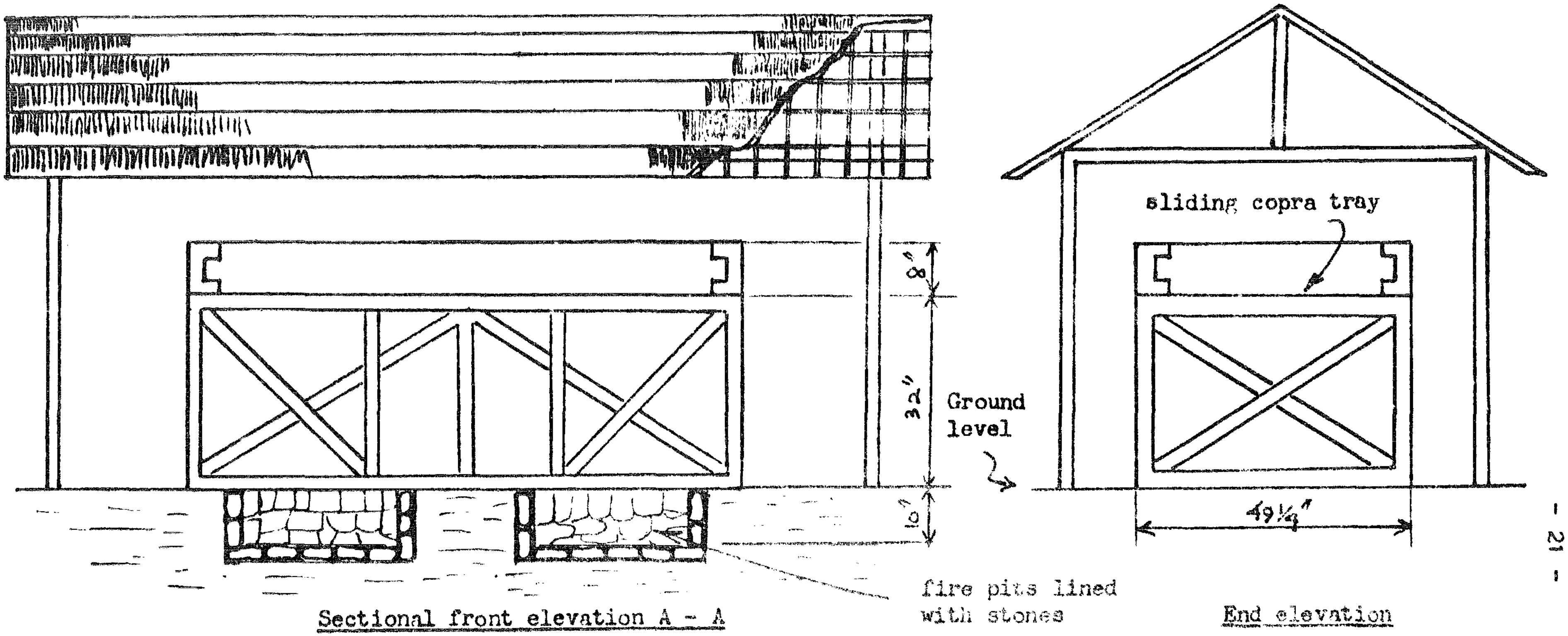
Only one man is needed to operate this dryer. The capacity is 1000 nuts or 222 kg of dry copra per batch lasting 2 days. The fuel consumption is equivalent of 1250 whole husks which is 125% of the nuts being processed. If coconut shell only is used, the consumption just balances the availability - that is 100%. Hence all the husks (100%) and 20% shells (which is equivalent to 25% husk shortage) are used. This enable the balance shells left over to be converted to coconut shell charcoal which has a ready market for export.

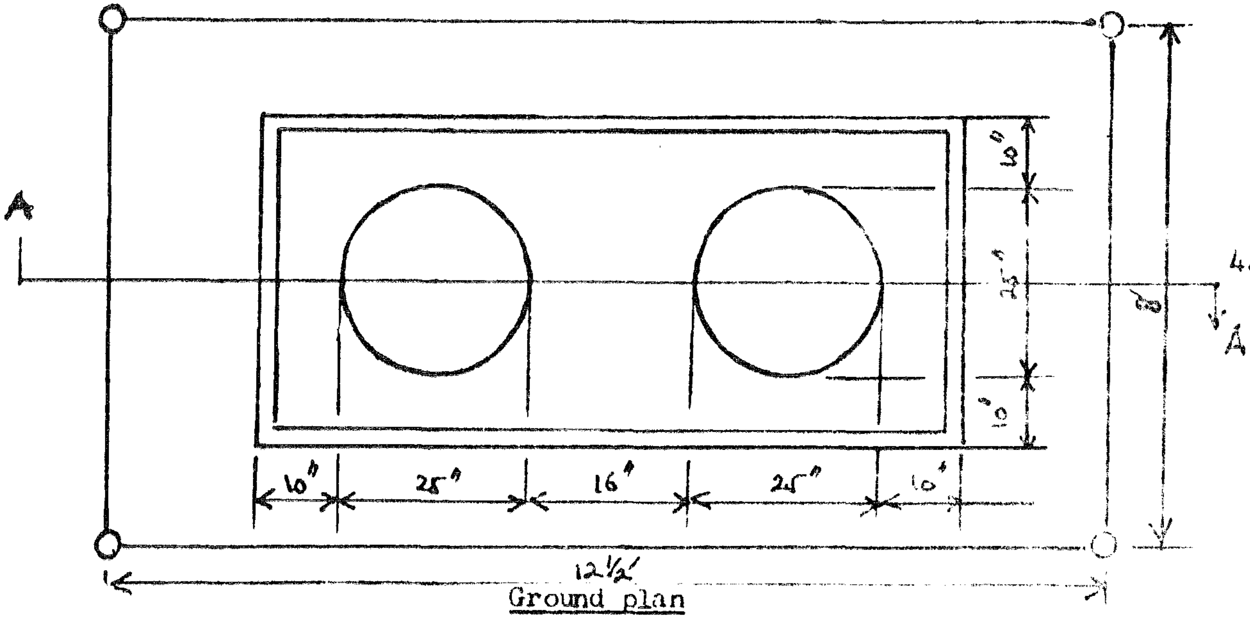
On the basis of 1000 nuts per batch, 2 batches per week and 50 working weeks per year, the annual capacity is 100,000 nuts (or 22.2 tonne dry copra). On the basis of 4020 nuts yield per ha per year, this dryer can service 25 ha of coconut land. The investment cost for 100 tonne dry copra capacity per year is therefore US$ 3000.

4.1.4 Marshalles type dryer in Micronesia (TTPI)

The origin of this dryer is obscure and is referred to by other names in copra producing areas of the Trust Territories of the Pacific Islands. It is very suitable for farmers with small and large holdings in coconut. The Farm Institute uses this dryer exclusively. The people of Marshall Islands, Kusie, Ponape and others use it. Figure IV illustrates this dryer which has a capacity of 500 nuts per batch.

The agricultural extension bulletin on construction and operation of the "Marshalles" type copra dryer is published to assist farmers to produce better quality copra for export.





4.1.4 "MARSHALLES" TYPE DRYER IN MICRONESIA

FIGURE IV

The features of this natural draft hot air dryer are given as: -

-	Fuel economy	- use 100% shells only
-	Speed of drying	- only about 13 hours
-	Requires less labour	- This means more time for other activities such as fishing.
-	Improved quality copra	- This means better prices
-	Cheaper and easier dryer to build	
-	Requires very little maintenance	

Instructions on the construction of the dryer are as follows: -

- Location of the dryer should be near the farmers home to enable keep watch during drying. The dryer should however not be sited so as to make the wind blow the smoke towards the house.
- Choice of materials - Use locally available traditional materials as far as possible to keep the cost down from purchased materials.
- Use bush timber for the frame of the dryer and the roof. Logs or poles can be used for the posts supporting the roof. The roof can be made of coconut or other palm leaves.

The list of materials for construction of the tray and chamber is given hereunder:-

Timber: -

2" x 4" x 7' 6" long	3 units
2" x 4" x 7' 2¼" long	2
2" x 4" x 3' 10" long	2
2" x 4" x 2' 2¾" long	7
2" x 4" x 4' 1" long	2
2" x 4" x 2' 8" long	2
2" x 4" x 4' 3" long	2

2" x 2" x 1' 11¾ long	4
2" x 2" x 4' 6" long	2
2" x 8" x 7' 6" long	2
2" x 8" x 3' 10" long	2
1" x 1" x 3' 10" long	92

Miscellaneous items

Nails

Sheet metal liner (tobe cut to size) 26¾" x 19' 11"
(Cement coated, used jute bags can be substituted for above as covering for the drying chamber).
Sheet metal covers for fire pits. - Use old flat roofing sheets.

Usually in the Pacific Islands, coconuts (which are allowed to fall naturally) are gathered, axed whole into two halves and kernel scooped out for drying. For the purpose of this dryer, the coconuts are husked, split in two, kernel scooped out and the shell used as fuel.

The following operational procedure is laid out: -

Load the tray with the kernel. The tray is initially placed away from the pits. Fill the pits with half shells. Donot use husks or wood as they burn fast and give off uneven heat and will need constant refilling. Set fire to the shells. Cover the pits with old flat sheet, making sure that there are no leaks. After sometime, the smoking stops. Now close the door and push the tray of copra over the pits.

Check the temperature on the tray by feeling with the hands. The temperature should be about 135° F (57°C). (Note that when the temperature is 60°C or more, a human hand cannot maintain contact with an object but has to withdraw immediately on contact). If the temperature of the tray is excessive, open the door a little to let some heat out. If this is not done, the copra will be burned. If on the other hand, the temperature is right, the door should be kept closed for the first two hours and left partially open afterwards.

