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

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

INTEGRATED CASSAVA PROCESSING FACTORY.
CONCEPT EVALUATION OF CASSAVA CHIP PRODUCTION

(Project Reference P83/05 - US/INT/80/006)

VOLUME 1

PRODUCTION SYSTEMS, QUALITY CRITERIA AND TECHNO-ECONOMIC FACTORS

FINAL REPORT

Prepared by:

Minster Agriculture Limited
13 Upper High Street
Thame
Oxfordshire
England

and

P-E International Operations Limited
Park House
Egham
Surrey
England

CONTENTS

1.0 INTRODUCTION

1.0 INTRODUCTION

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

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

The aim of the present project is to define the requirement for high quality dried cassava chips suitable for a factory producing both human food and other products, and to recommend the best practical means for achieving their production and supply.

This necessitated a major review of known published data on cassava worldwide and an up-to-date assessment of current dried chip production practices in the light of the proposed Factory Concept, bearing in mind the conditions necessary for human consumption.

This final report comprises two volumes. 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.

The first stage of the study involved reviewing the published data 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. The review has produced a bibliography of over two hundred key publications. This is given in Appendix 8.

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

The study was carried out by a team including:

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

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

An interim report was sent to UNIDO, Vienna, in September and accepted on 11th October 1983. The draft final report was submitted in November and accepted in December 1983.

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.

The guidelines set out in this report complement the conceptual study of a factory for integrated cassava processing operations as described in the earlier UNIDO report. Already this has promoted considerable interest.

It is recommended that a specific country project now be undertaken to implement the results of the two studies. This would constitute a major first step towards greater utilisation of cassava's potential for improving the availability of widely accessible, quality processed food supplies that are guaranteed free of any danger of toxicity. In addition, it would also help to reduce imports in many developing countries.

2.0 SUMMARY AND RECOMMENDATIONS

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2.1 CASSAVA AND ITS POTENTIAL

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

The idea of an industrialised approach to processing cassava was first suggested many years ago. So far this has been implemented mainly for animal feed. The 1983 UNIDO 'Factory Concept' report illustrates in detail the potential for increasing food supplies, producing industrial products and, in many cases, reducing imports in a number of countries.

However, in the past a number of cassava processing schemes have failed owing to the absence of a concept properly thought through, particularly with respect to reliable raw material supplies. The present project remedies this deficiency and confirms the conclusions of the 1983 UNIDO report which recommends the implementation of a cassava processing project.

(Section 3)

2.2 OVERALL CONDITIONS FOR CASSAVA SUPPLY

The economic implications in terms of land area, distances, transport requirements and organisation were examined for a dense and also a sparse population scenario, with population densities ranging from 60 persons/km^2 to 11 persons/km^2.

In a densely populated region, up to 400 km^2 total land area may be needed to supply the 'standard' processing factory defined in the 1983 UNIDO report. This implies an 11 km operating radius from the centre. In a sparsely populated region, some 900 km^2 are needed, an operating radius of 16½ km. Despite the greater transport distances, it is the sparse region that tends to produce more favourable supply conditions because larger farm sizes result in greater handling efficiency.

The case studies illustrate how important it is to examine in detail at farm level the crop growing conditions, the individual 'own use' family requirements and, hence, the likely output of cassava chips available for sale to a processing factory.

Finally it is vital at the feasibility stage to evaluate the overall agricultural and economic conditions of the area with respect to items such as alternative markets for cassava, credit availability, production inputs, labour availability, extension support and likely rotation crops. Perhaps most important of all is the need to assess the broad implications of encouraging increased cassava output, the effect on the local population and the likely result of other changes that may occur once a processing factory has been established. The extent of care and depth in evaluating such considerations is clearly a key factor in determining the successful implementation of a cassava project.

(Section 6)

2.3 THE NEED FOR HIGH CROP YIELD

The raw material, mainly dried cassava chips, forms a significant cost element for a cassava factory. Up to 90 percent of the cost of dried chips arises from the cassava crop production and these production costs, in turn, depend very much on the agronomic yield. It follows that a key factor in the economic success of a cassava processing factory is the maintenance of a sufficiently high yield. This must be encouraged and controlled by suitable extension assistance and liaison between factory and growing facility.

(Sections 4 and 5)

2.4 TYPES OF CASSAVA FARM

Cassava can be grown either on traditional small farms or on larger mixed farms. Alternatively, a large plantation unit could be located near the processing factory. In order to spread the risk and reduce cassava's tendency to deplete the soil when grown exclusively, it is recommended that cassava raw material be supplied by relatively small farms where the farmer has an incentive to grow cassava on a rotation basis, both as a food crop for his own use and for cash sale to the processing factory. In general, specific cassava plantations are not recommended. Larger mixed farms may be appropriate in some countries where local conditions make it profitable to produce cassava in this way. However, experience suggests that cassava is most likely to be viable in conditions where it is difficult to grow cereal crops and it is under these conditions that small farms are the most likely scenario.

(Section 4)

2.5 PROCESSING FRESH ROOTS INTO CHIPS

Once harvested, the perishable fresh cassava must be processed within forty-eight hours. This can be done either by the farmer direct or by a central chipping and drying facility. The latter requires substantial capital outlay and it is recommended therefore that, in most cases, chipping and drying on the farm is the most economic method.

Farm chipping is done by hand at present. There is a need for a small inexpensive hand chipper to reduce this labour and a suitable design project is recommended. For bulk chipping, a machine such as those currently used in Malaysia is recommended in the short term. These produce chips of a satisfactory size and shape with good drying characteristics. However, there is a need to modify this static design with the mobile features of machines used in Thailand. It is recommended that the necessary design study be undertaken.

(Sections 4 and 5)

2.6 CHIP DRYING

Drying chips at farm level is best done using simple raised drying platforms made of local materials. The chips must be raised above ground to avoid the health risk of contamination by animals. Furthermore, this increases the drying rate.

Drying chips in bulk is best done using a fenced-in concrete drying yard on the lines of those in Thailand. The capital cost (of the order of $150,000 in Thailand in 1983) and increased costs of transporting fresh roots to a central chipping and drying yard must be compared with the alternative of local farmer chipping and drying for each individual project.

(Sections 4 and 5)

2.7 ROAD SYSTEM AND TRANSPORT

A suitable road system capable of being used by trucks up to 8 tonnes between farms and the processing factory is a prerequisite for the establishment of a cassava processing factory.

The provision of transport of cassava chips from farm to factory is a significant cost factor. In addition, it is a vital element to the incentive and control of the producing farmer. Normally, transport is best organised by the factory so as to ensure a regular collection schedule during the harvesting season. The requirements can vary substantially with local conditions and must be calculated in detail for each set of circumstances.

(Section 4)

2.8 CHIP STORAGE

Storage of dried chips is best done under controlled conditions at the factory. Capacity for at least six months' supply is recommended, but preferably the whole season's needs should be catered for. However, temporary storage can be undertaken by the farmer where necessary as the space requirements are small.

(Section 4)

2.9 CHIP QUALITY AND STANDARDS

Good quality chips are those of the right size and shape with good drying characteristics, of low moisture and high starch content, and containing a minimum of foreign matter. Microbiological contamination should be minimised by fast drying and suitable precautions during chipping, drying and transportation.

(Sections 5 and 6)

Official quality standards in most countries relate mainly to the production of animal feed. Recommendations for dried chip quality for the cassava processing concept, therefore, have been developed empirically as part of this project.

(Section 6)

2.10 HAZARDS TO HEALTH

The key health hazards in cassava chips are microbiological contamination during processing and cassava's inherent HCN toxicity. The growth of fungi and bacteria is minimised by correct drying and subsequent storage and, in general, is not a problem where chips are to be used in a processing factory. However, contamination by animal excreta during drying and storage should be carefully controlled.

(Sections 5 and 6)

Cassava's HCN toxicity is often thought to be well understood and under control. Unfortunately the study has shown that this is not universally the case. In parts of Asia and Africa, chronic HCN poisoning has affected significant sectors of population over the years, as a result of inadequate detoxification by traditional washing and cooking methods. (Sections 3 and 6 and Appendix 2).

2.11 THE CASE FOR A CASSAVA PROCESSING FACTORY

The hazard of toxicity is virtually eliminated by producing food in a cassava processing factory. It is recommended most strongly, therefore, that the concept used should be to overcome the serious health problem which is still prevalent in some parts of the world. This factor alone is a strong argument in favour of the cassava processing concept.

The combination of economic and health factors outlined makes a strong case for carrying out a full feasibility study in a suitable country. One possibility is to select a territory currently suffering from HCN toxicity health problems, thus providing opportunities not only for their early alleviation but also for further research. It is anticipated that this would lead to establishing a cassava processing factory which would benefit the local community and, at the same time, serve as a model for other countries.

The implementation of the cassava processing concept is very strongly recommended. It can make a significant contribution to the economics of many developing countries. Even more importantly, it is of potential benefit to the health of several million people.

2.12 ECONOMIC VIABILITY

No generalised statement of economic viability is practicable since conditions vary too widely in different countries. The main cost components in producing dried chips comprise fresh root production, the chipping and drying conversion process and transport. The need to maximise crop yield has already been mentioned as the most important single parameter in producing competitive dry chip raw material.

