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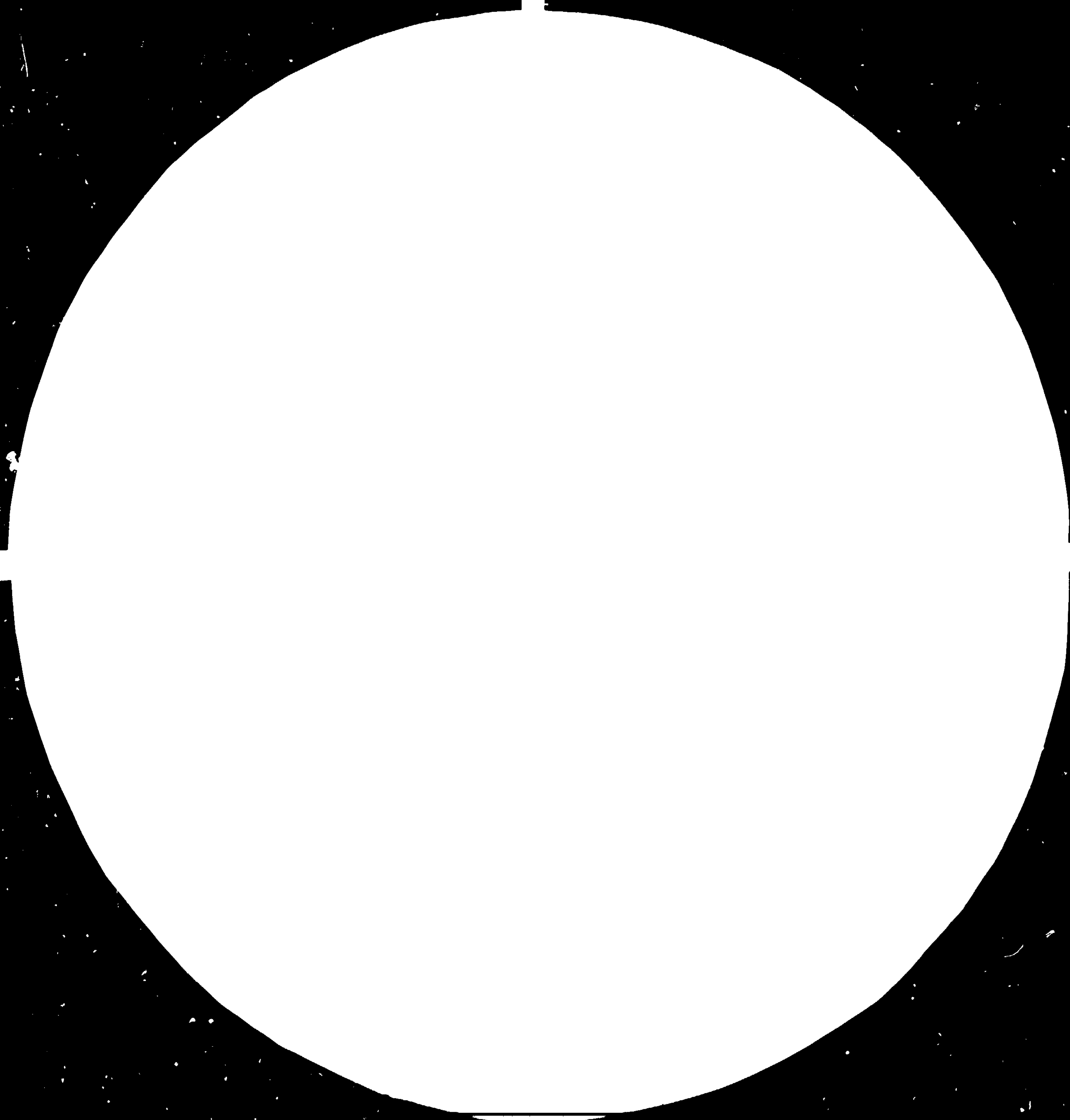

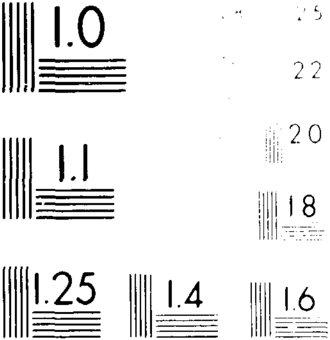
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A FACTORY CONCEPT FOR INTEGRATED CASSAVA PROCESSING OPERATIONS

US/INT/80/006

SUPPORTING AND BACKGROUND INFORMATION ON THE PRODUCTION OF CASSAVA CHIPS*

Based on the study and evaluation work carried out in Thailand, Indonesia, Malaysia and Colombia by P. B. Steghart of P-E International Operations Ltd., U.K. and Dr. D. W. Wholey of Minster Agriculture Ltd., U.K. on contract with UNIDO

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1.0 INTRODUCTION

In February 1983 UNIDO published the Report "A Factory Concept for Integrated Cassava Processing Operations". This describes the concept of setting up one or more factories to make a whole range of products derived from cassava. By this means the potential of cassava both as a source of food and also for use in industrial products can be expanded greatly.

A key factor in the success of a cassava processing factory is the reliable availability of good quality raw material - cassava. However, fresh cassava roots deteriorate rapidly and in many instances cannot provide a regular supply for more than a small part of the year. To overcome this difficulty, the UNIDO Report proposes the use of dried cassava chips as a possible alternative raw material. The Report outlines the need for a dried cassava chip product of uniformly high quality if it is to fulfil the needs of a factory producing both human food and other products.

The aim of the present project is to define the requirement for high quality dried cassava chips and to recommend the best practical means for achieving their production and supply.

The first stage of the study involved a major literature review at the International Centre for Tropical Agriculture - CIAT - in Cali, Colombia. The CIAT library contains virtually all significant publications and research data on cassava worldwide. A detailed review of many hundred items concerned specifically with cassava chips and related topics has produced a bibliography of over two hundred key publications. This is presented as Appendix 10.

The second stage of the work programme comprised visits to two major producers of cassava - Thailand, where chips are produced commercially in large quantities - and Indonesia, where dried cassava is produced primarily for human food. In addition, the team briefly visited Malaysia for further studies.

This final report comprises two volumes of which this is Volume 2. Volume 1 describes the background to cassava development; it sets out the techno-economic factors affecting raw material supply illustrated by two case study scenarios and goes on to recommend appropriate technical production methods and quality criteria. Volume 2 contains the relevant background of current practices and supporting information on tree production and processing of cassava chips.

The study team comprised:

P.B. Steghart (P-E International Operations)	Team Leader
Dr. D.W. Wholey (Minster Agriculture Limited)	Cassava Specialist

In addition part-time inputs were provided by Dr. Allan Rodger (P-E International Operations), Economist, and D.R. Atkinson, Economist, who led the previous Factory Processing Concept Study.

The team wishes to thank the UNIDO staff in Vienna and also in Thailand and Indonesia for their helpful and friendly co-operation. In addition, the team is most grateful to the staff at CIAT, Colombia, and to the many other organisations and individuals who have contributed substantially to this project.

2.0 CASSAVA CHIP AND PELLET PRODUCTION PRACTICES - CURRENT METHODOLOGY

Cassava chips are produced in many cassava-producing countries where they form a stage in traditional food preparation techniques. It is only relatively recently, i.e. post 1945, that animal feed and industrial purchasers have turned their attention to cassava chips. The sale of the purchases made has, however, tended to dominate the scene and the mention of the topic "cassava chips" is frequently interpreted to be a reference to the large-scale trade in animal feed raw material between Thailand and the member states of the European Economic Community.

The following paragraphs, which deal with the various stages involved in converting roots attached to growing plants into dried chips or pellets in a transportable, storable state, present a global overview gleaned from a combination of literature review, visits to cassava growing countries and previous personal experience of the consultancy team.

2.1 HARVESTING

The operations associated with removing the roots from the growing plant in the soil and their preparation for transport from the field are discussed in this chapter. Many factors related to the agronomy, climate and soils influence the harvesting operations. Whereas hand harvesting accounts for most of the world's cassava production there is currently a great deal of interest in the mechanisation of the harvesting operation. These topics are discussed separately.

2.1.1 Maturity Period of Cassava

The economic yield of the cassava plant is produced in the form of a cluster of swollen tuberous roots varying in number from one to a dozen or more, but usually between five and ten.

The cassava plant begins to accumulate appreciable starch reserves in the tuberous roots onwards from the third month after planting. In theory a cassava producer could commence harvesting operations at any point after the third month. However, to maximise productivity from a particular crop it is normal to delay harvesting until nine or more months after planting.

The delay between planting and harvesting varies with the climate and the variety of cassava. Low temperatures slow and eventually arrest growth and yield-accumulation in cassava. Similarly, drought arrests development and in areas with long dry seasons, e.g. in excess of 4 months, it is the frequent practice to grow cassava over a two-year period in order to maximise crop yield.

2.1.2 Agronomic Factors Influencing Harvesting Operations

The shape and dimensions of both the individual root and the cluster of roots vary with variety, orientation of the cutting used to establish the plant and the type and fertility of the soil in which the plant was grown. All of these factors are known to influence speed and efficiency of harvesting operations in qualitative terms and are worthy of elaboration. Unfortunately little reliable quantitative information has been reported.

The variety of cassava grown has a strong influence on the characteristics of the roots produced, in terms of root shape, number and both external and internal properties. Various authors have devised descriptive keys for the classification of cassava root shape. Among the most comprehensive is that of Cours (1951), which classifies cassava roots according to the type of attachment to the plant and the shape of the individual root. Appendix 1 presents the classification in greater detail.

Briefly roots are classified into sessile (no peduncle) and peduncular types; and conical, fusiform, conical-cylindrical and cylindrical shapes. Cours (1951) proposes these factors and varietal characteristics, although it is reported from CIAT (Cock et al 1978)* that roots developed from deeply buried cuttings tend to have longer peduncles than shallow planted cuttings. Similarly a normally peduncular variety produced sessile roots when established using rooted shoots (Wholey & Cock 1975) instead of the standard stem - cutting.

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* In Weber E.J. et al, 1978.

The shape and presence of a peduncle does not necessarily affect the yield of roots, but does affect the labour required to harvest the crop. Plants with roots conical or conical/cylindrical in shape with short peduncles are much easier to harvest (both by hand or machine) than fusiform and cylindrical roots, with long peduncles.

The distribution of the root cluster within the soil also greatly influences the ease of harvesting.

The method of planting the cutting strongly influences the spatial distribution of the root cluster. Cuttings planted in the vertical position tend to develop roots from the base of the cutting distributed radially like spokes from a wheel hub. In the case of cuttings planted in the inclined position there is a similar tendency for roots to develop at the cutting base but distributed radially in a fan, resembling the outspread fingers of a hand. Horizontally planted cuttings develop roots both at the cutting base and from the nodes along the cutting, in a less regular pattern than the previous methods.

The spatial distribution of roots seriously affects the ease of harvesting. Experience indicates that inclined cuttings may be the easiest to harvest as the position of the roots can, to a certain extent, be determined by the direction of inclination of the cutting. Limited excavation using a hoe or spade, followed by a pull, frees the roots from the soil. Roots developed from vertical or horizontal placed cuttings require much more substantial excavation to lift the roots.

The soil type in which the crop is grown and the degree of thoroughness of land preparation operations affect the spatial distribution of the roots in the soil and therefore affect harvesting operations. Shallow soils or soils only shallowly ploughed or hoed prevent deep root penetration. Thus roots are distributed close to the soil surface and harvesting is relatively easy. Unfortunately the restricted volume of soil also reduces root yields resulting in poor productivity.

2.1.3 Influence of Soil and and Weather on Harvesting Operations

In addition to the effects of soil on the penetration of roots, which indirectly influence harvesting, the condition of the soil at harvest time is a major factor affecting harvest operations.

Soils with a high clay content become sticky when wet and harvesting roots in these soils is very difficult, if not impossible, during rainy periods. Not only is it difficult to physically expose the roots and pull them from the wet soil, but the mechanical disturbance of the soil tends to render it cloddy and difficult to cultivate in the following season.

Clay soils tend to bake into massive, almost impenetrable blocks during long dry periods. Harvesting cassava roots from such soils during the dry season is laborious, time consuming and frequently results in significant losses through broken roots. Due to these reasons, clay soils are avoided for large-scale cassava production and are generally restricted to smallholder production.

Harvesting from clay soils is therefore difficult during both extremes and seriously limits root availability for the processing industry.

Sandy soils are much more amenable to harvesting operations. They allow rain to percolate from the surface and do not cling to the roots in the way of clay soils. During dry periods the soils remain friable and cassava harvesting operations are not impeded. Unfortunately sandy soils tend to be of lower nutrient status than clay soils and their ability to support high yields is limited. Nevertheless they are attractive from the viewpoint of the cassava processing as roots can be harvested at all times except during periods of severe water logging.

2.1.4 Harvesting Cassava by Hand

The cassava crop is traditionally harvested by hand. The operation is laborious, requiring a combination of digging, pulling and lifting. It has been estimated that under average conditions a worker can be expected to harvest

750 kg of roots in one day. This relatively low output is not a problem to subsistence growers harvesting for their immediate needs. However, when significant amounts are required, the rapid rate of root deterioration means that either additional labour must be employed or mechanised harvesting practised, so that sufficient roots are harvested within one day.

The harvesting operation varies slightly with location and variety grown. In many areas the plant is lifted in its entire form before the roots are separated from the stem. In other areas the foliage is removed the day before lifting operations commence, leaving a basal stump of stem as a handle to facilitate pulling the cluster of roots from the ground.

The mature portion of the stem is used as a source of cuttings for the next crop. As the stem is usually stored in long lengths until shortly before planting, it is usual for the stem to be selected from the foliage removed at the time of root harvest.

The degree of digging required during harvesting operations varies with the type of soil, the spatial distribution of the root cluster within the soil, and the soil-moisture conditions. An easy-to-harvest variety in a sandy soil can be pulled from the soil without any preliminary excavation. A more difficult to harvest type, e.g. with long cylindrical roots, can be pulled from the soil, but there is a strong likelihood that root breakage will occur, requiring some digging to recover broken pieces.

Cassava grown in heavy soils with large clay contents usually requires some preliminary excavation with a hoe or spade. Once the soil covering the roots is removed a strong sharp pull will usually result in most of the cluster becoming free of the soil. Where the heavy soil is wet, the amount of force required to release the roots is significantly greater, reducing the rate of harvesting operations.

2.1.5 Mechanical Harvesting of Cassava

The increasing cost and scarcity of labour has resulted in the development of mechanical cassava harvesters.

The advent of large-scale cassava plantations in Indonesia, Malaysia, Brazil, Nigeria and other West African countries during the 1970s attracted the attention of harvesting machinery producers. As a result, a number of mechanical harvesting devices were designed and produced in various parts of the world.

However, in comparison with the quantity of cassava produced on a global scale, plantation-grown cassava represents a small minority. As a result the sales of cassava harvesting machinery has been disappointing.

By far the majority of the cassava produced in the world is grown by farmers with less than 5 hectares of land. Few such farmers possess a tractor and rely on hand labour supplemented by draft animals, pedestrian tractors, and twin-axle tractors from contractors and/or government tractor pools. Machinery producers would be better advised to produce equipment sufficiently rugged to interest agricultural contractors and government tractor pools rather than produce equipment at low prices, and probably flimsy, in the attempt to interest small farmers.

A number of approaches have been proposed to the mechanical harvesting of cassava. These vary from harvesting aids, e.g. lifting clamps attached to the tractor's hydraulic lift, through trailed implements, to fully self-propelled machines.

A frequent problem encountered by tractor drawn harvesting equipment is that of trash. This, a combination of crop residue and weeds, blocks the cutting blade and frequently results in the implement pushing a large volume of soil until the tractor is halted. To date no machine has been produced which will satisfactorily deal with cassava foliage as a standing crop. A mechanical trash remover must be capable of reducing the entire volume of the crop canopy into pieces so small that they do not germinate in the soil following harvesting, thereby serving as disease and pest reservoirs and endangering subsequent cassava crops. As the basal portion of the stem frequently exceeds 3 cm in diameter, the shredding machine required is quite substantial. Returning crop residue to the soil is sound agronomic practice as the organic matter improves the physical and chemical properties of the soil, and reduces the crop's demand on artificial sources of fertiliser.

A number of cassava harvesters are currently on the market. These vary from lifting blades, which undercut the roots and make the roots free of the soil before depositing them on the ground, to more complicated machines with chain elevators. These separate the roots from the soil before dropping them on the ground or conveying them directly into a trailer.

Successful mechanical harvesting demands that cassava be planted in parallel rows at regular intervals. This is facilitated by hand planting into pre-formed ridges, or mechanical planting. To date none of the commercially available mechanical cassava planters produce ridges. The smaller burden of soil encountered by mechanical harvesting of ridged crops minimises draft and therefore energy requirements. Therefore ridged cultivation is to be preferred to flat planting systems. There is a need to redesign existing mechanical cassava planters so that cuttings are planted in the inclined or vertical position into ridges. In this way a root cluster with easy harvesting properties, in regular parallel ridged rows, will be produced. All these factors mitigate towards easier mechanical harvesting.

Comparisons between an Australian mechanical harvester, incorporating a power-take-off driven chain-elevator* and a prototype machine incorporating a wedge section lifting body developed by CIAT, was reported by Kemp (1978)** and Leihner (1978)**. Both machines performed well under test conditions; largely weed-free, friable clay/loam soil at CIAT.

Table 2.1 compares work rates for the two machines on flat, ridged and bed methods of cultivation.

** In Weber E.J. et al (1978).

* Produced by Richter Engineering Pty. Limited, Boonah, Queensland.

TABLE 2.1

WORK RATE COMPARISONS FOR THE RICHTER AND CIAT HARVESTING MACHINES*

		Draft Force (kN)	Work Rate ha/hour	% Broken	% Leavings
Richter	Flat	16.4	0.123	16.7	18.5
	Ridged	10.8	0.123	0	5.2
	Bed	13.3	0.111	17.5	18.5
CIAT	Flat	23.9	0.316	7.6	2.4
	Ridged	15.8	0.316	9.0	20.4
	Bed	20.8	0.284	31.9	6.5

* Figures for the standard planting density of 1 x 1 m, i.e. 10,000 plants per hectare, have been extracted from Kemp (1978).

The CIAT machine worked faster under the test conditions but it was surmised that the Richter machine would be more effective under adverse, particularly wet conditions, due to the lower draft force and better soil/root separation due to the moving chain conveyor.

In a follow-up trial Leihner (1978) showed that both the Richter and CIAT machines were more efficient at recovering roots of a variety classified as "difficult-to-harvest" than hand harvesting. Broken and skinned roots were higher following mechanical harvesting but these aspects are not important where roots are to be chipped or otherwise processed within the next day or so.

In Minster Agriculture Limited's experience, the currently available equipment for mechanical harvesting of cassava is insufficiently robust for large-scale estate-style harvesting or requires large horsepower tractors.

2.1.6 Root Damage During Harvesting

Root damage is very difficult to avoid during harvesting, whether by hand or by mechanical means. Slicing, chopping and bruising are unavoidable even when hand harvesting, as it is impossible to predict the exact location of each root. Where the roots are destined for the fresh market, physical damage must be avoided as the rate of deterioration has been shown to be related to the incidence and degree of damage (Booth 1975). However, when the roots are destined to be chipped, sliced or macerated for starch extraction within hours of harvest there is little point in trying to achieve damage-free cassava roots. Thus roots destined for processing tend to be harvested with less care than those for the fresh market. Similarly the daily output of roots from a manual harvesting team can be expected to be higher where the roots are destined for processing.

Whether harvested by hand or machine, cassava roots come out of the ground as a group attached to the original cutting. Individual roots may break off during harvesting operations and in the case of manual harvesting it is usual to inspect the group of roots for incomplete roots and broken peduncles, so that further excavation may be carried out to recover the broken roots. There appears to be a dearth of information on the percentage of unrecovered yield from commercial farms. This can be quite substantial where management supervision is poor and the fact that cassava roots do not have the capacity to regenerate means that large-scale wastage goes unnoticed.

Many managers and labour contractors try to overcome this by paying labour on the basis of weight of roots harvested; however, in a heavily yielding crop there is little incentive for the individual labourer to spend time digging around blindly for parts of roots.

Subsistence and small farmers trying to maximise productivity from a small piece of land rarely leave behind broken roots.

2.2 ROOT PREPARATION

2.2.1 Subdivision of the Root Cluster

Having harvested the cluster of roots and the pieces of broken roots, the next operation is to break up the cluster by chopping the roots at the point of connection with the original cutting, i.e. severing the peduncle. This is universally done using a heavy knife or hoe as the peduncle is usually very fibrous and resists attempts at breaking off.

The removal of the individual roots in the field is necessary to improve the efficiency of root transportation. Unless they are removed from the cluster, roots cannot be packed properly. As cassava roots have a comparatively low value: volume ratio it is very important that the transport space, whether it be in a basket or truck, should be used as efficiently as possible.

2.2.2 Root Trimming

The degree of root trimming depends on the ultimate destination of the roots. In the case of roots destined for the fresh market it has been shown that roots deteriorate at a slower rate if they are detached cleanly through the narrowest part of the peduncle (Booth 1975). However, where roots are destined to be macerated for starch production the presence of the woody peduncle has been shown to cause increased wear on machinery. In this case, therefore, the roots tend to be trimmed at the point where the peduncle and root fuse, sometimes with the associated loss of a small portion of the "shoulder" of the root.