Turn the copra in the tray with a shovel after about 2 hours and cover with three single layers of jute bags. The copra should be turned in this manner so that the copra will dry evenly. After the first fire goes out, two more firings are carried out, along with turning of copra as in the first firing. No care is needed after the second turning of the copra but it is wise to check temperature during the process. The correct skills and temperatures can be acquired after a few batches.

Once the copra is properly dried and cooled for 1 day, it is bagged in jute sacks.

Only one man is required to operate this dryer. The capacity is 500 nuts or 111 kg dry copra (4500 nuts per tonne dry copra in TTPI). A batch lasts practically 2 days. The fuel consumption is 100% of the shells. The platform area is 7.2 ft x 3.8 ft which is 27.4 sq. ft. (2.5 m^2). The density of nuts is 200 nuts per m^2.

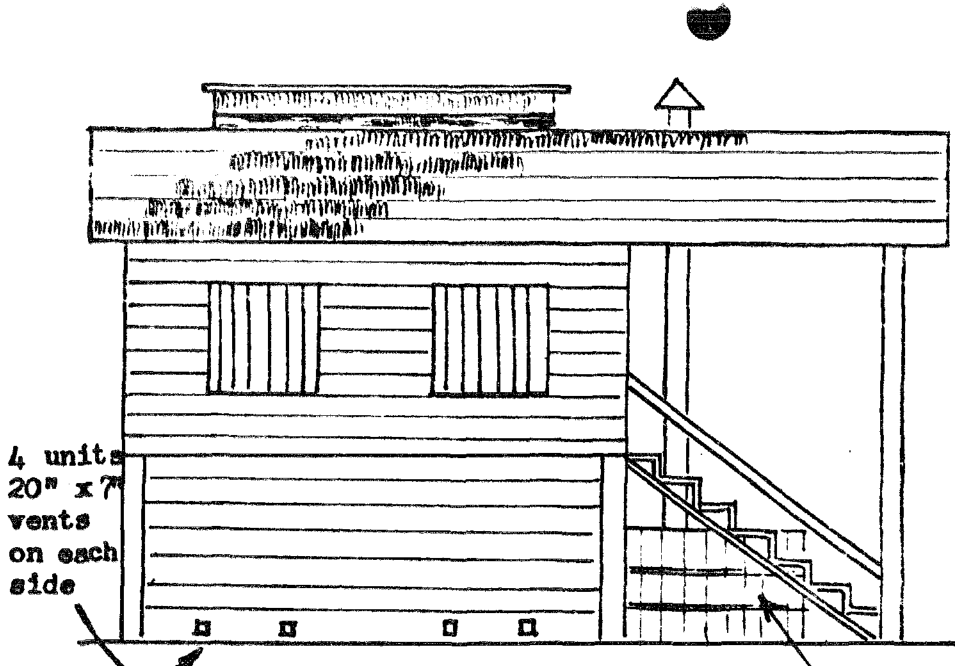
On the basis of 500 nuts per batch, 2 batches per week and 50 working weeks per year, the annual capacity will be 50,000 nuts or 11.1 tonne dry copra. For a yield of 2725 nuts per ha per year, this dryer can serve 18 ha (40 acres) of coconut land.

4.1.5 "WESTEC" estate copra dryer of Western Samoa.

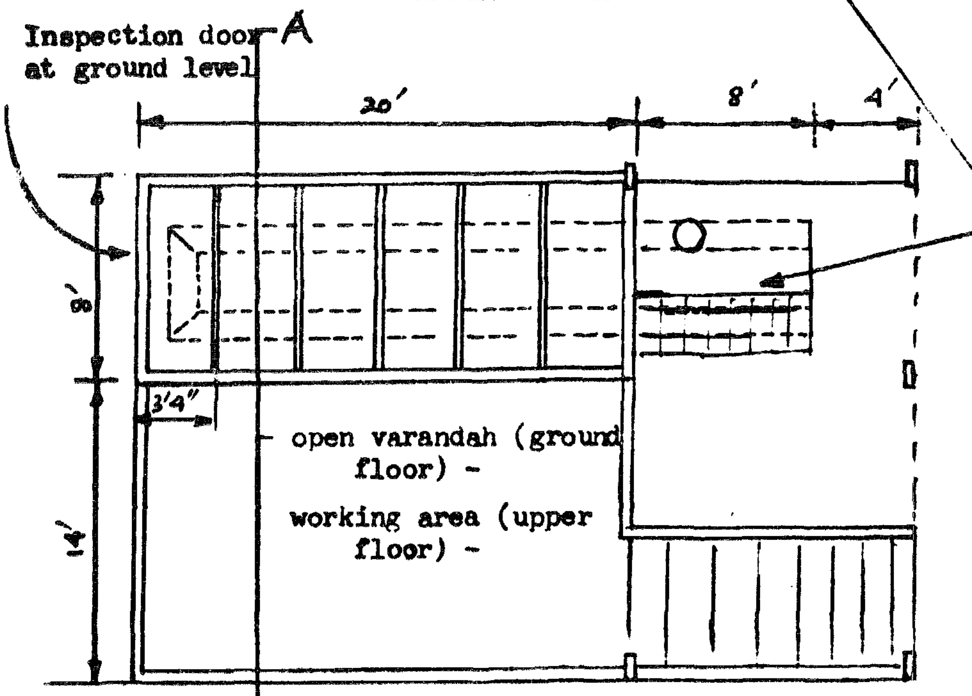
The Western Samoa Trust Estates Corporation (owned by the government) introduced this large capacity dryer for their estates from the 1950s.

The dryer shown in figure V consists of 6 drying rooms located on the upper floor. Each drying room 8 ft x 3 ft 4 inches has 14 levels for trays to slide in and out. At each level, 3 trays could be inserted into the depth of 8 ft. This makes it 42 trays per room. Each tray, approximately 2½ ft deep x 3 ft wide has a wooden frame and ½" wire mesh. The maximum loading for one tray is 30 lbs (13.6 kg) of wet kernel. The 6 drying rooms can hold a maximum of 252 trays. The drying rooms have hinged doors to facilitate loading and unloading copra. The rooms are totally enclosed with wooden planks so as to direct the warm air upwards and escape at the top which is left open. The upper floor of timber construction provides working space for loading, unloading, transfer of trays and packing finished copra. On one side of the upper floor, a half wall provides protection for the workers whilst admitting light above it. Access to the upper floor is by a wooden stairway within the building.

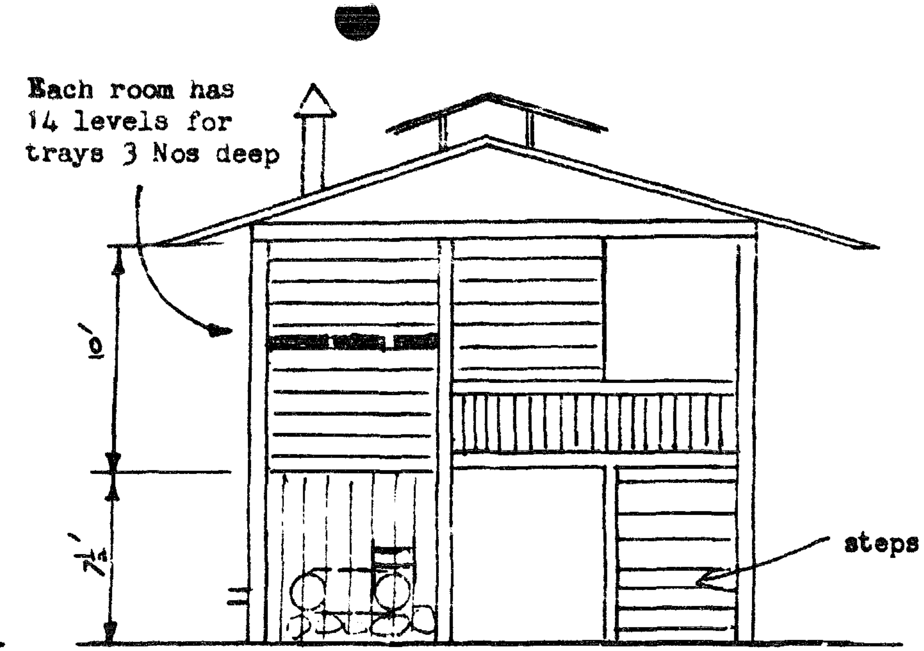
At the ground level 18 steel drums are arranged inside the lower portion of the drying chamber. The drums are interconnected air-tight with an overlap and laid out forming a 'U' shape with 8 each way and 2 for the bend. The last drum is connected to an 8 inch diameter chimney, of about 25 ft height. The first drum is made of thick steel as it is subjected to high temperature being the drum immediately next to the furnace. The rest of the drums are second hand 44 gallon petroleum drums. These drums are usually replaced every six months due to corrosion. The second drum (next



Front elevation



Plan of upper floor



Sectional end elevation A - A

furnace at
ground level

4.1.5 "WESTEC" ESTATE COPRA DRYER OF W. SAMOA

FIGURE V

to the thick steel drum) however needs replacement twice a week. The drying chamber at the end near the flue bend has an inspection door. This also serves the purpose of entry to the chamber for repair work etc. The chamber has 4 vents 20 inch x 7 inch on each side at the ground level to facilitate entry of fresh air for circulation.

The furnace is installed outside the drying chamber. It is constructed out of fire bricks held together by an angle iron framework with cross bracings. One foot above ground level, heavy fire bars are fastened to hold the husk and shells during combustion whilst allowing the ash to drop down to the ground. The furnace dimensions are approximately 8 ft x 3 ft wide x 4 ft height.