To determine the viability of a proposed factory, the feasibility study must assess in detail all the factors described in this report and compare the alternative production methods and locations available. In each case dried chip costs can be built up from the three main cost components.

It is recommended that upper and lower limits for permissible raw material input costs be tested using the computer model developed for the 1983 UNIDO 'Factory Concept' report. This will produce a range of product selling prices and, hence, calculate accurately the viability of the proposed factory against a range of assumptions and cost parameters. On this basis a rational decision on whether to proceed can be taken.

(Section 4)

3.0 BACKGROUND TO CASSAVA DEVELOPMENT

3.0 BACKGROUND TO CASSAVA DEVELOPMENT

This section describes the background to the cassava crop, its origins and its current role in the nutrition and industrial sectors of tropical countries. In addition, it presents a brief description of the integrated cassava processing concept which links this report to the earlier UNIDO report.

3.1 THE CASSAVA PLANT

The cassava plant is a woody-stemmed, short-lived perennial shrub which ranges in height between 1 - 3 m when mature. The economic component of the cassava plant is the cluster of roots borne at the base of the stem, which comprises mainly water and starch. The protein content is very low. The root also contains significant quantities of hydrocyanic acid (HCN) which produces its characteristic bitter taste. This gives rise to the need for detoxification for human consumption. Cassava is usually regarded as falling into two broad categories: the 'bitter' (high HCN content) and the 'sweet' (low HCN content). In practice there are many different varieties.

3.2 WORLD GROWTH OF CASSAVA

Cassava originated as a crop plant in South and/or Central America in pre-Columbian times. During the 16th century Portuguese traders introduced it to the west coast of Africa, where it became an important food. The crop was then shipped to the east coast from where it spread inland until, by the early 20th century, cultivation of cassava was practised in most climatically suitable parts of the African Continent. The adoption of cassava as a crop was actively encouraged by colonial administrators who recognised its ability to produce food even under severe drought conditions. Cassava's hardiness led it to become the traditional 'famine reserve' and subsistence farmers themselves soon came to recognise its utility in their cropping programme. The crop frequently features as the last in the rotational cycle, where it 'mops up' the residual fertility of the soil before the land is abandoned to natural regrowth for the fallow period.

Cassava was introduced to Asia via India during the 17th century, again by Portuguese voyagers. Other introductions via the islands of Mauritius and Reunion penetrated Ceylon and Java. It became an important cash crop in the then Malaya and the Dutch East Indies at the turn of the 19th/20th century and cassava plantations were developed for starch, pearl barley and tapioca production for export to Europe. Unfortunately this large-scale production was introduced at a time when artificial fertilisers were rarely used in the tropics. As a result cassava became recognised as a 'soil depleting crop' at this time, a reputation which it bears to this day, despite the widespread availability of artificial fertilisers, which easily counter the effect.

Global production of cassava highlighting major producer countries is summarised in Table 3.1. During 1971 to 1981 world output has increased by over 30 percent. In its continent of origin, South America, production has fallen over the ten years, mainly as a result of Brazil's reduced output. In Asia it has more than doubled over the same period, putting that continent on an equal basis with Africa as the dominant producer region.

Much of the upsurge in Asia results from the dramatic increase in cassava production in Thailand. According to the FAO statistics, growth in Thailand's production has averaged nearly 19 percent a year during the 1971-81 period, placing Thailand as second in the world output rankings after Brazil. Some of Thailand's output is converted into pellets for animal feed; however a major part of world production is still utilised for starch and human food.

3.3 TRADITIONAL PREPARATION AND USES

Cassava is prepared and used as a food by diverse methods which have developed in different parts of the world. Examples include simple boiling, steaming, frying, grinding or pounding and fermenting. These have resulted in a wide range of traditional food products, such as Nshima and Fufu in Africa and Peujeum in Asia, which render the root palatable or convert it into a storeable form. A list of traditional methods of processing and preparation is given in Appendix 1.

TABLE 3.1

WORLD PRODUCTION OF CASSAVA ('000 MT)

	1969-71	1981
World Total	**96,696**	**127,262**
Africa	**38,339**	**47,818**
Mozambique	2,549	2,850
Nigeria	9,473	11,000
Tanzania	3,373	4,650
Zaire	10,232	13,000
Other	12,712	16,318
North and Central America	**783**	**954**
South America	**34,444**	**30,677**
Brazil	29,922	25,050
Colombia	1,380	2,150
Paraguay	1,442	2,000
Other	1,700	1,477
Asia	**22,943**	**47,584**
China	1,938	3,276
India	4,993	5,817
Indonesia	10,695	13,726
Philippines	436	2,300
Thailand	3,208	17,900
Vietnam	950	3,400
Other	723	1,165
Oceania	**187**	**229**

Note: Countries producing in excess of 2 million tonnes of cassava in 1981 have been selected.

Source: FAO Production Year Book 1981

3.4 CASSAVA TOXICITY

The poisonous HCN content of cassava increases in concentration from the core outwards, the outer layers having much the highest concentration. This is well known and roots are usually peeled at an early stage in traditional food preparation, thereby avoiding the most obvious danger of acute poisoning. However, all peeled roots still contain significant amounts of HCN, even the 'sweet', low HCN varieties. This residual HCN can be virtually eliminated by thoroughly washing pulped or chipped roots, by soaking the roots for several days, by allowing or encouraging (by inoculation) the roots to ferment, or by cooking to a sufficiently high temperature.

However, there is a surprising degree of ignorance and corresponding lack of published information on HCN levels in traditional cassava food products. Unfortunately it can take a decade or more for mild cyanide poisoning to manifest itself irreversibly in the form of goitre or cretinism. These dangers of chronic toxicity have been known for some time in general terms; nevertheless, some traditional methods of cassava food preparation such as lightly steaming do not eliminate the cyanide content. As a result, the effects of chronic toxicity still affect significant areas of population in parts of Africa and Asia. A major virtue of the factory processing concept is that the resultant food products would be completely free of any such dangers.

This topic and how to overcome these problems is discussed further in Section 6.1.6. and in Appendix 2.

3.5 NUTRITIVE VALUE OF CASSAVA

Cassava is essentially a starch food, and as such is one of the most efficient producers. The chemical composition of the root is typically:

Water	62 percent
Carbohydrate	35 percent
Protein	1 percent
Others	2 percent

Cassava roots are relatively rich in vitamin C and calcium but poor in protein, other vitamins and minerals.

The main value of cassava is as a source of carbohydrate, and it is in fact one of the most important tropical staples. Its value is often underestimated, and together with other root crops, is often regarded as inferior to grain crops, partly because of its low protein content and partly because of cultural reasons. However, it has been calculated that in terms of production of food energy per hectare, cassava has much greater potential than cereals.

3.6 WORLD TRADE

Most of the world's cassava is consumed within the producer country. The proportion that is processed into a form which can be traded internationally is relatively small. The most recent trade data available indicate that world trade in cassava products is still dominated by cassava pellets for animal feed from Thailand to the EEC, and starch from Thailand and other countries to Japan, USA and Taiwan (Table 3.2).

TABLE 3.2

WORLD TRADE IN MAJOR CASSAVA PRODUCTS IN 1981 ('000 MT)

Exporters		Importers	
PELLETS			
Thailand	5,682	Netherlands	3,486
Indonesia	418	Germany (FR)	1,600
		Belgium	1,073
		France	681
	6,100		6,840
STARCH			
Thailand	248*	Japan	79
Brazil	9	USA	36
Malaysia	n.a.	Taiwan	76*

* 1980 figure as 1981 figure not available.

n.a. = not available.

Recent reports suggest that international cassava markets for traditional products are unlikely to experience any significant growth at present price levels. Likely outlets in domestic markets appear to be primarily for starch, starch derivatives and animal feed.

3.7 THE EMERGENT MODERN FACTORY PROCESSING CONCEPT

Despite the substantial amount of cassava already produced, a large potential still exists on a global level for exploiting cassava by suitable processing methods.

The world food situation requires further expansion of food supplies, both in quantity and quality. Many developing countries presently import products which deplete precious foreign exchange. Cassava can be converted to high quality food in a great variety of products such as starches, flours, syrups, glucose, and food and feed grade leaf protein. Furthermore, a number of industrial products such as alcohol, sizes and glues can be produced. In many countries there are opportunities both for reducing imports and for creating or increasing exports.

Out of this recognition of cassava's under-utilised potential, there emerged the concept of developing and integrating its production and processing in an economic manner. A number of cassava processing schemes have failed in the past owing to the lack of a properly thought through integrated concept. However, it is now recognised that a careful analysis of the raw material supply, the process itself and the potential market outlets is necessary to achieve a successful balance for an economic cassava processing operation.

In order to utilise cassava to an optimum extent with all the socio-economic implications involved, its production needs to be organised so as to make it suitable for factory scale processing. To achieve the necessary economic production flexibility, a modern cassava processing factory has to be based on the production of a variety of cassava products which can be adjusted to prevailing market demands. The principle of optimum utilisation requires close links with the agricultural producers to ensure an adequate, reliable raw material supply, especially in the light of fresh cassava's perishable nature.

The earlier UNIDO report "A Factory Concept for Integrated Cassava Processing Operations" published in February 1983, describes the approach set out above. It elaborates the concept of setting up a factory to make the whole range of products which can be derived from cassava. It sets out the agronomy requirements, describes the potential markets for such a factory's products and defines the appropriate technology and outline design of the factory, together with a financial evaluation of the project. The country chosen to test the concept was Zambia and, in a companion volume to the above report, the project is evaluated specifically for Zambia and its national markets.