Where roots are destined for human food, but are sun-dried first, e.g. gapiek, the woody and therefore unpalatable peduncle is trimmed off in the field at the time of harvesting. In contrast, where roots are destined specifically for animal feed, after chipping and drying, little attention is paid to the presence of, or even amount of, peduncle attached to the root. As discussed later under "Quality Standards and Control (Section 2.7)", the EEC limit of 5 percent fibre is sufficiently generous to allow the inclusion of at least most of the peduncle.

In circumstances where labour is remunerated on the basis of weight of roots harvested, the peduncle-trimming operation is frequently carried out incorrectly in the attempt to increase wages.

2.2.3 Root Peeling

In most instances any peeling of roots that is carried out is performed in the factory or kitchen immediately before processing. Most of the cassava chips destined specifically for animal feed are not peeled at any stage. However, in Indonesia where sun dried cassava chips are produced mainly for human consumption, with only the surplus going to animal feed, the roots are peeled in the field.

Peeling cassava involves the removal of the two outer layers of the root. The outer layer is a corky periderm, paper thin in most varieties. This layer peels off easily in some varieties. The inner layer of peel, the thickness of which varies with variety and diameter of root, is made up of phloem with associated parenchyma and sclerenchyma cells. This layer is normally 2.5 mm in thickness and contains substantially higher concentrations of cyanogenic glucosides than the fleshy inner regions of the root. Traditional users are aware of the bitter taste of the peel and normally remove it at some stage during food preparation. Reports from country districts of Southern Java, where the population relies heavily on cassava chips as a major source of dietary calories, indicate that in periods of critical food shortage only the corky outer layer of the peel is removed before the roots are chipped and dried.

Root peeling in the field is performed usually with a knife. Easy to peel varieties are peeled by slitting the peel longitudinally along the length of one side of the root. The knife blade and fingers are then used to roll back the peel from the fleshy portion of the root. Difficult to peel varieties are often peeled by whittling the two layers of peel with a knife using an action reminiscent of sharpening a pencil. This type of peeling operation is less satisfactory than the previous technique described as it usually results in the removal of some of the flesh with the peel and/or some of the peel is left adhering to the flesh.

The rationale for peeling in the field is not clear, other than reducing the weight of material for transportation to the village where the subsequent processes involved in chip production are carried out. Cassava peel undoubtedly returns nutrients to the soil, but equally could be fed to livestock.

2.2.4 Soil Contamination

The majority of cassava varieties produce roots with a rough exterior. This tends to encourage particles of soil to adhere to the roots. The quantity of soil is influenced by the clay content of soil and the weather conditions at harvesting. High clay soils, especially when wet, can contribute to heavy contamination. In contrast dry sandy soils result in roots with very little soil contamination. As with much of the information relating to cassava production technology, there are plenty of qualitative reports but little quantitative data.

Large clods of soil can be removed from the roots during trimming operations. However, in wet clay soils total soil removal is impossible. Roots with rough outer skin and uneven surface tend to carry more soil than smoother roots.

2.3 ROOT TRANSPORTATION AND STORAGE

Cassava roots are bulky and transportation over long distances is difficult to justify in economic terms. When one couples this with the rapid deterioration in quality of fresh roots, the complex problem associated with transportation of fresh cassava roots is appreciated.

2.3.1 Transportation

Currently cassava is transported using a wide range of methods which depend on the quantity of cassava involved, the terrain and the presence, or absence, of roads.

2.3.2 Scale of Operation

Small-scale producers harvesting cassava for their own family's subsistence transport the roots in baskets or metal bowls. As these are frequently carried home on the head, thereby freeing the hands for carrying tools and implements etc., the quantity of roots is limited by the carrying capacity of the individual.

Larger quantities are carried on the backs of pack animals in baskets or sacks (typically in Latin America) or in animal drawn carts. Up to 100 kg of roots or more (especially in the case of a cart) can be transported. Where roads exist motorised pick-up trucks and small lorries are increasingly used. Only where large-scale processing is carried out, e.g. Thailand and South Sumatra, Indonesia, are large trucks used on a regular basis.

2.3.3 Source of Transport

As few growers possess means of transport other than their own physical capabilities and/or animal power, large volumes of cassava roots are transported to the processors in vehicles owned by second parties. Depending on the size of the load the farmer will pay to hire the vehicle for the journey or, if the load is smaller than the capacity of the vehicle, the farmer will pay a transport charge on a weight or volume basis.

In some cases, where many small independent growers have cassava roots offered for sale, intermediate traders become involved who pay for the roots at the farm gate, transport them at their own cost and when a full load of roots has been collected in this, sell it to the processors at a delivered price. Further discussion of these practices is presented later in this report under 'The Economics of Chip and Pellet Production' in Section 3.

2.3.4 Time Frame

Due to the perishability of fresh cassava roots, the growers normally organise the transportation of the roots on the day of harvesting (where small quantities for subsistence requirements are involved), or on the day following harvest. A Malaysian survey showed that processing commences in less than 48 hours after harvest of roots.

In countries where the roots are to be sold as a fresh vegetable, the roots are packed in sacks or baskets for transport together with a quantity of fresh leaves removed from the crop at the time of harvest. The leaves have a three-fold role to play:

- They indicate the freshness of the roots, cassava leaves becoming brittle after 2-3 days.

- They help to identify the variety of cassava.

- They help to keep the cassava roots moist when packed around and above the roots.

Where prices are fixed on the basis of visual appearance of roots, or on starch content, there is an incentive for farmers to transport their roots to market, or the processor's facilities, as soon as possible after harvest. Depending on variety and the conditions prevailing at the time, cassava roots begin to deteriorate within 24 - 48 hours after harvesting, the first visual symptoms of deterioration being a brown-blue streaking within the flesh of the root visible when the root is cut or broken.

In addition to the visual symptoms of deterioration, biochemical changes occur which lead to a diminution of starch content and deterioration in starch quality in the root. Thus the processor associates visual symptoms of vascular streaking with reduced starch content and quality. This is of particular relevance to starch processors, but to chip producers starch content is of secondary importance. Even low dry matter cassava roots (70 percent moisture) still contain 74 percent starch when dried down to 15 percent moisture. Therefore there is not the same degree of urgency for cassava farmers to get their roots to the chipping plant.

In general no price premiums are payable for quality unless the roots are so badly deteriorated that the chip producer will not accept the roots. However, chip producers are known to adjust the prices they pay for fresh roots in accordance with the conversion ratio of fresh roots: chips which may vary from 2.2 to as high as 3.0 depending on the season and the composition of the roots.

In situations where starch factories and chipping yards are in open competition for fresh roots, the farmer will try to sell his roots for starch if the quality of the roots is high, i.e. freshly harvested and with high measurable starch content. Where the farmer knows that his roots are not fresh, or that the crop is immature and root starch content will be low he will not attempt to sell to the starch factory but will market directly to the chipping yard

2.3.5 Root Storage

In spite of major advances in root storage techniques developed at CIAT and elsewhere during the past twelve years (Booth 1975, Wheatley 1983 pers. comm.), no storage of roots is practised on a commercial scale in chip producing countries. Post harvest deterioration and storage problems are described in Appendix 2.

2.3.6 Clamp Storage

Some success has been achieved storing relatively small quantities (100 kg) of roots in straw and soil clamps but the method has proved unreliable and repeatability has been a problem.

2.3.7 Box and Bag Storage Techniques

More consistent successes have been achieved storing even smaller quantities in containers filled with moist packing material, e.g. boxes filled with sawdust or peat. Latterly a few kilos of roots placed in polythene bags have been shown to be a successful storage method for periods up to two weeks. Even though the external appearance of roots is little affected, there are internal changes in texture and biochemical changes have been demonstrated.

These limit the storage period where the cassava is destined for the fresh root market.

The costs associated with the fresh root storage techniques so far developed are beyond the reach of the chipping industry and so there is little likelihood that any storage of fresh roots using the currently available techniques can be envisaged.

2.3.8 Other Storage Techniques

Other high-cost storage methods whereby cassava can be stored, i.e. low temperature controlled environment, and surface waxing are even more beyond the cost limits of the chip producer.

2.4 CHIPPING PROCEDURES

Chipping, as a preliminary to sun-drying as a method of overcoming the rapid post-harvest deterioration of cassava is a traditional practice carried out in many cassava producing countries.

Traditional processing methods have been extensively reviewed by Lancaster et al (1982). In South America, the home of the cassava crop, chipping in the accepted sense does not seem to have been a traditional practice. The principal varieties were "bitter", i.e. high cyanide types, and therefore detoxification was of paramount importance during food preparation. Roots were first peeled and then grated into a pulp rather than chipped into pieces. Graters varied from rough stones, prickly palm roots, shells and fish skins to sharp stones, splinters, bones or teeth set into basketwork or wooden frames. Metal graters were introduced by early European colonisers.

African traditional preparation techniques were transposed from indigenous root crops, e.g. yams, but it was only when settlers from Brazil entered West Africa after 1800 that preparation techniques based on South American practices gained a foothold. Due to the toxicity problems with cassava, it is the South American detoxification technology that really made the crop a relatively safe addition to the African diet.

Cassava chipping as a preliminary to further processing is carried out in many parts of Africa using manual techniques. These w'll be described in the appropriate section below.

In Asia, chipping is carried out in the production of food for both humans and livestock. The large industry involving the export of sun-dried cassava chips based on Thailand and latterly Indonesia has revolutionised chip production technology. Manual chipping techniques have given way to mechanised techniques based on European equipment introduced during the 1950-60s, although much of Indonesia's cassava is still hand processed.

The following paragraphs detail current methods of chip producing using both manual and mechanical techniques.

2.4.1 Manual Chip Production Techniques

In South America, the long experience gained by the inhabitants who first developed cassava into a food crop at least 2,500 years ago, has meant that simple chipping and sun-drying methods have been improved upon at the traditional level to the point of rendering them virtually obsolete. In Brazil a form of chips subsequently sun-dried into "Carima", a basic famine reserve foodstuff, is briefly reported. The preferred "Farinha de Mandioca" is the most produced foodstuff from cassava. It is in Africa, and particularly Asia, where cassava is a relatively new introduction, that manual methods of chip production are common.

2.4.1.1 Timing of Manual Chipping Operations

In the context of this report, chipping operations are related solely as a preliminary to sun-drying. The timing of the operation is therefore to a certain extent pre-determined by the availability of roots to convert into chips, and the weather.

In the parts of the tropics which have fairly regular, pre-determined climatic patterns, cassava planting operations are usually linked to periods of rainfall during which the soil can be tilled, the cuttings germinate and the young plants develop. Although the timing of cassava harvesting operations is more flexible than cereals or pulses, the fixed planting time does, to a certain extent, determine the harvesting period of the cassava crop. As crop development and deposition of starch in the roots slows down and eventually ceases during a severe dry season, it is an opportune time to harvest the crop and use the dry conditions to process the crop into sun-dried chips.

The actual month during which manual cassava chipping operations are carried out varies widely both within and between countries. This is dependent on the availability of labour, soil conditions and other such factors. Farmers' priorities must be recognised, and whereas cassava harvesting conditions may be ideal from the soil moisture aspect, a farmer may give a higher priority to harvesting a more valuable cereal or pulse crop which could shatter or be eaten by birds or rodents if not attended to.

Therefore no hard and fast rule can be applied to the timing of cassava chipping operations. The interaction between individual agricultural systems and the climate determine the most favourable time, which varies from locality to locality. Nevertheless most manual cassava chipping operations occur during the dry season so that a reasonably storable product results which can be stored until the next crop is ready for harvesting for food.

2.4.1.2 Root Reception and Preparation

In the previous section the practices associated with field harvesting operations, such as removing individual roots from the root cluster, trimming and peeling roots in the field, were discussed. Practices such as root trimming, root washing and peeling continue when the transported roots arrive at the home or small processor from the field.

It is not clear whether soil is washed from the roots on arrival from the field but the relative scarcity of water in many rural areas in tropical countries, especially during the dry season when cassava harvesting and sun drying is at its peak, would probably exclude the practice. The subsequent procedure of peeling (discussed below) renders the washing of the exterior of the root redundant. It is therefore safe to assume that where root washing is practised it is most frequently carried out after the roots are peeled.

2.4.1.3 Root Soaking

In some parts of the world, cassava roots are immersed in water as a preliminary to chipping and sun-drying. This practice is prevalent in parts of Africa where a slightly sour flavour is preferred in the foodstuffs prepared from the dry cassava chips. In north-west Zambia freshly harvested cassava roots are placed into sacks which are then tied and immersed in water filled pits along the sides of rivers or in dambos (inland drainage basins). After approximately 3 days (longer in the dry season) the sack is removed from the water and the roots removed.

Root soaking, in addition to imparting a sour flavour to the final food, has been shown to significantly reduce the cyanide content of the root. Studies in Zaire (Bourdoux et al 1982)* demonstrated that soaking "bitter" cassava roots reduced the HCN content of roots (Table 2.2).

TABLE 2.2

EFFECTS OF SOAKING CASSAVA ROOTS IN WATER FOR PERIODS OF UP TO 5 DAYS

Soaking Period (days)	Residual HCN Mean (mg/kg)	Percentage
0	108.2	100
1	59.5	55
2	45.8	42
3	20.6	19
4	11.8	11
5*	2.9	3

Note: After 5 days the roots decomposed.

* In Delange F, et al 1982.

Further analyses showed that during soaking the linamarase enzyme was not deactivated as autolysis continued until linamarin was exhausted, all the HCN having been released and presumably lost in the water in which the roots were soaked. This confirms that soaking is an excellent method of detoxification as the bound cyanide (in the linamarin) is removed in addition to the free cyanide.

2.4.1.4 Root Peeling

The almost universal knowledge in cassava consuming areas that cassava peel is unpleasantly bitter results in the frequent practice of root peeling before preparation into food. Even during food shortages peeling of roots is continued in Zaire.

It was described previously in this report that cassava root peel is made up of two portions, the thin corky outer layer and the thicker under-peel (see 2.2.3 above). In the majority of cases "peeling" implies the removal of both layers of peel. However, in south India a form of chips is produced where only the corky outer layer of peel is removed before the chips are sun-dried.

The thicker inner layer of peel is rich in cyanide and laboratory analyses have shown that the peel contains as much as 10 times more HCN than the underlying flesh of the root on a weight for weight basis. Peeling losses are rarely reported but it is known that some varieties have a larger peeling percentage than others. A comparison between 7 Indonesian varieties showed peeling losses varied between 16 and 30 percent (Hirose 1976 quoted in Nojima and Hirose 1977). Further details of hand peeling techniques have been mentioned in Section 2.3.

2.4.1.5 Splitting and Chipping Roots

In order to achieve a thorough sun-drying effect it is widely understood by traditional growers/processors that cassava chips should be thinly sliced. However, in many areas where labour is scarce (or farmers and their families are busy doing more important duties), cassava roots are cut into chunks, quarters, halves or even "dried" entire. This practice of leaving roots in large chunks leads to inadequate drying in many (if not most) instances and leaves the interior of the chunk in a semi-fermented state. This undoubtedly imparts a musty, fermented flavour to the food which in many parts of the world appears to be preferred. Thus it is proposed that the apparently "inefficient" chipping method used by traditional producers is a method whereby cassava is processed into a semi-fermented "tasty" foodstuff which has an extended shelf life.

The actual procedure of splitting or cutting the roots into chunks is performed using a heavy knife. Cutting the roots into thinner slices or chips is a more tedious operation with the added danger of wounding the operator's hands.

Therefore a range of simple cutting aids have been developed which are described in more detail later in this section.

2.4.1.6 Rate of Peeling and Splitting Operations in Indonesia

Large scale peeling and splitting operations were carried out in the south Sumatran province of Lampung during the early 1970s. Work studies provide some estimates of output per operator (Ishida, 1976, quoted in Nojima and Hirose 1977). Ten kilogram samples of roots took between 16 and 22 minutes to peel. This equates to 16.5 hours to peel 500 kg of roots, a standard rate quoted in the Lampung area. Peeling losses varied between 16 and 18 percent with variety Genjah Lampung. Chipping time varied with the type of "chip" being produced.

Cut into 1 cm cubes	7.5 minutes per 10 kg of peeled roots
Cut into large chunks	7.6 minutes per 10 kg of peeled roots
Cut into 2 cm thick slices	7.95 minutes per 10 kg of peeled roots

This is a surprising result considering the difference in chip size produced by the different methods.

2.4.1.7 Mechanical Aids to Hand Chipping

In addition to the ubiquitous knife a number of small cutting aids have been developed to assist in the root slicing/chipping process. Cutting aids are particularly useful where uniformly thin slices are required, as the thinner the slice and the greater the degree of uniformity required, the greater the danger of the operator accidentally wounding his/her hands

As rasping is regarded as a distinct operation from slicing or chipping, the various raspers are not described in this report. Rasping is normally a preliminary to squeezing or pressing rather than sun-drying. Sun drying rasped material would lead to high losses due to wind blown particles, especially during the final drying stages.

Two cutting aids have been observed, both in Indonesia, where thin cassava slices are prepared as a human food. These slices are deep fried in oil and served as a snack, resembling potato crisps in Western Europe. One slicer is in the form of an adjustable metal blade mounted in a frame so that when the root is pushed repeatedly over the blade thin slices of root are removed.

The other machine observed is produced by the Food Technology Department of the Gadjah Madah University in Jogjakarta, Java, Indonesia. The machine is basically a revolving metal disc which incorporates a knife blade slicing thin pieces of roots fed against the face of the disc through an aperture. The cutting disc is rotated by hand using a simple handle.

Both cutting aids produce root slices 1-2 mm in thickness, usually circular in shape, reflecting the cross section of the root.

2.4.2 <u>Large Scale Mechanical Chip Production Techniques</u>

The advent of the use of sun-dried cassava chips as a source of animal feed and industrial raw material (e.g. South Korean alcohol produced based on Thai cassava chips), has led to the development of mechanical chipping machines. By far the largest cassava chipping industry has developed in Thailand where more than 12 million tons of cassava roots were processed through locally produced mechanical chipping machines during the 1982/83 cassava season. In neighbouring Malaysia a small internal cassava chip industry has existed for over twenty years producing livestock feed for the local market. Both countries have independently developed mechanical chipping machines which have gained international reputations. As the machines are sufficiently different they are discussed separately , together with other prototype machines, below.

2.4.2.1 Timing of Mechanical Chipping Operations

Currently all the mechanical chipping operations appear to be devoted to producing chips for sun-drying. Therefore the periods of most intensive chip production occur when cassava roots are available for processing, and when weather conditions are most suitable for sun-drying operations.

During the early 1970s a number of oil-fired mechanical dryers were constructed in various parts of the world designed to dry cassava chips independently of the weather. Although some of these machines started large-scale production of high quality chips and pellets, the sudden increases in oil prices during the mid 1970s forced the closure of these operations. Exhaustive enquiries have failed to discover any cassava chip drying operations currently operating which use any source of energy other than the sun.

The major cassava chip producing countries, Thailand and Indonesia, concentrate their chipping operations during the dry season. This occurs from December to April/May in Thailand which is north of the equator. In Indonesia, which is south of the equator, the dry season begins in May and extends until September/October.

During periods when prices are high for dried chips (i.e. demand is great) and roots are available, some sun-drying will be carried out even at the height of the rainy season. Quality will be much poorer as discussed later in this report.

In Malaysia, which does not enjoy a marked dry season, cassava chip production continues throughout the year. Root availability is not seasonal as planting and harvesting operations are not necessarily linked to wet/dry seasons. The Malaysian cassava chip industry appears to have developed a technology which is appropriate to the comparatively wet climate as will be discussed in the following sections which discuss machine design and drying procedure.

2.4.2.2 Root Reception and Preparation

Depending on the quality standards imposed upon the finished chips, the roots may be inspected and prepared before being fed into the chipping machine.

In Malaysia, where sun-dried chips are sold in the local markets to pig and poultry producers, attention has to be given to the visual appearance of the chips. Hence a white, clean chip is preferred. In order to achieve this appearance roots are chipped and dried before root discolouration attains serious proportions. It is usual to process roots within 48 hours of the time of harvesting. However, delays may occur due to rain preventing sun-drying operations. The backlog of unchipped roots begins to deteriorate after 2-3 days at the chipping factory, producing brown chips, mainly due to primary (physiological) deterioration. As no large-scale storage systems exist to prevent primary deterioration, the processor has two alternatives:

- to chip and dry deteriorated roots
- to discard the deteriorated roots

Chip producers rarely discard roots but will chip deteriorated roots and admix the discoloured chips produced with better quality chips from freshly harvested roots in the hope of achieving a sale.

Due to the type of blade used on Malaysian machines (described below) the roots are inspected and trimmed where necessary to remove woody material such as peduncles from over-mature (and therefore fibrous) roots, and pieces of cuttings, stem bases etc.

The majority of Malaysian cassava is grown in friable, free-draining soils. These tend not to be sticky, therefore serious soil contamination appears not to be a problem, although ash contents of up to 5 percent have been reported (Manurung 1974)*.

In Thailand which produces cassava chips for export principally to the EEC, little attention is paid to root quality in terms of primary deterioration, and content of fibrous material. Unlike the Malaysian situation where sun-dried chips are sold in an unaltered form, the vast majority of Thai chips are pelleted before export. During the pelleting process the browning due to primary deterioration is masked and as the quality standards set up do not include visual appearance there is no price premium (or penalty) payable.

