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UNIDO-DEVELOPED TECHNOLOGIES

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38/6

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INTRODUCTION

One element of the work programme of UNIDO is to make available to developing countries technologies that have been successfully employed in other comparable countries. It is considered that the large amount of technological information that UNIDO has accumulated could be used to a larger extent than has been the case to date. In order to achieve this, a selection is necessary, keeping in mind the needs and capabilities of developing countries.

During the preparatory work for this document, an inventory of technological documentation within UNIDO was made. A prerequisite for inclusion was that the technologies have to be developed, modified or adapted by UNIDO. Another criteria for selection was a certain degree of originality. Variations of simple agricultural implements, for example, were not considered to be innovative enough for inclusion at this time.

In an attempt to provide something of interest to a larger group of developing countries, technologies of varying degrees of complexity have been chosen. Two of the technologies presented in this document are of a relatively basic nature, one dealing with wood drying and the other with cassava as a raw material. The remaining three technologies are of a slightly more complex nature and are therefore better suited to countries with a reasonably well developed infrastructure. These technologies relate to castor bean meal de-toxification, cultivation of algae, and a poly-functional pilot-scale laboratory respectively.

The underlying philosophy is that, to be worthwhile, a technology should be economic in one way or another. This could, for example, be through the utilization of hitherto unexploited resources for export or local consumption, better processing methods of traditional raw materials or improved manufacturing processes for established products. Whatever the case, a certain amount of value added as a result of the application of the technology in question is desirable.

The five technologies presented in this document were selected from the roster of technologies below. The roster is the result of an extensive search of available UNIDO documentation of technologies. The list represents a selection, not necessarily exhaustive, of technologies that have been developed, adapted or modified by UNIDO and which could be considered for dissemination among developing countries. In the interest of established as well as potential entrepreneurs in developing countries it is hoped that it will be possible to make further technologies available to the public in a not too distant future.

ROSTER OF TECHNOLOGIES DEVELOPED, ADAPTED OR MODIFIED BY UNIDO

	MICRO-FICHE	INTIB	UDT
OILS & FATS			
Coconut oil	16270	(x)	
Rice bran oil technology	15300	x	
Palm oil extract	15168	x	
Essential oil	14399	x	
Oil, groundnut and copra	13730	x	
Essential oil	11415	(x)	
Poly-functional laboratory		x	x
AGRO-INDUSTRY			
Cocoa	17081	x	
Tomato	16387	x	
Flour milling	16021	x	
Pineapple dehydration	15944	(x)	
Soy milk	15871	x	
Sea weed	15847	x	
Pres. of coconut stem & ...	15399	(x)	
Tropical fruits	15303	x	
Fruit & vegetables	15105	x	
Tofu	14550	x	
Papaya	13276	x	
Tomato	11474	x	
Corned beef cannery	9590	(x)	
Dates	7149	x	
Soft drinks	7146	x	
Castor bean de-toxification		x	x
Spirulina algae		x	x
Cassava as a raw material		x	x
Balanites Aegyptiaca		x	x
LEATHER			
Goat skin tanning	15413	x	
Last production	14692	x	
Fish leather	no documentation		x

TOBACCO			
General, cigs and cigars	16442	x	
General, cigs and cigars	7093	x	
WOOD			
Solar kilns	16027	x	x
Solar kilns	14694	x	x
METALLURGY			
Bacterial leaching, copper	16946	x	x
Gold from waste	16457	x	x
Up-grading of alumina	16102	x	x
DEMONSTRATION PLANTS			
Tannery effluent treatment	16260	x	
	14085	x	
RUBBER			
Powdered rubber	11053	x	
Liquid natural rubber	15517	x	
TEXTILES			
Cotton processing (no UDT)	16596	x	
Dyeing	14903	x	
CHEMICAL INDUSTRY			
Bentonites			x
Mobile brick-making plant		x	x

SOLAR TIMBER DRYING KILNS

Introduction

Inadequate wood drying is a major factor in preventing the manufacture of high quality wood products in many developing countries. Failure to remedy the situation is due partly to the lack of knowledge of the fundamentals of wood drying and how to measure accurately wood moisture content, partly to the lack of knowledge of seasoning kilns, both solar and conventional, and how to construct and operate them and partly to a reluctance to spend large sums of foreign exchange on drying equipment which is not well understood. The conventional kiln equipment comes in a wide range of makes, employing different methods of drying, whose relative merits are also poorly understood and many of which are of too large a capacity and of too high a price to be acceptable for most developing countries. An important extra factor preventing development is the difficulty of obtaining foreign exchange for the original purchase of the equipment or for spare parts and accessories necessary to keep the equipment operating.

Notwithstanding the problems, wood drying is a necessity both for sawmills and the wood-using industries, such as joinery and furniture makers and the producers of pre-fabricated housing. Especially in the tropics, timber should not be left lying in heaps in the sun as the resulting uneven drying decreases the value of the timber or even renders it unsalable.

Solar kilns have proved to operate quite successfully under tropical conditions and offer the chance of bringing kiln drying within the range of possibility for the smaller firms.

The solar kiln is easy to operate in an acceptably efficient manner. Provided vents are not opened too much with slow drying refractory woods at the critical time when surface drying and shrinking starts, the quality of drying will be good. Optimum drying speed may be more difficult to achieve without practice but the basic techniques of achieving good quality drying are not difficult to acquire and very little operator time is needed to control the kiln.

The case for kiln drying becomes even stronger if one considers the furniture and housing industry. The required degree of drying varies depending on where the products are to be used. In a humid tropical climate drying to 17-18% mc. may be sufficient whereas temperate climates with central heating will require drying to 8-9% mc.

Characteristics of conventional and solar kiln drying.

The conventional kiln controls both humidity and temperature according to schedules prescribed for different timbers; the severity of drying possible, in terms of height of temperature and lowness of humidity, varies according to the timber being dried. Two processes are taking place: the first being the removal of water fror the surface of the wood and the second the movement of water or vapour from the interior of the wood to the surface. In all slow-drying woods the latter is limiting and rate of drying depends on rate of movement through the wood. Given an adequate moisture gradient this is to a very large extent temperature-dependent provided case-hardening and collapse do not occur. Kiln schedules are designed to keep these defects to a minimum and final steam treatments are designed to relieve stresses at the end of drying.

With solar drying it is not possible to control temperature other than by raising it above ambient by 10-20°C in the middle of the day. Humidity can be very considerably controlled by opening or closing vents to remove or retain humid air produced by evaporation of water from the wood. Typically, the simple greenhouse-type solar kiln in the tropics reaches a temperature of about 40°C, in the middle of the day, in the early stages of drying, dropping to about 3-4°C above ambient at night. Midday humidities are around 80-90% provided vents are not opened too far and rise to nearly 100% at night if fans are shut off. As drying proceeds, midday temperatures rise to as much as 50-55°C on clear days with humidities as low as 40-50% in the later stages of drying while night temperatures drop to 2-3°C above ambient and humidities rise to 60-80%. Day temperatures, therefore, follow fairly closely the slower conventional kiln schedules while at night temperature gradients in the timber may help to speed vapour diffusion from the centre to the surface of the wood. Solar kilns, therefore, become more competitive, compared with conventional kilns, when drying slow-drying, hard heavy timbers. All kiln drying is best done after a preliminary period of air drying except for very fast drying woods where fast schedules can be used or for timbers which deteriorate if not kiln dried from green.

Very refractory woods may require careful air drying with end sealing and shading to prevent too rapid air drying and checking and splitting. The higher humidities in a solar kiln may often be less severe on the timber than air drying.

Advantages and Disadvantages of Solar Kilns

The advantages of solar kilns over conventional kilns are as follows:

- lower capital cost (by a factor of 5-10 for greenhouse types);
- lower running cost for power and labour;
- less skill required to operate them adequately;
- ease of construction and maintenance;
- continuous supervision not needed (no boiler man);
- high quality of drying because it is slow; and
- little maintenance required other than replacement of glazing material.

The disadvantages are:

- small capacity;
- slower drying (by a factor of 1.5-3 times depending on timber species and thickness);
- glazing materials have relatively short life (1 year in the tropics for horticultural polythene and 2-3 years for Melinex); and
- glazing materials are fragile although they can be repaired.

Different Designs of Solar Kilns

Solar kilns can be divided into the following three main design types:

- greenhouse kilns
- kilns with integral box collectors
- kilns with external collectors.

Greenhouse kilns

This is the simplest and cheapest type of kiln, where the kiln is a single structure containing the timber stack and heat absorbing surfaces in the same chamber. It can be single or double glazed. It has a size limit and unless very "stretched" beyond the dimensions of the stack alone, it is probably not efficient over a 12-15 m^3 capacity.

Kilns with integral box collectors

Box collectors, normally of prismatic shape with one side glazed, are more efficient than flat plate collectors if painted black on internal surfaces. A kiln built up of a series of boxes of this type can be built to dry efficiently 20-25 m^3 of timber at a time for a stack of 8-10 metres long. For longer stacks a greater volume is possible. The cost of this type of kiln is greater, but not very much greater, than for the greenhouse kiln.

External Collector Kilns

These kilns are less limited in size since efficient, well insulated external air or water filled collectors can be manufactured of any size and the hot air or water pumped into the kiln chamber, which is also efficiently insulated. These kilns are very much more costly, and they are more difficult to control and operate.

If solar kilns are to be widely accepted and used, the main constraints preventing the use of kilns need to be addressed. These constraints are:

- scarcity of necessary materials and spare parts; and
- insufficient knowledge of monitoring and control of kiln operation and measurement of moisture content of timber.

Principal materials for solar kilns

(a) Glazing materials for kilns:

- Melinex 071 or similar. "Tedlar" from Du Pont is a more durable but more costly alternative;

- Horticultural polythene for kilns using this as a glazing material;
- PVC repair tape.

(b) Motors, fans and switchgear:

- All fans are standard 24 inch fans with ¼ hp rated, single phase, high temperature wound motor.

(c) Kiln monitoring equipment:

- Single, small, thermostatically controlled electric ovens for oven-drying wood samples at just over 100°C;
- Simple scales for weighing wood;
- Moisture meters, preferably of a standard make which can be calibrated for local timbers;
- Simple wet and dry bulb thermometers for use in checking temperature and humidity in kilns and in wood stores and stacking sheds;
- Spare batteries and probes for moisture meters.

INSTRUCTIONS FOR OPERATING THE KILN

GENERAL

The kiln operates in a manner which is part way between the method of operation of conventional kilns and air drying. In the former both temperature and humidity are controlled and, within the limits of the controls, any combination of temperature and humidity is possible. In dehumidifier kilns control is mainly by humidity and the temperature is relatively low. With air drying both temperature and humidity are controlled by the weather and conditions are outside the control of the operator except that stack or shed orientation and protection of stacks from direct sun or rainfall by shed or stack roofs is possible; and sealing of timber and covering of ends of stacks are also possible to prevent too rapid drying and end cracking of the timber.

With solar drying it is not possible to control temperature other than by increasing the temperature over ambient outside temperature using the greenhouse effect of the kiln glazing. The temperature inside the kiln will be controlled by the amount of radiation falling on the kiln, by the temperature outside the kiln and by the general efficiency of the kiln in trapping the radiation and converting it to heat.

Unlike air drying, however, the kiln traps air and vents control the quantity of air allowed into and out of it. Humidity, therefore, is much more controllable than temperature and it is relative humidity which controls the final equilibrium moisture content of wood more then temperature.

The following table shows average equilibrium moisture content (e.m.c.) of wood at different temperatures and humidities:

Temperature	15°C	30°C	50°C
Relative humidities			
80%	18.25	16.80	15.25
60%	13.25	12.10	10.50
40%	9.50	8.50	7.25
20%	5.90	5.25	4.30

It is clear, therefore, that the relative humidity of the air passing over by the timber very largely controls the e.m.c. of the timber but in a closed kiln a rise in temperature will lower relative humidity and will at the same time speed up the attainment of the equilibrium moisture content by speeding up the rate of movement of water through the wood and its evaporation at the wood surface.