In assessing the question of raw material supply, the above "Factory Concept" report recommends that in countries such as Zambia, where cassava is grown largely as a subsistence crop, farmers should be motivated to grow it also as a cash crop. It emphasises that a factory should be set up only when cassava raw material supplies from farmers are assured.

Furthermore, that report concludes that in most situations it will not be practicable for a processing factory to rely solely on fresh roots for its raw material. The logistical problems are formidable because of fresh cassava's perishability and, in any case, the transportation costs are excessive if the growing area is not immediately adjacent.

The "Factory Concept" report therefore recommends the use of sun-dried cassava chips as the main source of raw material for the proposed processing factory. The yield of starch from sun-dried chips will not be as high in quality or quantity as that of fresh roots. However, this is of lesser importance in the case of several end products such as glucose and dextrins. For the production of the highest quality starch, the factory would buy fresh roots from the immediate vicinity. A flow diagram showing the various alternatives for processing fresh roots through to the key end products is shown in Figure 3.1.

In the light of this emergent factory processing concept it became clear that the production of dried cassava chips of suitably high quality is a prerequisite to the success of such a project. A modern integrated factory

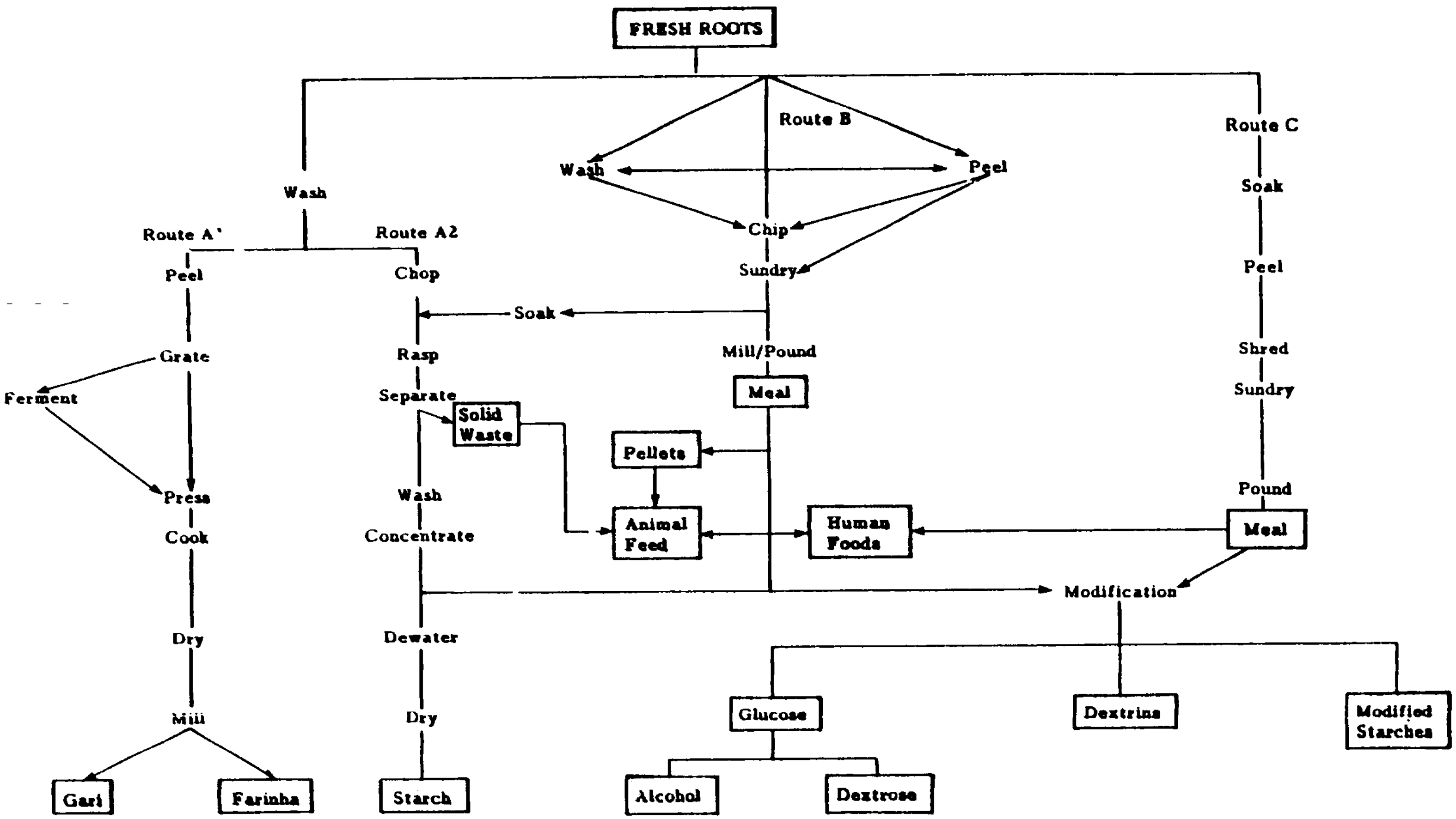


FIGURE 3.1

PROCESSING ALTERNATIVES FOR CASSAVA

needs a guaranteed supply of raw material. Dried chips weigh much less than fresh roots (40 percent) and can be stored fairly easily. Thus they overcome the major logistical and cost problems associated with relying on fresh roots and they provide greatly increased production security because a buffer store sufficient for several months' output can be readily built up by the factory.

Having established in the "Factory Concept" report the critical importance of the availability of dried chips in the right quality and quantity, UNIDO commissioned the present project to define the precise requirement for dried cassava chips and to recommend the best practical means for achieving their production and reliable supply.

The remainder of this report discusses quality considerations and standards for dried cassava chips, recommends appropriate production techniques and goes on to describe the necessary organisational framework for the supply of dried chips illustrated by two case study examples.

4.0 SYSTEMS OF PRODUCTION: TECHNO-ECONOMIC FACTORS, CASE STUDY SCENARIOS, AND ECONOMIC VIABILITY

4.0 SYSTEMS OF PRODUCTION: TECHNO-ECONOMIC FACTORS, CASE STUDY SCENARIOS AND ECONOMIC VIABILITY

This chapter sets out the main techno-economic factors affecting the raw material supply for a cassava processing factory. It goes on to illustrate the practicalities of setting up a cassava production system using two case study scenarios. Finally, there is a brief commentary on the economic viability of such a system.

4.1 TECHNO-ECONOMIC FACTORS

The decision to establish a cassava processing factory will be taken in the context of a sufficient potential market for the end products and the ready availability of cassava raw material. Section 3.7 explains the need for dried chips as a major source of supply for a cassava factory to ensure steady economic operation throughout the year.

This section sets out the appropriate techno-economic operating conditions and goes on to illustrate them using two case study scenarios. These give quantified examples of a particular set of conditions based on the study team's researches of current practice. They are set out so that alternative calculations can be made for any other situations that may be encountered.

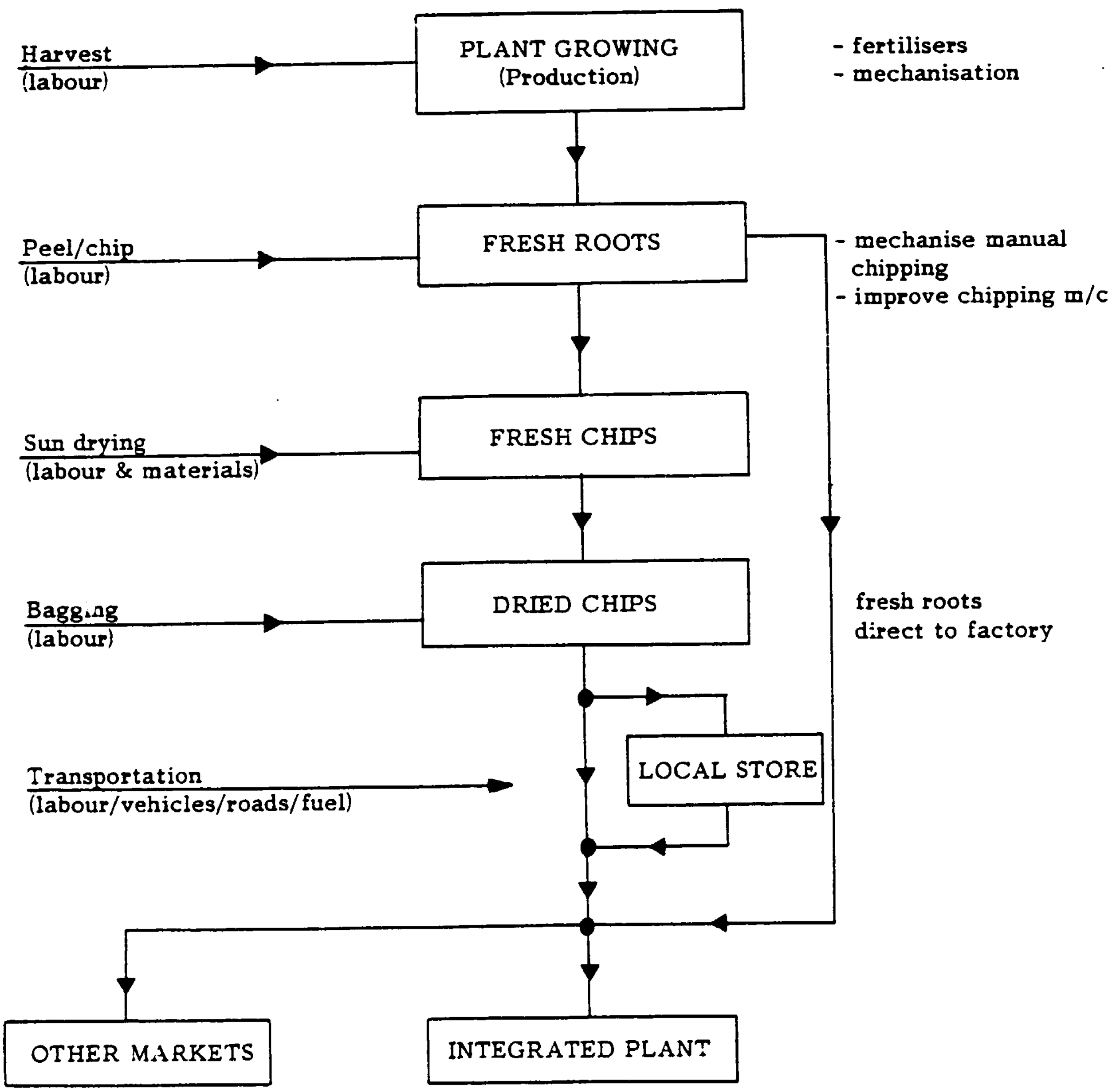
The following flow chart (Figure 4.1) shows the activities needed for the production and supply of dried chips to an integrated cassava processing plant and the main inputs to the various operations.