As discussed later, the EEC quality standards as they affect Thai cassava chips/pellets are sufficiently generous to permit some fibrous material such as peduncles and pieces of stem bases. The design of the Thai chipper blade, with large perforations, will tolerate relatively large pieces of stem without causing machine blockage; therefore there is little incentive for the Thai cassava chipper to inspect roots and trim woody material.

Soil is, however, a problem to Thai cassava chip manufacturers, especially on alluvial soils during the rainy season. When roots arrive at the chipping yard with high soil contamination, some operators pass the roots over a specially designed elevator which has a chain conveyor. This "tumbles" the roots and encourages the soil to be rubbed from the surface of the roots as they ascend the elevator on their way into the chipping machine.

It is usual for starch processors to wash soil from roots as a preliminary to macerating the roots. However, no root washing facilities have been observed or reported for use with chipping/sun-drying operations. This aspect is discussed further under "Quality Control" later in the report. (Section 2.7).

In all mechanised chip producing areas roots are dumped in heaps as close to the chipping machine(s) as possible to reduce handling costs. During unloading and feeding the roots into the chipping machine soil is knocked from the roots. In small Thai and Malaysian chipping operations roots

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* In Araullo E.V. et al (1974).

are handled, i.e. thrown individually without concern for damage, breakage, bruising etc. This rough treatment does remove much of the soil adhering to the roots. However, with the recent introduction of tractors with front loaders it is possible that a greater quantity of soil contamination in the chips and pellets will result.

2.4.2.3 Thai Chipping Machines

As stated above, the Thai chipping machine is responsible for processing a huge quantity of cassava roots each year and from the viewpoint of throughput must be considered a successful design. However, from the standpoint of chip quality in terms of particle geometry and the related particle drying characteristics, the machine is less successful than other designs. Nevertheless, against the backdrop of the Thai cassava industry and its market price structure the Thai cassava chipper performs an adequate job.

Whereas the literature frequently refers to "The Thai Cassava Chipper", there are in fact a number of commercially available mass-produced chipping machines in Thailand. These however share a common feature which is the mechanism used to chop the roots.

The cutting mechanism common to Thai chippers is a circular metal plate into which perforations reminiscent of a vegetable grater are cut. The original Thai chippers incorporated the covers of 44 gallon oil drums as blades. These were perforated with 60 cutting edges, using a chisel. However, the material from which barrel covers are made is mild steel, not the ideal metal from which to manufacture blades. Currently blades are specially manufactured from discs of steel with up to 120 perforations (in 24 radii) punched into the disc.

The circular cutting disc is mounted on a horizontal shaft using four bolts to facilitate replacement. Interviews with machine operators revealed that the cutting discs are replaced frequently (ten or more per season is not uncommon). Motive power is provided using internal combustion or electrically driven motors. Roots are fed into the machine from above via a feed hopper and the chips (more accurately described as chunks) are captured in a circular cover over the cutting blade. Most chippers incorporate a short, rubber-belted conveyor which transports the chips which fall from a hole in the bottom of the circular cover, and deposits them in a heap or into lorries, trailers or wheelbarrows.

Throughput of Thai chipping machines varies from 10 to 50 tonnes of roots per hour. Smaller capacity machines are usually fed with roots by hand using shovels or baskets. Larger capacity machines are increasingly fed by tractors equipped with front-loading shovels. These can either be second-hand earthmoving equipment or specially constructed equipment designed for use with cassava.

The chips produced by the Thai machines lack uniformity and vary in size from tiny particles 2-3 mm in diameter to chunks 3 cm in diameter. In fact, entire small thin roots can frequently be observed among chips on the drying floor, having passed almost unscathed through the perforations in the cutting disc.

Increased machine throughput is achieved by applying pressure to the roots being fed into contact with the cutting disc. This is achieved by having a large volume feed hopper with larger machines. At least one chipping operation feeds roots into chipping machines by unloading roots onto a horizontal endless-belt conveyor. In this case the cutting discs are mounted into a wall so that chips pass from one side of the wall to the other and fall onto a conveyor for transport to the drying floor.

In addition to replacement of entire cutting discs, the cutting edge of the perforations in the disc is sharpened using files or carborundum wheels mounted in electric hand drilling machines.

2.4.2.4 Malaysian Chipping Machines

As in the case of the Thai chipping machines, published reports frequently refer to <u>the</u> Malaysian cassava chipper. Again there are many variants and as the Malaysian chipping industry is infinitely smaller than the Thai industry almost every commercially operating machine is unique in some detail. However, the cutting wheel of all Malaysian chippers observed in commercial use is a feature common to all machines.

The Malaysian cassava processing industry is mainly concentrated in Perak State with some activity in the south of the neighbouring state of Kedah. The town of Ipoh in Perak has a considerable engineering industry resulting from the town's long association with tin mining. This engineering capability has resulted in the development of the cutting wheel common to all Malaysian chipping machines.

The wheel is a circular disc, usually of half-inch (12 mm) mild steel plate about 1 metre in diameter, with slots machined into the disc to receive removable, adjustable cutting blades. A central hole is provided, together with bolt holes, so that the wheel can be attached via a flange to a horizontal shaft.

The cutting wheel, shaft and motor (petrol, diesel and electric variants have all been observed) are mounted in a wooden frame normally constructed by the local carpenter. Mobile chipping machines exist, with wheels and a tow bar attached to the frame. Roots are fed against the cutting wheel from a hopper mounted in the top of the frame.

Cutting blades are made in a tin-plate shop in Chemar, a village a few kilometres to the north of Ipoh. Various size blades are available and blades with various types of cutting edge are also manufactured. Blades are hand made from 16 SWG mild steel sheet. Pieces of sheet, pre-cut to size, are mounted on a piece of RSJ modified by filing grooves into the metal. A clamp device, together with metal pegs which fit into holes punched into the piece of sheet, retains the "blade" in place whilst the cutting edge is created.

An oxyacetylene torch is used to heat the side of the blade to be made into the cutting edge. The blade is heated to red heat and simultaneously "formed" using a hammer and drift, shaping the edge of the blade into corrugations. A proprietary case-hardening substance is applied to the corrugated area in an attempt to increase the wearing capacity of the blade. Three sizes of corrugation are available. Fine blades, used to produce thin cassava chips for chicken feed, are only made to special request as demand for this blade is small. Medium and coarse pitch corrugations are available from stock. Blades are sold in sets of six, as there are usually six slots provided in the cutting wheel (however 4 and 8-bl ded variants have been observed).

Blades are mounted into the cutting wheel using two bolts. The blades are slotted permitting the adjustment of the cutting edge of the blade as it wears away with use. Blades are equipped with two wire guides brazed into place. These retain the blade in position against the cutting wheel and can be adjusted by bending to the individual requirements of the chipping machine operator.

Blades are quickly and easily removed for sharpening or replacement. Sharpening, done on a daily basis on bigger yards, is performed by using a round file or electrically driven carborundum grinding wheel. Under constant use, chipping blades require replacement each month.

Roots are thrown into the hopper by hand or in baskets. The roots come into contact with the chipping blades in a random manner so that chips varying in length from 2-3 cm to 20-30 cm are produced, depending on the diameter and length of roots and the attitude at which the root makes contact with the cutting wheel.

Chips fly 1-2 m from the cutting wheel and land in a heap on the floor in front of the machine. The brown corky outer peel of the roots, together with much of the soil, tends to separate from the chips during the cutting operation and, being lighter in weight than the chips, tends to fall to the ground below the cutting wheel.

Depending on the pitch of corrugation of the cutting blades used, the chips vary in thickness from 3-6 mm and are usually semi-circular in section. Long chips usually break into smaller pieces during drying and dry chips rarely exceed 10 cm in length.

All metal cassava chippers have been produced by an engineering foundry in Ipoh and a number have been exported. The danger of all metal construction is the destructive properties of the HCN liberated in the roots at the moment of chipping. Pulpy fragments of root splatter all around the chipping machine and the HCN corrodes metal which it contacts. A sack is frequently placed above the cutting wheel to prevent the pulp flying into contact with, and subsequently corroding, the corrugated iron roofs which normally protect Malaysian chippers.

The corrosion of metal results in the need to replace a mild steel cutting wheel about every 6-7 years. One large chipping operation in Malaysia installed stainless steel cutting wheels to obviate the corrosion problem.

2.4.2.5 Prototype Chipping Machines Produced at CIAT

Many other chipping machines have been designed and a few are in commercial operation in different parts of the world. Some are modifications of Thai and Malaysian type machines. CIAT has redesigned both machines and currently favours the Thai design due to difficulty in producing the Malaysian type corrugated blades. CIAT's Thai-type machine is simpler than the larger machines used in Thailand as it does not have the endless-belt conveyor discharge.

The prototype chipping machine developed by CIAT, which is currently being used by a small farmer co-operative on the Atlantic coast of Colombia, incorporates elements of the Malaysian type machine, e.g. the frame and large diameter wheel, but the feed hopper is larger than that of the typical Malaysian machine (which increases the force with which the roots are pushed against the cutting edges), and a Thai-type perforated cutting wheel is used. This produces small chunks rather than the long strips of the Malaysian-type machine. The cutting wheel has 39 perforations arranged in 6 radii, with 6-7 perforations along each radius. The machine is powered by a 3 HP gasoline motor.

CIAT's research programme is aimed at, among other things, the redesign of the intake chute of the chipper, the redesign of the chipping wheel to improve chip homogeneity and to design a protective device near the chipping wheel to prevent oversize chips.

Tests during operations on the Atlantic Coast show that the machine will process between 828 and 1,610 kg of roots per hour with a mean figure of 1,291 kg. Four men are required to operate the machine, one emptying sacks filled with roots, two feeding the machine and one pushing the roots down the feed hopper. It is planned to construct a ramp to improve the efficiency of chipping operations by reducing the number of operators.

The modified Malaysian type machine produced by CIAT has 4 corrugated type blades. A cover reminiscent of the Thai type chipper collects the chips, therefore the partial soil and peel separation that occurs with the original Malaysian machines does not take place.

A third prototype machine has been constructed at CIAT and is based on a recent Brazilian design. A rotating metal drum with baffle plates throws roots against a cutting blade located in conjunction with a series of rotating metal discs. By adjusting the thickness of metal spacers between the discs and the position of the cutting blade, chips of different dimensions can be produced. As the machine is still being evaluated and modified its likely performance is as yet unknown. The machine has the design capability of producing square section bars 10 mm thick, which were shown by Roa (1974) to be efficient particles from the point of view of sun-drying.

2.5 CHIP DRYING PRACTICES

The drying of both freshly harvested and prepared foodstuffs as a means of preventing its deterioration is a practice which goes back to the origins of civilisation. As cassava is assumed to have been a crop plant in the Americas for many thousands of years, the practice of drying the roots as a method of preservation can be assumed to date back as far as the crop itself.

Small scale drying of cassava and cassava products is carried out in virtually every location that the crop is grown. In Brazil and West Africa where cassava is mainly processed into 'farinha de mandioca' and 'gari', both similar products, the final stage in the process is the drying of the fermented dewatered mash. As this study concentrates on the production of sun-dried cassava chips the drying of other cassava products is considered irrelevant, and current methods used for chip drying are concentrated upon.

A review of factors affecting cassava chip drying is given in Appendix 3.

2.5.1 Small Scale Natural Drying of Cassava Chips

In its most rudimentary form, cassava drying involves placing peeled whole, or crudely divided roots in any sunny position to dry. This practice still continues in many parts of the world and the locations in which the roots are placed varies with local availability. In Java roots can be seen spread on soil within the village precincts, on stones in the river beds, on tiled roofs, on straw mats between houses and on pavements and the edges of metalled roads. In short the chips are placed in exposed spots which heat up in the sun, but are out of the way (where possible) of people, animals and vehicles. The danger of theft prevents the practice of leaving chips to dry in locations away from the village where they cannot be watched.

The local inhabitants' understanding of the factors affecting drying is shown by the Indonesian practice of hanging incompletely split roots of cassava on wire fences. In this location exposure to moving air on all sides leads to efficient drying, and protects the chips from contact with the dusty ground.

In African countries the drying of crops on raised platforms constructed from wood and grass/bamboo/reeds etc has been practised for many years. Cassava chips are dried on such platforms in Zambia, and the resulting products are relatively uncontaminated having been kept out of contact with the soil or with dust blowing at ground level.

Losses, damage and contamination from wandering livestock, dogs and chickens are greatly reduced and the advantages in terms of theoretical drying efficiency (discussed in Appendix 3) are gained. The platform raises the chips into a zone of moving air thereby speeding up the drying process.

The rate of drying under primitive small (village) scale conditions varies with the size of 'chips' prepared (discussed under 'Chip preparation' above), the climate and the nature of the product required. In Central and

Southern Africa, where cassava roots are soaked as a preliminary to drying, the 'chips' are in fact chunks of soft pulpy root separated by hand from the peel and the fibrous core of the root. These particles are water soaked and having a greater initial moisture content than unsoaked chips take longer to dry. No reports of experiments on the drying of soaked roots have been identified, thus this appears to be an area requiring elucidation.

Large particles of cassava tend to be more difficult to dry thoroughly than smaller thinner particles. This is due to the need for the moisture from the core of the particle to diffuse to the surface. When the surface is almost totally dry the moisture trapped in the core diffuses out with difficulty. Thus whole roots or halves and quarters of thick roots dry with difficulty and even when sold as 'dry' contain in excess of 20 percent moisture. Such is the case with 'gaplek' a traditional cassava based human food of Indonesia which is also exported for use as animal feed.

Depending upon the weather gaplek normally takes up to a week before the moisture content is acceptable for storage requirements or for sale. Interviews indicated that gaplek is sold when drying is inadequate and the purchaser may continue the drying process to increase the gaplek's shelf life or make it a more saleable commodity. Reports of 'dry' gaplek with a mcisture content of between 20 and 25 percent are commonplace.

2.5.2 Large Scale Natural Drying of Cassava Chips

The demand for cassava chips for livestock feed, principally by the countries of the EEC has stimulated the development of large scale commercial drying operations principally in Thailand.

Other countries have, from time to time, entered the trade with the EEC, but the cassava chips in the majority of cases were the result of small scale chip production at the farmer level such as that still occurring in Indonesia.

Cassava chips have been imported by European countries, especially Germany, since before World War II but it was only when the EEC was formed, and grain prices were supported at above the world prices that the interest of other European feed millers turned to cassava. The Dutch and Belgian livestock feed industries began using significant quantities of cassava chips in the early 1960s.

As a result of growing EEC demand the cassava growing, chipping, drying and pelleting industries grew rapidly during the 1960s and 70s. The Thai cassava industry is stratified with farmers selling their roots to chip producers who then dry their roots on concrete floors before, in turn, selling the dried chips to pelletizers or directly to exporters.

The standard Thai-type chipping machines, described in the previous section, chop the cassava roots into irregular chunks varying widely in size up to 3 cm in diameter. The 'chips' are spread exclusively on to concrete floors to dry in the sun. No other technique for chip drying has been reported for Thailand.

Actual operations at the chipping and drying yards vary depending on factors including size of operation, availability of labour locally and management capabilities of the individual entrepreneur. Some drying yard operators arrange to chip the roots during the night so that the chips are spread in the first hours of daylight so that best use is made of available sunshine. However, it appears that most operators begin chipping roots early in the morning after dawn using high throughput machines to reduce the duration of the chipping operation. thereby making more time available for the sun drying operation.

2.5.2.1 Spreading the Chips

Thai-type chipping machines are equipped with small endless-belt conveyors which transport the chips away from the chipping blades. Previously a common sight on Thai chipping yards were two-wheeled barrows made of wood and sheet metal used to transport chips from the chipping machine to the drying yard. These barrows are still common on smaller yards, but the bigger yards have replaced wheelbarrows and their operators with tractor mounted shovels and similar implements. Still other operators use wooden blades mounted on the front of tractors, lorries and even old cars. These vehicles push a heap of chips from the machine to a location on the floor where they are spread out to dry by hand. Experienced operators can spread the chips using the blades and shovels, but this operation is difficult as a layer of chips less than 5 cm deep is required.

Hand spreading of chips involves the use of large bladed shovels used in a sweeping arc to spread the chips evenly over the floor.

The general move towards the mechanisation of chipping yard operations has led to the development of chipping spreading machines. These machines developed and constructed in Thailand resemble European seed drills for cereals. A long wooden box with inward sloping sides is mounted on two wheels and provided with a tractor hitch. At the base of the box a rotating rod with metal fingers attached feeds the chips through a slot in the base of the box. The rate of revolution of the feeding mechanism is controlled by the speed of the ground wheels. Adjustment appears to be possible so that the chip loading rate can be changed.

2.5.2.2 'Turning' the Chips

In order to speed up the sun drying process, which normally takes from 2-3 days under normal dry season Thailand weather conditions, the chips are 'turned' at regular intervals. Traditionally wooden rakes, with tines spaced at 5-10 cm intervals, were developed for this purpose but large chipping yards found it increasingly more difficult to find the score or more casual labourers to operate the rakes as and when the weather dictated.

During the past three years motorised rakes have been developed for turning the chips and can be seen on many larger drying yards. These machines are fabricated locally using whatever scrap is available, eg the front part of a motor cycle, a petrol engine and a two-wheeled axle. The motorised rakes quickly turn the chips by drawing rubber-tipped spring mounted tines through the layer of chips at regular intervals. At the drying yards visited the motorised rake was started hourly and completed the task in 10-15 minutes allowing the operator to carry out other tasks.

2.5.2.3 Collecting the Chips

As it takes 2-3 days before the chips are dried sufficiently so that they can be stored or sold there is a risk that rain will fall on the chips whilst they are spread on the yard. With the threat of rain or at nightfall, the chips are collected together into heaps and covered to protect them from rain. Small portable corrugated iron roofs on wooden frames were once used to protect these heaps, but due to their weight, and the time that operators needed to put each roof in place their use is declining. It is now more commonplace to find drying yard operators using plastic sheets and truck tarpaulines to protect heaps of chips, with pieces of wood and old tyres put on them to prevent their loss in windy conditions.

The actual collection of chips into heaps is done in small yards using wooden blades mounted on broom handles to push the chips along. Larger yards use blades mounted on tractors or lorries and specialised front-loader tractors produced for the cassava industry. Significant quantities of dust, mainly starch, appear to be lost during chip pushing and turning operations.

When the chips are dried to the satisfaction of the drying yard operator they are collected and prepared for transport to pelletizers or exporters or stored. In the past it was normal to pack dry chips into jute sacks of 70-80 kg. However the advent of bulk loading and unloading facilities has led to an increase in the transportation of chips in bulk.

2.5.2.4 Moisture Content of Chips

As the majority of the cassava chips exported from Thailand are pelletised, there is no necessity to dry the chips below 18 percent moisture content as the pelletising process heats the pellets and dries off the final 5 percent moisture to bring the pellets down to the required 13 percent.

A small proportion of Thai chips are still exported as chips. These are dried down to 13 percent on the drying floors before loading and despatching direct to the exporter.

2.5.2.5 Malaysian Drying Operations

The Malaysian cassava chip industry is much smaller than its Thai counterpart, but the operations of the drying yards were similar until recently. The large scale introduction of mechanised operations by drying yard operators in Thailand has changed this. Malaysia's cassava drying industry is contracting due to the inability to compete with imported cereals and Thai cassava chips, thus there has been no incentive to invest in new capital equipment. Hence hand spreading and turning are the norm. However, use is made of old tractors with wooden blades attached to push chips out onto the floor, and into heaps before rain, at the end of the day and when chips are dry.

The better drying characteristics of the Malaysian-type chip usually results in the drying period being restricted to two days. This in turn results in the chips being whiter in appearance than Thai chips. As Malaysian chips are sold entirely on the local market there is no requirement to pelletise. e local feedmills insist on properly dried chips so that drying yard operators continue the drying process until the chips dry below 13 percent moisture content.

2.6 PELLETING OF CASSAVA CHIPS

In order to reduce the bulk density of cassava chips, and in an attempt to reduce material losses in the form of dust and fines during the loading/unloading operations the process of pelletising was introduced in the early 1960s.

Imported machinery produced a hard pellet which being sold under a trade name became known as 'Brand pellets'. Local engineers soon began to produce pelletising equipment for sale to cassava exporters hoping to cash in on the savings to be gained in converting chips to pellets. Unfortunately locally produced pelletising equipment failed to generate the high pressures needed to produce really hard pellets due to engineering and metallurgical constraints. Pellets produced using local equipment were not properly cooled after pushing through the dies resulting in the collapse of the pellets. The resulting 'pellets' known as native pellets are high in dust and by the time they reach their European destination are almost entirely meal. Environmental pressures in Europe have reacted unfavourably to the pall of starchy dust which invariably resulted during unloading operations.

Cassava chips can be converted into good quality pellets providing the appropriate steps required are followed. However the small profits to be made in pelletising have tended to lead to short cuts in production techniques with resultant poor quality products.

Hard ie 'Brand' pellet operations mill and steam chips prior to their pressing through the die. This results in a uniform consistency and if cooled properly a smooth exterior that resists handling operations. In contrast native pellet operations frequently press unmilled chips through larger diameter dies without cooling facilities. The combination of larger 'pressed' pellets and lack of cooling, results in the native pellets falling to pieces very soon after their manufacture.

The impact of pellet quality on market price is discussed in Section 2.7.3. The introduction of pelletising can also be coupled with the practice of adulterating the pellets in order to extend the raw material and increase profitability. During the 1970s sand, cassava stems, root refuse after starch extraction, maize cobs and rice hulls all found their way into cassava pellets. The resulting outcry from the European purchasers led to the enactment of new legislation and tightening up of existing regulations set up to monitor, and police quality standards. The current quality of Thai cassava pellets is reported to be much improved over the 1970s levels.