The ability in the solar kiln to control air exchange in the kiln by opening or closing vents, therefore, gives an ability to control humidity particularly since water is being removed continuously from the wood in the kiln is adding to the humidity in the kiln unless it is vented. The most important factor affecting wood drying is, therefore, to a large extent controllable by the vents: an appreciation of this fact is necessary in operating a solar kiln.

OPERATION OF VENTS IN CONTROL OF DRYING

Air flow of vents is controlled by air pressure inside and outside the kiln at each vent; air flow through the outlet vents varies considerably but is between 0.25 and 0.5 m/sec.

With an external humidity of 60% and 21°C temperature and an internal humidity of 60% and 32°C the net loss of water through the vents, if they are 5 cm open, is approximately 15-30 kilograms per 12 hour day assuming that fans are not operated at night and that water is not lost then. The actual quantity of water which needs to be removed per charge can be calculated and this degree of opening will allow adequate removal of water from slow drying dense woods. It would allow removal of water from the average charge of timber in about 40 days assuming there were no leaks in the structure and no loss by condensation.

In practice, however, water condenses at night on the outer cover of the kiln and drains to the floor. If this is then allowed to drain out through small perforations in the polythene floor a greater quantity of water can be removed in a given time; the water is removed in a low energy state as a liquid rather than as high energy vapour and the kiln acts as a partial dehumidifier.

At this degree of vent opening 112 - 225 m^3 of the air are vented per hour and since the kiln air volume is about 57 m^3 the air is changed from 2-4 times per hour with a considerable loss of heat in the process. <u>There is, therefore, every reason to remove water as far as possible by condensation rather than by venting.</u>

SCHEDULES FOR DIFFERENT TIMBERS

Selected examples of conventional kiln schedules in Annex 1 are taken from "The Kiln Operator's Handbook" by W C Stevens and G H Pratt to illustrate the operation of normal kilns. Fast drying woods are dried at faster, more severe schedules with higher temperatures and lower humidities than slow drying woods. Those liable to surface checking or warp require high humidities in the early stages of drying when the surface is drying and shrinking while the interior is still wet and swollen. To avoid case hardening it is important witn slow-drying woods to avoid low humidities.

With a solar kiln it is not possible to adhere to a strict schedule and the art in operating the kiln is to ensure that the kiln dries the timber as fast as possible with a minimum vent opening to prevent heat loss and reduction of humidity below an acceptable level. In all wood drying most water is lost in the early stages of drying as the easily removed surface water evaporates and the free water within the cell lumens moves to the wood surface. Later in drying the amount of water evaporating from the surface of the wood is reduced since the rate of movement through cell walls is limited.

With fast drying woods it is important to remove sufficient moisture in the early stages of drying and if the timber is green the vents need to be opened fully and then gradually closed as drying proceeds. It is probably more efficient to use the kiln to complete drying after a preliminary period of air drying for these timbers since air drying is almost as fast as the kiln above 30-40% mc. The kiln is designed to be easily moved from stack to stack and if two stack bases are built side by side one can be used for air drying under a stack cover while the other is used for kiln drying and then the kiln is moved to the partially air dried stack while a new stack is built and air dried on the first stack base.

Used in this way the kiln will probably dry one and a half times the quantity of timber it would dry if drying from green in the kiln.

Slow drying, difficult woods may not stand air drying under stack covers because of low humidities in the middle of the day particularly in dry climates, in tropical dry seasons or in temperate summers. It may, therefore, be necessary to dry these timbers from green in the kiln. This can be done without causing defects even at high temperatures for a solar kiln provided that humidities are kept high in the crucial period when the wood surface starts drying below 25-30% mc. With these woods the vents need to be kept well closed particularly in hot, dry weather; provided this is done, humidities will stay high enough. Measurements of humidity show that relative humidity drops in the middle of the day but rises again at night, particularly if fans are switched off so that the wood surface has a partial reconditioning every night. This relieves surface stresses in the wood and gives good quality drying of even the most difficult woods.

Later in the drying of both fast and slow drying woods it is possible to keep vents only slightly opened because less water is being removed from the wood surface and the temperature is required to move the water more rapidly through the wood.

CONTROL OF FANS

There is little benefit to be gained from running fans at night except with charges of fast drying woods when they have high moisture contents and humidities are very high in the kiln. If humidities are over 89-90% during the day it is probably advisable to keep fans going at night, particularly if mould or blue stain start forming on the wood. With slow drying woods and drier charges of fast drying woods fans should be switched off about an hour before sunset and on an hour after sunrise.

MONITORING OF KILN PERFORMANCE

Periodic measurements of air temperature and humidity inside the kiln, and preferably also outside the kiln, plus measurements of wood moisture content are necessary to check kiln performance.

Measurements of temperatures and humidities at 8 am, noon and 4 pm are desirable, but not essential, while periodic moisture content measurements are essential.

TEMPERATURE AND HUMIDITY MEASUREMENTS

Temperature and humidity measurements can be made using a single wet and dry bulb thermometer or a whirling hygrometer which should be swung for at least a minute before readings are taken. Wet and dry bulb chart recorders are expensive but give a continuous record of temperature and humidity.

MOISTURE CONTENTS OF THE WOOD

Moisture contents of the wood can be measured either by the oven drying and weighing method described in any text book on kiln drying or by moisture meter. Most moisture meters use an electrical resistance method which is accurate up to 30-40% mc but inaccurate at higher moisture contents; a few have scales which measure higher moisture contents more accurately.

KILN RECORDS

Annex 2 gives methods of keeping records and forms on which they can be kept and it is suggested that they are kept in full at least until the drying characteristics of the timbers and different thicknesses of them are well known. It is always essential to keep records of timber moisture content in order to know when drying is complete.

KILN SCHEDULE A

Suitable for timbers which must not darken in drying and for those which have a pronounced tendency to warp but are not particularly liable to check.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	95	35	87	30.5	70
60	95	35	83	28.5	60
40	100	38	84	29	50
30	110	43.5	88	31.5	40
20	120	48.5	92	34	35
15	140	60	1C5	40.5	30

Annex 1

KILN SCHEDULE B

Suitable for timbers that are very prone to check.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	105	40.5	101	38	85
40	105	40.5	99	37	80
30	110	43.5	102	39	75
25	115	46	105	40.5	70
20	130	54.5	115	46	60
15	140	60	118	47.5	50

SOLAR KILN RECORDS

These are designed to record the performance of the kiln in relation to the climatic variations and the type and dimensions of timber being dried in it.

There are three record sheets, one recording the temperature and humidity inside and outside the kiln, one recording the moisture content of the wood in the kiln, and one recording seasoning quality. They should be completed as follows:

FORM 1 Temperature and humidity measurement sheet

Form 1a is for use where a wet and dry bulb chart recorder is used inside the kiln and a whirling hygrometer outside and Form 1B is for use where the whirling hygrometer or wet and dry bulb thermometer are used for both inside and outside measurements.

In Form 1A wet and dry bulb readings are read off the charts and the temperature and the time of day at which it occurred are recorded for each day. The whirling hygrometer readings are taken at 8 am, noon, and 4 pm or as near as possible to these times. The times must be the same each day.

It is desirable to make the recordings every day but if recordings with the whirling hygrometer are not possible at weekends, they can be omitted.

FORM 2 <u>Timber moisture content measurement sheet</u>

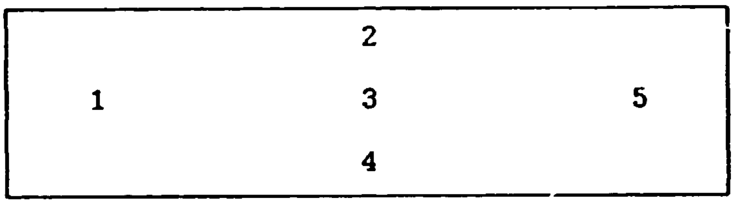
Here measurements should be made every 3-5 days (avoiding weekends). With fast drying woods of small thickness drying is faster and measurements should be more frequent than with slower drying thicker timber.

The initial moisture measurement should be made by taking at least 5 samples, weighing, oven-drying and re-weighing to give the moisture content percentage (MC %).

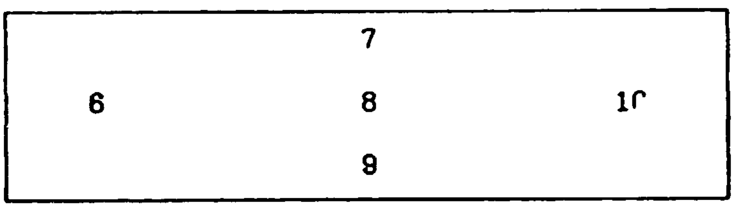
$$MC\ \% = \frac{\text{green weight - oven dry weight}}{\text{oven dry weight}} \times 100$$

After the moisture content measurement other measurements should be made with an electrical moisture meter. The measurements should be made at five points at each side of the kiln stack as shown in the following diagrams.

<u>Facing stack from the fan side</u>



<u>Facing stack from the rear side</u>



<u>Note</u>: 6 will be the other side of the stack from 5; 10 & 1, 2 & 7, 3 & 8, and 4 & 9 are opposite each other.

The points should be 1 board from top or bottom of the stack for 2, 4, 7 & 9 and in the centre of the side and in the centre of the side of the stack for 3 & 8. Points 1, 5, 6 & 10 should be just over 30 cm from the end of the board and 1, 3 & 5 and 6, 8 & 10 should be located in different pieces of timber.

Each measurement should be marked on the wood with its number using pencil or felt pen.

If measurement is made using a moisture meter with a hammer electrode with long probes and an electrode with short probes, the internal and external moisture contents of the wood can be measured as follows:

Knock the long probes into the wood at the positions marked using the hammer electrode (without screwing the probes to the electrode) for 2½ cm. They should both be knocked into the centre of the edge of the piece of timber so as to measure as far as possible the moisture content of the wood in the middle of the piece of wood, one inch from the edge. The probes should be left in that position until the timber is dry when they should be carefully removed using pincers, damaging the insulation on their surface as little as possible. Remeasurement is made by tapping the electrode gently onto these probes, making sure that there is good electrical contact (possibly even with rusty probes) and taking a reading.

Surface moisture content readings can be made using the short probes which are pushed into the wood near the long probes every time a measurement is made.

Short and long probe measurements are then recorded on Form 2 under position and S or L.

In this way gradients of moisture content between the inside and outside of the wood can be determined at different times during the drying period.

FORM 3 <u>Seasoning quality record</u>

Where possible, this should be completed by a trained grader. Defects are divided into five categories and after examination of all pieces in the kiln charge, the grader should tick the appropriate category column against each defect. Definition of category of defect can vary according to timber dimensions and the general drying properties of woods. The grader should judge whether the defect is small or large for the particular species and timber dimensions and mark accordingly. No attempt, therefore, is made here to define categories for each defect. At the bottom of the form, however, space is given to put in an average timber grade for the charge.

Case hardening should be measured using the prong test described in most books on wood seasoning.