The major factors affecting the successful establishment of a cassava processing plant are:

- agronomic factors;
- continuity of supply of cassava raw material;
- facilities for chipping and drying fresh roots;
- a suitable road system and transport;

FIGURE 4.1

INPUTS AND ACTIVITIES FOR CASSAVA DRIED CHIP PRODUCTION



- factory location and distribution arrangements;
- availability of finance, materials, management and organisation;
- market demand and project viability.

The remainder of Section 4.1 sets out the key points under the above headings. Recommendations for detailed production techniques are given in Section 5.

4.1.1 Agronomic Factors

Obviously the processing factory will be sited in an area whose soils and climate will support the growth of cassava. Ideally the factory should be located in an area not only where cassava is well suited to local conditions, but also where cassava is better adapted to those conditions than other crops. In this way the processing venture is more certain of long term security in obtaining raw materials.

Cassava will tolerate soils of low inherent fertility and irregular rainfall. Whereas the crop's ability to survive in such circumstances may be of critical importance to the local population, such circumstances are not ideal for the establishment of a processing facility. As detailed in Section 4.2 the raw material costs and their transport are critical for the success or otherwise of the processing venture. Low yields and the necessity to collect raw material over an extensive area will tend to produce high costs for both raw material and transport.

Although no global study of geographic areas most suited for cassava production has been carried out, it is possible to identify a distinct trend. In the lowland humid tropics, the rapid rate of soil weathering and the subsequent leaching of nutrients leaves acid soils which tend to be low in nutrients. Whereas maize can produce adequate yields under many such circumstances, when the soil becomes very acid (e.g. below pH 5.0), maize production becomes very difficult due to the crop's preference for soils of higher pH. It is in such circumstances that root crops, especially cassava, take over as the major carbohydrate producing crop, as cassava will thrive in soils with pH as low as 4.5 (or even lower). This tolerance to acid soils, coupled with cassava's relative lack of critical growth periods when rainfall is essential (in contrast to cereals) renders the crop ideal for areas with acid soils and unreliable rainfall.

On a global basis these conditions prevail in the wetter parts of the tropics on soils formed in situ, i.e. not recent alluvial deposits. A band of cassava soils can be identified crossing northern South America and down the Atlantic coast of that continent as far south as central Brazil and into Paraguay. In Africa a belt of cassava soils covers the equatorial zone from Guinea on the west coast and passes through all the coastal countries as far as Angola. The belt crosses eastwards across the continent through Zaire, Congo, Zambia and Malawi to the east coast countries of Kenya, Tanzania and Mozambique. In Asia the cassava belt crosses southern India, Sri Lanka to include Thailand, Malaysia, Indonesia and Papua New Guinea.

It is not intended to present a detailed discussion of factors to be considered when selecting a site for a cassava processing operation. These are discussed more fully elsewhere.[1] However, it should be stressed that extensive cultivation of cassava in an area is not a sufficient reason to construct a processing factory. In order for the factory to succeed it is essential to establish that a sufficient surplus of cassava is either currently available or can be made available on a regular basis for a foreseeable period into the future. It is necessary to balance the requirements of the current population with the productive capacity of the land and the quantity of non or under-productive land available for future expansion. Sufficient flexibility must be identified within the overall cassava production system to cater for increases in population and still provide raw material for processing.

Alternatives for increasing cassava production include:

- opening up new areas of land to production;

- intensifying production from previously under-utilised land;

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1 James E. Austin "Agroindustrial Project Analysis", John Hopkins.

- increasing cassava yields from existing production areas by improved agronomic systems;

- providing incentives or support services (credit, extension, prices etc.);

- adjusting prices so that cassava becomes more profitable to the farmer than other crops suitable to the prevailing conditions.

Other factors may be important on an individual basis but these serve to indicate the forethought which is required before embarking upon a processing venture.

4.1.2 The Infrastructure Needed to Ensure Continuity of Raw Material Supply

A cassava processing factory needs a sufficient, guaranteed supply of fresh roots, whether these are supplied direct or are first processed into dried chips.

Alternative methods of producing the cassava exist ranging from the large one-crop production units to the small subsistence farmer:

- a cassava plantation large enough to guarantee the factory's raw material requirements;

- several medium to large farms where cassava is one of a number of crops grown;

- a large number of small mixed farms assuming a dense population;

- a large number of small mixed farms assuming a sparse population.

4.1.2.1 Cassava Plantations

This type of production unit is defined as one which produces entirely, or predominantly, cassava. A number of such production units exist in the tropics, normally associated with processing factories producing gari (West Africa) or starch (Indonesia).

In agronomic terms it is not desirable to plant an extensive area of land with one crop for successive years. Pests and diseases build up and become difficult or even impossible to control without resorting to expensive chemical control programmes. Cassava harvesting results in deep disturbance of the top soil, and recurrent cropping with cassava leads to soil erosion. Similarly, cassava is an efficient exploiter of the soil's nutrients and unless a properly managed fertiliser programme is adopted the crop will deplete the natural fertility of the soil with little or no return from crop residues. Therefore, unless large applications of fertiliser nutrients, especially potassium, are added each year crop yields will drop to uneconomic proportions. Unfortunately, traditional cassava prices have been inadequate to cover such expensive and recurrent inputs such as fertilisers and crop-protection chemicals.

A number of cassava plantations, each set up to produce raw material for a processing factory, without any flexibility in terms of land or equipment etc. for producing rotational crops, have failed in South East Asia.

It is considered that establishing a plantation producing cassava as its only crop is the least desirable method of catering for a cassava processing factory's needs. A linked plantation-processing factory is highly vulnerable to serious problems developing on the plantation, and a less totally dependent system for ensuring raw material supply is recommended.

4.1.2.2 Large Mixed Farms

This type of production unit is a familiar feature of the temperate regions, but is relatively scarce in the tropics. Holdings of this type are frequently referred to as 'commercial farms' even though they may be state owned as well as in private hands. The term 'commercial' in this context indicates that virtually the entire production of the farm is disposed of by sale through commercial outlets, in contrast to 'subsistence farms' which consume a significant proportion of their production. (These latter types of holding are discussed below).

Large mixed farms would produce cassava as one of a number of crops, or cattle enterprises, from which the farm's income derives. This system has agronomic as well as economic advantages. Crop rotation reduces the danger of disease and pest build-up on one particular site, and allows soil stabilisation (and to a certain extent rejuvenation) by sowing cereal and/or leguminous crops after the cassava crop. These do not entail large scale disturbance of the soil, as does cassava; and leguminous crops can 'fix' significant quantities of nitrogen to enrich the soil.

The success of large-scale mixed farming ventures rests as much on market security as it does on management and financial control. Managers of such enterprises select crops to grow for which there are good prospects in the market place in the quantities, and at the times he will produce. Such a manager will only produce cassava, which is impossible to store and expensive to distribute, if there is a processing facility nearby which will offer a guaranteed market at a firm price. It is quite likely that a wise large-scale mixed farmer will choose to produce on a contract basis, requiring a market and price on paper before planting cassava in his rotation.

Large-scale mixed farming operations in the tropics tend to develop in areas where cereal/legumes/grazing rotations can be practised. These tend to be commodities with international demand and therefore easy to market in large quantities and (usually) profitable to produce. For this reason the number of such farms which produce cassava as a crop in rotation are very few. Nevertheless, in areas where cereals are risky due to low pH and unreliable rain, cassava/legumes/grazing rotations could be attractive and a cassava processing operation would provide the stimulus required for such large-scale mixed farming operations.