2.7 QUALITY STANDARDS AND THEIR CONTROL

In common with many agricultural commodities, certain standards apply to cassava in some countries, especially those involved in international trade where customer confidence is an important factor for trading continuity.

2.7.1 Quality Standards for Fresh Cassava Roots

When cassava roots are to be sold as a fresh vegetable their quality in terms of visual appearance both externally and internally is very important. Roots with mechanical damage sustained during harvesting and/or transport frequently remain unsold in a discerning market and are disposed of as raw material for processing or animal feed. Cassava roots destined for processing are subject to less rigorous quality standards in terms of visual appearance but the compositional quality in terms of dry matter content and starch content is important.

Cassava destined for gari, farinha de mandioca and starch requires to be soil-free to prevent contamination of the final product. Hence a soil tare is levied by certain large-scale factories.

The major factor in terms of cassava root quality is the content and quality of the starch component. The majority of starch factories in South-East Asia have a method of payment to suppliers based on starch content. The actual methods used to determine starch content vary from a visual method, which involves breaking the root and inspecting the exposed surface of the root, to the use of specific gravity balances, some of which have been calibrated for cassava. A strong relationship between starch content and specific gravity has been determined (Wholey and Booth, 1979). In Thailand it is standard practice for starch factories to pay farmers a price related to specific gravity of a representative sample of roots.

The simplicity of the method and the low cost of the equipment render it useful not only to starch manufacturers but also chip processors who have been reported to be using a price differential based on starch content (Titapiwatanakun, 1981).

The rapid deterioration of cassava roots is also linked to a deterioration of the quality of starch granules. The granules become pitted due to enzymatic and micro-biological attack which affects their sedimentation rate. This in turn is regarded as indicative of starch quality. However, the colour and textural changes associated with the deterioration of cassava roots are less important to the cassava chip industry. In Malaysia where the product is marketed locally, chippers try to obtain a white product, but roots with vascular streaking and secondary deterioration can be frequently seen at chipping/drying yards.

In Thailand the discolouration of roots does not appear to cause any impediment to their sale and roots in any condition, providing they will pass through a chipping machine, appear to be saleable. Reports lament the high population of fungi and bacteria in Thai cassava products but the steady demand for them, in spite of the poor quality, appears to have resulted in a general lack of quality control at the fresh root stage.

2.7.2 Quality Standards for Cassava Chips

Cassava chips are produced in most of the cassava-growing countries of the world but formal international quality standards are relatively scarce. This demonstrates the relatively small amount of international trade in the commodity.

The dominant international market for cassava chips and pellets is the EEC, for which strictly enforced standards exist. These standards cover the feeding quality of the dried cassava in terms of starch content and fibre content, the inert fraction resulting from soil contamination and the moisture content. The current EEC standards are:

Fibre:	Not more than 5 percent
Ash:	Not more than 3 percent
Starch:	A minimum of 62 percent
Moisture:	Not more than 13 percent

It is understood that the permitted moisture content may be relaxed by one-half of one percent during Thailand's rainy season, in recognition of the difficulties in maintaining chips and pellets at low moisture in a humid environment.

Setting up quality standards can lead to their exploitation by less scrupulous traders and until recently the Thai-EEC cassava trade was in jeopardy due to adulteration of cassava products. As most of this adulteration was related to pellet production the topic is discussed further in the relevant section.

The EEC standards for cassava chips and pellets are enforced through a system of quality control checks carried out on behalf of both the Thai authorities and the European importers by laboratories in Thailand. A certificate of quality is required by the Thai authorities before an export permit for the shipment is granted, assuming that the sample under scrutiny meets the quality restrictions. The certificate of quality is issued by one of a number of laboratories, both government or privately owned (but government approved).

European importers usually purchase on the basis of a certificate of quality issued by a laboratory in Thailand. Private laboratories often act on behalf of European purchases by sub-sampling consignments before they are shipped and analysing them as an 'independent' assessment of the quality of the cassava product. It is in the interest of the Thai quality control laboratory to accurately describe the consignment by using appropriate sampling methods and accurate laboratory analytical techniques. Corruption of personnel involved in quality control procedures has been and will probably always be a significant problem. Strict legal enforcement of regulations by the Thai Authorities, with stiff penalties for those who break the rules, has had a beneficial effect during the past five years.

Providing the roots are not harvested at an immature stage or allowed to deteriorate beyond 2-3 days between harvesting and chipping it is relatively easy to maintain the 62 percent starch content. Some care is required to avoid penalties due to too much ash in the sample. The ash content of a sample normally reflects the quantity of soil left adhering to the exterior of the roots during the chipping and drying process. Some ash can be picked up in the sample from the cement drying floors due to normal wear and tear but this rarely contributes as much ash to the sample as soil. Simple root cleaning equipment is currently available in Thailand, and sees frequent use during the rainy season when the problem is most severe.

Limits on the quantity of fibre in the cassava chips are set to control the amount of indigestible material to mono-gastric animals. Properly trimmed roots rarely produce a chip sample with a high fibre content. The 5 percent limit is exceeded when over-mature and therefore fibrous roots which are improperly trimmed are used in the manufacture of chips. Improperly trimmed roots can still be attached to fibrous stem material.

The most difficult quality standard to achieve is that which limits the moisture content of the chips. This is not only the case for the Thai cassava trade with the EEC, but also the 'gaplek' trade for human consumption in Indonesia. Two factors are at play here:

- the difficulty to achieve a 'dry' product;
- the temptation to under-dry the product, i.e. to sell water.

Discussions with Thai cassava chip and pellet producers indicate that chips are regarded as dry enough for pelletting at a moisture content of 16-18 percent. This is in spite of the pelletisers stating that the optimum moisture content for their requirements is 14 percent. Chips with a moisture content of over 14 percent result in poorer quality pellets which are more expensive to produce due to increased die pressure requirements, from having a 'stickier' product to force through the die aperture. The pellet quality aspects which relate principally to the animal feed trade are discussed later in this section.

Insufficiently dried cassava chips deteriorate rapidly in storage and during shipment. Not only does the deterioration result in the breakdown of starch due to enzymatic action, but the organisms which are responsible for the breakdown may themselves be harmful to the consumer, be it animal or human. This deterioration not only results in devalued livestock feed in terms of feedstuff but also may contain toxic substances. This aspect of cassava is inadequately documented, but the few reports that exist mention the presence of undesirable fungi such as Aspergillus flavus.

An aspect of quality in cassava chips which has been largely ignored by the EEC livestock feed industry, at least in terms of import standards, is that of residual cyanide content. Recent studies by Tropical Products Institute (TPI) have confirmed that cyanide exists in both the free and the bound form in cassava products. Whereas much of the free form of cyanide is volatilised or otherwise broken down during sun drying, there are significant quantities of bound cyanide which remain in the dried product. So long as the cassava chips are only introduced into stock feed in small quantities little danger exists. However, where humans consume large quantities of sun dried cassava chips over significant periods of time there is a real danger of cyanide toxicity with associated damage to the nervous system and the thyroid.

Where sun dried chips are destined for human consumption, especially where cooking methods are ineffective in detoxifying the bound cyanide, much attention has to be paid to the subject of cyanide content and its eradication.

Recent research carried out in Zaire has indicated that soaking is effective in destroying most of the bound cyanide in cassava chips.

2.7.3 Quality Standards for Cassava Pellets

Whereas this study is not intended to investigate cassava pellet production in any great depth, some aspects of pellet quality are worthy of mention. As pellet quality is largely pre-determined by the raw material from which they are composed, the previous paragraphs which describe how soil, fibre and moisture contaminate chips are relevant in terms of compositional quality.

Physical characteristics of cassava pellets are currently causing concern to cassava traders, especially the large quantities of fine particles ('dust') which feature as a significant portion of each cargo. Environmental considerations in the port of destination where pellet cargoes are trans-shipped from large bulk transports to small inshore and river/canal vessels, are resulting in pressure to reduce dust in pellet consignments.

Dust results from poor quality pellets which break apart during transport and storage. Many causes are responsible for the break up of pellets, including inadequately dried chips, missing out the chip grinding stage during pellet production, low die pressures into low performance pelletising presses, and inadequate cooling of pellets as they emerge from the dies.

Price premiums are paid by European importers for 'hard', i.e. dust-free pellets, from time to time. However, at times of peak demand for cassava products the premium may disappear completely, removing the incentive for pellet producers to produce hard dust-free pellets.

3.0 THE ECONOMICS OF CHIP AND PELLET PRODUCTION

3.1 INTRODUCTION

This section of the report sets out the costs of chipping and drying operations in Thailand and Indonesia and presents such data as are available on the basic economics of chipping operations. This information has been used to develop case studies of alternative scenarios for the production of cassava chips. These are presented in the First volume of this report.

The main price and cost data are from Thailand where chips are produced solely as part of a commercial cash crop operation and where significant investment has been made in premises and plant. Information from Indonesia is mainly in the form of physical data.

3.2 THAILAND

3.2.1 Outline of Chipping and Drying Operation

Cassava chipping and drying operations in Thailand are organised on a commercial scale on the following lines:

FARMER	transport of fresh roots	CHIPPING YARD	transport	CUSTOMER
- Growing tubers - Harvesting		- Mechanical chipping - Sun drying in concrete yard - Bagging for transport		- Pelletising and subsequent export - Direct export

A broader diagram of processing channels in Thailand is given in Appendix 4.

Generally the farmer or collecting dealer fills a small to medium size truck (up to 8 tons) with fresh roots and sells them to a chipping yard within a radius of some 15 km. The transport is usually hired by the farmer. The truck may visit two or three yards in order to obtain the best price.

In most cases chipping yards can rely on a sufficient supply of fresh roots without having to go out and look for them. Even in 1983 when root supplies were scarce, chipping yard owners interviewed did not feel the need to actively pursue supplies.

The fresh roots are unloaded at the chipping yard where they may remain for up to two or three days in a heap, usually in the open air. They are then loaded into a chipping machine by mechanical shovel. The chips thus produced are spread over the concrete yard to dry which takes, on average, three working days. The chips are turned over frequently using either a manual rake or a mechanised chip flipper. They are piled up and covered over if there is a danger of rain. Finally the dried chips are piled up, bagged and loaded onto trucks for delivery to the customer, normally a pelletising mill.

3.2.2 A Typical Thai Chipping Operation

The size of most chipping yards lies between about 1 ha producing around 2,000 tonnes of dried chips annually and 5 ha producing over 10,000 tonnes a year. A typical example is a chip producer with the following equipment and staff.

Throughput	25,000 tons fresh roots converted to 11,250 tons dried chips
Drying Yard Area	4.8 ha laid to concrete
Office and Storage Space	for 2 months output
Staff	12 full-time and 3 part-time employees
Machinery	1 chipping machine 2 front loading mechanical shovels 4 chip flippers 1 scale or weighbridge 1 starch testing equipment

The costs associated with this operation are given under 'Yard 1' in the next section.

In addition the operation might have its own trucks to deliver dried chips to the customer. Alternatively hired transport is used or the customer may provide his own.

The operational cycle is based on the drying time - 25 to 30 hours of sunshine for the loading density normally used in Thailand. It is important to appreciate that this drying cycle - normally 2½ to 3 days in the dry season - will determine the cost effectiveness of any given operation. In the example quoted above, the 250 day season comprises some 83 operational cycles; in each cycle 300 tons of fresh roots are chipped which takes about 8 hours. This site of just under 5 ha gives good practical machine utilisation for dayshift working in a three day cycle.

3.2.3 Historical Costs of Chipping and Drying Operations - 1981

Costs and investment figures in 1981 for three yards of different sizes on a comparable basis were obtained from a field survey carried out by Dr. Boonjit Titapiwatanakun of the Department of Agricultural Economics, Kasetsart University, Bangkok. A summary is set out in Table 3.1 below.

TABLE 3.1

COMPARISON OF CHIPPING AND DRYING COSTS AND INVESTMENT FOR THREE THAI YARDS IN 1981

COSTS & INCOME (1981 prices)	Yard 1 Baht/T	Yard 1 %	Yard 2 Baht/T	Yard 2 %	Yard 3 Baht/T	Yard 3 %
Raw Material	1,511	89	1,056	75	1,188	84
Fuel, Wages, Maintenance & Transport Costs	124	7	251	18	184	13
Interest and Depreciation	15	1	64	5	40	3
Profit Before Tax	50	3	29	2	9	1
Selling Price of Dried Chips	1,700	100	1,400	100	1,420	100
Annual Output of Dried Chips (T)	11,250		3,000		1,600	
CAPITAL EMPLOYED	Total Investment in '000 Baht					
Machinery and Equipment	694		1,014		459	
Concrete Chipping Floor	210		150		65	
Go-down and Buildings	210		600		60	
Total Fixed Investment	1,114		1,764		584	
Return on Capital	50%		5%		2½%	

Source: Department of Agricultural Economics, Kasetsart University, Bangkok.

A detailed analysis of these figures is given in Appendix 5.

As mentioned earlier, these data must be interpreted with considerable care. Chipping yards are reluctant to disclose their true profits and furthermore, most yards deal in other commodities such as rice and groundnuts. It is seldom possible to attribute costs solely to cassava chip production. Nevertheless, despite these constraints, the data provide a guide to the operating costs that would be incurred by a new operation.

The figures quoted are for a year's operation in 1981. They are the most detailed modern costs known to be available. These data were compared with information obtained by the study team from current operations and discussed with experts in Thailand. As a result, the following broad conclusions emerge:

- As might be expected, Yard 1 with its higher throughput has much the lowest unit costs and also the highest profit. These figures are considered the most reliable of the three by an expert in the trade.

- The raw material cost lies usually between 80 percent and 90 percent of the dried chip selling price. Obviously it is the cost of fresh roots production that has the greatest influence on the total cost of producing dried chips on a mechanised, high volume basis.

- It follows that any attempt to reduce the overall cost of dried chips as a raw material must concentrate on minimising the cost of supplying fresh cassava roots. A reduction in current mechanical processing costs would provide only marginal overall savings.

- Profit on sales is low - between ½ percent and 3 percent of the selling price of dried chips. However, selling prices fluctuate substantially, especially out of season, so that profitability can vary substantially.

- Many yards effectively act as commodity traders in dried chips and also other produce. This may produce substantial cash contributions to the business as a whole.

- Machinery and equipment is often bought secondhand and this reduces the capital employed in existing businesses. This is a feature of a relatively highly developed country where secondhand equipment is readily available.

- Depreciation rates do not provide for realistic replacement costs. If depreciation were set at a realistic figure, many of the smaller yards would operate at a loss.

- The concrete yard is shown at a very low historic cost in all cases, one-tenth of the current cost for Yard 1.

- It follows that, even though current chip prices are historically very high, investment in new chipping facilities would bring extremely low returns.

The detailed operating costs for Yard 1 are considered to be the most reliable. They are set out in Table 3.2 on the next page.

Energy (electricity and fuel) and labour costs account for 60 percent of the total. The balance of expenditure on energy as against labour will obviously vary with the degree of mechanisation.

Maintenance and repair account for a further 10 percent or so; thus the direct cost of chipping and drying accounts for nearly 70 percent of the total conversion cost from fresh roots to chips and this appears to be typical.

TABLE 3.2

OPERATING COSTS FOR CHIPPING AND DRYING
YARD 1 - 4.8 HA

	'000 Baht		Baht/T Dried Chips	%
Raw Material Input (25,000 T)		17,000	1,511	-
Electricity	180		16	12
Fuel and Oil	444		39	28
Wages	320		28	20
Administration	7		1	1
Maintenance and Repair	138		12	9
Transport to Customer	304		27	19
Direct Conversion Costs	1,393		124	89
Depreciation	90		8	6
Interest on Working Capital	78		7	5
TOTAL CONVERSION COST	1,561		139	100%
Profit Before Tax	564		50	
Overall Chipping Cost		2,125	189	
SALES OF DRIED CHIPS (11,250 T)		19,125	1,700	

Transportation is the other significant item. Its importance is further illustrated by analysing the figures in a different way and extracting the transport element of the delivered fresh roots price:

	Baht/T Dried Chips	%
Fresh Root Cost (excluding Transport)	1,444	85
Local Transport of Fresh Roots and Dried Chips (15 km)	94	5½
Chipping and Drying Costs	97	5½
Interest and Depreciation	15	1
Profit	50	3
	1,700	100

The above transport costs at 30 Baht/T per journey are only for local carriage over a distance of 15 km or so. Thus, even for local supplies which are normally available in Thailand, the cost of transportation is of the same order as the other conversion costs put together.

Where longer distances are involved, transport could easily amount to between 10 percent and 15 percent of the total selling price of dried chips, or in the region of double the cost of chipping and drying.

In considering any kind of concentrated chipping and drying operation on Thai (or Malaysian) lines, a vital parameter will be the geographic disposition of both sources of fresh roots supply and of the customer. The layout of the supplying farmland is the dominant factor; fresh roots transport accounts for 70 percent of the total carriage charges because of their high bulk. Thus, the economics of any chipping and drying facility will depend crucially on its throughput matching the availability of fresh roots throughout the drying season from within a comparatively short distance.

3.2.4 Current Chipping and Drying Costs in Thailand -1983

During the field visit to Thailand the study team obtained information on operational costs and on the investment required to set up an operation in 1983 values. The following data are given in Thai Baht and also in US dollars.

TABLE 3.3

OPERATING COSTS FOR A 3.8 HA CHIPPING YARD IN THE KHON KAEN AREA - APRIL 1983

		Cost of Dried Chips/Tonne Baht	US$	%
Cost of Fresh Roots (19,500 T) including Transport		2,472	107.95	92
Energy	35			
Wages	50			
Repair and Maintenance	18			
	103		4.50	4
Depreciation	18		0.79)	
Interest	12		0.52)	2
Profit	37		1.62)	
TOTAL CONVERSION COST	170		7.42	6
Transport to Customer	50		2.18	2
		220	9.60	8
SELLING PRICE DRIED CHIPS (8,125 T)		2,692	117.55	100%

As discussed earlier, the transport costs of fresh roots are included in the delivered price to the yard but amount to some 3 to 4 percent of the chip selling price.

3.2.4.2 Capital Employed

TABLE 3.4

CAPITAL COSTS QUOTED BY CHIPPING YARD IN THE KHON KAEN AREA
APRIL 1983

	Original Cost	Current Replacement Cost	
	Baht	Baht	US$
Chipping Machine	75,000	103,000	4,500
Sand Extractor	30,000	60,000	2,620
Scale (weighbridge)	180,000	300,000	13,100
Two Payloaders (shovellers)	400,000	560,000	24,450
Two Trucks	360,000	900,000	39,300
Tractor for Grading	200,000	322,000	14,060
Chipping Floor (3.8 ha)	250,000	1,560,000	68,120
Building	230,000	405,000	17,690
TOTAL FIXED INVESTMENT (Baht)	1,725,000	4,210,000	
TOTAL FIXED INVESTMENT (US$)	75,330		183,840

The total profit before tax earned in the season was 8,125 T x 37 Baht/T = 300,625 Baht, giving a historic return on capital of 17 percent. However, if a new investment were to be made, the return falls to 7 percent, a rather unattractive figure.

3.2.4.3 The Key Parameters of the Cassava Chip Drying Business

Although it may be argued that many businesses operate with a low return, the cassava chip business must be seen in the context that it is highly vulnerable to small price fluctuations in the farmers' supplies of fresh roots. This is illustrated by the equation:

$$p = S - (Rk + c + t)$$

where p = profit
S = selling price of dried chips
R = price of fresh roots
k = conversion factor of roots to chips
c = conversion cost
t = transport cost

In the example quoted, at current market prices:

$$p = S - R \times k + c + t$$
$$p = 2{,}692 - (1{,}030 \times 2.4 + 133 + 50)$$
$$p = 2{,}692 - (2{,}472 + 183)$$
$$p = 37$$

Clearly it is small changes in either the market prices S or R, and in the conversion factor k, which will have the greatest influence on the profit p. This encourages the trading mentality among chip producers and it is mainly this element that makes the business attractive because of the chance of higher profits if chips become scarce in the market. It also encourages adulteration of the raw material and/or chips to increase the solids content (and hence the profit) as much as possible within the limits of imposed quality controls. Moisture content is also maximised for the same reason. The relationship between k and root dry matter and final moisture content is shown in Table 3.5 below.

TABLE 3.5

VARIATION OF ROOT:CHIP CONVERSION FACTOR k WITH ROOT DRY MATTER CONTENT AND CHIP FINAL MOISTURE CONTENT

	Root dry matter content (%)			
	30	32	34	36
Chip final moisture content (%)				
10	2.99	2.81	2.65	2.50
12	2.93	2.75	2.58	2.44
14	2.87	2.69	2.53	2.39
16	2.80	2.62	2.47	2.33
18	2.73	2.56	2.41	2.28
20	2.67	2.50	2.35	2.22

The high risk element makes the low return inherent in a new investment situation increasingly unattractive under present market conditions in Thailand. This problem has been aggravated by the EEC import restrictions. Furthermore the market has become more volatile and difficult under the arbitrary quarterly quota system imposed by the Thai authorities. This situation makes for instability and speculation.

3.2.5 Pellet Production in Thailand

The pelletising process has been described in Section 2.6. As is well known, pellets form the bulk of the end product of cassava chips, providing an economic means of bulk transportation to the European animal feed market.

The 1981 survey of cassava processing costs mentioned in Section 3.2.3 gave the cost comparisons for three native pellet plants as set out in Table 3.6 following. Further details are given in Appendix 6.