Annex 2

FORM 1A **Temperature & Humidity Measurement Sheet**
(Daily measurements)

Species __________ Charge No. ______ Timber thickness ______

Date	Inside kiln				Outside kiln						Remarks
	Dry bulb		Wet bulb		8.00		Noon		4 pm		
	Max+ Time	Min+ Time	Max+ Time	Min+ Time	Dry	Wet	Dry	Wet	Dry	Wet	

Annex 2

FORM 1B **Temperature & Humidity Measurement Form**
(Daily measurements)

Species __________ Charge No. ______ Timber thickness ______

Date	Inside kiln						Outside kiln						Remarks
	8.00		Noon		4 pm		8.00		Noon		4 pm		
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	

Annex 2

FORM 2

<u>Timber Moisture Content</u>
(Measurement every 3-5 days)
<u>Measurement Sheet</u>

Species __________ Charge No. ______ Timber thickness ______

Initial Moisture Content (by oven drying) ________

Date	Position	1		2		3		4		5		6		7		8		9		10		Note
	Moisture Content %	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	

Annex 2

FORM 3 **Seasoning Quality Record**

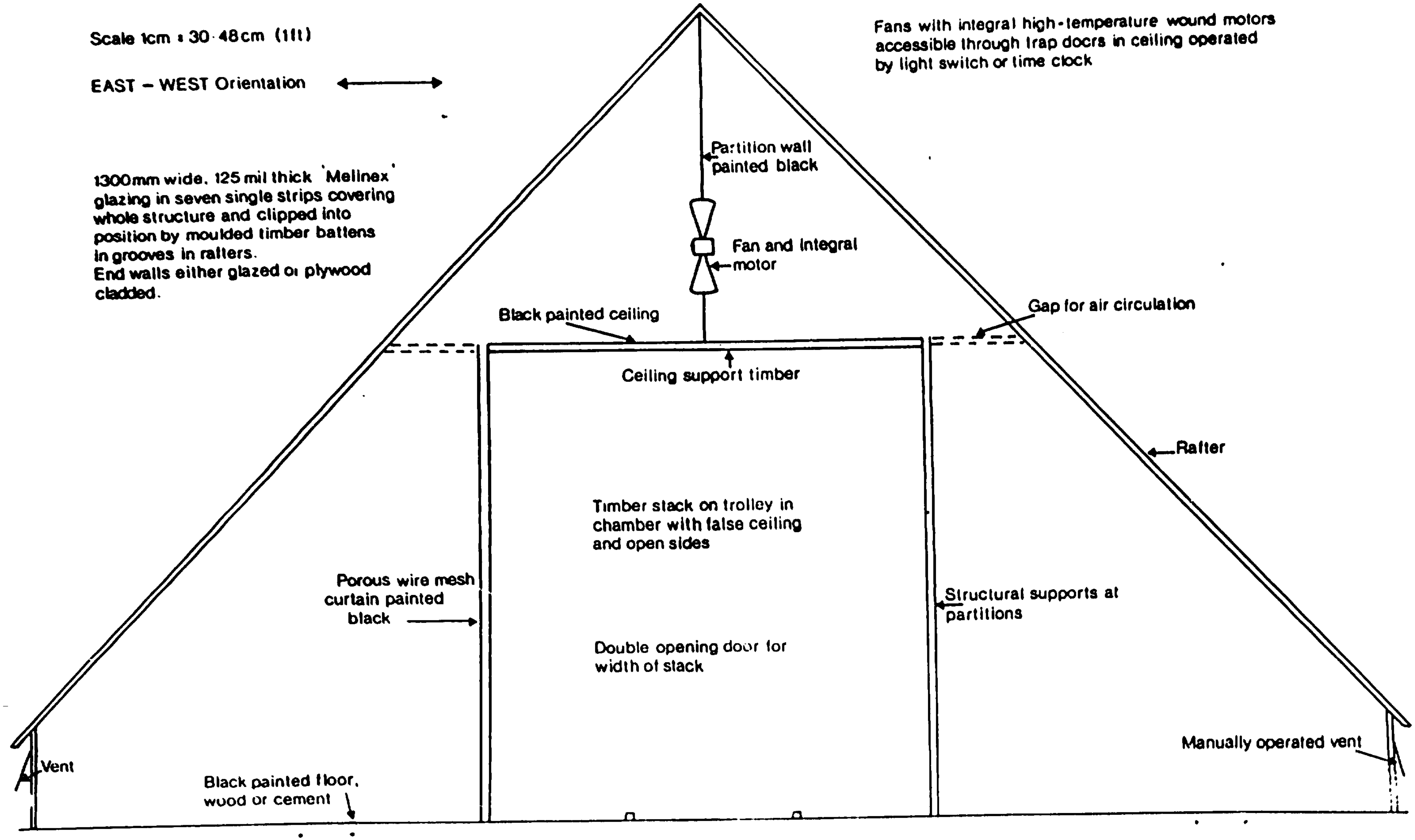
Species __________ Charge No. _______ Thickness __________

Defect	Quality Category					Remarks
	1	2	3	4	5	
Surface Checks						
End Split						
Bow						
Spring						
Cup						
Twist/Warp						
Collapse						
Case Hardening						
Blue Stain						
Mould or Other Stain						

Note: Category

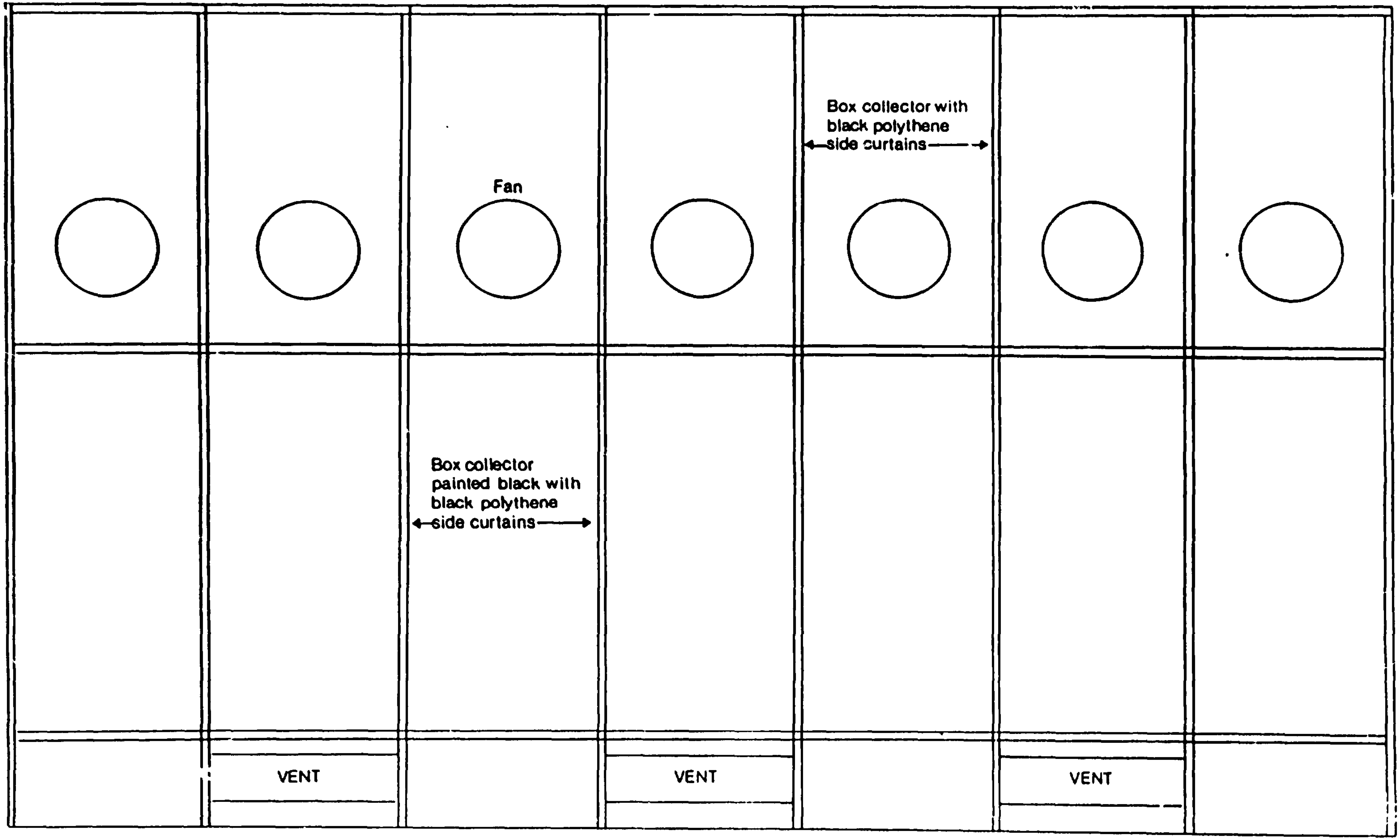
1 = Very slight or no defect
2 = Slight
3 = Moderate
4 = Severe
5 = Very severe

END VIEW OF PROPOSED NEW KILN



SIDE VIEW OF PROPOSED NEW KILN

Scale 1cm = 30·48cm (1ft)



DE-TOXIFICATION OF CASTOR BEAN MEAL

UNIDO has developed, within the framework of project US/GLO/77/033, a new technology for de-allergenization of castor bean meal.

The introduction of this new technology would greatly improve the economics of castor bean processing as at present the meal (or pomace) can only be sold at low prices as a fertilizer.

Complete details of the technology for production of non-toxic castor bean meal free of allergen are available from the UNIDO Secretariat.

INTRODUCTION

Because of its high and unique oil content, castorseed (*Ricinus communis* L.) has a variety of potential uses. The residue of an oilseed after the oil has been expelled is called pomace or meal. Economics of most oilseed processing plants are therefore based on two valuable major products, oil and meal. However, contrary to high usefulness of castor oil, castor meal at best can only be used as a fertilizer, far below its potential value as a source of feed protein and carbohydrate, because of several harmful substances it contains. This fact affects industrial castorseed processing economy very unfavourably.

A poisonous heat-labile protein called ricin, a toxic alkaloid component called ricinine, and a powerful and very stable allergen known as CB-1A (Gardner et al., 1960) are the risks of major concern in castorseed industry. Ricin is easily destroyed by heat and is even usually detoxified during desolventization. The amount of ricinine in castorseed is very small relative to toxicity and it presents no particular problem for feed uses as long as moderate levels are fed (Mottola et al., 1968). However, the principal castorseed allergen retains its immune precipitating and allergenic properties even after heating for 1 hour at 110°C at pH 5.9.

The allergen content of several varieties of castor meals ranged 6.1-9.0%, while commercial castor meals contained 0.092-4.2%, equivalent to about 1 to 55% of the allergen content of solvent extracted raw seeds (Coulson et al., 1960). It indicates the effectiveness of industrial processing in reducing the potency of allergen by modern milling practices. But, the sure way to effectively control the allergen problem is the development and implementation of a practical detoxification and deallergenation technology available for industrial application.

The previously reported trials to destroy allergen by chemical and/or physical methods indicated that reactions were too drastic to destroy not only the target material, castor seed allergen, but also the essential amino acids needed for animals. Furthermore, no practical scaled-up evaluation of the experimental treatments and measuring the nutritive value and acceptability of products as animal feeds have been undertaken.

A technologically and economically sound detoxification and deallergenation method, when appropriately applied, will substantially increase the commercial value of castor meal by permitting it to be traded as a protein feed ingredient instead of only as a cheap fertilizer as at present. To achieve this goal, it will be necessary to carry out in-depth biochemical evaluation of the treatment as well as a thorough safety, acceptability and nutritional evaluation of the final product through feeding tests of several species of animals.

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CONCLUSIONS

Based on the research work made, the following conclusions are made:

1. Ricin is completely destroyed during pre-pressing of castor seeds and/or desolventization of solvent extracted meals.

2. The hemagglutinin reaction technique is relatively simple, sensitive, and reproducible to be adapted as a routine analytical tool for ricin toxicity testing. Toxicity of ricin and other toxic substances was determined by the red blood cell agglutination test.

The procedure of Gardner et al. (1960) was slightly modified to prepare the red blood cell corpuscle and sample extracts to carry out the hemagglutinin test. The steps involved in the preparation of red blood corpuscle are shown in Figure 1.

Citrated whole human blood

↓

Centrifugation (650 x g, 5 min.)

↓ → Plasma (discard)

Supernatant

↓

Washing with 0.85% saline solution

↓

Centrifugation (650 x g, 5 min.)