The extra floor space at the ground level is used for scooping out the coconut kernels. This is well ventilated as it is open from both ends. Usually, a separate shed is made available for this scooping out operation.

The roof of the dryer is made of corrugated galvanized iron sheets and a jack roof is provided for exhaust of moisture laden air.

The bill of materials for construction of the dryer is given hereunder: -

<u>For drying rooms</u>

Pinewood	3" x 6" x 18 ft	4 pieces
"	3" x 6" x 15 ft	2
"	3" x 4" x 14 ft	4
"	2" x 6" x 10 ft	26
"	2" x 4" x 10 ft	16
Rustic	1" x 10" x 18 ft	24
"	1" x 10" x 14 ft	12

T. G.	1" x 6" x 17 ft	24 pieces
"	1" x 6" x 13 ft	24
Flat galvanized iron sheets 3 ft 26 gauge		20 sheets
Hardwood girders	4" x 6" x 16 ft	1
"	4" x 6" x 15 ft	1
"	4" x 6" x 12 ft	2
"	4" x 6" x 11 ft	1
"	4" x 4" x 16 ft	1
"	4" x 4" x 15 ft	1
"	4" x 4" x 8 ft	1
Hardwood joists	2" x 8" x 14 ft	21
"	2" x 8" x 8 ft	8
Hardwood studs	2" x 4" x 8 ft	28
"	2" x 4" x 10 ft	22
Hardwood plates	2" x 4" x 16 ft	2
"	2" x 4" x 12 ft	2
"	2" x 4" x 8 ft	1
"	2" x 4" x 16 ft	1
"	2" x 4" x 14 ft	1
"	2" x 10" x 12 ft	1

For flooring: -

Hardwood planks	1" x 8" x 14 ft	21
"	1" x 8" x 16 ft	21
"	1" x 8" x 12 ft	12

For side walls: -

Hardwood planks	1" x 10"	1152 linear ft

For roof: -

Hardwood rafters	2" x 6" x 21 ft	11
"	2" x 6" x 6 ft	11
Hardwood purlins	2" x 3"	450 linear ft
Corrugated galvanised iron sheets 3 ft x 9 ft		24 sheets
Corrugated galvanized iron sheets 3 ft x 6 ft		24 sheets

For doors and shutters: -

Hardwood planks	1" x 12" x 12 ft	9 pieces
"	1" x 12" x 14 ft	3

For stairway: -

Hardwood	2" x 12" x 14 ft	3
"	2" x 12" x 12 ft	8
"	4" x 4" x 7 ft	4
"	4" x 4" x 12 ft	1
"	2" x 4" x 16 ft	2

Miscellaneous items: -

Creosote	(wood preservative)	15 gallons
Cement	112 pound bags	150 bags
Nails	4"	112 lb
"	3"	112 lb
"	2½"	112 lb
"	2"	28 lb

For furnace and flues:-

Square bricks	1428 pcs
Taper bricks	280 pcs
Fire clay	6 bags
Coarse salt (94 lb)	½ pcs
Furnace door	1 pcs
Fire bars (heavy)	1 pcs
44 gallon drums (second-hand)	17 pcs
Thick steel drum	1 pcs
Chimney 8 inch diameter	25 ft

The estimated cost of construction namely materials, labour and supervision (1980 prices) is WS$ 20,000 (US$ 23,300)

The estimated annual maintenance costs (1980 prices) is WS$ 3000 (US$ 3500)

The effective plan area of the six drying rooms is ($2\frac{1}{2}$ ft x 3 trays) x (3 ft x 6 rooms) which is $7\frac{1}{2}$ ft x 18 ft = 135 sq ft = 12.5 m^2. This is the platform area in plan. However due to the use of trays (at 14 levels), the useful area is 14 fold. The effect of this is rapid flow of air circulation as the depth of kernel on any tray is very little. The total height of the loading of 14 levels of trays is 10 ft (3.0 m). The nominal capacity for each room is 1000 lb (average 25 lb for 40 trays) green copra at 50% moisture. The total capacity for 6 rooms is 6000 lb green copra per day. The life of these dryers is 10 years.

Naturally fallen nuts are gathered by groups of men every 2 to 4 weeks for any given plantation area. The whole nuts are loaded onto trucks from collection points and transported to the kiln area. Workers assigned to the kiln area axe the whole nut into 2 halves longitudinally. Another set of workers scoop the kernel out - with a metal instrument giving rise to "finger cut" green copra.

The operation of the furnace requires 1 man each for 3 shifts but there is no firing between midnight and 6 am the following morning. The dryer however retains its heat throughout. At 6 am the furnace is loaded with more fuel to heat the dryer for the day's operation. By 8 am a group of about 2 men responsible for the actual operation of the dryer report for work. They unload the copra from the previous day and reload any underdried copra to the 7 upper levels. This clears the 7 lower levels for the loading of fresh kernel in the morning.

The green copra "cut" or scooped by the men besides the kiln area; is loaded onto the trays, the load for each tray not exceeding 30 lb. These trays are placed in the dryer at the 7 lower levels. After drying the fresh kernel for about 2 hours, the upper levels are cleared as the underdried copra from the previous day's processing would have dried completely. Thereafter the lower trays are transferred to the 7 upper levels and subjected to further drying of 12 hrs. This enables load new kernels to the 7 lower levels before midday thus maximizing the capacity utilization. The total of 14 hrs drying is usually adequate for making good copra. A second shift of men operating the dryer unload the 7 upper levels which are adequately dry, before going off duty at midnight. The operations of loading, transfer and unloading trays take about 1 hour each.

The movement of the copra on a "contra flow" basis ensures production of good quality white copra as the wettest copra is placed at the lower levels which are hotter.

The fuel used is husk with shell intact. It is for this purpose that the whole nut is transported to the kiln area. The consumption is only 30% of the coconuts being processed, reflecting very efficient heat exchange for a hot air dryer. The main reasons for this efficiency are (a) large capacity which reduces unit heat losses (b) long flues (large area for heat exchange) giving maximum opportunity to transfer heat. The surplus of 70% of husks with shell intact is sold to people of the area who use it as domestic fuel.

The daily capacity of 6000 lb (2727 kg) green copra with 50% moisture corresponds to 3190 lb (1450 kg) of dry copra with 6% moisture. On the basis of an out-turn of copra at 5300 nuts per tonne dry copra, the daily capacity is equivalent to 7685 nuts. The dryer works 6 days a week. For a 50 working week year, the annual capacity will be 435 tonne dry copra or 2.3 million nuts. On the basis of a yield of 6000 nuts per hectare per year, one such dryer can serve 380 ha (840 acre) of coconut land. In actual practice however, such a dryer is installed for about every 200 ha or 440 acres.

The cost of the dryer is US$ 23,300 and the maximum capacity is 435 tonne dry copra per year. On the basis of 100 tonne dry copra capacity per year, the investment cost is US$ 5350.

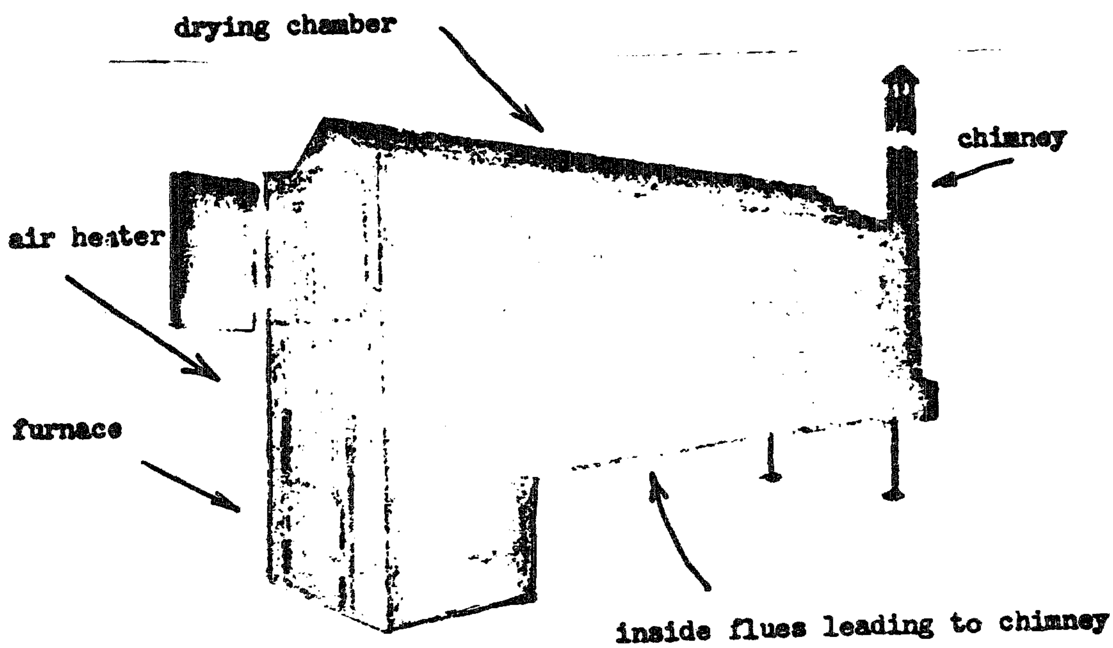
4.1.6 Chula dryer model NDO - natural draft

Chula dryers; first introduced in 1923, are manufactured by Tyneside Engineering Ltd, Elswick, Newscastle-on-Tyne, England. They are used in Sri Lanka and India for the manufacture of edible white copra. For chula dryers working on the forced draft technique, see technology sheet "MANUFACTURE OF COPRA BY INDIRECT HEAT DRYERS WITH FORCED DRAFT HOT AIR (Method D 2).