TABLE 3.6

COMPARISON OF NATIVE PELLETISING COSTS AND INVESTMENT FOR THREE THAI PLANTS IN 1981

COSTS & INCOME (1981 prices)	Plant 1 Baht/T	Plant 1 %	Plant 2 Baht/T	Plant 2 %	Plant 3 Baht/T	Plant 3 %
Raw Material	1,771	81	1,771	81	1,667	75
Energy	58	3	70	3	158	7
Labour and Administration	38	2	31	1	37	2
Repair and Maintenance	21	1	29	1	58	3
Transport	180	8	180	8	200	9
Finance	34	1	38	2	43	2
Profit	98	4	80	4	46	2
Selling Price	2,200	100	2,200	100	2,208	100
CAPITAL EMPLOYED	Total Investment in '000 Baht					
Machinery and Equipment	1,105		1,540		777	
Buildings and Office	825		256		410	
Go-down	1,200		-		-	
Return on Capital	60%		69%		24%	

Source: Department of Agricultural Economics, Kasetsart University, Bangkok.

The figures for Plants 1 and 2 are remarkably similar. In the case of Plant 3, energy costs seem excessive. In all cases transport costs are high and exceed the actual conversion costs in the first two plants. Return on capital, based on historic figures, appears to be very good. However, no data were available regarding the return on a new investment but the figures do suggest that producing native pellets is a profitable investment if it is well managed, even on a replacement cost basis.

Hard pellets are preferred by an increasing number of European customers owing to dust pollution problems with the native products. The costs of producing hard pellets in one plant are set out in Table 3.7 on the next page.

This plant is approximately ten times the size of the three native pellet plants and this is reflected by the economies of scale achieved in labour, administration, repair and maintenance costs. The very much higher investment nevertheless produces a good return on capital; in this case the return of 30% is realistic because the plant started operations in 1980, only a year before these costs were incurred. Further details are given in Appendix 7.

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TABLE 3.7

HARD PELLETISING AND INVESTMENT COSTS FOR THAI PLANT IN 1981

COSTS AND INCOME (1981 prices)	Baht/T	%
Raw Material	1,836	85
Energy	107	5
Labour and Administration	28	1
Repair and Maintenance	14	1
Transport	-	-
Finance	89	4
Profit	81	4
Selling Price	2,156	100
CAPITAL EMPLOYED	Total Investment in '000 Baht	
Machinery and Equipment	23,955	
Buildings, Office and Go-Down	17,000	
Return on Capital	30%	

Source: Department of Agricultural Economics, Kasetsart University, Bangkok.

3.3 INDONESIA

3.3.1 Outline of Dried Gaplek Production and Distribution

Much of the cassava grown in Indonesia is for human consumption and much processing of fresh roots is done on a village scale. A detailed description of cassava production systems, consumption, processing and marketing in Java is given in the dissertations presented to the Food Research Institute of Stanford University by Roche, Unnevehr et al. (see Appendix 10).

In general, growing and processing are carried out by the farmer who produces dried gaplek in the farm area before selling it to a local trader. The production of gaplek is described in Section 2.2. The overall process is illustrated as follows:

FARMER ———	LOCAL TRADER ———	WHOLESALER ——	CUSTOMER
- growing - harvesting - peeling - splitting roots - sun drying	- collect - transport - (produce gaplek)	- buy and sell gaplek - further drying - storage	- consume - pelletise - export

This is a simplified illustration which concentrates on the gaplek chain and does not show the direct marketing of fresh roots by the farmer nor their purchase by starch factories and others. As indicated, the gaplek may be made also by a local trader having agreed to purchase fresh roots either before or after harvesting. The wholesaler who serves local retailers or pelletisers and exporters may dry the gaplek further as well as storing and selling it. A comprehensive illustration of cassava processing in Indonesia is given in Appendix 8. The relatively long and more complex distribution chain is a reflection of the large number and high density of producers in Java and of the localised processing of roots into gaplek.

3.3.2 The Time and Cost of Gaplek Production

Few detailed rigorous cost data on processing cassava roots are available because the opportunity cost varies according to the season and consequent other pressures on the time of farmers and their families. When the women have little to do, the 'cost' may be marginal; during harvesting of other crops it will be high.

However, measurements of the quantities of roots processed by a family unit have been made by various observers. The results are shown in Table 3.8 below.

TABLE 3.8

COMPARISON OF LABOUR INPUTS FOR PROCESSING
FRESH CASSAVA ROOTS - PEELING AND CHIPPING

Source	Kg Fresh Root Output: kg/hour
Ishida, 1975	20 - 24
Nelson, 1980	25 - 37
P-E/Minster, 1983	25 - 35

Although the two lower figures agree closely, the P-E team's observations suggest these represent maximum output rates motivated by an observer rather than the run-of-the-mill average achieved in practice in the absence of unusual pressures.

The following examples are based therefore on the minimum figures of 20 kg per hour for peeling and slicing.

3.3.2.1 Production of Dried Cassava on a Farm/Village Scale

Two village situations are illustrated in Table 3.9, as found in Indonesia and elsewhere, one more densely populated with 2.5 ha of land per family, and the second assuming a relatively sparse population density with 5 ha per family. It is assumed that each family of six persons consumes 150 kg per head per year and that economic conditions are such as to encourage the family to grow cassava on 20% of its total land area, the remainder being under other crops.

TABLE 3.9

COMPARISON OF DRIED CASSAVA PRODUCTION BY FAMILIES OCCUPYING 2.5 HA and 5 HA

		Dense	Sparse
A	Area of land/family	2.5 ha	5.0 ha
B	Area under cassava	0.5 ha	1.0 ha
C	Yield (10 tonne/ha)	5.0 tonnes	10.0 tonnes
D	Required for home use (based 150 kg/cap/year)	900 kg	900 kg
E	Available for sale	4.1 tonnes	9.1 tonnes
F	Home use roots to be chipped/dried (i.e. 50% of total)	450 kg	450 kg
G	Total cassava to be harvested & chipped (i.e. E & F)	4,550 kg	9,550 kg
H	Quantity of cassava harvested over 48 day period (2 months)	95 kg/day	199 kg/day
I	Man day units used in cassava harvesting (400 kg/m.d.)	0.25 m.d.	0.50 m.d.
J	Time available for peeling/chipping AND other farming duties (assuming 8 hour day)	6 hrs	4 hrs
K	Quantity peeled/chipped during J-2 hours	80 kg	40 kg
L	Extra assistance required from wife/family	0.75 hrs	8 hrs
M	Quantity of chips prepared	1,820 kg	3,820 kg
N	Quantity of chips prepared for sale	1,640 kg	3,640 kg

Notes

J Assume 8 hours working day.

K Assume 2 hrs/day required for other farm duties and loading/unloading/repairing drying trays.

M Using 2.5 conversion factor.

The drying areas required are 24 m and 50 m for the 2.5 ha and 5 ha land areas respectively, based on a loading rate of 8 kg/m for two days output (2 x H kg) in each case. This assumes a two day drying cycle.

Examples of the costs of collection, handling and distribution, obtained during a major survey in 1980, are set out in Tables 3.10 to 3.12 below.

TABLE 3.10

GAPLEK MARKETING MARGINS FROM FARM TO EXPORTER'S FACTORY GATE - 1980

(Rupiah per kilogram)

	1. Trenggalek	2. Gunung Kidul	3. Kediri	4. Malang
Farmer price	34.0	45.0	45.0	38.5
Harvest	n.a.	n.a.	n.a.	1.0
Process	n.a.	n.a.	n.a.	1.5
Moisture loss	4.5		2.0	
Transportation	5.0	2.0	1.5	2.2
Returns to local trader	1.5	1.0	1.5	1.8
Local trader sale price	45.0	48.0	50.0	45.0
Transportation	5.0	5.0	3.5	5.0
Loading	1.0	.5	.2	1.0
Moisture loss	3.0	1.5	.3	1.0
Return to wholesaler	1.0	1.0	1.0	1.0
Factory gate price	55.0	56.0	55.0	53.0
Total margin	21.0	11.0	10.0	14.5
Kilometers between first and final sale	189.0	306.0	178.0	145.0

Source: Field Survey by L. Unnevehr (1980).

Notes

1. Farmer harvests, processes and sells partly dry gaplek in rural market to local trader, who delivers to wholesaler.

2. Farmer harvests, processes and sells dry gaplek in rural market to local trader who delivers to wholesaler.

3. Farmer harvests, processes and sells dry gaplek in rural market to local trader who delivers to wholesaler.

4. Farmer sells before harvest to local trader who delivers to wholesaler. Farmer price converted to gaplek equivalent at 2.0

TABLE 3.11

FRESH ROOT MARKETING MARGINS FROM FARM

TO STARCH MILL - 1980

(Rupiah per kilogram)

	1. Garut	2. Kediri	3. Malang
Farmer price	20.0	18.0	18.0
Harvest	1.0	1.0	n.a.
Porterage	3.0		
Load	.2		.2
Transportation	4.0	1.0	3.0
Moisture loss	.4	1.1	.7
Return to local trader	1.4	.9	1.1
Factory gate price	30.0	22.0	23.0
Total margin	10.0	4.0	5.0
Kilometers between first and final sale	45.0	1.5	15.0

Source: Field Survey by L. Unnevehr (1980).

Notes

1. Pre-harvest sale to local trader who sells peeled roots to medium-scale starch factory. Porterage wage includes peeling of roots.

2. Pre-harvest sale to local trader who delivers unpeeled roots to household starch firm. Harvest wage includes loading. Transportation is cattle cart.

3. Farmer harvests and sells unpeeled roots at roadside collection point to local trader who delivers to medium-scale starch factory.

TABLE 3.12

GAPLEK MARKETING MARGINS FROM FARM TO RURAL RETAIL - 1980
(Rupiah per kilogram)

	1. Trenggalek	2. Kediri
Farmer price	50.0	50.0
Losses	7.0	
Transportation	2.0	
Return to local trader	6.0	5.0
Local trader sale price	65.0	55.0
Return to retailer	10.0	5.0
Retail price	75.0	60.0
Total margin	25.0	10.0
Kilometres between first and final sale	20.0	5.0

Source: Field Survey by L. Unnevehr (1980)

Notes

1. Farmer harvests, processes and sells wet gaplek in rural market to local trader who sells to rural retailer. Retailer extends 50 percent credit to consumers.

2. Farmer harvests, processes and sells in rural market to local trader who transports by bicycle to another rural market to sell to retailer.

3.3.3 Production of Dried Cassava for Direct Human Consumption as Against Industrial Use

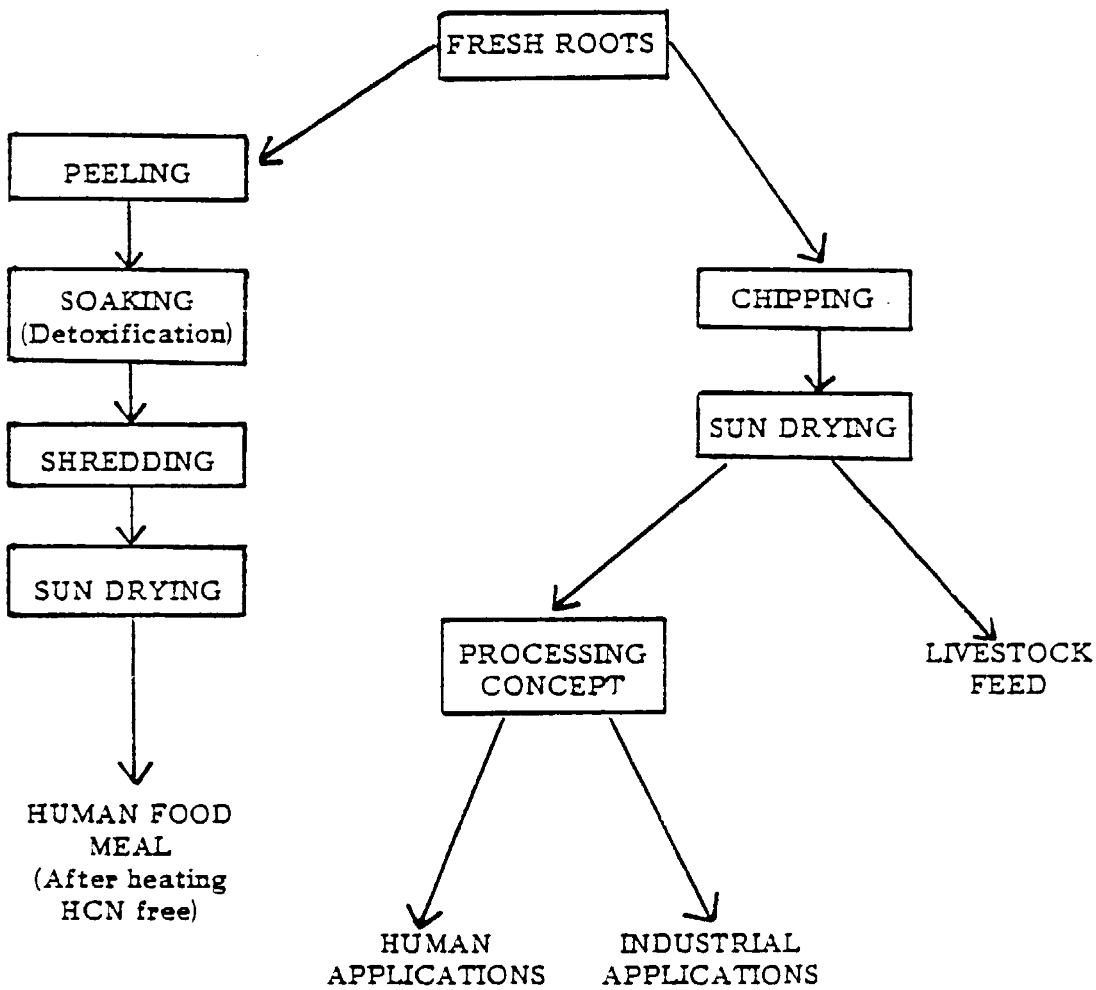
A recent paper published by the International Development Research Centre, Ottawa (Cassava Products: HCN Content and Detoxification Processes by Ermans et al) sets out the conditions for adequate detoxification of cassava roots for human consumption. The full text of the paper is reproduced in Appendix 9.

Until now most observers have assumed that cooking in water or even the sun drying process provides adequate detoxification for cassava. Studies carried out in Zaire under the auspices of the University of Brussels show that, while thoroughly soaking fresh roots detoxifies them efficiently, neither sun drying nor many cooking processes hitherto thought safe in fact detoxify the roots down to a safe level for direct human consumption. The findings suggest that the consumption of dried gaplek in the form of tiwul (pounded into flour, mixed with water and steamed), which is universal in Indonesia, can lead to endemic goitre where dietary iodine levels are low. Comments by senior staff at the Institute of Research and Development for Agro-based Industry, Bogor indicate that goitre may be a problem in some areas of Java where gaplek forms an important component of the diet eg Gunung Kidul. The Ministry is already making efforts to replace the direct human consumption of gaplek by other foods as far as possible.

This new and more specific illumination of an otherwise well-known problem has serious implications. It strongly suggests that any production of sun dried unpeeled cassava chips must be organised and carefully controlled in such a way as to avoid direct human consumption of the chips, or chip products without first soaking and then heating to a sufficiently high temperature to detoxify the chips. This may pose a substantial dilemma in the context of encouraging farmers to produce dried cassava at village level. Dried cassava that is subsequently processed into starch poses no problems. The danger lies in storing dried chips as a famine reserve and subsequently preparing food without adequate detoxification.

Clearly there are dangers inherent in a programme encouraging dried chip production unless the most rigorous controls are established and adhered to. A flow diagram of the alternative processing channels is shown below.

ALTERNATIVE CASSAVA PROCESSING ROUTES



APPENDIX 1

ROOT CLASSIFICATION
G. COURS (1951)

(See accompanying sketch)

POINT OF ATTACHMENT

Cassava roots are connected to the original cutting used to establish the plant by a peduncle. This peduncle varies in length from being almost absent (sessile) to being more than 10 cm in length. An intermediate situation where the peduncle is from 1 to 3 cm in length is common. Thus a classification is proposed:

- Sessile: peduncle less than 1 cm in length. Roots apparently attached directly to the cutting.

- Peduncular: peduncle between 1 - 3 cm in length.

- Long-peduncular: peduncle exceeds 10 cm in length.

Individual cassava roots vary in shape . Four groups have been identified:

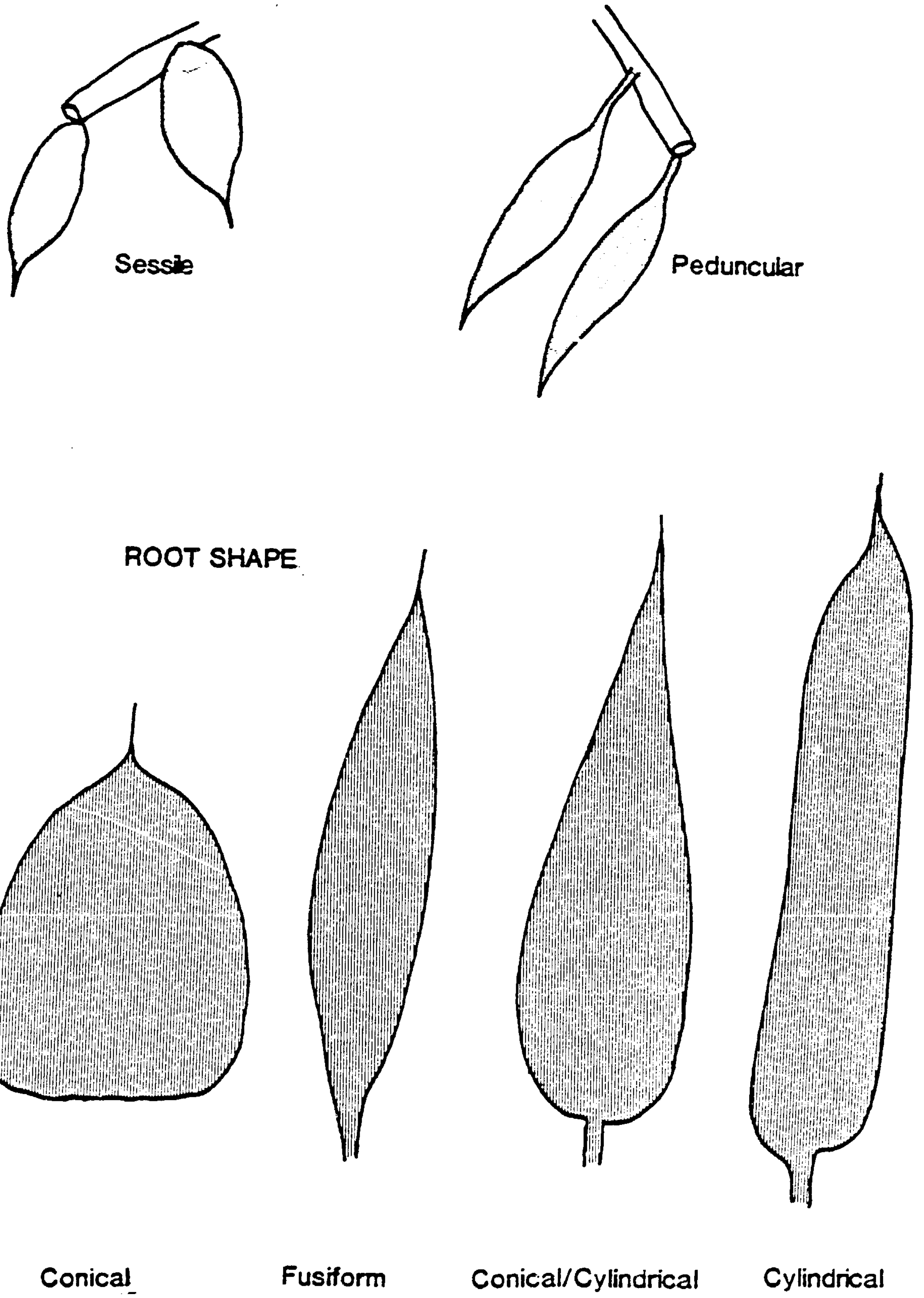
- Conical: generally sessile.

- Fusiform: maximum diameter mid-way along root tapering from the centre to the extremities.

- Conical/cylindrical: maximum diameter at the proximal end, tapering towards the distal end.

- Cylindrical: similar diameter along most of root tapering abruptly at the proximal and distal ends.

FIGURE A.1 ROOT CLASSIFICATION



Cassava roots also vary in terms of length and diameter. These factors are dependent on the growth and maturity of the individual plant and the soil. More mature plants, of high yielding qualities grown in fertile soil under optimum moisture and temperature conditions, will produce large roots, i.e. retaining their characteristic shape but being longer and larger in diameter.

APPENDIX 2

POST HARVEST DETERIORATION AND STORAGE OF FRESH CASSAVA*

One of the major limitations to increasing the consumption of cassava as a human food is the short storage life of the roots once they are harvested. The roots deteriorate rapidly, the loss in quality resulting in their being unacceptable for human consumption and other industrial uses.

POST HARVEST DETERIORATION

The most important part of the cassava root is the flesh, composed of xylem parenchyma, in which the starch is deposited. In the core of the root is found the fibrous central xylem vessels, whilst the peel is made up of phloem cells together with sclerenchyma and a corky outer layer.