↓ → Supernatant (discard)

Precipitate

↓

Repeat centrifugation (650 x g, 5 min.) three times with a 0.85% saline solution

↓

Dilution to 10 times its volume with 0.85% saline solution

↓

Store under refrigeration until used

Figure 1. Preparation of red blood cell corpuscle for use in ricin agglutination test.

For the ricin agglutination test, ten test tubes were placed in a rack and 0.9 ml of saline solution was pipetted into the first tube and 0.5 ml each in subsequent tubes. To the first tube was added 0.1 ml meal extract, and the contents mixed using a Vortex mixer. One half (0.5) of this mixture was transferred to the second tube and the contents mixed. The same procedure was then repeated down the line so that all ten tubes were prepared. The dilutions of meal extract in the tubes were thus 1:10, 1:20, 1:40 and so on. Then, 0.5 ml of red blood corpuscle solution was added to each tube and mixed vigorously. The contents of the tubes were centrifuged at 500 x g for 2 minutes, and the appearance and characteristics of the red blood agglutination were observed after shaking the tube gently. The following ratings were then made:

+4: Complete agglutination with no dispersion by gentle shaking.

+3: Complete agglutination with some breaking up by gentle shaking.

+2: Agglutination, but complete breaking up of blood in the agglutinated particles.

+1: Agglutination, but easily dispersed to visible agglutinated particles.

The highest dilution showing +1 rating was defined as the "titre". The value of the titre represents the amount of ricin present in the sample extract. The procedures used for ricin agglutination test are summarized in Figure 2.

0.5 g castor meal + 24.5 ml physiological saline solution

↓ 20 mg/ml concentration

Mixing and stirring for 1 hr

↓

Filtering with Whatman No. 3 filter paper

↓

Sequential dilution

↓ 0.1 ml solution + 0.9 ml saline (A)
0.5 ml A + 0.5 ml saline (B)
0.5 ml B + 0.5 ml saline (C)

continue dilution up to 10th tube

Addition of 0.5 ml red blood corpuscle solution

↓

Mixing and standing for 5 min

↓

Centrifugation (480 x g, 2 min.)

↓

Shake tubes gently
Rate the extent of agglutination

Figure 2. Procedures used for ricin agglutination test.

3. Sodium hydroxide-sodium hypochlorite mixture, calcium hydroxide, sodium bicarbonate, sodium hydroxide, and sodium hypochlorite, in the order of preference, are very effective in destroying CB-1A when used in combination with proper heat treatment. However, chemical treatment alone is not as effective in destroying CB-1A.

4. A significant amount, as much as 90% of the residual CB-1A, is destroyed at total chemical concentrations of 1.5%. At 2.0% level, the destruction is almost complete (more than 98%).

5. Extruders are very effective high temperature-short time chemical reactors for destruction of CB-1A if used with proper chemicals. Extrusion alone, however, is not as effective for CB-1A destruction

6. To be effective, the extrusion temperature should reach at least 130°C, and preferably around 150°C.

7. proper mixing of chemicals with the meal is of paramount importance for effective destruction of CB-1A.

8. Extrusion processing of chemically treated castor meal is readily adaptable for scaled-up commercial production of detoxified and deallergenated castor meal as demonstrated by Wenger X-20, X-25, and X-200 runs.

9. The detoxified and deallergenated castor meal is safe for use as animal feeds as demonstrated by chick and swine feeding studies.

10. Both the immunodiffusion technique and the dilution technique in conjunction with the immunodiffusion technique are somewhat time-consuming, but these methods are extremely sensitive, specific, and reproducible for qualitative and quantitative determinations of CB-1A, respectively, to be used as standard quality control methods.

Qualitative Determination

Allergenic effects of castor seed products were determined quantitatively using the immunodiffusion technique of Ouchterlony (1968) with several modifications as described in Figures 3 and 4. Water extracts of castor seed products which contain crude CB-1A antigen were prepared routinely according to the procedure shown in Figure 5. For the qualitative analysis of allergen, the antigen extract was directly applied into peripheral wells against antibody in the center well (Figure 4).

4.5 g Agar or agarose and 4.25 g sodium chloride
in 1,000 ml deionized water

↓

Heat in 100°C water bath for 20 min. or more

↓

Pour 10 ml melted agar onto 3.5" dia disposable Petri-dish

↓

Perforate the solidified agar with a 4 mm dia gel puncher
to make 6, 6-7 well sets (Figure B) per Petri-dish

↓

Apply samples (12 μl each) and antibody (12 μl)

↓

Place in refrigerator for 8-10 hours until immunodiffusion
lines appear most clearly before smearing occurs

Figure 3. Procedures used for double immunodiffusion method.

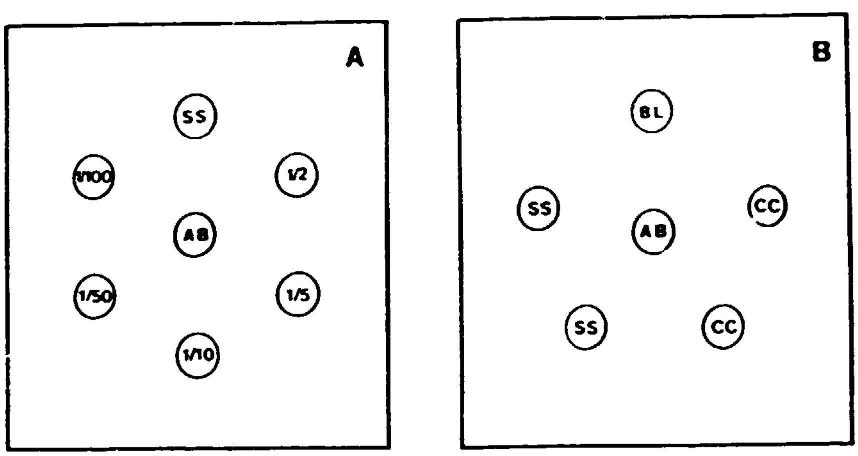


Figure 4. Sample illustration of wells perforated for double immunodiffusion (B) and dilution technique with double immunodiffusion (A). SS: sample, AB: antibody, BL: blank, CC: control, ½ - 1/100: dilution factor.

20 g ground castor sample
(size less than 25 mesh)

↓

Add 50 ml, 0.85% saline solution

↓

Shake overnight (approximately 15 hr) at 250 rpm
in a 250 ml Erlenmeyer flask at room temperature

↓

Filter through Millipore
(pore size 25 μm)

↓

Crude CB-1A antigen

↓

Stored refrigerated or frozen
for immunodiffusion test

Figure 5. Preparation of CB-1A antigen for use in double immunodiffusion test.

The formation of one or more precipitin lines between center well (antibody) and the peripheral wells (antigen) was interpreted as the presence of allergenic antigen while the absence of precipitin lines was interpreted as the absence of the antigen, CB-1A. The minimum level of antigen needed to form detectable precipitin lines by naked eyes is not known at this time.

Quantitative Determination

For the quantitative estimation of the allergen, a dilution technique was applied to the double immunodiffusion method. The original or known amount of CB-1A solution was normally diluted to 1/2, 1/5, 1/10, 1/50, and 1/100 ratios. The peripheral wells were then filled with these diluted CB-1A solutions along with the unknown sample as demonstrated previously in Figure 5. After development of the precipitin lines between the antibody (center well) and the surrounding antigenes (peripheral wells), the dilution which showed the most closely matching precipitin line intensity with that of the unknown sample was used to estimate the relative amount of antigen present in the unknown sample.

11. The rocket immunoelectrophoresis can determine the amount of CB-1A very accurately, but it is very difficult and time-consuming to master the technique for use in routine assays. The method described by Axelsen and Svendsen (1973) was followed. The step-by-step procedures are summarized in Figure 6.

12. The low PER (Protein Efficiency Ratio) values obtained from rat feeding studies indicate that the treated castor meal may not be used as the sole source of dietary proteins for animals.

Three Agarose Immunoelectrophoresis Tablets
in 15 ml deionized water

| (1% Agarose concentration)
v

Heat in a 100°C water bath for 20 min. or more

|
v

Cool to 55°C

|
v

Add 0.3 ml antiserum and mix gently
to prevent air bubble formation

|
v

Cast on a 10 cm x 10cm glass plate
and allow to solidify

|
v

Punch 4 mm sample wells, spacing 5 mm apart
and 10 mm from the edge of the plate

|
v

Place in an Electrophoresis Cell and connect the gel
with buffer (IEP Buffer IV, Monthony, pH 8.6)
using an Ultra Wick

|
v

Apply 0.01 ml sample in each well

|
v

Develop at 10 mA until tracking dye,
bromophenol blue touches anode

|
v

Staining (coomassie brilliant blue) and
de-staining (methyl alcohol:H_2O:acetic acid=5:5:1)

|
v

Dry at room temperature for 1 day

|
v

Measure the peak height

Figure 6. Procedure used for rocket immunoelectrophoresis

RECOMMENDATIONS

The experimental results thus far obtained strongly suggest that the technology for commercial production of detoxified and deallergenated castor meal for use in animal feed is now available for implementation. The castor bean industry is therefore advised to consider the following recommendations to implement the new technology with UNIDO assistance.

1. Analyze the economics of implementing this new technology for the existing castor bean processing facilities under prevailing conditions on a case-by-case basis.

2. Determine the market potential for the new product.

3. Set up demonstration and/or production plants using the new technology at current castor seed processing facilities.

POLY-FUNCTIONAL PILOT-SCALE LABORATORY FOR PLANT EXTRACTION

The importance of medicinal plants as a source of drugs and therapeutic agents in contributing to the health care programmes and economies of developing as well as developed countries is well established. Medicinal plants are utilized in three main ways: (a) they can be used unmodified as therapeutic agents; (b) they provide natural products for direct use or for the partial synthesis of drugs; and (c) they provide molecular models used by scientists to synthesize new drugs.

In order to improve the economics of the sub-sector, there is a need to up-grade cultivation techniques and improve production technologies of pharmaceuticals derived from plants. The operations for the attainment of such developments are:

(a) Agronomic activities relating to the improvement of the percentage yield of the required active principles within the plant itself, i.e. genetic improvement;

(b) Technological activities, which are primarily directed towards generating technologies appropriate for the processing of each plant species. Considerable research and development efforts go into these activities. The process of extraction, isolation, formulation and, where relevant, synthetic manipulation becomes the acquired knowledge and property of the technology holder who has carried out such development efforts;

(c) Chemical activities pertaining to the isolation and characterization of the chemical structure of the individual phytochemical constituents of the plant. They also include the development of quality control methods and the chemical modification of structures so as to obtain the desired biological effects. These chemical activities are characteristic of the established approach to industrial drug development; and

(d) Biological activities covering the main operations designed to ensure the safety and efficacy of drug preparation, including toxicological testing etc. to meet pharmaceutical regulatory requirements.

In order to improve the supply of medicinal plants as raw materials or as processed products, guidelines have been prepared by the United Nations Industrial Development Organization (UNIDO) with the aim of assisting developing countries in this regard.

Keeping in view the significant role of medicinal plants and the important areas of activities related to their utilization, there is an urgent need for developing countries to begin generating some of the needed technologies themselves. For the promotion of industrial utilization of medicinal plants, UNIDO is focusing its attention on the following main areas:

(a) Technology for the genetic improvement of medicinal plants;

(b) Factory-produced herbal medicine;

(c) Process technology development and product standardization.

A. Technology for genetic improvement of medicinal plants

There is a general need to transform the practice of collecting wildly grown plants into a standard method of cultivation of medicinal plants in order to stabilize supply, maximize effective chemical contents and improve returns in developing countries embarking on the cultivation of these plants with a view to industrial processing. This calls for a concerted effort in improving knowledge about natural occurrences of medicinal plant species, their physical and chemical properties, agro-techniques concerning their cultivation and the genetic improvement of plant species through the use of conventional as well as new techniques. It also entails: the analysis of factors having a bearing on the choice of medicinal plants for genetic improvement; the improvement of selected medicinal plant species at national and regional levels; the collection, maintenance and long-term preservation of the genetic diversity of medicinal plants; selection; and the conventional breeding of priority plant species. Work should cover such techniques as: mutation and ploidy breeding; in-vitro culture techniques and the micropropagation of genetically improved medicinal plants; and protoplast fusion and recombinant DNA transfer techniques for the genetic improvement of medicinal plants.