However, given the 'chicken and egg' situation that a cassava mixed farm is likely to be attractive only after a processing factory is well established, it follows that such a source of supply would probably have to be planned well in advance. Careful consideration would need to be given to the effect on small farmers who might also form part of the supply pattern.

4.1.2.3 Small Subsistence Farms

The distinction made between this category of agricultural production unit and the one discussed in the previous section is not only a matter of scale of operation, but also the fact that a significant proportion cf the production of the subsistence farm is consumed on the premises. Only surpluses over and above the requirements of the farmer and his family are marketed.

Cassava is a crop favoured by the subsistence/partly commercial farmers across the tropics. It tolerates impoverished soils and unreliable rainfall and will virtually guarantee a crop when many cereal crops would fail.

The ability to store the crop by leaving it unharvested in the ground is a valuable asset, especially when land is relatively abundant, or the land cannot be used for more productive purposes due to a dry season. Roots can be harvested from the soil in accordance with demand, obviating the need to harvest, process and store all the crop at one time. Thus special buildings are not required and at the same time the crop is not exposed to the predations of insect and fungal organisms which result in storage losses.

The wide range of traditional foodstuffs which can be produced from cassava are attractive to the small producer. The crop forms an important staple for his family's needs, and can be converted easily into a saleable commodity with an extended shelf life in the farm kitchen.

For subsistence and small-scale commercial farmers the outlet provided by a processing factory is welcome, in that production over and above the consumption needs of the family can be sold for cash on a regular basis.

The great advantage of linking a processing factory to a large number of small producers is to spread the risk of failure of individual producers. Setting up a relatively large number of small scale producers can also introduce a co-operative element at the same time as allowing competition for a contract to supply raw material.

To illustrate the most likely circumstances in which a cassava processing factory might be established in developing countries, Section 4.2 describes two scenarios of small farms illustrated by case study examples.

A processing operation in the context of small farms providing the main source of supply requires a basic framework to operate satisfactorily. Motivating the small farmer is complex and depends on a variety of inter-related factors. Important conditions that must be satisfied include:

- a market for fresh roots;
- easy credit availability;
- availability of production inputs;
- availability of labour;
- prompt, regular collection of produce;
- an attractive price structure compared with other competitive crops;
- knowledgeable extension support;
- suitable alternate crops for the same soil.

In general, the 'return on labour' must be comparable with other crops. Reliability of income (as distinct from its magnitude) is obviously an important factor. A more detailed list of factors affecting the cost and availability of cassava raw material is given in Appendix 5.

The importance of considering these conditions and ensuring their fulfilment at the feasibility stage of establishing a cassava processing factory cannot be over-emphasised.

4.1.3 Facilities for Chipping and Drying Fresh Roots

A key factor in determining other practical and organisational aspects is how chipping and drying is done and by whom. The alternatives are to:

- chip and dry on the farm;
- transport fresh roots to a local village drying area and where relevant use a larger, powered chipping machine;
- transport fresh roots to a regional centre and chip and dry in bulk on the lines of Thailand or Malaysia.

These routes are illustrated in the following flow diagram (Figure 4.2).

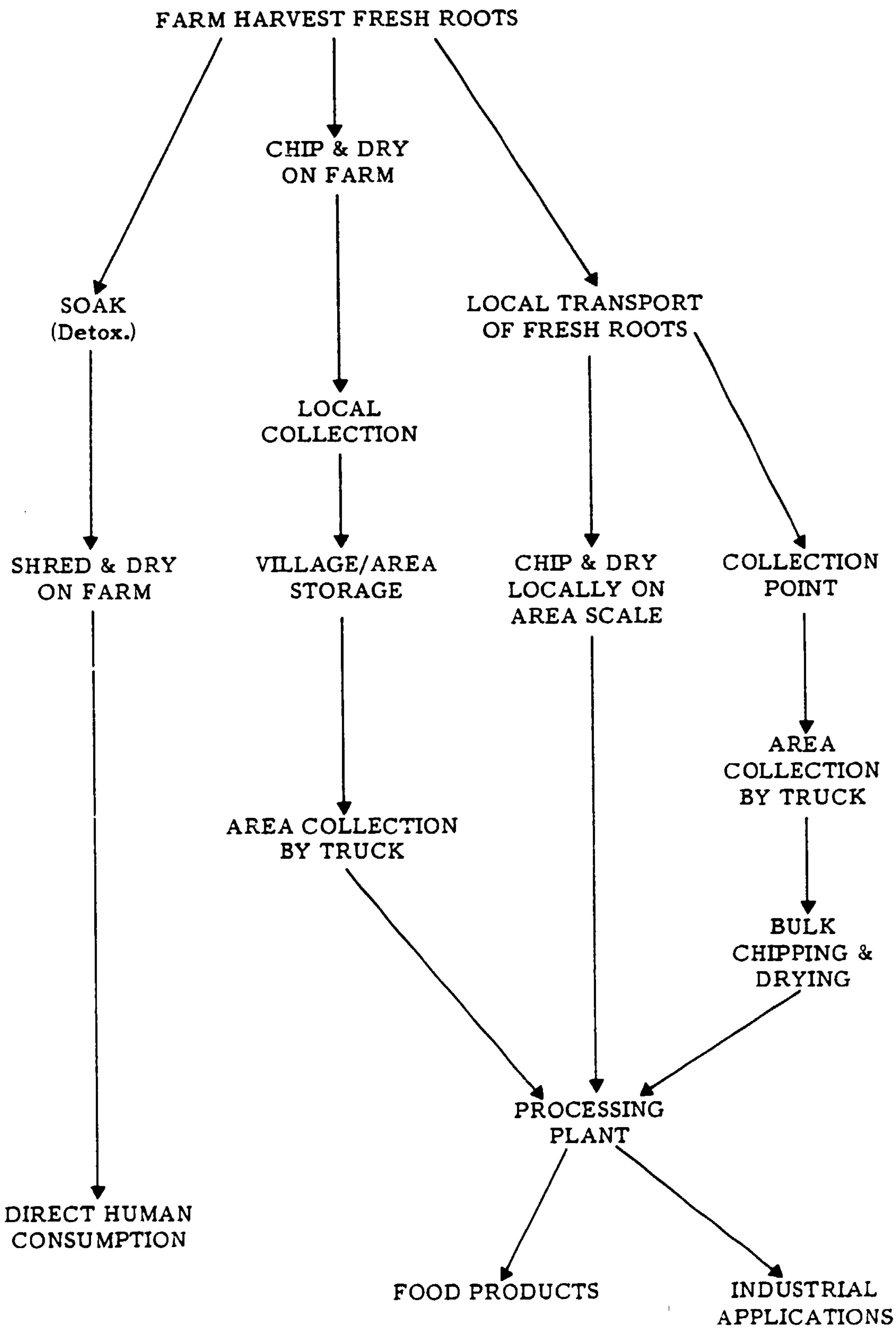
Obviously each route is applicable only in some circumstances and not in others. The three main alternatives for supplying a processing plant are discussed in turn.

4.1.3.1 Chip and Dry on the Farm

This is recommended for most small farm economies, especially where population densities are low. Capital costs are negligible and transport costs are minimised. Each farm is directly responsible for the quality of its own output and a price can be paid based on quality parameters. Current practice is to chip fresh roots by hand; no commercially available small machine suitable for the individual farmer exists at present (see Section 5.3.1).

FIGURE 4.2

ALTERNATIVE CHIPPING AND DRYING ROUTES



4.1.3.2 Local Village Area Drying and Chipping

This is likely to be suitable only in particular circumstances.

A local area drying system requires substantial capital investment in a drying area with chipping facilities (see Volume 2), and it is difficult to control the quality of fresh roots supplied by individual farmers unless the chipping facility is itself carefully controlled. However, it may be appropriate in some circumstances, such as extreme labour shortage and/or ready availability of capital and machinery, especially if a commercial situation such as in Thailand or Malaysia can be achieved. This depends on a reliable and reasonably steady market demand for dried chips and, to this end, there would need to be very close liaison between the chipping facility and the processing factory, either commercially or through a more direct management link.

4.1.3.3 Bulk Chipping and Drying

This would normally apply to a large scale production operation supplying one or a small number of drying yards. For example, the factory specified in the earlier UNIDO report 'A Factory Concept for Integrated Cassava Processing Operations' requires 5,750 tonnes of dried chips annually.

The necessary land requirement for volume drying, depending on the climate, would lie between 3 and 5 ha. The investment needed for a facility on the lines of those used in the Far East would be of the order of US$ 150,000 to 200,000. This figure could be much higher in certain countries; it can be evaluated only on an individual project basis. (See Volume 2 for costs in Thailand). Naturally this would be done during the feasibility study.

The main advantage of bulk chipping and drying is the scope for close management control of the operations and hence of product quality. The disadvantages are the much higher transport cost of fresh roots (which weigh 2½ times the equivalent of dried chips) and the substantial investment needed.

Bulk chipping and drying is recommended only when:

- good management is available;
- capital can be obtained;
- the facility can be located in the immediate vicinity of a compact growing area;
- there is a long, hot, dry season;
- plant and machinery are readily available and capable of being maintained reliably

The last point on maintenance is paramount, especially in relation to the fleet of vehicles needed to transport fresh roots. This is amplified in Section 4.2. Chip drying methods are discussed in Section 5.4.