The symptoms of deterioration appear during the first three days after harvest and appear as changes in colour of the parenchyma tissues and xylem vessels. Initially dark blue vascular streaks are seen. These later become brown or dark red, and even black due to darkening of xylem cell walls. The discoloured zones may spread to parenchyma tissues which become blue and appear desiccated.

The onset and severity of root deterioration is strictly related to the presence of mechanical damage, normally caused during harvesting. Other factors such as variety and agronomic (e.g. length of roots, presence of long peduncles etc.), texture and degree of soil compaction and method of harvesting (manual or mechanical) influence the amount of damage caused during harvesting. The proximal and distal ends of the roots are most prone to mechanical damage. Similarly the propensity of the outer corky layer of the root peel to adhere to the underlying parenchyma cells affects the roots' susceptibility to mechanical damage during harvesting operations and subsequent transportation. Due to these reasons, the first symptoms of deterioration are normally observed below areas of damage to the peel, or at both ends of the root.

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* Based on Wheatley et al (1983), in Dominguez C.E. (1982).

In addition to discoloration symptoms the root tissues may also be attacked by micro-organisms which result in rotting five to seven days after harvest. Blue/black streaking similar to that caused by mechanical damage may also be observed extending outwards from the margins of the zones of rotting.

Two classes of deterioration have been described:

- Primary or physiological deterioration, typified by blue/black or brown streaking concentrated below the peel.

- Secondary or microbial deterioration, caused by various fungi and bacteria behaving as wound-pathogens.

It has been amply demonstrated that the two classes of deterioration are distinct processes. It has been impossible to isolate micro-organisms from tissues affected by physiological deterioration. In contrast various fungi (including Penicillium, Aspergillus, Rhizopus, Fusarium) and bacteria have been isolated from roots affected by microbial deterioration.

CAUSES OF PHYSIOLOGICAL DETERIORATION

Few studies have been carried out on this subject until very recently. Post harvest root treatments such as immersion in hot water, storage under low temperatures or in low oxygen or carbon dioxide atmospheres reduce the deterioration of roots suggesting the participation of enzymes such as peroxidases in the process. Total peroxidase activity increases after the start of root decomposition.

Temperature and humidity affect physiological deterioration, especially when mechanical damage is present. Damaged roots deteriorate more rapidly when stored under conditions of low relative humidity (65-80 percent RH), than if stored in a moisture saturated environment. Tissue respiration was maintained at a higher rate under low humidity. These results demonstrate the critical effects of moisture loss occurring as a result of mechanical damage to root tissues.

Cytological studies and electron-microscopy have demonstrated that the changes in tissue colouration are responses to damage or wounds and that the symptoms extend rapidly along the length of the root. The initial damage response is the blockage of xylem vessels and the production of fluorescent compounds in the parenchyma. The blockages contain carbohydrates, lipids, and lignin-like compounds. During the initial stages free phenols, leucoanthocyanins and catequins can be identified in the xylem vessels. The pigments appear to be tannins.

The compound with the largest degree of fluorescence has been identified as scopolotin, a cumarin, which can be found in low concentrations in fresh roots, but which increases considerably during the 24 hours after harvest. This dramatic increase permits the scopolotin in the tissues to be seen under ultraviolet light. Application of scopolotin to fresh tissues rapidly induces the streaking symptoms of physiological deterioration. Roots showing resistance to physiological deterioration accumulate less scopolotin than susceptible varieties.

Unfortunately the biochemical mechanism whereby scopolotin is produced has yet to be identified.

FACTORS AFFECTING SUSCEPTIBILITY TO PHYSIOLOGICAL DETERIORATION

Varietal comparisons have clearly shown that some varieties are less susceptible to physiological deterioration than others. A positive correlation has been drawn between dry matter content of the roots and the degree of physiological deterioration. This hinders genetical improvement of both of these characters simultaneously.

In addition to variation between varieties, it has been demonstrated that the conditions at the time of harvest can also influence physiological deterioration within the same variety. Due to this it is difficult to generalise that some varieties are better than others until a comprehensive understanding of the mechanisms involved has been achieved.

In many cassava growing countries of Latin America, where the roots are to be sold as a fresh vegetable, it is a common practice to sell the roots still attached to the base of the plant. This practice has been shown to preserve the roots in the fresh state for a longer period than normal. Field trials at CIAT have shown that removal of cassava foliage (i.e. topping) three weeks before lifting the roots from the soil renders the roots resistant to post-harvest deterioration. A similar effect has been postulated for defoliating pathogenic organisms. Topping cassava plants has been shown to reduce physiological deterioration for up to nine weeks after the topping operation. However, the starch content of the roots decreases as the plant mobilises root reserves to support shoot replacement as a reaction to topping. In addition the texture and cooking quality of the roots from topped plants are inferior to those from plants harvested the traditional way (i.e. untopped). The use of growth inhibiting substances to prevent shoot production has been suggested. However, further investigations are required before topping to prolong post-harvest keeping qualities of roots can be recommended as a commercial practice.

TECHNIQUES FOR CASSAVA ROOT CONSERVATION AND STORAGE

To date no universal technique exists for conservation and storage of cassava roots at a commercial level. Sophisticated refrigeration techniques are limited in application due to their high costs. More simple lower cost techniques have demonstrated satisfactory results on an experimental scale, but none have been accepted into general practice. The following is a summary of reported techniques available for the post harvest preservation of cassava:

(a) **Traditional storage methods.** It is normal for small producers and subsistence farmers to harvest cassava as required by market demand or the needs of the family. As a result a significant proportion of farm land can be taken out of useful production in order to store cassava in the ground. In some places roots are stored in earth-covered mounds and kept moist.

(b) **Silos, boxes and containers.** Straw and earth silos (clamps) as used for potato storage have been tried with cassava roots. 300-500 kg of roots placed on a straw base and covered with straw and soil, with adequate ventilation and a drainage ditch, have been stored satisfactorily up to eight months. At temperatures below 40°C, and with good ventilation, roots 'cure' with the formation of a suberised layer, and wounds heal. Root quality approximates normal, with slight reduction in starch content and a proportionate increase in sugars. The method, although efficient at the experimental level, has not been applied in practice.

Wooden boxes and cardboard cartons are used in various places to transport roots from field to market. When sawdust or moist soil are used to fill the spaces between roots in the boxes or cartons, and the atmosphere is humid, the roots have been shown to resist deterioration. Experiments have shown that approximately 75 percent of the roots are of an acceptable quality after 4 weeks of storage. However, the delay of one day between harvesting and packing into boxes reduces the storage success to 49 percent. The boxed storage system in combination with low temperature (<15°C) storage is used to export cassava roots from Costa Rica and the Dominican Republic to the USA and Europe.

Satisfactory results have been reported where cassava roots have been stored in plastic bags or paper bags with a polythene layer after treatment with fungicide. A fungicidal treatment is essential to prolong storage beyond one month. Until the practice has been further evaluated from the consumer/operator health and environmental pollution standpoint, the practice cannot be widely recommended.

(c) **Paraffin waxing.** Roots submerged for one minute in melted paraffin wax with 2.2 percent fungicide, after which they are dried and stored at ambient temperatures, may conserve for a month or more. No noticeable loss of weight or acceptability were noted. Although technically feasible, the technique has yet to be put into practice.

(d) **Refrigeration and freezing.** As the physiological deterioration is the result of an enzymatic process, it is possible to inhibit the detericration by storing the roots at low temperatures.

Losses are very low when stored at 3°C. Low temperature storage permits the maintenance of good quality. However, the development of blue (moho) has been reported when roots are stored at 0-2°C.

Freezing is an effective method of storing roots and prevents both types of deterioration described above. Nevertheless, changes in texture and cooking quality can be detected. Freezing chunks of cassava roots in plastic bags is used in a number of countries to sell cassava in supermarkets with deep-freeze facilities.

In general the high costs associated with refrigeration and deep-freezing limit the utility of the method.

CONCLUSIONS

Recent investigations on post-harvest deterioration of cassava roots have increased understanding of a process which is primarily an enzymatic one related to the metabolic process of the root. To prevent or reduce deterioration it is necessary to prevent damage or wounding to the roots, normal during harvesting and transportation. It is necessary to intensify studies oriented towards in-depth aspects of pre-harvesting factors which may reduce susceptibility of roots to physiological damage.

In order to maintain post-harvest quality of roots, it is necessary to reduce moisture loss. The root-curing process normally requires a humid environment, which also favours the development of micro-organisms which promote microbial deterioration. A system of conservation should permit the maintenance of root quality for periods of relatively long duration (2 weeks or more). Similarly the system should prevent both types of deterioration. Whatever system is developed the most important factors are the economic feasibility and the ease with which it can be put into operation.

APPENDIX 3

FACTORS AFFECTING CASSAVA CHIP DRYING

The factors which affect the drying time of cassava chips include the following:

- chip geometry (ie shape and size)
- loading rate (ie quantity of chips per unit area of drying surface)
- air temperature, humidity
- wind speed
- moisture content of cassava roots.

In contrast with artificial dryers where many of the above factors can be controlled or overcome to guarantee a good quality product, natural drying methods are influenced by each of the factors.

3.1 CHIP GEOMETRY

Drying involves the movement of moisture from the interior of the chip to the surface, where it is evaporated by the surrounding air. Because of this, chip drying rate depends on the total surface area of chip and the rate of removal of moisture saturated air. Drying time can be reduced by reducing the roots into regular shaped particles of a size which permits the chips to retain their structural integrity, yet allows free circulation of air between the chips.

Most of the investigations have been carried out on chip geometry in relation to natural drying on cement floors or mesh trays. According to Roa and Cock (1973) optimum drying characteristics were obtained when the cassava roots were cut into rectangular bars 8 x 8 x 50 mm in size. Research in Thailand by Thanh et al (1978) compared the drying characteristics of chips prepared in different shapes and sizes:

<u>Circular</u> (2 variants)	-	Diameter 4.5 cm Thickness to 0.5 and 1.0 cm
<u>Rectangular</u> (4 variants)	-	Length 8.0 cm Width 2.5 and 5.0 cm Thickness 0.5 and 1.0 cm
<u>Cubic</u> (2 variants)	-	1.0 x 1.0 x 1.0 cm 2.0 x 2.0 x 2.0 cm
<u>Strips</u> (1 variant)	-	Length 6.0 cm Width 0.5 cm Thickness 0.1 and 0.2 cm
<u>Slices</u> (2 variants)	-	Thickness 0.1 and 0.2 cm

The particles of various geometries were dried on a cement floor during March and July 1975. Unfortunately no loading factors were reported so the interpretation of the results is difficult. However results indicated that chip geometry is an important factor in effiency of sun drying.

Experiments on concrete floors in Sumatra (Ishida, 1975, quoted in Nojima and Hirose, 1977) showed that 1 cm cubes dried quicker than 2 cm transverse slices, and traditional Indonesian gaplek chunks. Sixty percent of the fresh weight of the three sizes of root particles was lost after 10 hours exposure to sun in the case of 1 cm cubes. Two cm slices took 14.5 hours and gaplek still had not reached to 60 percent loss point after 16 hours of exposure.

Experiments using a drying chamber to compare three different chip geometries showed that 1.0 cm cubes dried faster than rectangular bars 1.0 x 1.0 x 5.0 cm and 1.0 cm thick slices (Ospina and Vasconcellos 1980).

Comparisons between chips produced by the Thai-type machine and a prototype Malaysian-type machine showed that under sun drying conditions the strips produced by the Malaysian-type machine dried more quickly.

3.2 CHIPS LOADING RATE

The loading rate is the term used to express the quantity of chips (in kilograms) placed per unit area of drying floor (in meters^2). It has been shown that loading rate is principally a function of the air flow over the surface of the bed of chips. In sun-drying chips on cement floors, the loading rate is limited by the limited movement of air at ground level. According to the climatic conditions, the optimum loading rate on cement floors appears to be between 5-10 kg/m^2.

Experiments in Thailand reported by Thanh et al (1978) showed that traditional Thai cassava chips dried quicker on cement floors which had been painted black to improve their thermal efficiency. The experiments showed that the same drying rate could be achieved on standard cement floors if the cassava roots were made into Malaysian-type chips ie strips before drying.

3.3 AIR TEMPERATURE, HUMIDITY AND WIND SPEED

The characteristics of drying cassava chips have been determined using artificial heat at three temperatures (55°, 66° and 77°C), air circulation speeds (31, 61 and 84 metres^3/min) and with chips at three depths 5, 8 and 10 cm (Webb and Gill, 1974). Findings showed that the drying process is one of natural diffusion with an initial phase of rapid drying, and a second phase much slower in rate. In the second phase, which commences when the chips have reached 30 percent moisture content the internal resistance against the removal of water is a more important factor than the other external factors. Further research by Chirife and Cachero (1970) demonstrated that with air circulation speed greater than 4,500 kg/h-m^2 drying rate does not alter until the bed of cassava exceeds a depth of 12 cm. Another outcome of their research was that cassava chips became toasted by temperatures greater than 84°C.

Unfortunately under natural drying conditions there is little that can be done to manipulate the ambient conditions. Nevertheless an appreciation of the effects upon cassava drying caused by variations in temperature, humidity, wind speed and solar radiation allow a better understanding of the drying process.

The natural drying process resembles that of articial drying in that two phases can be differentiated. In the first phase during which the chips lose moisture very quickly the wind speed is more important than the temperature and humidity of the air. When the wind is sufficiently strong the first phase of drying can be carried out during cloudy weather and even at night. Unfortunately during calm conditions, chips left on concrete floors overnight lose very little moisture.

The second phase in the drying process is marked by the slow rate of moisture loss. This can be speeded up by the application of heat. Unless the relative humidity of the air falls below 65 percent then the chips will not lose enough moisture to reach a storeable quality (eg 15 percent). During periods of prolonged rainfall cassava drying on concrete floors is abandoned until more favourable weather returns.

In order to speed up the drying process on concrete floors, especially the second phase, the technical feasibility of painting the floors black has been tested. Surface temperatures of the bare floor were increased by some 6½C (Thanh et al 1978), however the spreading of chips counteracts this effect and at loading rates exceeding 10 kg/m * the additional cost in painting the floor, or constructing floors using pigmented concrete, is difficult to justify in economic terms.

Experiments performed at CIAT to quantify the black floor effect (Best 1978) showed that the procedure shortened the drying time by approximately 2 hours. (Table A3.1).

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* Note: Commercial loading rates in Thailand approximate 6 kg/m .

TABLE A3.1

COMPARISON OF CASSAVA CHIP DRYING ON CONVENTIONAL AND BLACK SURFACED CONCRETE FLOORS (TOTAL HOURS BETWEEN 0800 AND 1800)

Loading Rate (kg/m^2)	Conventional	Black
5	12	10
10	19	17

A practical problem encountered during the CIAT trials was the dust problem. Fine particles of dried cassava, left as a residue on the surface of the concrete floor after drying a batch of chips, covered the black paint to a greater or lesser degree counteracting its beneficial effect. Regular washing of the black concrete floor was found to be necessary to retain the effect.

3.4 DRY MATTER CONTENT OF CASSAVA ROOTS

The dry matter content is affected by factors such as variety, stage of maturity and soil/climatic conditions. In general the range is from 30–40 percent, which significantly affects the conversion ratio of fresh roots to dry chips.

TABLE A3.2

CONVERSION FACTORS AS AFFECTED BY ROOT DRY MATTER CONTENT

Dry Matter Content of Roots (%)	Conversion Factor Roots: Chips (at 12% mc)
30	2.93
32	2.75
34	2.58
36	2.44
38	2.31
40	2.20

Processors favour obtaining roots with high dry matter content so that at a fixed processing cost per ton, a higher return in the form of chip sales can be recouped from the operation. In addition to the high proportion of dry matter in the roots, the lower quantity of moisture to be removed speeds up the drying process.

The concept of mechanical pressing of cassava chips prior to spreading on concrete drying floors has been proposed. However in practice although significant quantities of moisture are expelled the same moisture is lost rapidly during the first phase of sun drying and the effect of pressing on the reduction in total drying time has been shown to be small.

3.5 TRAY DRYING OF CASSAVA CHIPS

Investigations at CIAT (Roa 1974) showed that the drying rate of cassava is improved when the chips are exposed to aeration on all sides. Theoretical experiments showed that the best arrangement is to have vertically orientated drying beds, however practical considerations led to the development of sloping drying trays. Portable wooden framed trays, with bases of plastic mosquito screen to retain the chips, supported by wire chicken netting, were constructed. When placed on racks 30 cm above the ground, at an angle of 25-30° from the horizontal, chips do not slide, yet exposure to moving air is achieved. The dimensions of the racks developed at CIAT are 0.90 x 1.70 x 0.05 m.

Comparison between tray drying and conventional sun-drying on concrete floors showed the superiority of inclined trays in terms of drying rate (Table A3.3).

TABLE A3.3

DRYING CASSAVA CHIPS ON HORIZONTAL AND INCLINED TRAYS AND CONCRETE FLOORS (CIAT) 1976. TIME IN HRS BETWEEN 0800 AND 1800

Chip Loading Factor (kg/m^2)	Trays Horizontal	Trays Inclined	Conventional Concrete
5	7	6	12
10	14	11	19

Chips loaded at 10 kg/m were dried in a shorter period of time using inclined trays than half that quantity loaded on conventional concrete floors.

In management terms, however, it is difficult to capitalise on gains of a few hours in drying time when the gains all fall within the same day. In Table A3.3 only two lots of chips (trays loaded at 5 kg/m) dried within one day. All other treatments dried over a two day period. In order to regularise root delivery, chipping and spreading operations on a timetable basis the saving of part or a whole afternoon does not necessarily lead to huge savings in drying costs.

As reported above the initial phase in chip drying is speeded up by rapid air movement. Thus CIAT has shown that placing chips on drying trays to coincide with windy periods of the day speeds up total drying time. When predictably windy periods occur during the late afternoon and evening a substantial saving in drying time can be achieved using tray drying methods, the chips drying within the following day.

In practice however, night drying relies not only on regular windy periods but also on rainless nights, a risk few commercial operators would take.

A comparison of drying rates at different geographical locations was carried out by CIAT (Best 1978)* using inclined trays. The results shown in Table A3.4, demonstrated the influence of environmental factors on drying rate.

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* In Weber E.J. et al (1978).

TABLE A3.4

DRYING RATE OF CASSAVA CHIPS LOADED ON INCLINED TRAYS (10 kg/m^2) AT DIFFERENT LOCATIONS IN COLOMBIA

	Temp (°C)	Humidity (%)	Windspeed (m/sec)	Solar Rad cal/cm^2/sec	Drying rate*
Sevilla	31	68	1.0	0.71	13
Espinal	30	64	0.9	0.65	12
Palmira	26	66	1.2	0.61	13
Caicedonia	26	67	0.8	0.58	19
El Darien	24	70	1.9	0.73	12

* total hours between 0800 - 1800

The contrast in drying rates measured at Caicedonia and El Darien demonstrates the importance of windspeed and solar radiation in reducing drying time.

To date no commercial-scale cassava drying using the CIAT tray drying system has been attempted. It was pointed out that once the long term investment in laying down a concrete floor had been made there was little point in changing to a tray drying system. Calculations at CIAT showed the possibility of a 30 percent capital saving in the tray drying system, and savings in operating costs as tray drying obviates the need to rake the chips.

In summary, the pros and cons of the various systems proposed can be tabulated:

	Advantages	Disadvantages
Black-topped Floors	11-17 percent reduction drying time.	Dust accumulates necessitating washing.
CIAT Trays	1. Drying time can be as much as halved, or loading rate doubled with same drying time as concrete floors.	Care during loading, transporting and unloading trays required as trays easily damaged.

	Advantages	Disadvantages
2.	No need to turn chips reducing labour/ machinery inputs	Extra labour needed to load/unload trays
3.	Chips do not disintegrate during drying, therefore fewer 'fines' and potentially a better recovery	Difficult to mechanise as per situation in Thailand
4.	Trays can be covered in situ at night or during rainfall, with low cost plastic sheets.	Range of materials required may not be locally available
5.		High maintenance replacement cost

3.6 COMBINED DRYING SYSTEMS

The most inefficient component of natural drying is the initial phase during which only 25 percent of the moisture is removed during up to half of the total drying time. It has been proposed that artificial driers or solar-heated air driers could be used to speed up the initial drying phase.

Current work at CIAT is underway to test a solar-heated air drier. Air drawn through a solar heated 'collector' will be passed through quantities of cassava chips in drying bins equipped with perforated floors. Future plans include the design of a solid-fuel heat source to use coal, or wood. The use of cassava stems as a possible fuel has been proposed.

To quote Best (1978)*: "In conclusion there exist many options for improving the rudimentary methods of cassava drying that could be put into immediate use and evaluated under practical conditions". However a careful review of the economics of the various options is urged before expensive manpower, equipment and facilities are committed to programmes of theoretical research. Cassava occupies the role of a low value of cereal substitute in many of its current uses. Any significant increases in costs of processing pose a threat to the very existence of the industry.