B. Factory-produced herbal medicine

Properly promoted, a modern industry could emerge that is based on sound scientific principles and adapted for use in developing countries. In Asia, Africa and Latin America successful methodologies have been developed to utilize modern science and technology in the improvement of traditional pharmacopoeial preparations.

UNIDO has acquired extensive experience in technical co-operation with developing countries in the industrial utilization of medicinal plants. From this experience, the following criteria appear to be most crucial to the success of technology transfer in this field:

(a) Social acceptance of traditional therapies;

(b) Political will to utilize and improve these therapies using the techniques of modern science;

(c) The availability of an appropriate infrastructure: scientific research personnel, technicians, artisans, farm managers, agro-techniques, etc.;

(d) A nucleus of committed multi-disciplinary goal-oriented development personnel to commence activities;

(e) Concepts and initiatives in marketing new products both locally and outside the country;

(f) The potential for entrepreneurship.

C. Process technology development and product standardization

As a result of a considerable amount of research, a versatile poly-functional pilot-scale laboratory for plant extraction has been designed. This will enable developing countries to have access to suitable pilot-scale facilities for technology adaptation and development as well as product development.

The pilot-scale laboratory is equipped to carry out experiments on an intermediate scale, between that of a research laboratory and an industrial plant. The information and data obtained from such a laboratory can be applied to scale up a process and thus allow the undertaking of preliminary studies for the full industrialization of such a process. Furthermore, it is possible to adapt a pilot-scale laboratory for the production of small quantities of materials needed for sampling or to study the pharmacokinetics and chemistry of active compounds isolated in order to evaluate their properties. The poly-functional laboratory is designed and equipped to carry out a variety of operations, such as drying, crushing, solid-liquid extraction, liquid-liquid extraction, evaporation, chromatography, crystallization, etc.

The size of the apparatus installed will be calculated according to extent of use by the team of operators in order that the initial investment is recuperated with the least possible delay.

As opposed to a production unit, the direct aim of the poly-functional laboratory is not profitability, but the optimization of tests which will allow the selection of the best methodology and the most appropriate operating mode. An important role in the development of new products is also envisaged.

The cost of a pilot-scale laboratory such as the one described here, is in the order of 2 million US dollars. This figure is indicative and can vary greatly depending on the country of implementation.

The various types of industry with which such a laboratory might collaborate include:

- pharmaceuticals & bioactives
- essential oils & oleoresins
- pigments
- fixed oils
- tannins
- gums
- natural sweeteners
- pest repellents/pesticides

Premises

The area required for the installation of the poly-functional laboratory is about 700 m², ideally in an area with established infrastructure. The premises should consist of two separate buildings: the main construction (approx. 600 m²) and an annex of about 100 m^2, located at an appropriate distance from the main building in a secure area. The annex is for the storage of solvents and flammable substances.

The main building should contain an area with a high ceiling (8 m) that allows for the installation of tall apparatus, such as distilling columns, etc. It should also include an area destined for explosion-proof work. The building should provide for the following.

1) Technical premises:

   a) Steam generator
   b) Cooling system
   c) Compressed air generator
   d) Vacuum installation
   e) Electrical installation

2) Plant storage and crushing
3) Laboratory
4) Offices
5) Cold room
6) Mechanical workshop
7) Drying installation
8) Poly-functional premises
9) Washing facilities
10) Bathroom installations

1) Technical premises

The area of the technical premises will depend on the size of the equipment to be installed. Sufficient room should be allowed around the equipment to provide easy movement. Furthermore, the possible future installation of more equipment should be kept in mind. The technical premises should be both thermally and acoustically isolated from the rest of the building so as not to disturb work taking place in other areas of the building. The area should have direct outside access to avoid having to go through the rest of the building.

2) Plant storage and crushing (≈100 m^2)

The site provided for plant storage and crushing needs to be dry and have heating facilities. It needs to be equipped with shelves and cupboards for the storage of sacks containing dried plants. The crushers, a scale and an efficient ventilation system for the aspiration and removal of dust particles should be installed in a separate area. Facilities for the storage of botanical samples should also be included in this area.

3) Laboratory (≈25 m^2)

Before undertaking a pilot-scale extraction of raw materials, it is necessary to carry out a small-scale extraction of 10-100 g in the laboratory. Also, it is often in the laboratory that the final purification of products obtained from the pilot plant takes place.

4) Offices (≈25 m^2)

An office area with two rooms, one for the manager and one for the secretary, is foreseen.

5) Cold room (≈10 m^2)

This consists of a room equipped with shelves, designed for the storage of products at +4°C.

6) Mechanical workshop (≈25 m^2)

The workshop is equipped with a workbench and a set of electro-mechanical tools for the maintenance of the installations.

7) Drying installation

This consists of a room equipped with dryers for both plants and finished products.

8) Poly-functional premises

This is for storage and use of equipment not protected against explosions and is located some distance from the main working area.

9) Washing facilities

For the maintenance, washing and drying of laboratory glassware and other equipment.

10) Bathroom installations

Toilets, showers and washbasins.

EXPLOSION-PROOF PREMISES

Extraction site

The lay-out of this area is of great importance. It needs to be equipped with the following:

- Hot and cold water
- Deionized water
- Waste outlet
- Glycol/water circuit operating at -15°C
- Steam line at 3.5 bars
- Low pressure steam line
- Compressed air at 6 bars
- Vacuum installation
- Inert gas line
- Electrical power
  - 380 V three-phase
  - 220 V monophase

The above installations must skirt around the room. Outlets every 3 m will ensure easy connection of equipment. Mounting the equipment on wheels or on carts will add to the flexibility of the laboratory.

The installations should be built from reinforced concrete. In case of explosion, the building's light roof should blow out first. Several emergency exits are required and the electrical installations must be explosion proof. Battery-powered lights must be located at the exits and suitable ventilation must be provided in the work area. Air conditioning must be adapted to prevailing conditions.

The extraction area will have a central gutter and a waste outlet connected to a waste water processing plant.

PERSONNEL

The operation of the pilot-scale laboratory is supervised by an 8- or 10-man team consisting of engineers, technicians, lab assistants, an electro-mechanical engineer and a cleaner. Particular care must be given to training the employees, who must be capable of ensuring both the operation and maintenance of the installations.

EQUIPMENT

For a list of required equipment for the pilot-scale laboratory, please see Annex 1.

APPARATUS REQUIRED TO EQUIP A PILOT-SCALE LABORATORY

TECHNICAL PREMISES

Steam generation: 250 kg/h of steam at 4 bars. The generator should be supplied with soft water.

Refrigeration: Refrigeration unit operating with glycol/water, equipped with air condenser. For the supply of glycol/water at -15°C, 45,000 Fg/h at 24 kW are required. External 100,000 kCal/h air condenser.

Vacuum installation: Vacuum provided by liquid ring vacuum pumps, one at 100 m^3/h and two at 25 m^3/h.

Electrical installation: One 315 oil transformer. Primary voltage 15,000/20,000, adjustable to 2.5%, equipped with normal accessories.

PLANT STORAGE AND CRUSHING

- Stainless steel crusher with sieve, equipped with 2.2 kW three-phase 220/380 V 50 Hz motor. Auxiliary motor to operate the oscillating shovel of the feeding apparatus. The whole is mounted on a metal frame.

- All steel box balance with simple pendulum mechanism on a steel axis. Range 5 - 60 kg, graduated in 100 g increments.

- All steel balance, placed on the floor, with simple pendulum mechanism on a steel axis. Max. load 200 kg, graduated in 200 g increments.

- Industrial type vacuum cleaner for dust removal.

- Shelves and cupboards.

OFFICES

- Office furniture and accessories.

COLD ROOM

- Refrigeration unit.

- Shelves.

DRYING INSTALLATION (for plants and finished products)

- Lyophilizer with trap capacity of 15 kg ice/24 h. Cooling power 4,500 Fg/h. Two-stage vacuum pump for 35 m^3/h capacity.

- Stainless steel mobile atomizer. Evaporation capacity: 1 to 6 kg water/h. Maximum inlet temperature 350°C; outlet temperature 120°C.

- Stainless steel-cased ventilated oven. Power 2,000 W/220 V

- Stainless steel vacuum oven, heated by automatic circulation (thermosiphon).

WASHING FACILITIES

- Washing machine for laboratory glassware.

- Double sink units equipped with hot, cold and deionized water.

LABORATORY

- Laboratory glassware, reagents, magnetic stirrers, rotary evaporators, chromatography columns, fraction collectors, thin-layer chromatography, melting point apparatus, stirrers powered by electric motors and compressed air, UV lamp, efficient hood, laboratory furniture, water baths, precision balance, pH meter, small laboratory equipment.

EXTRACTION PREMISES

Solid-liquid extraction

- Stainless steel powder mixer with lid. Nominal capacity of 20 l, equipped with explosion-proof motor, chain and sprocket wheel drive, standard joints.

- Stainless steel conical percolator, 80 l capacity, equipped with lid and drain tap.

- 2 stainless steel Soxhlet type extractors, 20 l capacity, steam heated, with accessories for solvent evaporation.

- Stainless steel floating-filter extractors, 150 l capacity, equipped with explosion-proof motor and accessories for use in steam distillation, extraction by hot or cold maceration, extraction under reflux and distillation.

- Stainless steel EF 2 extractors, 300 l capacity, which can be used for maceration, percolation, vacuum drying, filtration under pressure, reflux and solvent recovery.

- All glass solid-liquid extraction apparatus consisting of the following:

  - 150 l evaporating flask
  - DN 150 heat exchanger
  - DN 200 column
  - DN 200 condenser
  - 30 l extraction vessel
  - 2 glass Soxhlet extractors, 20 l capacity, each equipped with one 20 l flask, one heat exchanger immersed in the 20 l flask, one condenser and one DN 150 Soxhlet.

Liquid-liquid extraction

- Liquid-liquid extraction apparatus consisting of the following:
  - 2 centrifugal separators
  - 1 separator
  - 1 mixer

The whole installation is equipped with explosion-proof motors.

- Liquid-liquid extraction apparatus of glass:

  - two 50 l feed vessels
  - two dosage pumps
  - two 50 l receiving flasks
  - one DN 80 extraction column
  - mobile glass tanks
  - cylindrical reactor vessels equipped with stainless steel frames, with 30, 50, 100, 150 and 200 l capacities.

- DYNAVAR O type motor/agitator with a three-phase explosion-proof motor, 1.1 kW at 1,500 rpm, equipped with speed regulator and support column.

- Type 316 stainless steel vessels and tanks in the following sizes: 5, 10, 20, 40, 80, 150, 300 and 500 litres.

- Super-D canter SDC P 600 made of type 316 stainless steel, equipped with vibration proof chassis and supports; 5.5 kW three-phase motor.

- Stainless steel AS 16 super-centrifuge equipped with dosage head or separator, 3 kW three-phase motor.

Distillation and evaporation

- Distillation column and 50 l glass vessel equipped as follows:

  - one 50 l evaporating vessel
  - two DN 150 heat exchanger
  - one 50 l reaction vessel equipped with juice pump
  - one DN 200 column
  - one pneumatic timer
  - one DN 200 condenser
  - 1 trap, 1 cooler, and 5 and 50 l receiving flasks
  - automatic circulation (thermosiphon) glass extractor for 20 l flask, equipped with a 20 l flask, DN 150 heat exchanger, a DN 100 column, two 20 l receiving flasks and a trap
  - DN 150 thin film evaporator equipped with a dosage pump and 5 and 10 litre receiving flasks
  - 1 steam-heated 20 l rotary evaporator

Chromatography

- Glass column chromatography apparatus equipped with a) 200 l reaction vessel, and b) DN 100 chromatography columns

- Modulprep HPLC stainless steel chromatography columns, with diameters of 20, 40 and 80 mm, equipped with a pump, a control unit, refractometer, UV spectrophotometer, recording device and fraction collector.