The NDO dryer (figure VI) is a natural draft dryer, capable of producing 800 kg dry copra in 24 hours continuous operation. It consists of two parts: drying chamber and air heater. The long drying chamber rests at one end on the air heater and at the other on steel supports. Its steel framework, in sections convenient for transport and erection, is covered with asbestos-lined steel-sheet panels. Each end is closed with strong double doors of asbestos-lined steel fitted with a simple but strong bolting device. Steel slides are fitted inside the chamber to hold a number of trays, of a size convenient for handling, on which the copra is spread to dry. These trays have angle steel frames and bottoms of expanded steel mesh.

The air heater consists of a furnace and flues. The furnace is of cast iron and specially designed to burn wood, dry coconut husks, and other solid fuel. The inside of the furnace is protected by a special cast-iron lining in sections which are durable and renewable. The drying air enters around the sides of the furnace and is heated by passing through heating chambers. It is then carried through the flues along the bottom of the drying trays. Regulators are provided on the furnace door and on the chimney base to regulate the draft. A thermometer outside the chamber indicates the temperature during drying.

Seasoned mature coconuts are selected for charging the dryer. They are husked, split in two, kernels scooped



4.1.6 CHULA DRYER MODEL NDO - natural draft

FIGURE VI

out and loaded straightaway to avoid discoloration. Within 20 minutes of lighting the fire the drying can begin. The NDO drier is essentially a continuous dryer. The trays loaded with kernel are put in at the cool end of the drying chamber. When a tray of dried copra is taken out, it is replaced by a tray of wet coconut at the cool end, and the intervening trays are pushed along the steel rails provided. Thus the trays gradually progress toward the hot zone of the drier, as charging and emptying go on continuously. Six trays of copra can be unloaded approximately every four hours. It is essential to make certain that each tray is fully loaded. Since this is a natural-draft furnace, no motor or motive power of any kind is required.

The daily capacity of the dryer is 800 kg of dry copra. On the basis of 4925 nuts per tonne dry copra for Sri Lanka, this capacity is about 4000 nuts. For a 6 day week and 50 working weeks per year, the annual capacity is 240 tonne or 1.2 million nuts. On the basis of a yield of 5000 nuts per ha. per year, this dryer can serve 240 ha. or 530 acres.

4.1.7 Pearson dryers

Pearson patent dryers of English make are used in Sri Lanka for the production of edible white copra. The dryers are available in 2 models:-

Small model - capacity 300 kg dry copra per day
Large model - capacity 1500 kg dry copra per day

The large model is double ended, with two stoves on either side and a common chimney at the centre. The stoves are made of fire brick. Flue gases from the stoves pass through four sets of large steel flue pipes, arranged beneath the four drying tables. At the inner end of each set of pipes, there is an adjustable damper. The stoves are located in a pit 5 ft below ground level. The lowermost drying table is about 7 ft (2.1 m) above the pit or 2 ft above ground level. This arrangement facilitates economical working as well as enlarges the capacity of the dryer.

The sides of the drying chamber are enclosed all round from the floor to the roof, with air openings near ground level. These openings are shuttered to regulate the supply of air for circulation so as to control the temperature of the hot air.

The kiln is made of a steel frame building 40 ft x 56 ft covered with corrugated galvanized iron (G I) sheets, and outside walls of brick and cement. The inner walls are made of angle iron and Tee iron framing and corrugated G. I. sheet claddings. The flue pipes are fabricated from mild steel sheet and flanged as required and set into junction boxes. The main pillars of the building are of round mild steel sections. At it's apex, the kiln is provided with a special ventilation roof, through which the chimney rises.

For this dryer, deshelled fresh coconut kernels are loaded. For efficient operation, the coconut meat is loaded to a depth not exceeding 12 inches (0.3 m) on to three levels on the trellised drying tables. The dryer works on a continuous basis with any given lot of kernels taking 5 days to dry.

The fuel recommended by the manufacturers is firewood and butt-ends of coconut fronds etc. Coconut shells should not be used as the acidic fumes produced would corrode the flues and other metal parts, reducing the life of the dryer. The collection and transportation of large quantities of butt-ends of coconut fronds may not be practical and economical. Hence the operation of this dryer is advantageous where firewood is abundant.

The large model, when in regular operation can put out 1500 kg of dry copra daily. This corresponds to a daily intake of 7500 nuts based on the out-turn of copra in Sri Lanka. On the basis of 6 working days a week and 50 working weeks a year, the annual capacity will be 450 tonne dry copra or 2.25 million nuts. For a yield of 5000 nuts per ha. per year, this large model can cater to 450 ha. or 1000 acres.

The small model has a single stove and a chimney designed on the same principle as the large model.

The small model, when in regular operation can put out 300 kg of dry copra each day. This is a daily intake of 1500 nuts. On the basis of 6 working days a week and 50 working weeks a year, the annual capacity will be 90 tonne dry copra or 450,000 nuts. This means - the dryer can serve 90 ha. or 200 acres of coconut land.

4.2 Materials for construction:-

The indirect heat natural draft dryers of local construction with much traditional material are cheap. The maintenance costs are however high because for rural coconut areas with rural incomes replacement of flue tunnels with second hand steel drums is too expensive for small farmers.

The indirect heat natural draft dryers presented in the latter part of this technology sheet which are capable of making edible white copra are constructed out of steel. These dryers therefore are expensive. In order to economise, the dryers are designed for large capacities.

In each section, the materials used for construction have been presented in detail.

4.3 Summary of design features of indirect heat natural draft hot air dryers.

Type of dryer	Batch Capacity (nuts)	Platform area (m2)	Density of nuts per m2	Height of platform above fire-pit (m)	Height of copra load (m)	Approx fuel usage
WESTEC village dryer (W. Samoa)	2000	6.7	300	1.8	0.2	67% husk +67% shell intact
KUKUM dryer (Solomon Islands)	1000	6.7	150	2.0	0.1	67% husk +67% shell intact
Philippine version of kukum dryer	1000	6.7	150	1.5 + baffle	0.1	100% husk +20% shell
"Marshalles" dryer (T T P I)	500	2.5	200	0.8 (above baffle)	0.15	100% shells
WESTEC estate dryer (W. Samoa)	7700	12.5	615 (14 trays)	2.3	3.0 (1 layer per tray)	30% husk +30% shell intact
CHULA dryer model NDO	4000 (daily)	N.A	N.A.	N.A.	N.A.	N.A. (solid fuel)
Pearson dryers:-						
Small model	1250 (daily)	N.A.	N.A.	2.1	0.3	N.A. (solid fuel)
Large model	7500 (daily)	N.A.	N.A.	2.1	0.3	N.A. (solid fuel)

Note: N.A. = Information not available

4.4 Summary of operational features: -

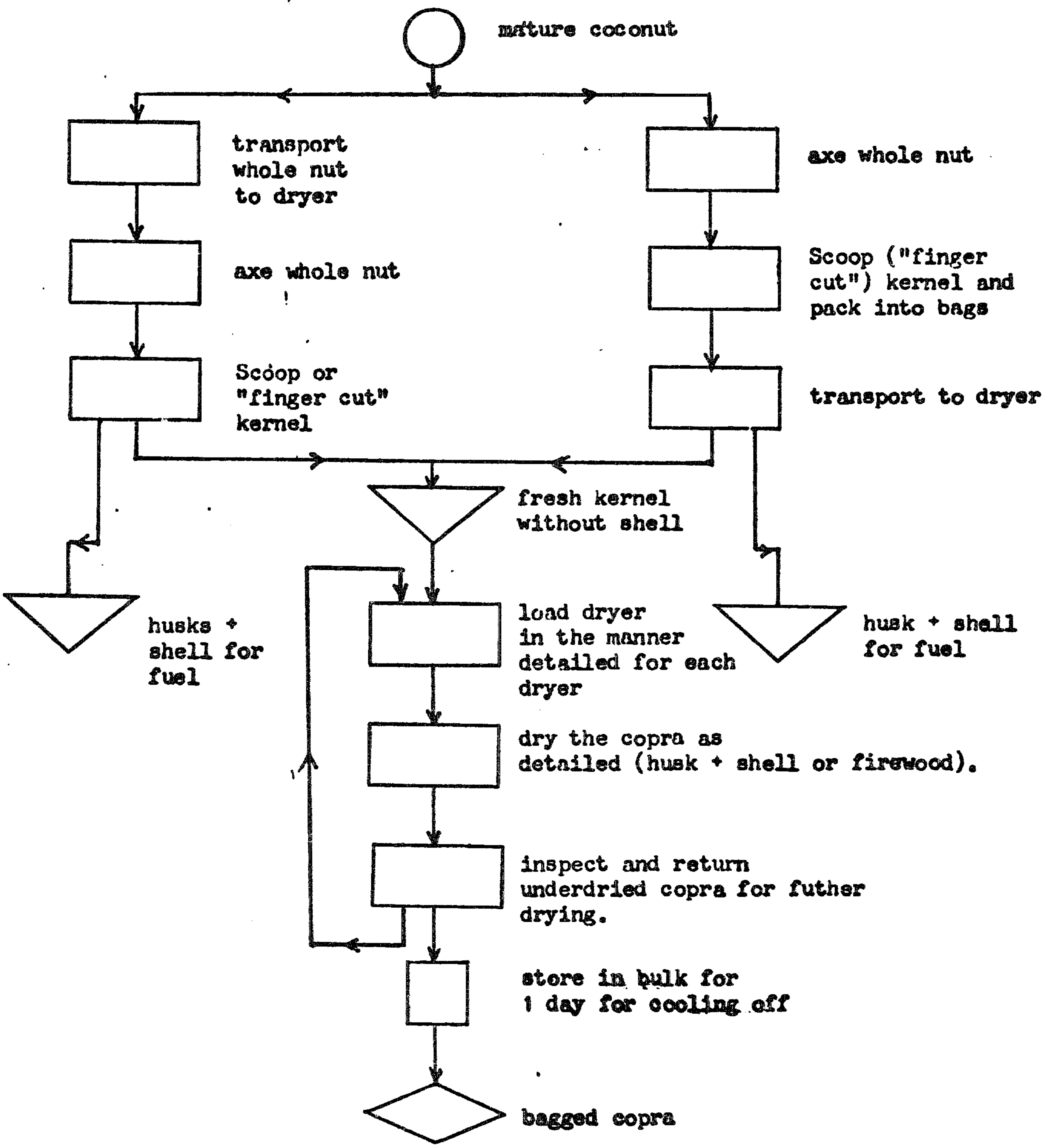
Type of dryer	Arrangement of nuts when loading platform	Removal of shells	Rotation of copra (turning)	Number of firings
WESTEC village dryer (W. Samoa)	Random	Scooped out before drying	No	2 firings during 2 nights (12 hrs each)
KUKUM dryer (Solomon Islands)	Random	Scooped out before drying	No	2 firings during 2 afternoons (8 hrs each)
Philippine version of Kukum dryer	Bottom layer upwards	After 1 firing	After deshelling	2 firings during 2 days (8 hrs each)
"Marshalles" dryer (T T P I)	Random	Scooped out before drying	After 2 hrs heating + once more later	3 firings (4 hrs each)
WESTEC estate dryer (W. Samoa)	Random	Scooped out before drying	No	1 firing of 14 hrs.
CHULA dryer model NDO	Random	Scooped out before drying	No	(24 hrs. continuous)
Pearson dryers: -				
Small model	Random	Scooped out before drying	No	Continuous firing
Large model	Random	Scooped out before drying	No	Continuous firing