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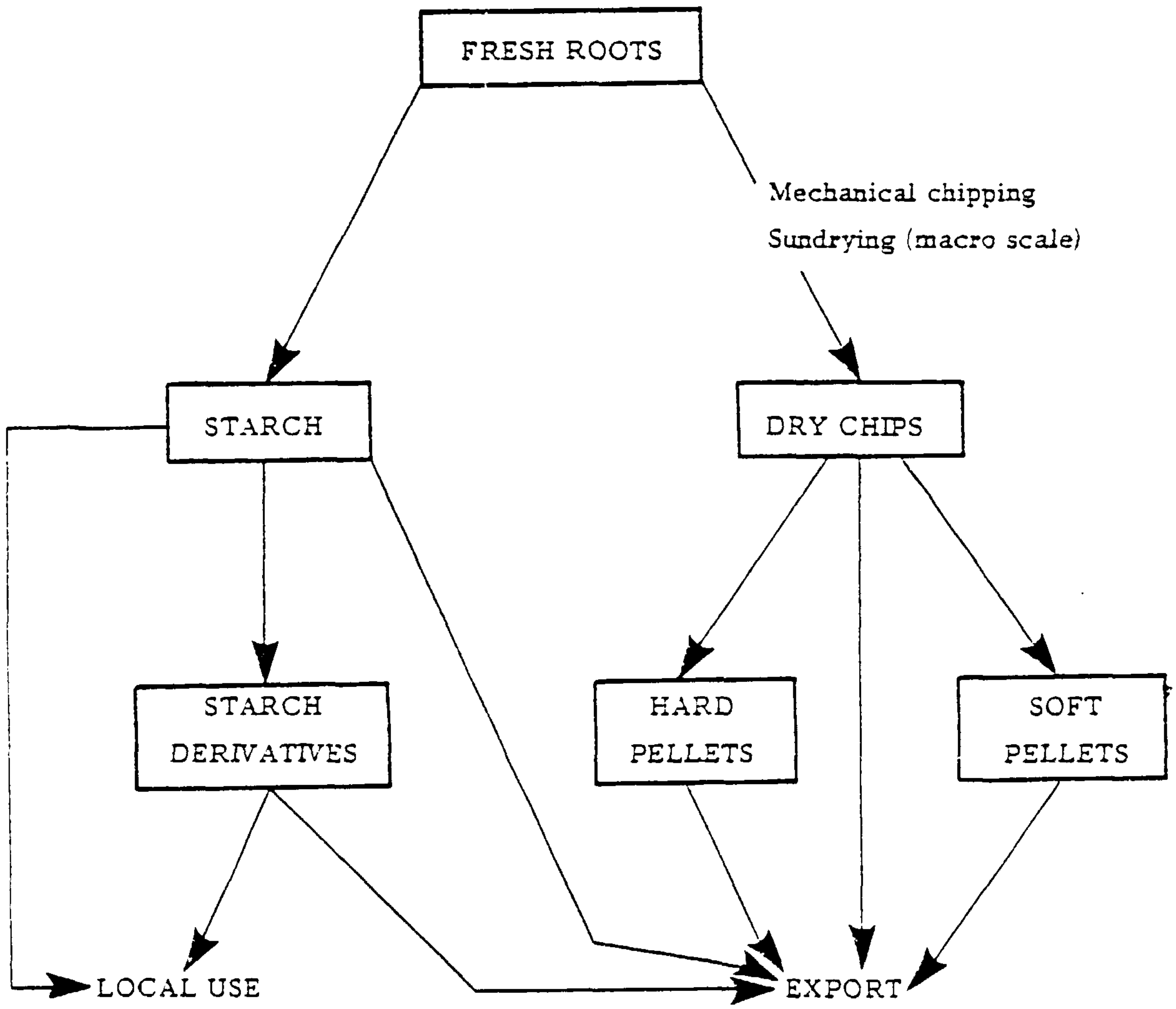
* In Weber E.J. et al (1978).

APPENDIX 4

PROCESSING CHANNELS: THAI CASSAVA INDUSTRY



APPENDIX 5

CHIP PRODUCTION COSTS - THAILAND 1981

EXPENDITURE AND INCOME	EXAMPLE 1 '000 Baht		EXAMPLE 2 '000 Baht			EXAMPLE 3 '000 Baht				1 Baht/T Dried Chips	2 Baht/T Dried Chips	3 Baht/T Dried Chips	1 % Cost per T	2 % Cost per T	3 % Cost per T
2,500 T fresh roots @ 680B		17,000	6,600 T @ 480B fresh roots		3,168	3,800 T @ 500B		1,900		1,511	1,056	1,188	89	75	84
Electricity	180			18			14			16	6	9	1	.4	.6
Fuel	384			180			46			34	60	29	2	4.3	2
Oil	60			22			4			5	7	3	.3	.5	.2
Wages Var	8			110			61			28	109	113	1.7	7.8	8
Fixed	312			216			120								
Office	7			6			10			0.6	2	6	-	.1	.4
Repair and Maintenance:															
M/C	11			11			15			9	60	19	.5	4.3	1.3
Vehicle	95			170			15								
Building	2			5			4			0.2	2	3	-	.1	.2
Chipping Yard	30			15			5			3	5	3	.2	.4	.2
T[illegible]rt to customer	304			-			-			27	-	-	.6	-	-
[illegible]	1,393			753			294			124	251	184	7.3	18	13
[illegible] on	90			139			52			8	46	33	.5	3.3	2.3
[illegible]	78			52			12			7	17	8	.4	1.2	.6
CONVERSION COSTS (excluding profit)	1,561			944			358			139	315	224	8.2	22.5	15.8
NET PROFIT	561			88			14			50	29	9	3	2	.6
OVERALL CHIPPING COST		2,215			1,032			372		189	344	233	11	25	16
11,250 T Chips @ 1,700 B/T		19,125	3,000 T @ 1,400 B/T		4,200	1,600 T @ 1,420 B/T		2,272	Selling Price	1,700	1,400	1,420	100%	100%	100%
CAPITAL EMPLOYED															
Chipping machines		70			140			30		6	47	19	6	9	5
Lab starch testing equipment		4			4			4		-	1	3	-	-	1
Scale		120			170			45		11	57	28	11	10	8
Vehicles: 2 bulldozers (2nd hand)		420	2 bulldozers		200			380		45	233	238	45	43	65
4 small vehicles		80	4 small		500										
Chipping floor (30 rai = 4.8 ha)		210	vehicles		150			65		19	50	41	19	9	11
Go-down & office buildings		210	(7 rai- ..12 ha)		600			60		19	200	38	19	37	10
TOTAL FIXED INVESTMENT		1,114			1,764			584		99	588	365	100	100	100
LOAN FROM BANK (8 days costs)		600	(24 days costs)		400	(10 days costs)		200							
RETURN ON FIXED INVESTMENT %		50			5			2.5							

APPENDIX 6

PRODUCTION COSTS OF 3 NATIVE PELLETISING PLANTS - THAILAND 1981

EXPENDITURE AND INCOME	EXAMPLE 1 '000 Baht		EXAMPLE 2 '000 Baht		EXAMPLE 3 '000 Baht			1	2 % Costs	3
20,000 T chips @ 1,700B		34,000	16,000 T @ 1,700B	27,200	6,500 T @ 1,600B	10,400	Dried Chips	80.5	80.5	75.5
Electricity	1,000		1,000		880					
Fuel	83		55		86		Energy	2.6	3.2	7.2
Oil	30		27		20					
Wages: Var	60		136		99					
Fixed	300		320		108			0.9	0.1	0.2
Office	360		20		24		Office	0.9	1.3	1.5
Repairs & Maintenance:										
Machinery	300		300		250					
Vehicle	70		100		60		Repairs & Maintenance	1.0	1.3	2.6
Building	40		50		50					
Transport	3,465		2,765		1,248		Transport	8.2	8.2	9.0
	5,708		4,773		2,825			13.6	14.1	20.5
Depreciation	210		257		90					
Interest	94		75		75		Finance	1.5	1.7	1.9
Tax (0.75%)	346		253		103					
Conversion Costs (excluding profit)	6,358		5,358		3,093		Conversion	15.1	15.8	22.4
PROFIT	1,882		1,234		285		Profit	4.4	3.7	2.1
OVERALL PELLETISING COST		8,240		6,592		3,378				
19,200 T pellets @ 2,200B		42,240	15,360 T @ 2,200B	33,792	6,240 T @ 2,208B	13,778	TOTAL	100%	100%	100%
CAPITAL EMPLOYED										
Pelletising machinery		700		920	400			22.4	51.2	33.7
Moisture testing equipment		13		15	26			0.4	0.8	2.2
Sand testing equipment		22		5	3			0.7	0.3	0.2
Scale		20		150	100%			0.6	8.4	8.4
Vehicles		350		450	210			11.2	25.1	17.7
Factory building		800		200	300			25.6	11.1	25.3
Go-down building		1,200						38.3		
Office building		25		56	150			0.8	3.1	12.6
TOTAL FIXED INVESTMENT		3,130		1,796	1,189		TOTAL	100%	100%	100%
LOAN FROM BANK		1,000		800	700					
RETURN ON FIXED INVESTMENT		60%		69%	24%					

APPENDIX 7

PRODUCTION COSTS OF A HARD PELLET PLANT - THAILAND 1981

EXPENDITURE & INCOME		'000 Baht			% Costs	
177,083 T chips @ 1,763B			312,197	Chips		85.2
Electricity		13,000		)		
Fuel	Boiler	4,500		)		
	Vehicle	480		Energy)	5.0	
Oil		200		)		
Wages	Fixed	80		Labour)		
	Variable	4,200		)	1.2	
Office		540		Office	0.1	
Repair & Maintenance:						
	Machinery	2,000		Repair)		
	Vehicle	220		and)	0.7	
	Building	200		Maintenance)		
Transport		-				
		25,420			6.9	
Depreciation		3,745			1.0	
Interest		11,400			3.1	
Conversion Costs (excluding profit)		40,565				11.0
Profit		13,758				3.8
Overall Pelletising Cost			54,323			
170,000 T pellets @ 2,156B			366,520			100%

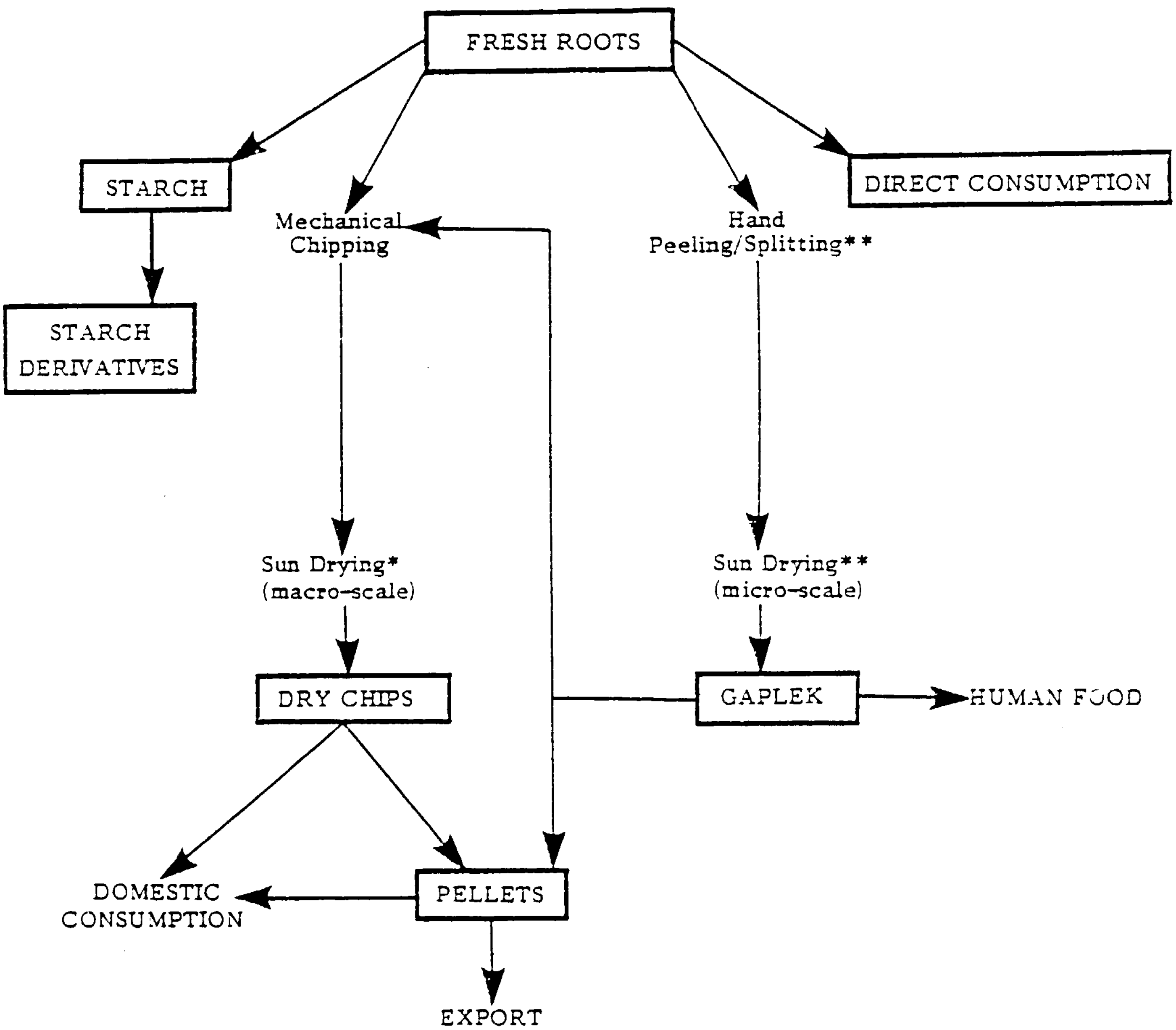
CAPITAL EMPLOYED

Machinery	25,000
Laboratory	45
Scale	210
Vehicles	3,700
Buildings and Go-down	17,000
TOTAL FIXED INVESTMENT	45,955
LOAN FROM BANK	60,000
RETURN ON FIXED INVESTMENT	30%

APPENDIX 8

CASSAVA

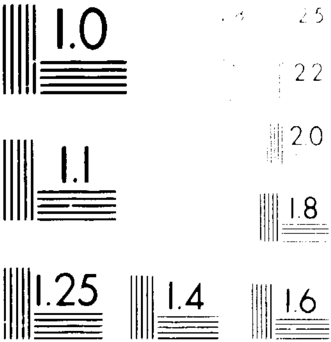
INDONESIAN PROCESSING ROUTES



* These processes are carried out in full comprehension that the material is for animal feed.

** These processes are carried out assuming that the gaplek will be used as human food.

84.08.23


1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

APPENDIX 9

COPY OF PAPER 'CASSAVA PRODUCTS: HCN CONTENT AND DETOXIFICATION PROCESSES'

BIBLIOGRAPHICAL NOTE

'Cassava Products: HCN Content and Detoxification Processes' is one of a number of papers published by International Development Research Centre, Ottawa, as part of the Monograph entitled: **'Nutritional Factors Involved in the Goitrogenic Action of Cassava'.** The monograph reports on the final phase of investigations carried out in Zaire.

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Chapter 5

Cassava Products: HCN Content and Detoxification Processes

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Dérivés du manioc : contenu en cyanure et processus de détoxification — Résumé — *Il existe dans les populations du Bas-Zaïre, du Kivu et de l'Ubangi une surcharge en SCN qui résulte de la consommation chronique de manioc. L'importance de cette surcharge et les modes de préparation du manioc sont très différents dans ces trois régions. Une étude comparative a donc été effectuée avec comme objectifs : 1) d'apprécier le contenu en HCN du manioc cru et des aliments dérivés du manioc; 2) d'analyser en laboratoire l'influence des processus de détoxification du manioc sur son contenu en HCN; et 3) de tenter de diminuer la surcharge en HCN chez des habitants de l'Ubangi en modifiant leurs habitudes alimentaires.*

L'analyse du contenu en HCN des tubercules (produit par l'hydrolyse de la linamarine) provenant des trois régions montre une dispersion très importante dans chaque région — 2–309 mg HCN/kg en Ubangi (180 échantillons), 12–205 mg HCN/kg au Kivu (28 échantillons) et 5–142 mg HCN/kg dans le Bas-Zaïre (25 échantillons). Il n'existe pas de corrélation évidente entre le contenu en HCN et les critères morphologiques. Cependant, il apparait que le pourcentage de tubercules considérés comme toxiques (> 100 mg HCN/kg) est faible (4 %) dans le Bas-Zaïre mais plus élevé et sensiblement identique (21 et 24 %) au Kivu et en Ubangi (Tableau 14).

D'autre part, l'analyse du contenu en HCN des aliments consommés par les populations des trois régions laisse apparaître des taux de HCN très faibles dans le Bas-Zaïre (fufu : < 1,0 et chickwangue : 1,3 mg HCN/kg), intermédiaires au Kivu (bugali : 6,3 mg HCN/kg) et relativement élevés en Ubangi (fuku : 17,3 et mpondu : 8,2 mg HCN/kg) (Tableau 16).

L'étude des processus de détoxification utilisés par les populations de ces trois régions montre que les variations des taux de HCN sont étroitement liées à des méthodes de préparation alimentaires différentes. Ainsi, le séchage au soleil, méthode de détoxification quasi générale en Ubangi, ne produit en réalité qu'une déshydratation partielle des tubercules avec une élimination fort incomplète (± 80 %) du HCN initialement présent dans le manioc (Tableau 19). La combinaison du séchage au soleil et d'une étape de fermentation, fort utilisée au Kivu, produit des aliments dont le contenu en HCN bien que non négligeable, est nettement plus faible que celui observé en Ubangi. Le rouissage du manioc en une ou deux étapes, largement pratiqué dans le Bas-Zaïre, constitue vraisemblablement le procédé de détoxification le plus efficace, la teneur en HCN des aliments consommés dans cette région étant de loin la plus faible (Tableau 17).

Une étude réalisée en laboratoire sur des tubercules amers collectés dans l'Ubangi, confirme que l'utilisation de techniques de détoxification plus poussées (par exemple le rouissage) permet l'obtention d'aliments dont le taux en HCN est négligeable (Tableau 18).

Dans l'Ubangi, une tentative pour diminuer l'apport en HCN en modifiant les habitudes alimentaires d'une famille très motivée a échoué (Fig. 11). Ceci confirme l'extrême difficulté d'introduire de telles modifications au sein des populations rurales.

En conclusion, les différences observées dans les trois régions rurales investiguées au Zaïre concernant le contenu en HCN des aliments dérivés du manioc proviennent en partie de différences dans le contenu en HCN du manioc cru mais surtout de

différences dans les processus de détoxification utilisés. Le rouissage apparaît comme la méthode la plus efficace. Une augmentation de la consommation de manioc et/ou une diminution de l'efficacité des processus de détoxification est susceptible d'entraîner l'apparition de troubles de la fonction thyroïdienne dans des régions actuellement non affectées.

The studies reported in chapters 2, 3, and 4 show that the rural populations of Bas Zaire, Kivu, and Ubangi have markedly higher concentrations of serum and urinary SCN than do control populations in Kinshasa and Brussels. The overload resulted from chronic intake of cassava products. These studies also show important differences among the concentrations of serum and urinary SCN from one region of Zaire to another as well as in the methods of preparing cassava-based meals.

The question therefore arose of whether these variations in SCN overload were caused by differences in the HCN content of fresh cassava or in the methods used to prepare the cassava products, or both, (De Bruijn 1971; Simons-Gérard et al. 1980).

A comparative study was carried out, therefore, in the three regions of Zaire to estimate the HCN content, first, of fresh roots collected locally and, secondly, of cassava-based meals prepared by the local inhabitants. As a third step, the various processing methods were reproduced in the laboratory at Gemena to assess their effectiveness in the detoxification of cassava. Finally, we attempted to decrease the SCN overload in inhabitants of Ubangi through nutrition education.

Material and Methods

Fresh cassava roots and leaves as well as the different cassava products commonly prepared and eaten in Ubangi, Kivu, and Bas Zaire were obtained from local inhabitants and analyzed for their HCN content. The preparation of the cassava products was studied in the three regions through house-to-house surveys and interviews.

In addition, cassava products were prepared in the laboratory at Gemena and the HCN content of the products determined at each step of the detoxification processes. A total of 739 samples were assayed for HCN determination. The HCN content reported for each sample in this study is the mean value obtained from five or six replicate assays of the same sample.

Results

HCN content of fresh cassava roots

The HCN content of fresh cassava roots collected in Ubangi ranged from 2 to 309 mg HCN/kg fresh weight (180 samples), in Kivu from 12 to 205 (28 samples), and in Bas Zaire from 5 to 142 (25 samples).

In all three regions, the wide range of individual results precluded calculating means. For this reason, and to allow more valid comparison between the results obtained in these regions, the individual values were classified into the three categories, based on HCN content, proposed by Bolhuis (1954), De Bruijn (1971), and Coursey (1979): *Innocuous*, less than 50 mg HCN/kg fresh peeled roots; *Moderately poisonous*, 50–100 mg HCN/kg; and *Dangerously poisonous*, over 100 mg HCN/kg.

The frequency distributions of HCN content of fresh roots among these three categories in Ubangi, Kivu, and Bas Zaire are shown in Table 14. The percentage of innocuous roots increased from 45% in Ubangi to 56 and 80% in Kivu and Bas Zaire, respectively. In contrast, the percentage of dangerously poisonous roots was almost identical in Ubangi (24%) and Kivu (21%) and was markedly lower in Bas Zaire (4%).

Table 14. Percentages of roots classified as innocuous (<50 mg HCN/kg fresh weight), moderately poisonous (50-100), and dangerously poisonous (>100) in the three areas.

	HCN content (mg/kg)		
Area	<50	50-100	>100
Bas Zaire	80	16	4
Kivu	56	22	21
Ubangi	45	31	24

As previously reported for Ubangi (Simons-Gerard et al. 1980), the measured HCN content of cassava roots did not correlate with the morphological criteria used by the inhabitants of the three regions to discriminate between sweet and bitter varieties. Consequently, no further attempt was made to distinguish between sweet and bitter varieties and the results obtained for the roots were pooled for each area.