Miscellaneous equipment

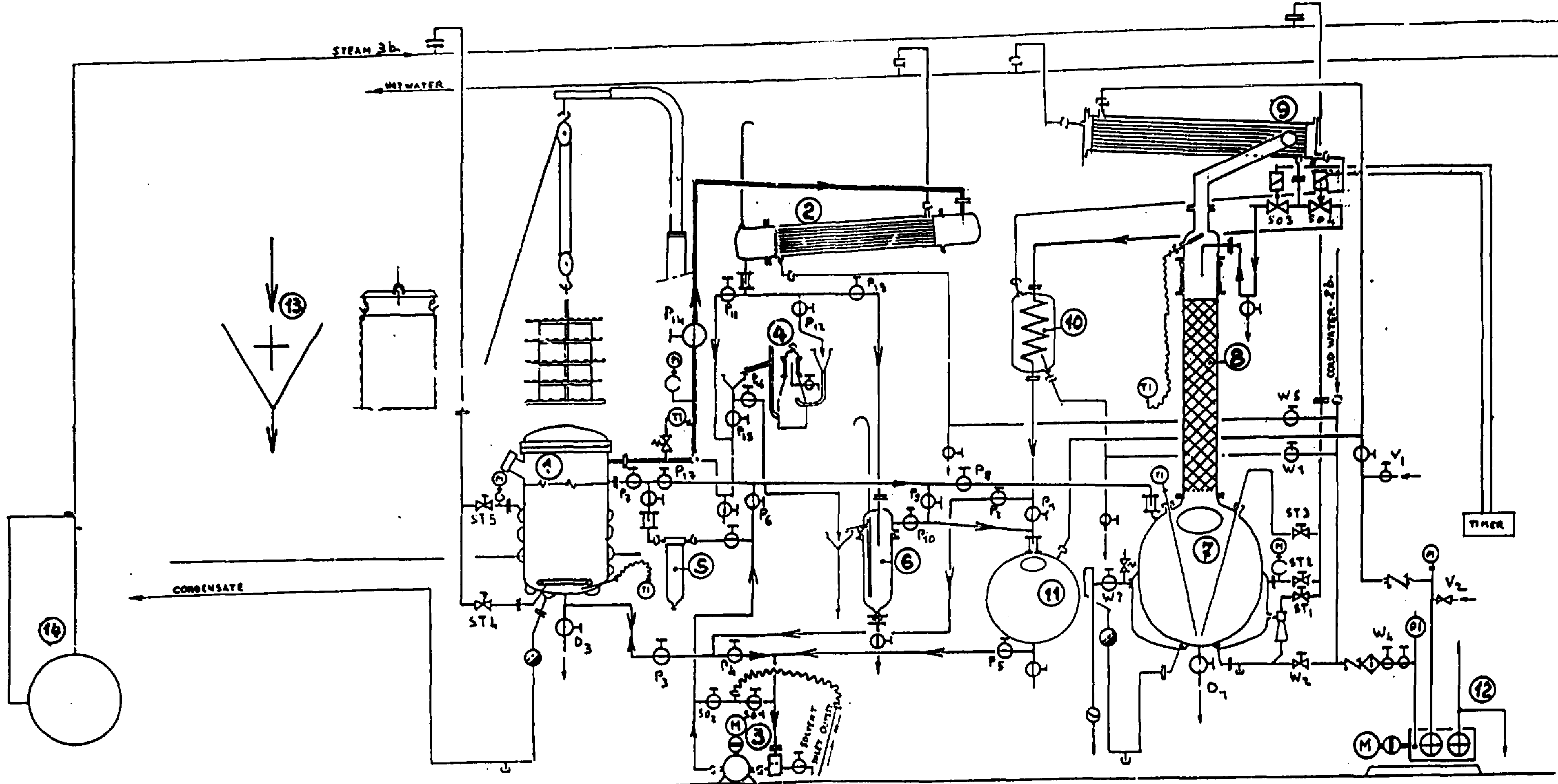
- Stainless steel Buchner filters, 400 and 800 mm diameters

- Distilled water apparatus with 50 l/h capacity

- Ultrafiltration and microfiltration laboratory units

- Ventilation systems for aspiration of toxic fumes, equipped with mobile aspirator mounted on the extraction apparatus. The fan should have a 3,600 m^3/h capacity, 1.5 kW at 2,800 rpm.

- Pneumatic temperature regulators.



14	1	STEAM BOILER
13	1	CRUSHER
12	1	VACUUM PUMP
11	1	RECEIVING TANK

10	1	COIL TYPE COOLER
9	1	HORIZONTAL CONDENSER
8	1	COLUMN
7	1	BOILER
6	1	DECANTER
5	1	CARTRIDGE FILTER
4	1	FLORENTINE FLASK
3	1	SELF PRIMING PUMP
2	1	CONDENSER
1	1	EXTRACTOR

COMMERCIAL UTILIZATION OF SPIRULINA GEITLERI J. DE TONI

The natural product that is the subject of this profile is Spirulina Geitleri J. de Toni, synonymous to Spirulina maxima which was known to the Aztecs, and in Far Eastern and African cultures as a food source.

Periodical controls by various governmental institutes for nutrition and food research reveal that this Spirulina is an exceptional natural product since only slight differences are observed in the composition when harvested in the different seasons of the year.

The product has a number of important uses: as a food complement; it is a valuable aid in raising mollusks, crustaceans and fish, for it stimulates their growth, sexual maturity, ovulation and early reproduction. It has also been used with great success in feeding bees as well as birds and cattle. The yellow and orange pigments contained in this product can be assimilated as natural colouring by chicken meat and egg yolks, ornamental birds and aquarium fish; it may also be used to give butter a brighter colour.

The product is now being consumed by humans. Japanese studies show that the product actually has a beneficial effect on persons with certain illnesses. The great variety of food products that can be used in combination with the Spirulina renders it very versatile as a food supplement.

UNIDO contributed to the setting up of the original pilot plant where simple technological equipment is used for the manufacturing process suitable for installation in developing countries, and in sponsoring research for the improvement of the inexpensive eutrophication techniques by aimed homogenization and carbonation (Annex A).

The chemical analysis of the dry algae powder reveals a high content of high quality protein, linolenic acid, a moderate content of carbohydrates, a low content of nucleic acids, significant amounts of several nutritional minerals and high content of vitamins A, B, B_{12} and E. Amino acid analyses show that most of the essential amino acids fulfil the FAO requirements and, in some cases, surpass the aminc acid content of other protein sources.

Toxicological studies have been carried out where several aspects of possible adverse changes were studied. Short, long-term and multi-generation feeding tests on laboratory animals fed with Spirulina products were undertaken. The results have revealed no adverse reactions whatsoever.

The cultivation of algae can be an answer to global protein shortages. Combined activities of the algae in waste water treatment and as a source of protein is of utmost importance considering the world's exploding population. Manufacturing modules should be established in developing countries possessing lakes with algae growth, thus trying to secure a good share of the world market for developing countries.

One of the most common pitfalls in trying to develop products intended to help in the solution of nutrition problems in developing countries, is the excess of technology. Often, costly processes are used to effect fancy and usually unnecessary changes in the products according to western food habits and preferences, which result in higher prices and low sales. The simplest technology is, in this case, sufficient to overcome any serious production problems, thus giving the best results in terms of a good relation quality-price. The technology described in this profile is a good example of an intermediate technology that may prove particularly beneficial to developing countries.

PRODUCTION PROCESS

1. Pre-concentration (Filtration)

For further processing, the concentration of the algae in the biomass should be 5-10 g/litre. Thus it is necessary to pre-concentrate the suspension that is taken from the cultivation tanks. This is achieved by passing the dilute suspension first over parallel inclined filters which concentrate the biomass to the desired 5-10 g/l. The screens are washed continuously. This wash water flows by gravity to a rotary filter. The screening surfaces are of nylon mesh. Wash water from the rotary screens contains 15-20 g/l algae.

2. Filtration-extraction

This step removes the remaining cultivation medium. The algae suspension is de-watered to a cake containing 15-20% solids on a vacuum filter.

3. Disintegration

A mechanical rupture of the cells results in a liquid with a specific viscosity. This step is also beneficial for improvement of the digestibility of the end-product. The proprietary type of disintegrator both fluidizes the product and pumps it to the next production stage, pasteurization.

4. Pasteurization

Pasteurization is necessary since the next step, namely spray drying, is not a guarantee for destruction of certain bacteria which are able to survive the short time of high temperature, followed by rapid cooling.

5. Spray drying

Spray drying is done through exposure to high temperature for a few seconds followed by a rapid cooling stage. With this method, the destruction of important amino acids, such as lysine, tryptophan vitamin and pigment is minimal.

6. Conditioning

Conditioning involves grinding the flakes that originate from the spray drying to a flour ready for packing and storing. The shelf-life of such a powder, as long as it is protected from the influence of light and heat, is virtually unlimited.

DECOLOURIZATION

For the production of a high quality protein product for human consumption a decolourization process is required. Research has been carried out in this respect and selected experiments are summarized below.

a) Decolourization with intense light treatment was performed with a 0.3% aqueous algae solution. The solution was decolourized in 24 hours under 5,000 foot candle illumination. No change in colour was apparent on illuminating a 4% solution at 100,000 foot candles for 24 hours. These results indicate that the above 0.3% solution is the minimal requirement for the decolourization process.

Light treatment needs long exposure causing a destructive influence on the pigment = photoinduced oxidation. Such oxidation is reported to oxidize the cell components (causing rancidity) and also reduce the yield of protein from 60% to 6%!

This process may be more suitable as a means of brightening the final product from which most of the colour has been removed by other means.

b) Decolourization by chemical bleaching using hydrogen peroxide. A suspension containing 5% peroxide with 1% Spirulina algae was stirred at 40°C for 23 hours. The colour of the suspension changed from the original deep green to yellow-brown. However, reaction of peroxide with unsaturated fatty acid substrates could lead to the formation of polymerized products, suspected of having carcinogenic properties. Further, hydroperoxide derivatives of fatty acids have been shown to have a deleterious effect on the synthesis of lipids in the livers of rats. Also it was found that the bleaching can have an adverse effect on the nutritive value of the product. It was established that the bleached Spirulina end product was unfit for human consumption due to its rancidity.

c) Decolourization by enzyme treatment. At least three specific enzymes are required to complete decolourization by removing biliprotein pigments, chlorophyll and carotenoids. Some of the enzymes are contained in Spirulina algae but their autolytic properties contribute to the reducing of the protein yield.

Enzyme treatments are characterized by slowness of reaction and a lower yield. In addition, the need to process in aqueous form would necessitate and add to solvent extraction and evaporation cost. For the three different classes of pigments, three different classes of enzymes are needed. Some of these enzymes are not commercially available. Furthermore, those that are available are invariably contaminated by other enzyme activities, such as

1) Protein carbohydrate hydrolyzing enzymes;
2) Fatty acid oxidizing enzymes;

3) Both 1) and 2) would alter the physical state and nutritive value of the protein and would lead to losses and to a higher cost of recovery operations.

d) Decolourization by solvent extraction. The raw material from Spirulina can be either in the form of dry powder or as a dehydrated paste. Extraction conditions can be controlled to minimize loss of protein. As the solvent can be recovered for re-use, there is no direct chemical consumption. Chlorophyll and carotenoid pigments can be removed by organic solvents, in particular the low boiling alcohols.

e) Ethanol extraction. One hundred grams of Spirulina maxima paste frozen for 1 month at -35°C were thawed and mixed with 500 ml of absolute ethanol. (Solvent: solids ration 25.6 w/w, blended with a high speed blender at 50°C for 5 minutes and centrifuged at 5,000 rpm for 10 minutes.