4.5 Cost and Capacity of the dryers

Type of dryer	Capacity equivalent in land area (ha.)	Batch Capacity (nuts)	Batch Capacity dry copra (kg)	Batch time (days)	Cost (US$)	Investment cost per 100 tonne annual copra capacity (US$)
WESTEC village dryer (W. Samoa)	33	2000	375	2	350	933
KUKUM dryer (Solomon Islands)	18	1000	188	2	180	957
Philippine version of Kukum dryer	25	1000	222	2	675	3000
"Marshalles" dryer (T T P I)	18	500	111	2	N.A.	N.A.
WESTEC estate dryer (W. Samoa)	380 (200 actual)	7700	1450	1	23,300	5,350
CHULA dryer model NDO	240	4000	800	1	N.A.	N.A.
Pearson dryers:-						
Small model	90	1500 (daily)	300	5	N.A.	N.A.
Large model	450	7500 (daily)	1500	5	N.A.	N.A.

5. <u>Process</u>: -

5.1 Process flow diagram: -



5.2 Description of process

In the indirect heat hot air dryers with natural draft, kernels are subjected to drying without the shell. The only exception to this is the Philippine version of the Kukum dryer developed recently.

As detailed in each section, mature coconuts are subjected to various pretreatments depending upon the practices existing in each country or region. The kernels are loaded onto the dryer and the dryer fired as described. The arrangement of kernel is generally on a random basis. In some cases, the copra is not turned or rotated during the drying operation. As can be seen, some of the simple hot air dryers have the copra turned. This gives uniform dryage. This however is not practical in the case of the commercially manufactured large capacity dryers. The use of a series of trays at different levels with very thin layers of kernel loading is the answer to this problem. By having thin layers of kernel, you facilitate easy air circulation through it, thus eliminating scorching and discoloration. Therefore rotation of the bed of copra is not required. The loading onto several trays ofcourse means extra labour.

After the required drying process, the copra is unloaded. Any underdried copra should be returned for further dryage. The dried copra is allowed to cool off for one day before bagging.

5.3 Product flow diagram: -

The copra wh ch has been dried properly using these dryers should have the moisture level brough down to 6% from the initial level of about 50%.

1880 kg wet kernel (50% moisture)

↓

1000 kg dry copra (6% moisture)

The out-turn of copra for different member countries on the basis of the national conversion rates is given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

6. Quality of finished product:-

Various copra grading practices exist in different coconut regions.

The Asian and Pacific Coconut Community has prepared "Uniform Standards Specification for Copra" (final draft April 1978). There are two grades specified irrespective of the process used for making copra. The characteristics specified for the two grades are given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

With the use of hot air dryers, it is possible to obtain excellent quality copra provided that certain care is taken during processing. Hot air dryers cannot be treated as miracle machines disregarding the many factors which contribute towards making good copra. The main areas are:-

(a) Minimum exposure and proper care during pretreatment of the coconut before drying. The more the kernel is exposed to air, greater the decline in quality. The maximum lapse of time between opening the nut and commencement of drying is 4 hrs. No drier however good, can make good copra starting with bad material.

(b) Condition of the flues in that they must not have leaks; in which case direct smoke will discolour the copra.

(c) Proper slope of the flues, and chimney height for proper draft. It is the writers experience to have observed many hot air dryers using old 44 gallon drum flues without a slope. The smoke comes out at the combustion end, gets drawn into the drying chamber (instead of fresh air) due to the convectional draft for the supposed hot air and the dryer works like a direct smoke dryer, defeating the purpose of the hot air dryer.

(d) Supervision and operational care to ensure correct temperatures, rotation of copra etc.

7. <u>Source of information</u>: -

7.1 Review and techno-economic evaluation of various copra production methods applied in the APCC region by M. Varnakulasingam and J. Camacho (UNIDO/APCC 1978)

7.2 Copra processing in rural industries by F. C. Cooke (FAO 1958) - formerly Director Coconut Research Institute of Ceylon and Department of Agriculture of Malaya.

7.3 Contributions from member countries and personal observations during field visits to member countries of the Coconut Community.

7.4 Statistical Year Book on Coconuts: - APCC 1979. The average nut production per hactare per year to determine the capacities of dryers on hactarage basis was calculated on a ten year average (1969 to 1978) of nut production and area planted as per tables 5 and 6 in the yearbook.

T.K.G.R. 1980.

Product Code:- CCCN 12.01 b
Technology sheet no:- I/33 to 36

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

AND ASIAN & PACIFIC COCONUT COMMUNITY

"Consultancy Service on Coconut Processing Technology"

(Project UF/RAS/78/049)

1. Technology sheet for : - COPRA MANUFACTURE BY INDIRECT HEAT DRYERS WITH FORCED DRAFT HOT AIR (Method D 2)

This method gives good quality copra in the shortest possible time.

2. Benefits of Technology : - Indirect heat dryers produce high quality white copra by heating the coconut meat indirectly. The products of combustion usually donot come into contact with the coconut meat. Instead, the hot combusted gases heat clean air through a heat exchanger without mixing with the air. This hot air in turn comes into contact with the meat, drying it. In the case of some dryers, the products of combustion get mixed with a large quantity of air and then this mixed hot air comes into contact with the meat to dry it. In this case, the thermal efficiency is high but the fuel has to be carefully selected.

The benefits of using indirect heat dryers with forced draft hot air are as follows:

2.1 Any type of fuel can be used:- husks, fronds, shells, firewood or oil. This however is not the case for those dryers mixing the products of combustion with fresh air for drying. Use of traditional fuels will minimize operational costs. Use of oil though expensive, is reliable as the system is automatically controlled.

2.2 Excellent quality white copra can be produced in the shortest possible time due to the forced draft of hot air.

2.3 Edible grade copra is possible if proper pretreatment of the kernel is ensured to avoid contamination and deterioration prior to drying.

2.4 Due to the excellent quality copra, deterioration during storage and shipment can be minimized. This means minimal loss of coconut oil during storage as well as better quality of oil when expelled.

The following are the disadvantages of using indirect heat dryers with forced draft.

(a) The large capacities and heavy investment limit their use for large estates with centralized processing.

(b) High costs of operation and maintenance.

(c) Need for diesel engines or electricity and skilled technical personnel.

3. Country of origin : - The hot air dryers presented in this technology sheet have been developed and commercially manufactured in England since 1923. These Chula dryers are manufactured by Tyneside Engineering Ltd, Elswick, Newcastle-on-Tyne, England.

These dryers are known to be used in Sri Lanka, India, Malaysia, Solomon Islands and Papua New Guinea. They may be in operation in other member countries as well.

Mention must be made of a new dryer that has been recently developed by R.A. Lister Farm Equipment Ltd., Raglan House, 56 Long street, Dursley, Gloucestershire

GL 11 4JB, England. This indirect heat forced draft hot air dryer has been installed in Fiji Islands. There are several capacities available.