4.1.4 A Suitable Road System and Transport

The cost of manual haulage or primitive transport over significant distances is prohibitive. To be part of a viable processing operation, cassava farm areas must have a network of roads capable of being used by trucks up to 8 tonnes or so, both between farms and the factory and between the factory and appropriate distribution points. A possible alternative may be the use of smaller (one to five tonne) vehicles for local collection from the farmer to an area store, but this has the drawback of doubling the handling effort.

The existence or establishment of a suitable road system is a prerequisite for a reliable supply operation. It is only on this basis that the cassava processing factory concept can be contemplated seriously.

4.1.5 Factory Location and Distribution Arrangements

The factory location will depend on the available road and/or rail infrastructure, proximity to any seaports in the case of export activity and the location of the raw material supply farms.

Since transport forms a major part of the 'value added' between fresh roots and dried chips, it is clearly desirable to site the factory as close as possible to the cassava producing areas. This will not only minimise the transport costs but increase the flexibility of usage of fresh roots as against dried chips. From the raw material supply aspect, the ideal location is in the centre of the cassava growing area.

However, these factors must be balanced against the requirements arising from the end product mix and the geographic disposition of industrial users, intermediate dealers, distributors and end users. Clearly these must be taken into account both in siting a processing factory and planning its sales. In the case of consumer products, population distribution and possible future changes (e.g. urbanisation) need to be examined. Other considerations include availability of labour, power, water and the accompanying infrastructure. These questions are detailed in the earlier UNIDO Zambia Report. They need to be evaluated individually on a project by project basis.

4.1.6 Finance, Materials, Management and Organisation

The requirements for finance and materials are dealt with comprehensively in the two earlier UNIDO reports.

Nevertheless, it is emphasised again that careful attention be given to the implications of:

- the availability of foreign exchange both for the initial setting up stage and also for supplies of spares, skilled/specialist servicing and other inputs on a long term basis;

- continuity of good management;

- the effects which such a new factory will have on its surroundings in terms of demands on infrastructure, alterations in market balances and development benefits to the region;

- human factors including local farming practices and social traditions.

Evidence of earlier cassava projects such as in South America suggest that these factors, especially the last named, can easily make or break a project. They need to be evaluated at the feasibility study stage.

The need for a processing factory's management to be in control of its source of supply is dealt with in Section 4.1.2. In those cases where a few locally situated large farms supply the raw material, direct management of one or more large chipping and drying units may be appropriate.

4.1.7 Market Demand and Project Viability

A cassava processing plant will be viable only if there is sufficient market demand for the range of products it is designed to produce and in the appropriate mix. Past experience points to the need for detailed economic and market analysis at the feasibility study stage of any proposed project (see earlier UNIDO report).

Starting with inputs of either fresh roots or dried chips, processed end products may be made from:

- dry chips and/or chip meal;
- starch;
- glucose.

A variety of food and industrial end products can be produced ranging from cakes, desserts and confections to textile or paper sizing, adhesives and alcohol. A full list is given in Appendix 6. This topic is elaborated in Section 4.2 of the earlier UNIDO report: 'A Factory Concept for Integrated Cassava Processing Operations'.

To test the viability of a cassava processing project in a given country, analysis on the lines of that already done in Zambia (see above UNIDO report) needs to examine:

- the local market potential for cassava based products including consumer characteristics, sociocultural factors and market structure;
- the likely product mix;
- competition;
- distribution and its costs;
- the price structure of fresh roots and chips raw material;
- profitability and its sensitivity to change in external factors;
- scope for exports and substitution;
- an overall economic evaluation.

The work done in the earlier UNIDO report includes a computer model designed for sensitivity analysis of the various factors influencing the viability of a cassava processing factory. It is recommended that this model be used to check out any proposed project.

4.2 CASE STUDY SCENARIOS OF DRIED CHIP PRODUCTION ON SMALL FARMS

Conditions in thirty or more cassava growing countries vary widely. Nevertheless large cassava farms are rare and, in general, cassava plantations are not recommended for most developing economies (see Section 4.1.2.1).

The vast majority of existing cassava production is carried out on small farms because this is the method best suited to the crop. It is recommended that where it exists this tradition be continued and, in this context, two alternative scenarios are considered:

- a densely populated territory;

- a sparsely populated territory.

The following examples describe these two scenarios, giving the recommended approach to cassava chip production in each case and the relevant quantification.

It is assumed in all cases that the cassava processing factory to be supplied will require a maximum of 5,750t dried chips per annum, the maximum volume of production specified in the earlier UNIDO report. This will be referred to henceforth as the 'standard processing factory'.

The majority of the cost of producing cassava in any form is incurred by the farmer - in the case of dried chips usually between 70 and 80 percent of the total. It is especially important, therefore, in the context of supplying a factory, to maximise yields which can vary from as little as 5t/ha in poor soil with no inputs to 25t/ha given a better choice of location and/or appropriate inputs. Clearly, a relatively modest increase in yield can transform the economics of a given situation.

The bulk of the remaining 'added costs' is divided between transportation, chipping and drying and the profit of middlemen where they occur. Of these, transportation is the largest item, sometimes as much as two-thirds of these added costs. In addition, where dried products are stored for long periods (such as in Indonesia) there may be substantial product loss through infestation.

The cassava chip production system set out below is designed to:

- be adaptable to any small farm community assuming road communication;

- minimise the transportation costs;

- use the simplest, most cost effective, chipping and drying system, having regard to availability of time and labour;

- create an organisation and control system that will guarantee raw material supplies to the factory on a regular basis.

The system recommended is shown on the following flow chart (Figure 4.3).

4.2.1 Production in Densely Populated Territories

The production system shown on the flow chart is dealt with in the context of densely populated territories. For the purpose of illustrating this scenario, it is assumed that each family averaging 6 persons farms a total land area of 2.5 ha. This is based on an analysis of land availability in selected countries, in Africa, Asia and Latin America (see Appendix 7).

Detailed techniques of individual operations are recommended in Section 5.

4.2.1.1 Harvesting, Chipping and Drying Operations

The economics of farm-based cassava chipping and drying are based on this crop's flexibility of harvesting time. It should be harvested and processed when other crops need little attention so that the opportunity cost of alternative activity for the normal farmer is low.

It is recommended that a rotational cropping system be adopted where 20 percent of the total land area is under cassava.

On the basis of manual peeling and chipping techniques currently available (see Section 5.3.1) and assuming a low level of other duties, the output of dried cassava per family is set out below (Table 4.1).

It is stressed that these numerical data may vary widely depending on the individual family needs. Thus the calculations will need to be adjusted for the circumstances pertaining to a particular country. Nevertheless the calculation framework set out is designed to be applied in nearly all circumstances.