The entire procedure was repeated twice for the three extractions with the following results:

Extraction No.	1	2	3
Colour of supernatant	dark green	dark yellow	yellow
Colour of residue	light green	blue green	blue

Final recovery of blue residue after three extractions was 9.79 g for a solids yield of 63 per cent.

The blue residue obtained by successive low temperature extractions with ethanol contains phycocyanin, the major blue pigment of blue-green algae. Phycocyanin is a biliprotein - a protein which has a bile pigment, chemically bonded to the protein chain. The pigment (or chromophore) is phycocyanobilin.

f) Methanol extraction. The good detachment capabilities of methanol for the extraction of the pigment are associated with the size of the alcohol molecule which enables it to penetrate to the sites of the prosthetic group of the pigment attachment to the protein.

Extraction parameters can be summarized in the following table:

<u>Soxhlet Extraction of Spray Dried Spirulina maxima Algae</u>

Solvent	Extraction Time (hrs)	Final Absorb. à 436 (10:1)	Product Yield,%	Product Colour
Methanol	1.5	1.02	60	blue
Ethanol	2.5	1.05	72	bl. green
Iso-propanol	1.5	.88	82	green
Acetone	4.0	.95	81	deep green
Ethylene Dichloride	3.0	.71	74	deep green
Hexane	4 +	.36	79	deep green

g) <u>Decolourization by percolation extraction</u>. Percolation was investigated through a pilot-scale operation. The unit was charged with 3.66 kg of dried algae. Condensed alcohol at 50°C was allowed to percolate over the algae at a rate of 75 - 100 ml/minute.

After 15 hours of percolation at 40 - 50°C and 50 litres of ethanol, pigment was still leaching out of the algae. The extraction process was stopped and the solids dried. The dried material had a greenish blue colour. The yield of material on a dry solids basis was 86 per cent.

The initial extract was very concentrated in pigment with a carotene strength of 0.29 mg/ml and a xanthophyll content of 0.28 mg/ml. Precipitation of insoluble matter appeared to have taken place as seen when the extract was decanted from its container. **Figure p. 46 of doc.**

MARKETING AREAS

Major marketing areas with considerable potential for expansion include:

1. Human food as a high protein and vitamin supplement;

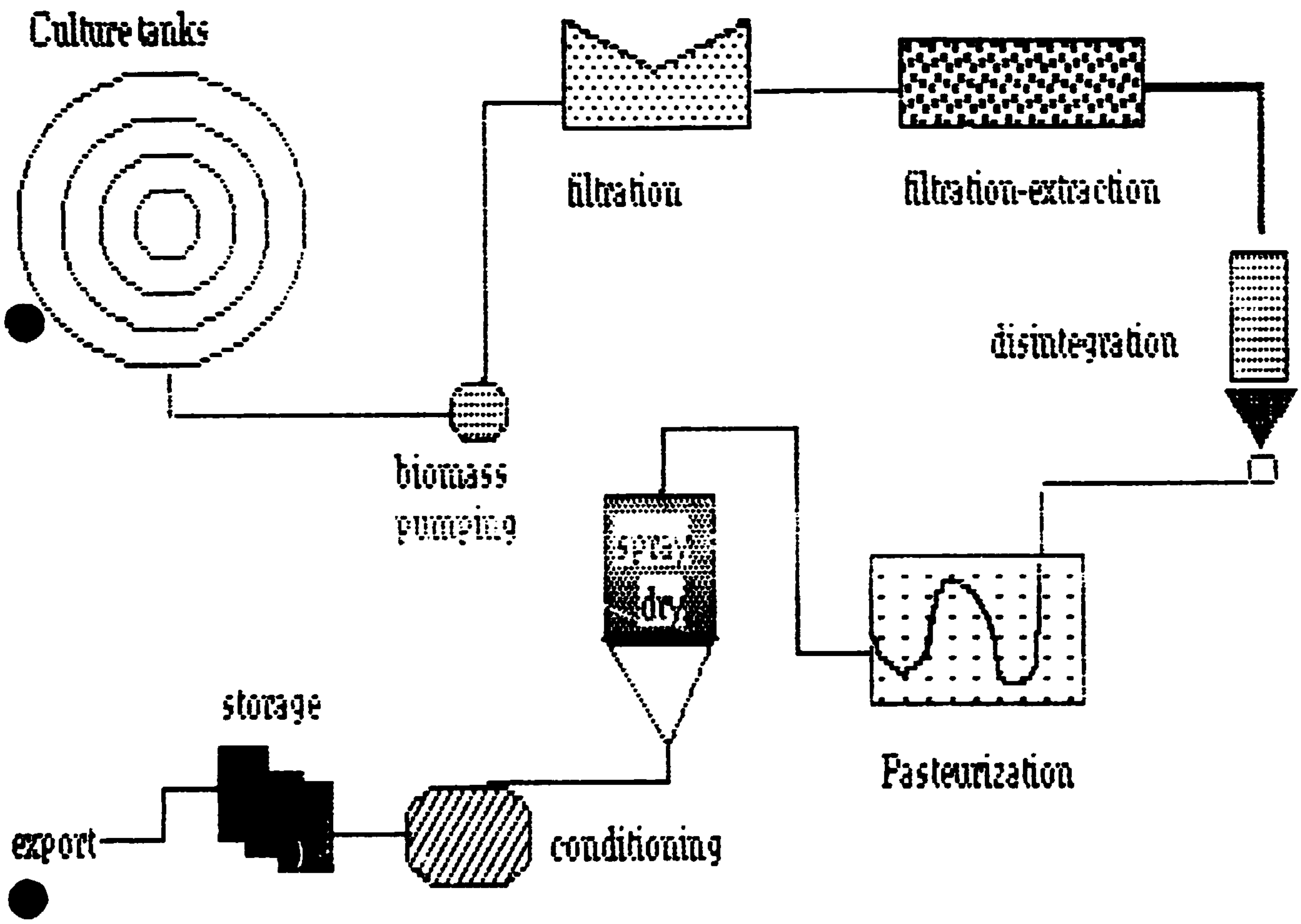
2. Animal feed additive for nutritive and pigmenting value;

3. Health food market;

4. Further development of a decolourized product and the commercial utilization of the pigment by-product which would facilitate market penetration and give added impact to the marketing of algae;

5. The development of what must be regarded as an almost infinite potential, namely the application of Spirulina for medical purposes;

6. The development of economic methods to obtain the algae product based on processing of waste and water recycling, using sclar energy only.



Flow chart for the cultivation and processing of Spirulina algae

CASSAVA CHIPS AS RAW MATERIAL

Introduction

Cassava in its various forms is a traditional food in many developing countries. An estimated 500 million people depend on it as a source of calories to a significant extent. In addition, some 10 per cent of world cassava production is processed and used in animal feed. Nevertheless there remains considerable under-utilized potential for exploiting cassava in processed food products and also in industrial applications.

In February 1983 UNIDO published the report 'A Factory Concept for Integrated Cassava Processing Operations'. It describes the utilization of cassava as an industrial raw material suitable for factory scale processing to make a whole range of products, such as starches, flours, glucose, dextrins, food products such as gari and feed grade leaf protein. The 'Factory Concept' report proposes the use of sun-dried cassava chips as the main source of raw material for the proposed processing factory. Dried chips provide a suitable alternative to the perishable and partly seasonal fresh roots. This is necessary to ensure a reliable, regular supply of cassava on an industrial scale to a modern integrated cassava processing factory.

In this profile the requirements for high quality dried cassava chips suitable for a factory producing both human food and other products are defined. It also contains recommendations on the best practical means for achieving their production and supply.

Some 130 million tonnes of cassava annually are produced worldwide with Africa and Asia the largest producers. Much of this is converted directly into food by traditional means, mainly manual.

Although the idea of an integrated approach to cassava production was first suggested many years ago, it has been implemented mainly for animal feed.

RECOMMENDED CHIP PRODUCTION TECHNIQUES

It is considered that the additional stages of processing required to produce chips which are of acceptably low 'bound' HCN content tc render them safe for human consumption in the form of meal, complicate the process or increase production cost to such an extent as to render them unacceptable. The additional stages involved would be either soaking the roots in water for a period of 3-5 days (which renders 'chipping' the soft, soggy root difficult), peeling and/or exposure to high temperatures unattainable by conventional sun-drying techniques.

Until reliable information is available no attempt should be made to integrate cassava meal and cassava starch production from a single unpeeled cassava chip raw material. Meanwhile the dangers of sun-dried chips being pilfered or otherwise diverted from an integrated processing factory for local meal production must be recognized.

Root Preparation in the Field

Roots should be removed from the clusters by severing with a knife (a hand operation). The woody peduncle which forms the union between the root and the stem should be removed in the field to reduce the fibrous contamination of the chip.

Physical damage, i.e. cutting, bruising, and breaking, is not a major problem where the roots are scheduled for chipping or processing within 1-2 days. Damage becomes a problem when the roots are held for a period exceeding 3 days (the actual limit depending somewhat on variety).

It is recommended that, in order to obtain chips of optimum colour and starch content, delays between harvesting and chipping be kept to a minimum. Ideally roots harvested one day should be caped on the following day.

Clods of soil adhering to roots should be removed during the trimming operation. In wet conditions, especially with clay soils, it is almost impossible to remove all the soil adhering to the exterior of the roots and, where soil-free roots are essential, provisions should be made for washing as a preliminary to subsequent processing.

Transportation of Roots

No universally applicable recommendations can be made other than to recommend the use of the most effective method available in the particular circumstances of each processing factory. This may range from a few roots in a basket on the head to a large truck with drop-down sides. Recommendations of a practical nature include the careful packing of roots to reduce air space between roots, and the avoidance of plant residues, e.g. stem sections becoming mixed in with the roots.

Storage of Roots

Fundamentally, roots cannot be stores more than 48 hours without significant deterioration taking place. There is no reliable on-farm technique available for bulk storage of cassava roots. Small-scale storage using boxes filled with moist sawdust, peat etc. and plastic bags can be used for small quantities of roots for the fresh market. The main concern is to avoid physical damage. For large-scale operations only two alternatives are available:

- leave the crop unharvested in the ground until required;
- process the crop within 48 hours of harvesting through a suitable organization.

Preliminary studies indicate that removal of the above ground parts of the plant, whilst leaving the roots undisturbed in the soil, imparts an extended shelf life on the roots once they have been harvested. This technique, once proven, may offer an interim measure, allowing for a 'buffer stock'.

However, until this system is shown to be effective on a large scale, no storage method can be recommended. It must be stressed that root deterioration sets in rapidly and many of the quality criteria of sun-dried chips are largely dependent on the degree of freshness of the roots at the time of chipping.

METHODS OF CHIP PRODUCTION

Various methods of preparing cassava chips exist, from simple hand operations with a knife to powered machines capable of large throughput. The choice of the chip production technique depends on the scale of the operation, which in turn depends on the size of the individual farm holding, the quantity of cassava produced on the farm and the density of cassava produced in any one area.

Small-Scale Chip Production

This scale of operation relates to the processing of cassava roots produced by a small-scale farmer, using his own or family labour.

Root preparation in terms of removing the soil by brushing or washing can be practised at the small-scale producer level. However, rural water supplies in the tropics are often scarce, especially during the dry season, the most likely time for cassava harvesting and chipping operations. Root washing is desirable when chips are to be processed for human consumption to reduce ash content.

Peeling roots prior to chipping is usual and preferable when the resulting product is for direct human consumption. This practice is linked with the general understanding that the HCN produced in cassava roots is concentrated in the peel.