4. Equipment: -

4.1 Description of equipment and operation

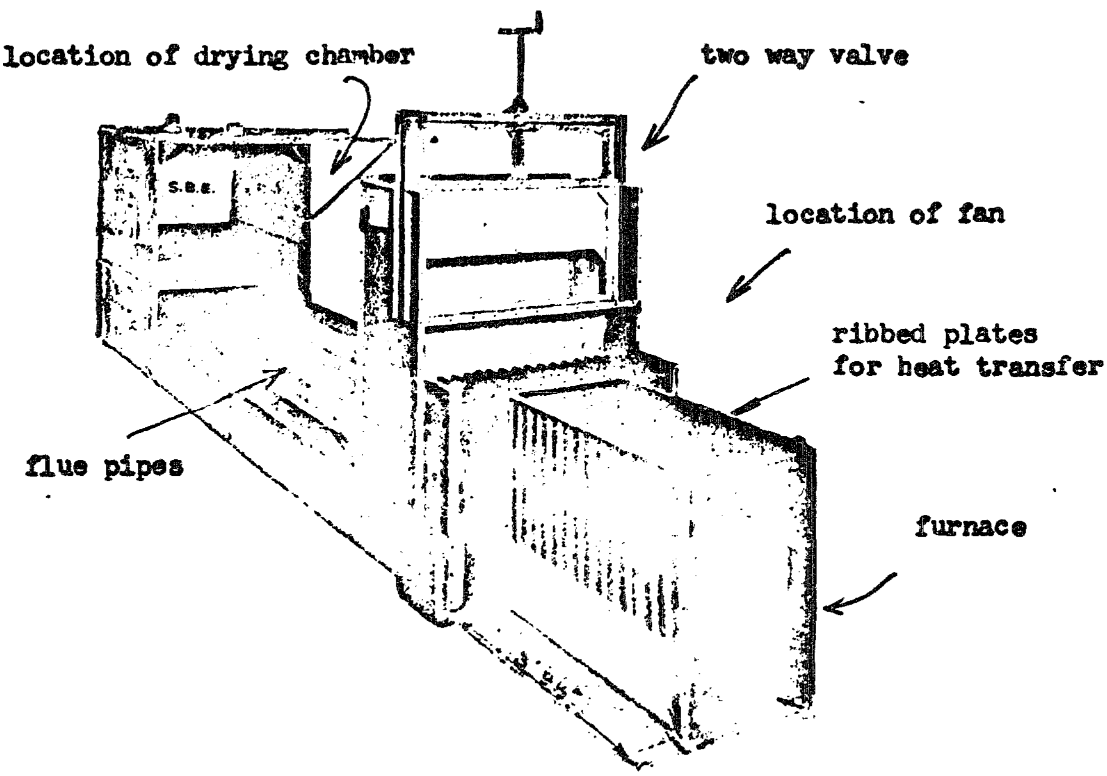
4.1.1 Chula hot air dryer model BDO (solid fuel)

This dryer has a capacity of 1200 kg of dry copra or about 2250 kg of wet kernel (50% moisture) per 24 hour working day. This corresponds to about 6000 nuts per day based on the out-turn of copra for Sri Lanka.

The dryer consists of a drying chamber and an air heater with a furnace and power drivenfan, all of which can be housed in a comparatively small building. This is illustrated in Figure I. In this figure, the dryer is shown without the drying chamber and fan etc. so that the furnace, the flue pipes and the two-way valve can been seen. The drying chamber is located above the flue pipe area., and the fan positioned above the furnace.

The furnace has machine-ribbed plates for maximum heat transfer. They are made of a special grade of cast iron. The furnace has an internal lining of the same cast iron in removable sections to protect the furnace casing from the heat. Under ordinary conditions, these inner plates last for a number of years and are replaced periodically when necessary.

From the furnace the flue gases pass through along jointless steel tubes into a small chamber at the other end of the machine, and then back through another set of tubes into another small chamber next to the furnace.



4.1.1 CHULA HOT AIR DRYER MODEL BDO (Solid fuel)

FIGURE I

The flue gases finally leave through a chimney which is connected to this second small chamber . Where the flue tubes enter the small chambers at each end of the machine, there are expansion joints to allow for expansion and contraction of the machine componants. The expansion joints comprise of sockets which when packed with the asbestos packing provided, form smoke-tight joints.

The air to be heated enters the machine at floor level through small doors on the sides and passes over the heated flue tubes and the ribbed furnace casing. The fan which is located above the furnace draws this air which has got heated and delivers through the coconut meat. The fan is the only moving part of the machine. It revolves on a shaft running on ball bearings attached to the outside of the machine. From the fan, the air passes to the drying chamber through a two way valve which enables the direction of the hot air to be reversed at will.

The drying chamber is located above the flue tube casing and is made of double sheet steel panels lined with asbestos. The bottom is formed of strong perforated steel plates and the space between this plate and the top of the flue tube casing forms an air passage.

Three discharge doors are fitted along one side of the drying chamber. The top is closed by three easy-running sliding doors which can be pushed open on rails projecting from the side of the machine. The small rollers upon which these doors run, can be withdrawn into the frames of the doors by the movement of a lever. This enables the doors when closed; to be lowered until they rest on the top flange of the chamber, thus preventing any air from escaping. Each sliding door is fitted with an exhaust air outlet which can be closed by a sliding shutter. There are two thermometers fitted, one to measure the temperature above the coconut meat and the other below.

On the side of the machine opposite to where the three discharge doors are located, a platform is fixed to facilitate the workers to load the machine with kernels.

To operate the dryer, the three discharge doors are shut and kernel loaded through the top sliding doors until level with the top. The kernel is usually without shell, thus maximizing the dryer capacity but the kernels tend to be broken up during the scooping out operation from the shell. It is possible to load the drying chamber with half kernels with the shell intact. In this case, there is a slight loss of capacity but, good unbroken half cup copra can be obtained because deshelling is nearly automatic after dryage.

All the outlets from the air chamber below the perforated plate are closed and the two way valve is raised in order to permit the hot air to enter the air passage below the copra bed. From here, the hot air passes through the perforated plate and upwards through the copra bed, exhausting from the open sliding doors at the top. After the first 2 hours of drying, the sliding doors are closed into position but the sliding shutters left open, thus offering some back pressure after the initial heating and dryage of surplus moisture. After a total of 12 hrs drying, the partly dried copra shrinks in depth by about 0.2 m. Now the direction of air flow is reversed. This is done by closing down the two-way valve, closing the shutters of the top sliding doors and opening the doors of the air passage below the perforated plate. These doors now act as outlets for the exhaust air after the hot air passes through the copra bed downwards. The reversed air flow is maintained for 8 hrs after which the air flow is reverted to the original direction for 2 hours.

During the total drying time of 22 hrs, the moisture gets reduced from 50% to about 6%. The copra is unloaded every 24 hrs, the unloading and loading of fresh kernel taking about 2 hrs.

The fan of this type of dryer can be driven by a diesel engine or a motor if electricity is available. The effort required to operate this dryer is merely to attend to the diesel engine (if not motorized) and load the fire. One good operator is capable of attending to 4 machines. It is important to note here that a good experienced operator is necessary to ensure that the correct temperatures are maintained during the drying. Excess temperature will discolour the copra whilst if the temperature is allowed to come down, complete drying cannot be obtained during the standard cycle time.

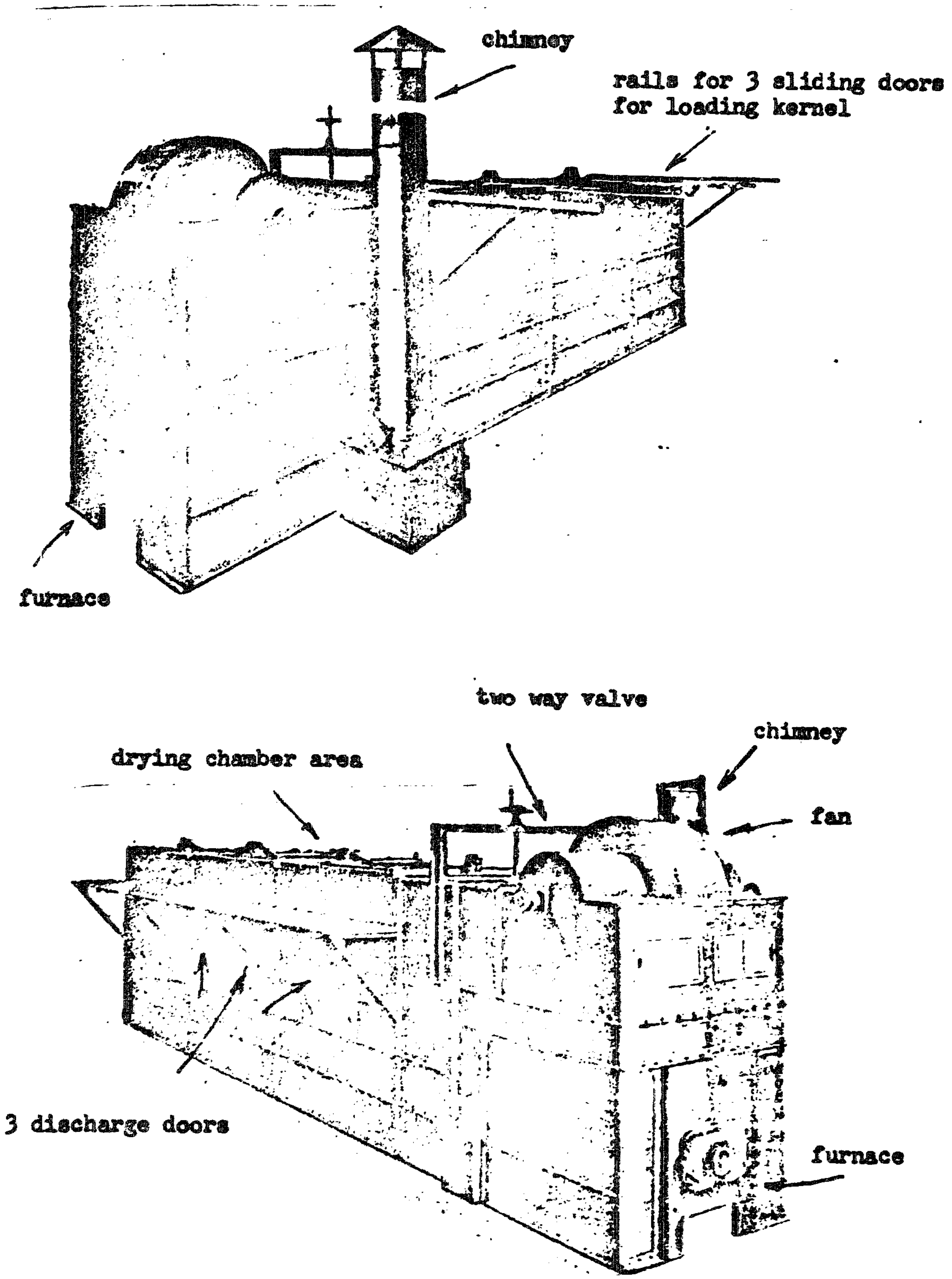
The capacity of this dryer is 1200 kg dry copra or 6000 nuts per day. On the basis of 5 working days a week and 50 working weeks per year, the annual capacity will be 360 tonne dry copra or 1.8 million nuts. For an annual yield of 5000 nuts per hectare (as in Sri Lanka), this kiln can cater to 360 ha or 790 acres.