FIGURE 4.3

FLOW CHART OF RECOMMENDED SMALL FARM CHIP PRODUCTION SYSTEM

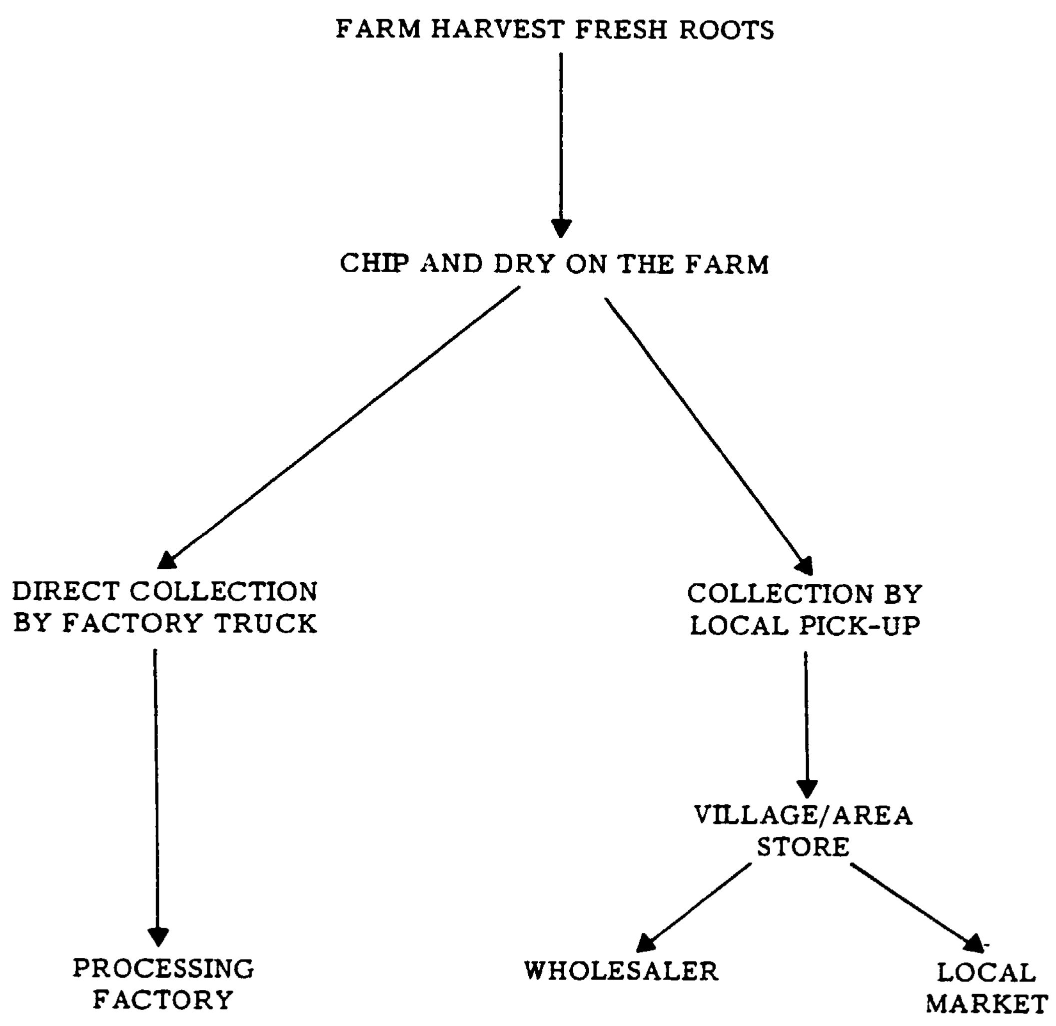


TABLE 4.1

OUTPUT OF DRIED CASSAVA CHIPS bY FAMILY OUCCUPYING 2.5 HA

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

4.2.1.2 Output of Dried Chips and Land Area Needed

Assuming that each family produces 1,600 kg (rounded down for convenience) dried chips in a season, the following table 4.2 sets out the land area needed to supply the standard cassava factory referred to earlier with 5,750 tonnes a year.

TABLE 4.2

LAND REQUIREMENT TO SUPPLY STANDARD CASSAVA FACTORY
DENSE POPULATION SCENARIO

A	Output per village of 30 families (30 x 1.6)	48 tonnes
B	Number of villages required to supply the standard factory (5,750 ÷ 48)	120
C	Area of each village (30 x 2.5 x 1.33)	100 ha
D	Area under cassava (30 x 2.5 x 20% x 120)	1,800 ha
E	Ratio total land area: village land (implies 60 persons/km^2)	3:1
F	Total land area supplying standard factory (B x C x E)	36,000 ha

This example results in a total land area required to supply a standard factory with 5,750t dried chips of some 360 km^2; this lies within a minimum operating radius of 11 km from the centre of the area.

It is worth noting that the ratio of total land area to village land does not affect the operating radius greatly; for example, an increase to 4:1 would increase the operating radius to only just over 12 km.

4.2.1.3 Transportation and Storage

The previous section has defined the land requirement for a cassava factory. The key variable cost lies in transportation - up to two-thirds of the total 'value added' from fresh roots to dried chips. It follows that the amount of transport needed, its organisation and the distances involved may well make the difference between profit and loss for a cassava factory.

Transport needs will be determined by:

- the production rate of dried chips by each unit: the family and, in turn, the village;

- the collection and delivery rates required;

- the geographic disposition of collection points for transport;

- the location of the factory.

Table 4.3 illustrates these points.

In this example, one 8t lorry would need to make 13 pick-ups every two days to fill its capacity, working 6 days a week to transport a total of (3 x 7.8t) = 23 4t dried chips. This is just below the weekly production rate of four villages.

It follows that, to collect dried chips on a weekly basis from the 120 villages needed to supply the standard factory's annual needs would require 30 lorries working full-time for just over the specified 8 week harvesting and drying period. This could be achieved by hiring transport where it is available. Clearly it would be uneconomic for the factory to purchase a fleet of this size for a such a short utilisation period. However, if the harvesting and drying period extends to 12 weeks, only 20 lorries are needed to perform the task.

TABLE 4.3

TRANSPORT REQUIREMENTS FOR STANDARD CASSAVA FACTORY
DENSE POPULATION SCENARIO - 2.5 HA PER FAMILY

A	Weekly output of dried chips per village during 8 week season (1,600 ÷ 8 x 30)	6,000 kg
B	Assumed number of collection points for each village (30 families)	10
C	Quantity of dried chips available at each collection point weekly (6,000 ÷ 10)	600 kg
D	Number of pick-ups to fill one 8t lorry (8t ÷ 600 kg)	13
E	Assumed weekly collection rate by one 8t lorry (13 every two days)	39 pick-ups
F	Quantity collected in each 2-day period of 13 pick-ups (C x D)	7.8t
G	Number of weekly journeys to processing factory	3
H	Number of villages served weekly by one 8t lorry	4

The advantage of collecting the dried chips on a continuous basis throughout the harvesting and drying season is that:

- the farmer is motivated to produce them regularly and on time;
- hence the system acts as a controlling mechanism;
- chip quality is maximised and easier to control;

- the storage of dried chips can take place under controlled conditions at the factory.

For these reasons, the system of collecting dried chips continuously throughout the season is strongly recommended.

The alternative is local storage of the chips, either by the farmers themselves or by a local middleman. This could reduce the transport needs to, for example, 10 lorries operating over a 6 month period. The storage facilities needed by an individual farmer are small: a rectangle containing 28 (i.e. 4 x 7) bags of 30 kg each would hold half his annual output. The choice must be based on the local conditions and should be implemented to allow flexibility.

In practice it is recommended that the processing plant operate its own small fleet of vehicles to provide a base load of transport and that additional transport be organised on a hire basis wherever possible so as to provide the maximum collection facilities during the peak season. The total transportation capacity needed under varying circumstances is illustrated in Table 4.4.

TABLE 4.4

NUMBER OF 8 TONNE LORRIES REQUIRED TO TRANSPORT A GIVEN TONNAGE OF DRIED CHIPS REQUIREMENT WITHIN THE CASSAVA SEASON

Tonnes Transported within Season (% Factory Annual Requirement)	Length of Harvesting/Drying Season (weeks)				
	8	12	16	24	30
1,440 (25%)	8	5	4	3	2
2,880 (50%)	15	10	8	5	4
4,320 (75%)	23	15	12	8	6
5,760 (100%)	30	20	15	10	8

The number of factory owned vehicles should be chosen to provide a suitable percentage of the total haulage requirement over the period involved, depending on the nature and availability of hired transport.

Further recommendations for the organisation of and assistance to small farmers to ensure reliable supplies of cassava are given in Sections 4.1.2/4.1.6.

4.2.2 Production in Sparsely Populated Territories

The basic small farm production system shown in the flow chart at the beginning of Section 4.2 applies equally to sparsely populated territories. The key differences, as might be expected, are likely to be:

- greater distances between farmers;
- hence, higher transport costs;
- higher land availability;
- as a result, increased land area per family;
- a much greater potential surplus of chips available for sale.

Clearly the question of transport costs is likely to be even more critical in determining the best organisation for a dried chip production system.

It will be noted that the output of chips available for sale is over double that of the previous example, because the amount needed for home use has reduced as a proportion of the total. Substantial extra labour input is now required (Item L); however, this should be readily available provided that the harvesting season is chosen so that other activity is at a minimum.

The quantified data presented in the following section are based on the assumption that, in a sparsely populated territory, each family unit will farm a total of 5 ha. This is double the figure used for the densely populated scenario and approximates to the order of magnitude for population densities in Zambia.

4.2.2.1 Harvesting, Chipping and Drying Operations

On a comparable basis to that described in Section 4.2.1.1, the output per family/farm unit is shown in the following table 4.5.

TABLE 4.5

OUTPUT OF DRIED CASSAVA CHIPS BY FAMILY OCCUPYING 5 HA

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

4.2.2.2 Output of Dried Chips and Land Area Needed

Assuming that each family can produce 3,600 kg dried chips for sale in a season, Table 4.6 sets out the land area required to supply the standard cassava factory with 5,750 tonnes a year.

TABLE 4.6

LAND REQUIREMENT TO SUPPLY STANDARD CASSAVA FACTORY

A	Output per village (30 x 3.6)	108 tonnes
B	Number of villages required 5,750 ÷ 108	54
C	Area of each village, 30 x 5 x 1.33	200 ha
D	Land under cassava (30 x 5 x 20% x 54)	1,620 ha
E	Ratio of total land area: village land (implies 11 persons/km²)	8:1
F	Total land area supplying standard factory (B x C x E)	86,400 ha

Thus the total land area required to supply the standard factory in this sparse population scenario is just under 900 km², two and a half times that of the previous example (4.2.1.2). This lies within a minimum operating radius of 16½ km from the centre.

The variation of land area and operating radius with population density is shown in Table 4.7.

TABLE 4.7

LAND AREAS REQUIRED TO SUPPLY STANDARD CASSAVA FACTORY
SPARSE POPULATION SCENARIO - 5 HA PER FAMILY

Average Population Density Person/km²	5	10	15	20	30
Total land area needed km²	1,944	872	648	486	324
Minimum operating radius km	25	18	14	12.5	10

4.2.2.3 Transportation and Storage

As already stated, the organisation of transport and layout of the cassava growing area will be exceptionally important in the use of a larger, more sparsely populated area. The basic parameters affecting transport needs (listed in Section 4.2.1.3) are illustrated in Table 4.8.