Where the chips are to be used as raw material for an integrated processing factory, the necessity to peel is removed as the HCN is eventually removed from the rehydrated chips during the starch separation process, and passes into the wash water. Care must be taken to ensure that chips from unpeeled roots do not become mixed with chips from peeled roots destined for human consumption, especially in areas where low temperature cooking procedures are followed. A possible method to avoid confusing the two types of chips would be to employ simple vegetable dyes sprayed onto dry chips destined for processing into starch and starch derivatives. A dye which washes out easily during the starch extraction procedure would be desirable, so as to prevent discolouration of the resulting starch.

Hand chipping using nothing more than a sharp knife is the most basic method of producing cassava chips. The system is adequate where up to 50 kg of roots are to be chipped per day. Cassava roots are not easy to slice, and tough fibres in the core of the root can deflect the knife. With hand slicing there is a tendency to prepare chips which are to thick, resulting in under-drying.

Although a number of hand operated cassava graters and slicers have been designed and built, no effective hand operated cassava chipper has been encountered.

Large-Scale Chip Production

This scale of operation relates to a village or farmers' co-operative situation where sufficient raw material is available to justify the purchase and operation of a powered chipping machine capable of chipping several tons an hour. Similarly, in a cassava growing area a commercial chipping venture may set up an operation requiring such large machines.

A number of machines exist which have been developed especially for large-scale production of cassava chips. Various models are, for example, 'mass produced' in Thailand. These incorporate a large metal disc which is notched to produce cutting edges which chop the cassava roots into chunks. The drying characteristics of these chunks (referred to as chips in Thailand) are poor, resulting in protracted, incomplete sun drying and brown, mouldy often moist 'chips'.

Whereas the large throughput and large intake hopper capacity of some Thai machines may be desirable characteristics for a large-scale chipping operation for animal feed, their undesirable chip geometry renders them basically unsuitable for chip production where high quality chips are required for an integrated processing factory for starch extraction.

The chipping machines used widely in Malaysia are smaller in terms of chips throughput than their Thai counterparts. The Malayan machines, however, produce thin root strips by means of a series of blades mounted on a large circular metal plate. The drying characteristics of the Malayan chips are much superior to those produced by the Thai machines, drying in less than two days in most circumstances.

METHODS OF CHIP DRYING

At current prices artificial drying using fossil fuels or electricity is uneconomic. Where cheap wood and peat occur these fuels may be considered, but it is generally accepted that sun drying of cassava is the only cost-effective method currently available.

Detailed information on the principles of sun drying of cassava chips can be obtained from the

Department of Industrial Operations
UNIDO
P.O.Box 300
A-1400 Vienna
Austria

Small-Scale Chip Drying

The technique of using raised drying platforms is recommended as being the most appropriate for small-scale drying. It is suitable for the quantities of chips produced using a knife or a simple hand or foot operated chipping machine.

The drying of such relatively small quantities can be carried out on a raised wooden platform of the type frequently seen in Central Africa and used to dry a range of crops. The platform raises the drying chips away from the dust of the bare earth in the vicinity of the village or homestead and discourages livestock, dogs, poultry and children from walking through the drying product and possibly contaminating it with faeces and/or urine.

A simple platform with dimensions 3 x 4 is capable of supporting 95 kg of chips (at a loading rate of 8 kg/m^2). Two such structures would be required where a two-day drying programme was achieved. The structure should be high enough from the ground to deter animals but not so high as to be vulnerable to damage from high winds, or be dangerous to people who may from time to time fall off.

Inexpensive, locally available materials of wood, reeds, straw matting can be employed in the construction of the platform. Permeability to air is an advantage and can lead to an increase in the chip drying rate. This small-scale approach to drying is recommended for the majority of situations where cassava is grown by local farmers.

Large-Scale Sun Drying

In countries where the scale of cassava cultivation , geography and the presence of good roads makes the transport of fresh roots economic, large-scale chipping and drying may be appropriate. However, such a system assumes the substantial availability of heavy transport which can be utilized for other purposes to make it economic. Such conditions exist in Thailand, for example, but may be difficult to reproduce in some developing countries.

A powered machine should be capable of producing 10 tonnes of chips per day, which requires a drying area of 6,000 - 8,000 m^2. This area is sufficient to dry the chips within a two day period, given dry weather.

The expense of setting up a drying floor is considerable and can be justified only when the cassava drying season is long and/or when other uses can be found for the drying area, e.g. drying other crops such as rice or groundnuts.

The construction details are greatly dependent on the availability of building materials locally and whether heavy equipment will be driven over, or placed on, the drying floor. The site should first be levelled and compacted. Surface drainage should be catered for by gently cambering the drying floor and providing canals to receive rainwater collected on the floor. The canals should be designed appropriately to reduce erosion hazard during the rainy season. A fence should be erected to keep out wandering livestock which may not only defecate on the drying floor, but also eat some of the dried chips.

A layer of aggregate, consistent with the required strength of the drying floor, should be spread and compacted over the soil base. A concrete topping should then be spread over the aggregate and smoothed to provide a drying surface which can be hosed down from time to time to remove chip debris and starch dust. This residue makes the drying floor sticky and slippery for wheeled vehicles, and also contaminates fresh chips being spread out to dry with micro-organisms.

Where heavy vehicles run on the drying floor, reinforcement should be provided. A steel reinforcing as used in concrete road construction is ideal. To avoid reinforcing the whole drying floor it is advisable to provide a 'hard' area for the loading and unloading of lorries.

It is commercial practice in cassava chip producing countries to disturb the chips whilst spread on the drying floor. This is considered necessary to 'turn' the chips so that the drying process is hastened and the chips are uniformly dried. Traditionally men or women equipped with wooden rakes carried out this operation by regularly walking through the chips, disturbing them as they pass. The chips are 'turned' at approximately hourly intervals as the workers progress backwards and forwards across the drying floor.

No studies have been carried out to determine the relationship between drying rate and the frequency of raking. In some countries increased labour costs and difficulties in employing gangs of unskilled workers on a casual basis (on dry days only) has led to the mechanization of the chip raking operation on many drying yards. These 'go-carts' with rakes attached rake the chips every hour, completing each raking operation in 5-10 minutes. Their passage through the chips, especially during the second day when the chips are nearly dry, leads to clouds of dust (i.e. mostly starch) and it is not known how much of the final product is lost during sun drying operations.

HANDLING AND STORAGE OF DRY CHIPS

Once the chips are satisfactorily dried, they have to be transported and possible stored before further processing..

Transportation of Chips

The transportation requirement may vary from the bulk movement of chips over a few hundred metres to transportation over hundreds of kilometres. Whatever the case, it is necessary that transportation methods should be such that:

- chips are not allowed to get wet;

- chips are not transported in open trucks over long distances leading to loss of fines.

Transportation of chips in lined sacks, polythene or paper bags is recommended to prevent moisture re-entering the chips and to reduce the loss of fines.

Storage of Dry Chips

Storage on the farm should be in lined sacks or polythene bags as recommended for transportation. Since these materials may not always be available, it is recommended that local storage be minimized where possible and that dried chips should be stored by the processing factory.

A minimum storage capacity at the factory of six months' supply is recommended. However, sufficient storage to handle the seasons operations is ideal.

QUALITY STANDARDS FOR CASSAVA CHIPS

Traditional cassava-based food products of producer countries have not generally been standardized and their quality is very variable. In international markets, legislation for quality control is widespread and large-scale trade has stimulated the development of standards for these products. Recommendations for dried chip quality standards are set out according to the following:

- external physical characteristics
- moisture content
- starch content
- ash content (sand)
- crude fibre content
- cyanide content
- microbiological content

External Physical Characteristics

The quality of chips is judged by their general appearance, i.e. colour, visible state of dryness, odour and chip geometry. Chips should have good clean, white/near white colour and be free from obvious extraneous matter including mould and insects.

Several size standards exist. Chip, length is important where thick chips, i.e. root chunks which are difficult to break, are concerned. Mechanical handling machinery is subject to blocking and a maximum chip length of 5 cm is recognized. In this profile a size of 50 x 30 x 10-15 mm is recommended.

Moisture content

The moisture content recommended as 'safe', i.e. which does not lead to rapid deterioration, is in the range 12-14 per cent. However, it must be recognized that in very humid environments it may be impossible to prevent reabsorption of moisture to levels well in excess of 14 per cent.

Starch Content

As starch is the most important component of cassava chips, it is desirable to create standards to maintain a high starch content. However, the different varieties and growing conditions make it impractical to lay down a single standard for all regions. The theoretical maximum is in the region of 80-85 per cent but current standards require less than this value.

It is recommended that, initially, a simple standard be developed and laid down by each processing factory in the range of 72-82 per cent for local purchasing purposes. Pricing should the reflect the starch content on a basis of what is achievable in that particular region.

Ash Content

This reflects soil/sand and sometimes cement dust contamination from the drying process and should not exceed 3 per cent.

Crude Fibre Content

This varies normally from 2 per cent up to 4-5 per cent, the higher value being tolerated from chips made from unpeeled roots which include the corky outer peel. This is acceptable for a processing factory which will eliminate unwanted fibre content in any case.

Cyanide Content

Since there is constant development in this field, it is strongly recommended that all HCN standards are reviewed using the most recent analytical techniques.

Where chips are to be used directly for human food, it is imperative that peeling and thorough soaking be practised to minimize HCN toxicity.

For a cassava processing factory, no cyanide content standard is necessary since the cyanide is removed during the processing.

Microbiological Content

Bacterial spore counts of moulds and fungi are not normally made for cassava chips, although microbiological contamination of cassava products is widely recognized. Recommendations have been made, however, that spore counts should not exceed 10 million per gram of material.

For the processing factory the key requirement is to avoid faecal contamination which carries the danger of pathogenic organisms such as E. coli, Salmonella, Shigella and Corynebacteria.

FACTORS AFFECTING THE COST AND AVAILABILITY OF CASSAVA RAW MATERIAL

The following factors need to be considered in detail, keeping in mind the local farming traditions and customs pertaining in a particular territory, in order to determine the likely costs and availability of cassava raw material for a processing factory:

- demand from competing markets for fresh roots;
- the alternative crops available;
- their easy of production and their profitability;
- the farmers' margins;
- any middlemen's margins;
- transportation costs and their percentage of production costs;
- the organization of transport;
- any government subsidies and/or support prices and their effect on the market;
- the pricing system(s) in operation;
- the feasibility and nature of production contracts;
- the use of multiple cropping;
- cost effectiveness of the current production systems and the scope for improvement.

END PRODUCTS THAT CAN BE PRODUCED BY AN INTEGRATED CASSAVA PROCESSING PLANT

MEAL OR FLOUR

Bakeries, pastries, alimentary pastas (macaroni)
Boiled in soups, sauces, gravies etc.
Bread extender
Porridge (gruel)
Fortified flour (with wheat, soya, peanut, vitamins etc.)
Improved bread flour (with added calcium stearyl lactate as a conditioner)
Protein enriched flour (fish protein concentrate, soybean isolate, casein etc.)
Selected amino acid enriched flour (lysine, tryptophane, methionine etc.)
Fermented (Eba)
Glues
Adhesives

STARCH

Baked goods
Desserts - puddings, pie fillings (sago)
Infant foods
Confections
Thickening agents (synthetic jellies)
Bodying agents (caramels)
Dusting agents (chewing gum)
Fermented beverages (beer)
Textile sizing and strengthening
Laundry starch
Paper sizing and bonding
Gums
Dextrins
Adhesives
Glues and pastes
Blended with peanut flour, non-fat milk solids, vitamins
Enriched with LPC, soy, corn, rice (pasta)
Alcohol
Acetone
Glucose
Oil well drilling

MODIFIED STARCHES

Pre-cooked soluble starches - 'instant' puddings
Thin-boiling starches (confectionery manufacture)
Oxidized starches
Improved starches (ex: added glyceryl monostearate as a binding agent)