1.2 Chula hot dryer air dryer model BD1 (solid fuel)

This dryer has a capacity of 2000 kg dry copra or 3800 kg wet kernel (50% moisture) per 24 hour working day. This corresponds to about 10,000 nuts per day based on the out-turn of copra for Sri Lanka.

The dryer is identical in design and operation to the chula dryer model BDO (section 4.1.1) except for a larger capacity. The dryer is illustrated in the figure II.

The capacity of the dryer is 2000 kg dry copra or 10,000 nuts per day. On the basis of 6 working days a week and 50 working weeks per year, the annual capacity is 600 tonne copra or 3 million nuts. For an annual yield of 5000 nuts per hectare as in Sri Lanka, this dryer can service 600 ha 1300 acres.



4.1.2 CHULA HOT AIR DRYER MODEL BD 1 (Solid fuel)

(Two views of the dryer)

FIGURE II

4.1.3 Modified Chula dryer model BDI (Mixed hot air, diesel fired) in Solomon Islands.

This Chula dryer model BDI which was originally fired by solid fuel has been modified locally to use diesel fuel and works on "mixed" hot air. A set of these machines is being utilized for centralised copra manufacture in the estate sector. The dryer is basically as illustrated in figures I and II in this technology sheet.

The main modifications are as given hereunder: -

The flue pipe heat exchanger and the chimney have been removed and a special combustion chamber introduced. Inside this combustion chamber, a white diesel (automotive grade) fired burner is worked. The burner is a low air pressure type model, the air supply coming from a centrifugal blower powered by a 2 HP electric motor.

When the equipment is working, the combusted gases (which are fully combusted) get mixed with a large quantity of fresh air. Due to the large mixing ratio, the 'mixed' hot air is clean. The main circulation fan is of centrifugal type powered by a 7.5 HP electric motor.

The fallen harvest is gathered on the estates at various points, whole nut axed and the kernel "finger cut" and packed into bags. These bags are transported by trucks and tractor trailor equipment to the dryer area. Whilst some kernels reach the dryers within 4 hours, those from the furthest areas appear to be exposed for 4 to 6 hrs which is longer than the desirable limit of 4 hrs.

To operate the dryer, "finger cut" kernel is loaded until heaped upto 8 inches (0.2 m) above the top level with the sliding doors kept open. This slight overloading helps to maximize the capacity from the nominal 2000 kg to 2250 kg dry copra per batch.

The burner is fired at "high burn" and the mixed hot air circulated upwards through the copra for 7 hours. During this time, the saturated air coming out of the top sliding door area is exhausted to the atmosphere. The temperature of the mixed hot air before passing through the copra is controlled at 140°F to 150°F (60°C to 66°C). The optimum back pressure during initial drying is about 1 ft head of water. At the end of 7 hrs of drying, the level of kernel shrinks down to about 8 inches below the top flange of the drying chamber.

The top sliding doors and shutters are now closed for reversing the air flow. The two way valve is raised to admit air from the top of the copra and make it flow downwards. The air doors provided in the air passage below the perforated plate are opened only slightly so as to permit exhaust of about 30% of the air. The balance of about 70% of the air (with it's heat) is recirculated through a regulated shutter. The burner for this second drying works at "low burn", conserving valuable fuel. The 30% air exhausted is made up with an equivalent amount of fresh air for the "low burn" of the burner.

The drying time for this reversed flow with partial circulation is 12 hrs with the temperature maintained at 140°F (60°C).

The total drying time is 19 to 20 hrs. Unloading takes 2 hrs and loading another 2 hrs. The total drying cycle takes 24 hrs.

The fuel consumption on a per tonne dry copra basis is maintained at 16 gallons of automotive diesel. This could be as high as 20 gallons if the recirculation technique was not used. If on the other hand, if pure hot air only was used through a heat exchanger, the fuel consumption would have been in the range of 30 to 40 gallons of furnace oil per tonne dry copra. Despite the modification for use of "mixed hot air and the partial recirculation system, the operation of these dryers has become very expensive due to high fuel costs.

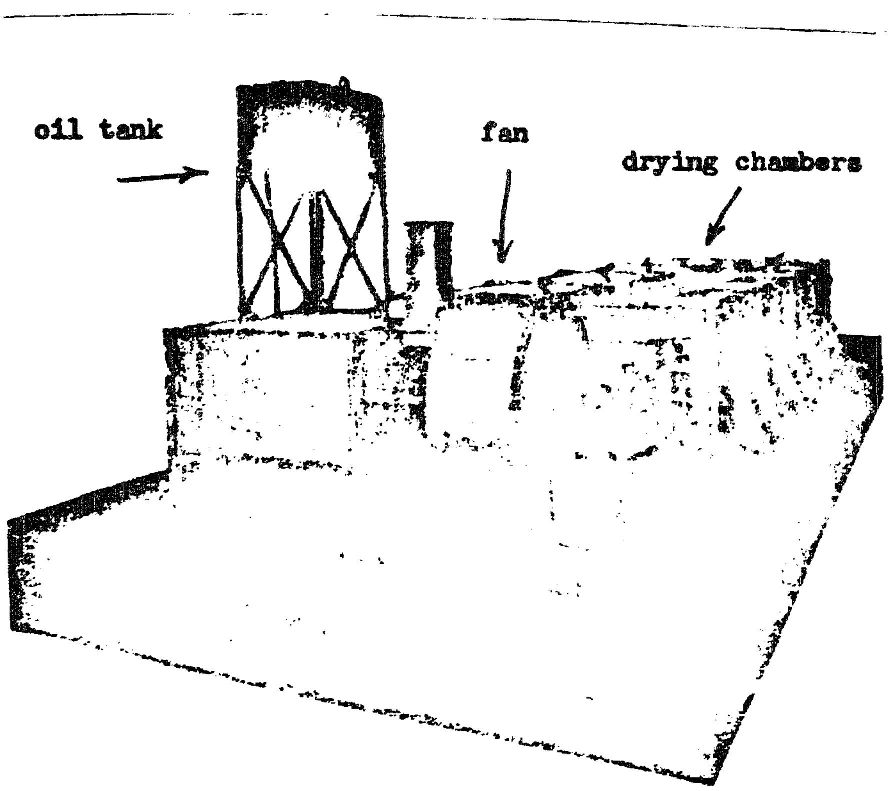
These dryers are operated in a battery of several units. One experienced operator for each of the three shifts could attend to 4 or 6 machines. The operator has to ensure that all units are working properly by checking the temperatures and if necessary adjusting the burners and regulating shutters etc.

Loading and unloading the set of machines is carried out on two shifts depending upon the times at which the "finger cut" kernel is transported to the centralized drying area. For each shift there is a separate group of men. The shift hours are 6 am to 2 pm and 2 pm to 10 pm. The number of men is based on an average of 1 man per dryer. Another group of men is responsible for bagging the dry copra which is left in bulk in the store for 1 day after the drying operation. This enables the surplus heat in the copra to move out as well as permit any surplus moisture (say 7 or 8%) to breathe out and be reduced to the optimum level of 6% or below.

The capacity of the dryer is 2250 kg of dry copra per day or 11,250 nuts (based on 5000 nuts per tonne in Solomon Islands). The nominal capacity is 2000 kg for the model BDI. This increased capacity is possible due to two factors. One: - overloading upto a height of 8 inches above the flange at the top and, Two: - Finger cut kernel have a better packing density. On the basis of 6 working days a week and 50 working weeks per year, the annual capacity will be 675 tonne dry copra or 3.375 million nuts. For a yield of 5500 nuts per ha, this dryer can service 615 ha or 1350 acres of coconut land.

4.1.4 Chula hot air dryer model BD2 (oil fired)

This chula dryer is similar to the model BD1 presented in section 4.1.2 but it can be constructed in various capacities ranging from 666 kg to 6000 kg dry copra per 24 hr working day, by the addition of unit drying chambers. See figure III.



4.1.4 CHULA HOT AIR DRYER MODEL BD 2 (oil fired)

FIGURE III

The air heater of this machine consists of an oil burner with thermostatic control, an air chamber and a fan worked by an electric motor.

The drying chamber is built up in units of 666 kg dry copra capacity. Several units can be added to the drying chamber within the limits of the capacity of the oil burner. The manufacturers have 3 sizes of air heaters for selection depending upon the capacity required.

In this model of dryer, the direction of airflow can be reversed as in models BDO and BDI. This ensures uniform drying of the copra.

Drying chamber units can be cut off from one another by division plates which donot obstruct the flow of air below the perforated plate. The various units can therefore be loaded independently at different times for continuous operation. As in the case of the other models, the drying chamber is loaded with kernels from the top and when ready, discharged from the side.