We noted no morphological differences among roots from Bas Zaire and Ubangi but roots and plants from Kivu were clearly different. The plants commonly cultivated in Kivu were smaller (30–50 cm high) and the vegetation less exuberant, the roots were also smaller (5–25 cm length) and more slender (3–5 cm diameter). In Bas Zaire, as in Ubangi, the roots were harvested after 6 months (sweet varieties) to 18 months (bitter varieties), whereas, in Kivu, young cassava stems were planted during September and the roots harvested in June to August of the next year for both sweet and bitter varieties.

As reported by many people living in Bas Zaire, the area was dramatically affected by drought during the previous 3 years. Moreover, many cassava plants were attacked by parasitoses locally known as "cochineal" or "cassava cholera."

Preparation of cassava products

The methods of preparing food items containing cassava varied greatly among the three areas. The different cassava products commonly eaten in the three areas (Table 15) were prepared by six general methods. In addition, raw cassava roots (mainly sweet) were occasionally eaten by inhabitants of the three areas, mainly between meals.

Boiled roots: Fresh roots were peeled and boiled in water for 20–30 min until cooked.

Maize and cassava gruel (fuku): *Fuku* was only eaten in Ubangi where it was the basic foodstuff of the local population. As reported previously, bitter roots were peeled, cut into small pieces, and spread on the ground for 1–2 days to dry in the sun. Dried pieces were bruised in a wooden mortar with steeped (12–24 hours) maize and a flour was obtained. The amount of maize added fluctuated with the period of the year. The flour was then gently heated on a pan and eaten as a gruel prepared with hot water.

Cassava paste: *Fufu* was the major constituent of diet in Bas Zaire. Bitter roots were soaked for 2–4 days (during the rainy season) or 4–6 days (during the dry season). They were peeled and soaked again for 1–2 additional days whenever possible, broken into small fragments, and finally sun-dried for 4–5 days. The grinding of the sun-dried pieces provided a flour that was boiled in water until a paste of firm and elastic consistency was obtained. Eventually, the paste was heated again in water and eaten like Italian polenta.

In Ubangi, the consumption of cassava paste, i.e., *fufu*, was only observed in urban areas. Small pieces of peeled roots, rarely soaked for 1–2 days, were sun-dried for 1–3 days and cooked in hot water until a consistent paste was obtained as in Bas Zaire.

In Kivu, cassava paste (*bugali*) was prepared from fresh roots that were peeled and sun-dried for 2–4 days. The roots were then buried in the earth for 4 days and sun-dried again for 2 additional days. Grinding and sieving gave a rather white flour that was boiled in hot water. When available, variable amounts of sorghum flour (obtained from ground grain) were added, giving the paste a brownish colour (*bugali ya mohogo na mutama*).

Chickwangue: As previously reported, *chickwangue* represented an important foodstuff only in the southern part of Ubangi. *Chickwangue* and *fufu* were rarely eaten by the villagers but were increasingly attractive foodstuffs in the urban communities. For example, in Gemena, the use of these products has in-

Table 15. Cassava pr ducts commonly eaten in Bas Zaire, Kivu, and Ubangi.

Cassava products	Local name: Bas Zaire	Kivu	Ubangi
Boiled roots	*Mateloko*	*Mohogo*	*Nsongo*
Maize and cassava gruel	—	—	*Fuku*
Cassava paste	*Fufu*	*Bugali ya mohogo*	*Fufu*
Chickwangue	*Nsua*, *Ntinga*, and *Nsesa*	—	*Kwanga*
Cassava leaves	*Nsaki*, *Kiselu*	*Sombe*	*Mpondu*
Sorghum and cassava paste	—	*Bugali ya mohogo na mutama*	—
Grilled roots	*Bikedi*	—	—

creased twofold during the past 5 years: the availability of regular salaries and the scarcity of cassava fields in an urban environment tended to increase the consumption of *chickwangue*, which could be bought ready to eat.

Chickwangue was prepared by soaking bitter roots for 2–6 days, and mashing them into a puree that was simmered to form a paste similar to *fufu*. The paste was wrapped up in a palm or banana leaf.

In Bas Zaire, *chickwangue (nsua, ntinga,* or *nsesa)* was the most popular food after *fufu*. Its preparation required several days of work: bitter roots were soaked for 2–4 days (in the rainy season) or 4–6 days (dry season), peeled, soaked again for 1–2 days whenever possible, and ground after drying.

To prepare *nsua*, flour was mixed with water and filtered through a jute bag. After removal of the water, the paste was wrapped in a leaf and eaten raw.

Ntinga was prepared by mixing the flour with water and filtering it through a jute bag. The paste was then stored in the dark for 1–4 days. Half of the paste was then boiled in water and mixed with the remaining uncooked paste. The mixture was wrapped up in a leaf and cooked again.

To prepare *nsesa*, cassava flour was mixed with water to form a paste. The lump of paste was covered with leaves and dried in the sun. After a few days, the leaves were removed and the paste was divided into "loaves" for subsequent sun-drying. The loaves were then ground to obtain a flour that was cooked like *fufu*, wrapped up in a leaf, and cooked once more.

Cassava leaves: Occasionally, cassava leaves accompanied *fuku* in Ubangi, *fufu* in Bas Zaire, and *bugali* in Kivu. In Ubangi, cassava leaves were quickly washed in cold water, ground in a wooden mortar, and boiled to obtain a spinach-like vegetable; palm oil, vegetable salt, and occasionally peanuts were added to produce *mpondu*. The same process was used in Kivu for *sombe*, which was only made with young leaves. *Sombe* was sometimes eaten with small fry. In Bas Zaire, cassava leaves were quickly washed in hot water, ground, and cooked in water for 1–2 hours; ground peanuts and, sometimes, fish were added.

Grilled tubers: Bikedi was a typical foodstuff in Bas Zaire. It was obtained from soaked bitter roots that were prepared in the same way as for cassava paste except that the soaked roots were not cut into pieces but were grilled with oil.

HCN content of cassava products

The HCN content of some of the cassava products prepared as described above were determined and are compared in Table 16. The scatter between the individual results was less than for fresh cassava roots and means could be calculated. As reported for fresh roots, cassava products from Bas Zaire had very low HCN content.

Fuku and *mpondu*, two typical food items from Ubangi, exhibited the highest values. In the Kivu area, *bugali* also contained appreciable amounts of HCN. As reported in chapter 2, *bugali* was prepared from cassava and sorghum grain, which also contains a cyanogenic glucoside (dhurrin) (Conn 1969). The HCN content of two samples of sorghum were

Table 16. HCN content of cassava products in Bas Zaire, Kivu, and Ubangi.

Food item	Number of samples	HCN content (mg HCN/kg) Mean ± SEM	Range
Bas Zaire			
Soaked roots	3	2.1±1.1	<1.0–4.2
Fufu	6	<1.0	<1.0–2.8
Chickwangue	8	1.3±0.5	<1.0–4.8
Kivu			
Flour	17	21.6±3.4	7.5–35.7
Bugali	19	6.3±1.0	1.4–10.8
Ubangi			
Fuku	39	17.3±1.1	3.1–22.6
Mpondu	22	8.2±1.3	<1.0–25.0
Fufu	12	1.5±0.4	<1.0–4.0
Chickwangue	17	2.7±0.6	<1.0–7.2

Table 17. Relationship between detoxification processes of cassava roots and HCN content of the main cassava products consumed in Bas Zaire, Kivu, and Ubangi.

Food item	Detoxification process	Mean HCN content (mg/kg±SEM)
Bas Zaire		
Fufu	Soaked twice and sun-dried	<1.0
Kivu		
Bugali	Fermented and sun-dried	6.3±1.0
Ubangi		
Fuku	Sun-dried	17.3±1.1

20.6 and 23.8 mg HCN/kg. Beans, another foodstuff widely eaten in Kivu, also contain linamarin (Dunstan and Henry 1903). The HCN content of dried beans collected in Kivu was 8.4 ± 7.5 mg HCN/kg (mean ± SEM; range, <1.0–15.9). Some other vegetables, for example, colocasses and green leaves, occasionally eaten by Kivu inhabitants, contained no measurable HCN.

The various detoxification processes for fresh cassava roots used in Ubangi, Kivu, and Bas Zaire and the resulting HCN content in the main food items eaten in these areas are shown in Table 17.

The lowest HCN content, in food from Bas Zaire, indicated that sequential soaking and sun-drying was apparently the most efficient detoxification process. Sun-drying alone, which is widely used in Ubangi, was less efficient and produced the food with the highest HCN content.

It must be emphasized that, because of the decrease in yield of cassava production and the food shortage now occurring in Bas Zaire, the local population has tended to shorten the period of soaking, particularly to avoid having roots stolen while they soak. If generalized, this reduced soaking might result in a progressive increase of the HCN content of the food in Bas Zaire as well.

Study of detoxification processing

The large differences noted in the prepared food items collected from the three areas of Zaire led us to reinvestigate which step was essential or critical in the detoxification processes.

Foodstuffs prepared in the laboratory at Gemena: The main foodstuffs eaten in the Ubangi area were prepared by our chemists in the centre at Gemena using unselected samples of fresh cassava roots and leaves, bought at the local market. The food items were prepared according to the same procedures as those used by the local inhabitants. However, we particularly tried to detoxify the food as much as possible using the same procedures. For instance, some cassava leaves were cooked 15 min, as did Ubangi inhabitants, and others were cooked 30 min to evaluate a more effective detoxification. In the same way, *fufu* was prepared by adding a 3-day soaking period, which is exceptional in the Ubangi area.

The remaining HCN content after each step of the preparation in different foodstuffs is shown in Table 18. The food items prepared in the laboratory were very efficiently detoxified. For all of them, the final HCN content was about 1.0 mg HCN/kg. By contrast, six workers of the research centre were asked to pre-

Table 18. HCN content of various food items from Ubangi during preparation.

Food item[a]	Detoxification stage	Remaining HCN Mean ± SEM (mg/kg)	%
Mpondu (6)	Fresh leaves	68.6±22.9	100.0
	Washed leaves (cold water)	63.9±19.2	93.1
	Dried leaves	66.1±40.3	96.3
	Boiled leaves (15 min in water)	3.7±2.2	5.4
	Boiled leaves (30 min in water)	1.2±0.8	1.7
Boiled cassava (8)	Fresh roots (sweet)	10.7±4.8	100.0
	Boiled roots (20 min in water)	1.3±1.3	12.1
Furu (12)	Fresh roots (sweet and bitter)	111.5±90.3	100.0
	Soaked roots (3 days)	19.4±23.5	17.4
	Dried roots (3 days)	15.7±21.5	14.1
	Uncooked *fufu* (flour and water)	2.5±1.6	2.2
	Cooked *fufu*	1.5±1.4	1.3
Fuku (10)	Fresh roots (sweet)	25.5±13.3	100.0
	Dried (1 day) and ground	193.6±85.0	759.0
	Dried (2 days) and ground	54.3±42.2	212.7
	Uncooked *fuku* (heated)	4.2±5.5	16.4
	Cooked *fuku*	1.2±1.2	4.7

[a]Numbers of preparations or roots shown in parentheses.

pare their own *ntondu* at the centre; the mean HCN content of their food items was 10.0 ± 10.5 (SD) mg HCN/kg, with individual values in the range of <1.0–25.0 mg HCN/kg.

These results indicate that, even in the Ubangi area, well detoxified foodstuffs could be obtained from the same products as those used by local inhabitants if the detoxification processing is handled adequately.

Drying and temperature: While preparing *fuku*, we observed an increase in the HCN content of the roots dried for 1–2 days (Table 18). This experiment was repeated with 11 roots and gave similar results (Table 19).

In a subsequent experiment, the roots were dried for 1–8 days. When the water removed was expressed as a decrease in the initial weight of the roots (Table 20), it was clear that the longer the period of drying, the larger was the amount of water removed from the tubers.

Table 19. Effects of drying on the HCN content in 11 cassava roots.

Drying period (days)	Remaining HCN	
	Mean ± SD (mg/kg)	%
0	70.4±53.0	100.0
1	95.5±65.9	135.6
2	91.1±89.6	129.4
3	56.6±43.8	80.4

Clearly, from Tables 19 and 20, the main effect of drying was the removal of water from the roots. Consequently, a large part of the HCN remained in the roots and the apparent increase in HCN content resulted only from disappearance of water.

To examine the effects of heating on the HCN content of the roots, six cassava roots were divided into four identical parts (longitudinal section) and heated in an oven to constant weight (Table 21). Slight heating again produced an increase in the HCN content due to the loss of water. At 105°C, however, about 60% of the initial HCN content was lost and, at 165°C, almost all the HCN was released. These latter temperatures were chosen because they exceed the decomposition temperature reported for linamarase (72°C) (Joachim and Pandittesekere 1944) and linamarin (150°C) (Cerighelli 1955). Such temperatures, however, are never achieved by the Ubangi population while preparing their meals.

Table 20. Effects of drying on the percentage of water removed from six cassava roots.

Drying periods (days)	Mean percentage loss of water ± SEM
1	14.1±3.2
2	51.1±2.5
3	61.1±0.6
4	64.5±2.0
5	68.9±4.3
8	70.0±5.3

Table 21. Effects of heating on the HCN content of six cassava roots.

Part	Treatment	Mean HCN content (mg/kg ± SEM)
1	Fresh roots	73.5±17.7
2	Heated at 60°C	116.7±15.3
3	Heated at 105°C	28.8±8.3
4	Heated at 165°C	<1.0

Effects of soaking: To explore the effects of soaking during detoxification, the remaining HCN content of roots soaked for 1–5 days was measured. Soaking for only 1 day released 45% of the initial HCN content (Table 22) and soaking for 4 days decreased the HCN content by about 90%. Soaking for more than 5 days was tested but the roots decomposed entirely.

Because autolysis was used for the HCN determinations, the results obtained for HCN contents must be regarded as the lowest possible values. Indeed, if the linamarase was destroyed for any reason, autolysis could not produce HCN from persisting linamarin.

The hypothesis that linamarase could be destroyed by soaking was tested by adding fresh cassava roots with extremely low HCN con-

Table 22. Effects of soaking for 1-5 days on the HCN content of six bitter roots.

Soaking period (days)	Remaining HCN	
	Mean ± SEM (mg/kg)	%
0	108.2±48.8	100.0
1	59.5±40.7	55.0
2	45.8±35.7	42.3
3	20.6±18.7	19.0
4	11.8±17.2	10.9
5	2.9±3.3	2.7

tent, which supposedly contained the enzyme, to bitter roots after 6 days soaking. Inasmuch as sweet cassava did contain excess linamarase, the data in Table 23 showed that the low HCN content observed in the bitter roots after 6 days soaking did not result from deactivation or release of the enzyme, but was actually due to the release of the linamarin originally present.

Table 23. Effect of sweet cassava, as a possible source of enzyme, on the release of HCN in bitter soaked roots.

Root sample	Mean HCN content (mg/kg ± SEM)
Fresh sweet (I)	2.4±0.2
Fresh bitter (II)	136.2±9.4
Bitter soaked for 6 days (III)	1.4±0.4
(I) + (III)	2.3±0.5

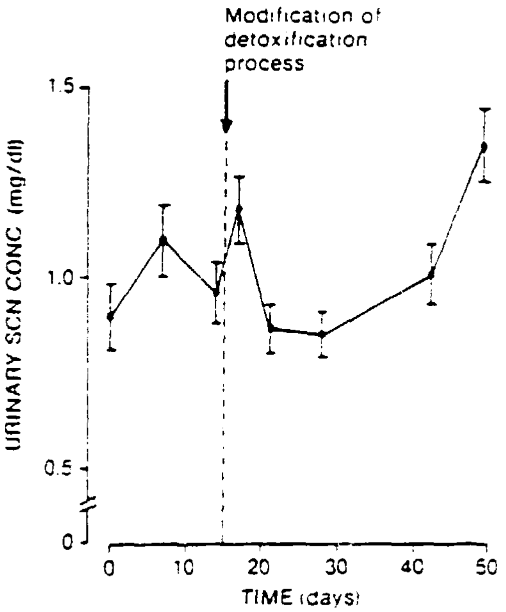

Fig. 11. *Changes with time in urinary SCN concentrations (mean ± SEM) in 29 persons in the village of Bokuda (Ubangi) during a trial of nutrition education.*

Trial of nutrition education in the Ubangi area

The trial of nutrition education was aimed at reducing SCN overload in humans by modifying their food habits. The investigation was carried out in the village of Bokuda, 25 km from Gemena. A family of 29 persons was asked to modify the preparation of their usual food (mainly *fuku*) by adding a 3-day period of soaking, 1 day drying of the soaked roots, and cooking the flour for 30 min. The reasons for these proposals were explained at length orally and with pictures. The formal consent of the whole family was obtained thanks to the very good relations between the research team and the head of the family, who was also the head (*capita*) of the village. Urine samples were collected on days 0, 7, 14, 21, 28, 42, and 49 for SCN measurement.

The mean urinary SCN concentrations obtained before the modification of processing (on day 15) were fairly constant and close to 1 mg/dl (Fig. 11). After the modification, there was a slight but not significant decrease in the mean urinary SCN concentration on days 21 and 28. Surprisingly, at days 42 and 49, the results were similar to or even higher than the initial values. All subjects exhibited a similar trend. The results were shown to the villagers and, on questioning, they explained that they had followed the protocol for only 3 days and after that had preferred to sell well detoxified cassava, i.e., *chickwangue*, at the market of Gemena to get some money.

This unsuccessful trial showed that, even with carefully prepared and apparently motivated people, changing the nutritional habits of a rural population is quite difficult.

Discussion

The HCN content of food items consumed in the three areas investigated decreases from Ubangi through Kivu to Bas Zaire. These variations reflect both a difference in the HCN content of fresh roots and, especially, the efficiency of the detoxification processes used in the three areas. The HCN content of fresh roots showed a wide scatter but, on the whole, the results seem to indicate that HCN content of the roots decreases from Ubangi through Kivu to Bas Zaire. Since no botanical determination or soil analysis could be performed, our data do not allow us to conclude whether the different HCN contents of roots are related to genetic or environmental factors, or both. However, we observed that cassava varieties growing in the Kivu area are quite different from those cultivated in Ubangi and Bas Zaire.

In the Ubangi area, cassava is most usually dried in the sun and soaking is rather exceptional. Samples of the main food eaten by the inhabitants, i.e., fuku, contain an average of 17 mg HCN/kg. The high HCN content observed in fuku is closely related to the detoxification process used in that area. Indeed, experimental studies show that sun-drying of cassava is an inefficient process of detoxification. As indicated in Tables 19–21, sun-drying of roots results mostly in a loss of water rather than release of HCN. During the preparation of fuku, we observed that the critical step of detoxification occurs while heating or boiling cassava flour. Studying the effects of heating, we observed that the temperature required for complete release of HCN from the roots (i.e., more than 150°C) is never reached during sun-drying or preparation of the meals.

Despite the efficient release of HCN noted in food items prepared in the laboratory (up to 95% of the initial HCN content), the traditional way of preparation of foodstuffs by the inhabitants results only in a partial release (about 80%).

In contrast, in Bas Zaire, soaking is universally used and detoxifies the roots efficiently. The reduction of HCN ranges from 45% after soaking for only 1 day to 90% after 4 days. The latter value is of considerable interest. Processing that includes sequential soaking (twice whenever possible), sun-drying, and cooking results in virtually complete release of HCN, as is shown by the very low HCN content in food from Bas Zaire.

In the Kivu area, detoxification processing that includes sun-drying and fermentation appears to be fairly efficient since the HCN content of foodstuffs is lower than in Ubangi but slightly higher than in Bas Zaire.

The apparently conflicting observation that the HCN content of foodstuffs is higher in Kivu than in Bas Zaire while serum and urinary SCN concentrations in humans are practically similar in both areas (see chapters 2–4) may be partly explained by seasonal variations in the consumption of processed cassava. In Kivu, as reported earlier, cassava is only eaten from July to November. When considering separately the group of 58 adults investigated in Kivu during July and August, when the food samples were collected, serum and urinary SCN concentrations were 1.10 ± 0.07 mg/dl and 2.59 ± 0.31 (SEM) mg/dl, respectively, i.e., values higher than those reported for adults in Bas Zaire or for adults in Kivu investigated between January and June. The role played by seasonal variations in the consumption of cassava in Kivu could not be further explored.

An attempt to reduce the SCN overload in apparently motivated inhabitants in the Ubangi area using nutrition education failed entirely. This underlines the well recognized difficulty of modifying the food habits of rural populations in Africa. Such an attempt requires a more sophisticated approach based on an accurate knowledge of the psycho-socioeconomic context of these populations.

Finally, we must point out that the nutritional value of cassava is reduced when it is processed (Longe 1980). In particular, Rajaguru (1975) has reported that soaking removes the soluble proteins.

In conclusion, the data reported indicate that the differences in the HCN content of cassava products eaten by the local populations of Ubangi, Kivu, and Bas Zaire are closely linked both to differences in the content of HCN of fresh roots and to the regional variations in traditional cassava processing. In this context, soaking may be regarded as the most efficient detoxification process. The differences in the HCN content of food items may account for the variations in the SCN levels observed in humans in the three areas investigated in Zaire.

From the available data, it can be expected that, if for any reason including food shortage due to socioeconomic conditions, the dietary supply of cassava increased or the efficiency of the detoxification process decreased, cassava toxicity for the thyroid in humans would become evident in areas that are now unaffected.

APPENDIX 10

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