The oil burner is automatically controlled by means of a thermostat and therefore is reliable in operation.

The maximum capacity is 6000 kg dry copra per day or 30,000 nuts (based on 5000 nuts per tonne). On the basis of a 6 day week and 50 working weeks per year, the annual capacity will be 1800 tonne dry copra or 9 million nuts. For a yield of 5000 nuts per ha per year, this dryer can serve 1800 ha or 4000 acres.

4.2 Materials for construction

These dryers are of sophisticated design catering to high capacities for centralized processing. All the dryers use cast iron and or steel componants with centrifugal fans powered by a diesel engine or electric motor. Some dryers use oil burners. In such cases, oil storage facilities with service tanks are necessary. Electrical installations are necessary if diesel engines are not used.

4.3 Summary of operational features: -

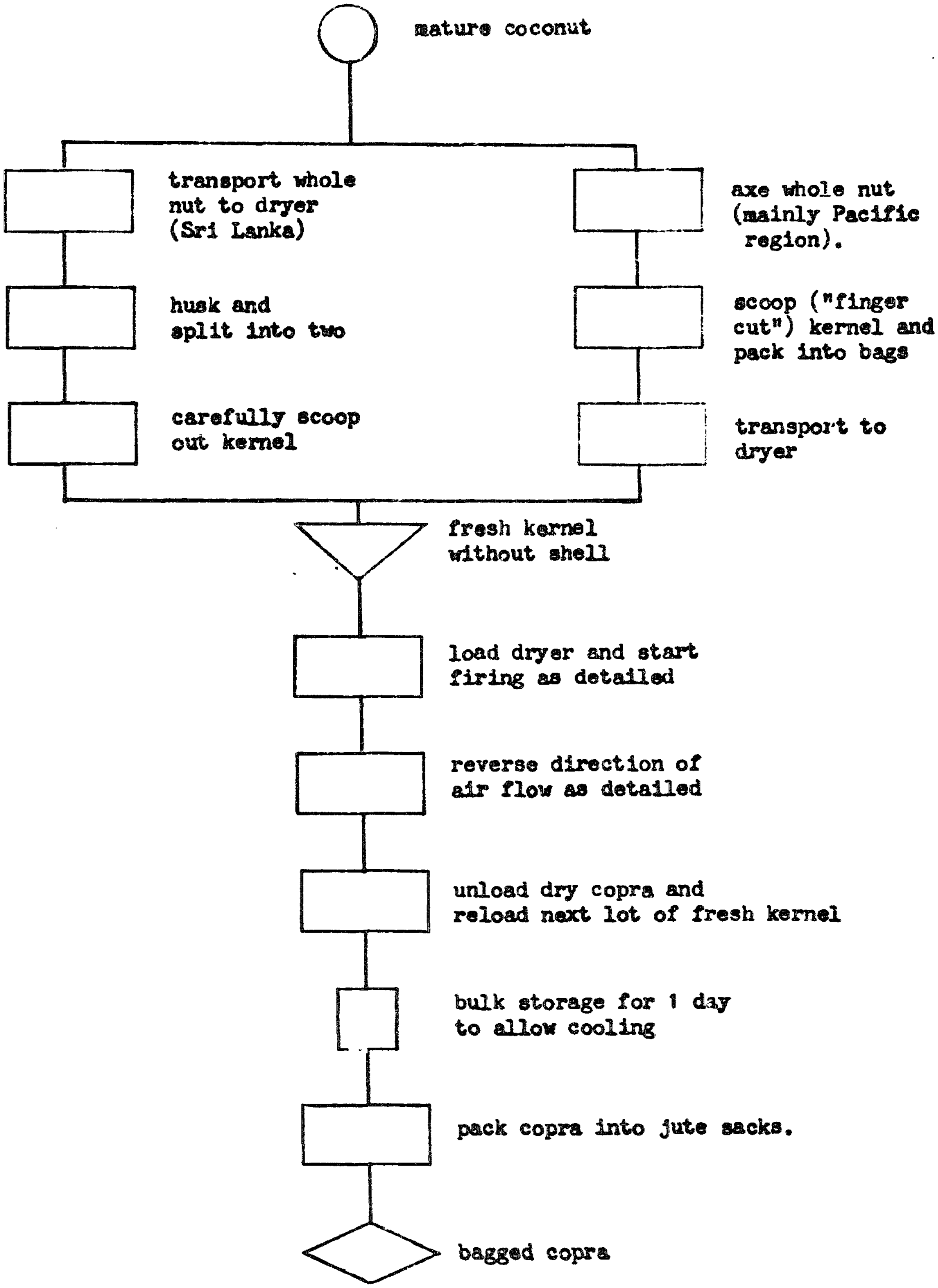
Type of dryer	Batch capacity (nuts)	Hours of drying	Fuel used	Power used
Chula dryer Model BDO	6,000	22	Firewood etc.	Diesel engine or electric motor.
Chula dryer model BDI	10,000	22	Firewood etc.	Diesel engine or electric motor
Modified chula dryer BDI	11,250	20	Auto-motive diesel	Electric motor
Chula dryer model BD2	30,000	22	Black diesel or fur-nace oil	Electric motor

4.4 Summary of cost and capacity of the dryers

Type of dryer	Capacity equivalent in land area (ha)	Batch capacity (nuts)	Batch capacity dry copra (kg)	Batch time (days)	Cost (US$)
Chula dryer model BDO	360	6,000	1200	1	N.A.
Chula dryer model BDI	600	10,000	2000	1	N.A.
Modified chula dryer BDI	615	11,250	2250	1	N.A.
Chula dryer multiple unit model	1800	30,000	6000	1	N.A.

5. <u>Process</u>: -

5.1 Process flow diagram: -



5.2 Description of process: -

In the indirect heat hot air dryers with forced draft, the kernels are dried without the shell.

In the Pacific region, the whole nut is axed into two; longitudinally and the meat taken out by a metal scoop. The "finger cut" green copra is packed into bags and transported by trucks and tractor trailors to the centralized processing area.

In certain areas, the lapse of time between opening the kernel and processing appears to exceed the maximum desirable limit of 4 hrs.

In Sri Lanka, the whole nut is transported to the dryer area and "seasoned" by storing under the shade for 3 to 4 weeks. Thereafter, the nuts are husked, split in two along the 'equator' and the meat scooped out carefully.

In other countries where the fibre industry is not developed, the nuts are husked in the field and the husked nuts transported to the dryer area. Sometimes they are split in two and water allowed to run out before transportation.

The kernel without shell is loaded as detailed in the case of each type of dryer. All the forced draft dryers have arrangements for reversing the direction of flow of the hot air. This is very important to obtain uniformly dried copra. This is the equivalent action to 'turning' or rotating the copra in some cases of natural draft systems (Direct heat smoke dryers method B, direct heat smokeless dryers - methods C1 and C2, Indirect heat natural draft hot air dryers - method D1). Forced draft systems give the quickest method for drying copra but is also the most expensive method.

The most important aspect of the operation is to control and maintain the temperature of the hot air within the desirable limits at the various stages. An experienced operator can ensure that the copra is dried without discoloration and within the standard drying time.

After unloading the copra, it is kept in bulk storage for 1 day before packing into bags. This serves two purposes. One, the heat is allowed to escape and Two, any excess moisture is breathed out leaving the copra at 6% moisture or less.

5.3 Product flow diagram: -

The copra which has been dried using these indirect heat forced draft dryers usually conform to 6% moisture level. Assuming the moisture level of the fresh kernel to be at 50% before dryage, we have: -

1880 kg wet kernel (50% moisture)

1000 kg dry copra (6% moisture)

The out-turn of copra for different member countries on the basis of the national conversion rates is given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE".

6. Quality of finished product: -

Various copra grading practices exist in different coconut regions.

The Asian and Pacific Coconut Community has prepared "Uniform Standards Specification for Copra" (Final draft April 1978). There are two grades specified irrespective of the process used for making copra. The characteristics specified for the two grades are given in the technology sheet "PRINCIPLES OF COPRA MANUFACTURE"

With the use of indirect heat forced draft hot air dryers, it is possible to obtain excellent quality copra in the shortest possible time. However, certain care has to be taken to ensure what is possible is achieved. There appears to be a tendency to treat such dryers as miracle machines. The following factors contribute towards making good copra: -

(a) Minimum exposure and proper care during pretreatment of the coconut before drying. The more the kernel is exposed to air or the more pieces the kernel is broken up into, greater the spoilage and the resulting decline in quality. The maximum lapse of time between opening the nut and commencement of drying is 4 hrs. No dryer, however good, can make good copra starting with bad material.

(b) Condition of the flues to ensure there are no leaks or else the smoke will discolour the copra. Besides flues kept cleaned would improve the efficiency of heat exchange.

(c) Cleanliness of the drying chamber particularly when the machine has been rested.

(d) Supervision and operational care to ensure correct temperatures are maintained and that the air flow is reversed to obtain uniform drying.

7. <u>Source of information</u>: -

7.1 Copra processing in rural industries by F.C. Cooke (FAO 1958) - formerly Director Coconut Research Institute of Ceylon and Department of Agriculture of Malaya.

7.2 Coconut Palm products by B.E. Grimwood (FAO 1975).

7.3 Contribution from member countries and personal observations during fields visits to member countries of the Coconut Community.

7.4 Statistical Yearbook on Coconuts - APCC 1979. The average nut production per hactare per year to determine the capacities of dryers on hactarege basis was calculated on a ten year average (1969 - 1978) of nut production and area planted as per tables 5 and 6 in the yearbook.

T.K.G.R. 1980.