TABLE 4.8

TRANSPORT REQUIREMENTS FOR STANDARD CASSAVA FACTORY
SPARSE POPULATION SCENARIO - 5 HA PER FAMILY

A	Weekly output of dried chips per village during 8 week season (3,600 ÷ 8 x 30)	13,500kg
B	Assumed number of collection points for each village (30 families)	10
C	Quantity of dried chips available at each collection point weekly (13,500 ÷ 10)	1,350 kg
D	Number of pick-ups to fill one 8t lorry (8t ÷ 1,350 kg)	6
E	Assumed weekly collection rate by one 8t lorry (6 per day)	36 pick-ups
F	Quantity collected each working day of 6 pick-ups (C x D)	8t
G	Number of weekly journeys to processing factory	6
H	Number of villages served weekly by one 8t lorry	4

In this case, one 8t lorry would fill its capacity every day making 6 pick-ups. In a 6 day working week the lorry could transport 48 tons of dried chips, given a sufficient availability of labour for loading at each farm location and unloading at the factory to achieve this daily turnround.

It needs 54 villages producing 108t each (3,600 kg x 30 families) to supply the standard factory's annual needs of 5,760t dried chips. It follows that the above scenario requires 15 lorries working full time for the specified 8 week harvesting and drying period.

This example assumes what may be an optimistic rate of pick-up and delivery time, i.e. filling and emptying one 8t lorry every day. Obviously this depends very much on the location of the factory in relation to the producing farms. If the factory is in fact in the centre of a 16½ km radius as defined in Section 4.2.2.2, the output is quite feasible. However, in the event that the work rate may be lower, the transportation requirement may be calculated from Table 4.9.

TABLE 4.9

NUMBER OF 8 TONNE LORRIES REQUIRED TO TRANSPORT THE STANDARD FACTORY DRIED CHIPS REQUIREMENT OF 5,760 TONNES

No. of calls per day i.e. loading rate - 1,350 kg per call	Length of Harvesting/Drying Season (weeks)				
	8	12	16	24	30
3	30	20	15	10	8
4	23	15	11	8	6
5	18	12	9	6	5
6	15	10	8	5	4

4.3 THE ECONOMIC VIABILITY OF A CASSAVA PROCESSING FACTORY

The viability of a cassava factory will depend on the competitiveness of its products. Conversely, the availability of raw material will depend on whether the price the factory can afford to pay for dried chips or fresh roots is high enough to persuade the farmer to produce them.

Table 4.10 shows the key cost components of producing dried chips and, as some form of yardstick, the current costs which are incurred in Thailand.

TABLE 4.10

KEY COMPONENTS OF DRIED CHIP PRODUCTION

	1983 Thai Costs $/Tonne Dried Chips
Production of fresh roots	108
Conversion to dried chips	7.50
Transport to factory	2
Price of dried chips to factory	117.50

Of course the cost breakdown in, say, an African country is likely to be rather different; and if the chips are farm produced it will be difficult to isolate the roots to chips conversion costs.

In order to determine the viability of a cassava processing factory in a particular location it will be necessary to estimate the cost of raw material from, for example:

	Reference
The local price of fresh roots	Local market
Costs of conversion (on farm)	
- labour for chipping @ 125 hours/tonne	Table 4.5
- loading/drying @ 25 hours/tonne	Table 4.5
Transportation: e.g. 11 vehicles operating at 4 calls a day over 16 week harvesting period	Table 4.9

These calculations can be made only in the context of a specific location and country. Alternative calculations of costs for a factory operated central chipping facility should be made also, using the cost structure which applies locally.

An example of current operating and capital costs for a centralised chipping facility in Thailand is given in Volume 2, Section 3.2.4. However, each such estimate must be based on local conditions and costs.

The two alternative approaches to dried chip production can thus be compared and the results incorporated in a specific feasibility study. It is recommended that two or three costings for each alternative should be made and the resultant raw material (i.e. dried chip) costs tested using the computer cost model developed for the earlier UNIDO 'Factory Concept' Report. In this way upper and lower limits of raw material input costs can be calculated for different factory profitabilities by testing these on the computer model. These upper and lower limit prices can then be checked back against the realities of the local market place in the cassava producing region in which the processing factory is proposed.

By checking the supply position against the factory operating model in this way, the feasibility study can determine accurately the viability of the overall factory processing concept and, most importantly, the implications of a range of assumptions and cost parameters.

5.0 RECOMMENDED CHIP PRODUCTION TECHNIQUES

5.0 RECOMMENDED CHIP PRODUCTION TECHNIQUES

This chapter sets out production techniques relevant for the type of chip required as raw material for an integrated cassava processing factory producing starch and starch-derived products. It is considered that the additional stages of processing required to produce chips which are of acceptably low 'bound' HCN content to render them safe for human consumption in the form of meal, complicate or increase production costs to such an extent as to render them unacceptable. The additional stages involved would be either soaking the roots in water for a period of 3-5 days (which renders 'chipping' of the soft, soggy roots difficult), peeling and/or exposure to high temperatures unattainable by conventional sun-drying techniques.

It is therefore recommended that a separate study of methods of preparation for sun-dried chips for direct human consumption be considered, and in-depth cyanide investigations be performed. Until reliable information becomes available no attempt should be made to integrate cassava meal and cassava starch production from a single unpeeled cassava chip raw material. Meanwhile the dangers of sun-dried chips being pilfered or otherwise diverted from an integrated processing factory for local meal production must be recognised and systems set up to avoid this occurence.

Quality considerations and standards for cassava chips are dealt with in detail in Chapter 6.

5.1 AGRICULTURAL CONSIDERATIONS

The quality of the raw material for processing is invariably influenced in some way by agricultural factors. This section presents the major factors which have an impact on both the quantity and quality of the cassava chips produced. Practical recommendations whereby chip quality can be improved are included where appropriate.

5.1.1 <u>Selection of Cassava Variety</u>

In processing terms the index of yield of cassava per hectare should be expressed as weight of starch recovered by unit area of land per year. It is therefore of critical importance that the variety(ies) of cassava grown should yield adequate quantities of roots and that these roots should be high in starch content. Reluctance to change from traditional varieties is often cited as one of the reasons why farmers do not readily adopt new varieties. Often it is due to a lack of planting material and/or confidence in the new variety.

It is recommended that a processing factory should set up a system whereby varieties of cassava with the characteristics which are considered important in processing terms, are produced in sufficient quantity for distribution to cassava growers.

The characteristics of cassava varieties for processing may vary slightly depending on location, climate etc; however the recommended characteristics are set out below:

- high starch content;
- high yield of roots;
- uniform, easy to harvest root cluster;
- harvestable within 8-9 months;
- resistance to pests/diseases;
- suitability to local climatic and soil conditions;
- roots remain acceptable over extended period in soil, i.e. don't become fibrous too quickly.

The management of the processing facility should influence the variety(ies) produced by local farmers by:

- exerting a pricing policy favouring certain varieties;
- extending credit for the production of required varieties;

- making available free/cheap planting material to growers.

A major proportion of the final product cost lies in the production costs of the cassava roots. It follows that the recommended influence on farmers can contribute substantially to the processing plant's success and profitability.

5.1.2 Agronomic Practices

By stimulating the adoption of good agronomic practices, yields and quality of the cassava crop can be significantly increased. This subject is sufficiently important to justify a separate report. However, the main principles are presented in the following recommendations. These cover selection of site through planting operations, material and labour inputs to method of harvesting and handling. The key factors are:

- level or gently sloping site to reduce soil erosion;
- medium to light textured soils to provide good drainage and assist root harvesting;
- thorough land preparation to promote deep rooting to assist growth and regular storage-root distribution to ease harvesting;
- application of appropriate fertilisers to support predicted yield;
- preparation of contoured ridges to promote drainage, reduce erosion and assist in harvesting;
- careful selection and preparation of planting material. Disease/pest-free plants selected as source of cuttings. Use freshly prepared cuttings 20-30 cm in length;
- attention to proper planting method (inclined/horizontal placement to facilitate harvesting);

- adequate weed control, especially during first 3 months after planting;

- harvesting roots using an efficient method to reduce loss of storage roots through breakage in the soil.

Harvesting frequently poses a problem to farmers, especially when a significant quantity of roots are required at one time. Labour availability can frequently be a problem as well as cash to pay casual labour. Mechanical cassava harvesters are available, but beyond the financial capabilities of small farmers. It is suggested for the future that a processing enterprise could consider assisting the cassava growers by supplying a unit with tractors, harvesters and trailers, together with a team of field workers, to harvest their cassava crop. The unit travelling from farm to farm on a pre-arranged basis could assist the processor in the control of raw material supply to the chipping area.

5.2 POST HARVEST - PRE PROCESSING OPERATIONS

This section describes the preparation of roots in the field, their transportation to the chipping operation/processing factory and any storage (in this 'holding') at either end.

5.2.1 Root Preparation in the Field

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

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

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

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

5.2.2 Transportation of Roots

No universally applicable recommendations can be given other than to recommend the use of the most cost effective method available in the particular circumstances of each processing factory. This may range from a few roots in a basket on the head to a large truck with drop-down sides. The economic and management implications of fresh root transportation are discussed in Section 4. Recommendations of a practical nature include the careful packing of roots to reduce air spaces between roots, and the avoidance of plant residues, e.g. stem sections becoming mixed in with the roots.

5.2.3 Storage of Roots

Fundamentally, roots cannot be stored for more than 48 hours without significant deterioration taking place. As described in Volume 2, there is no reliable on-farm technique available for the bulk storage of cassava roots. Small-scale storage using boxes filled with moist sawdust, peat etc. and plastic bags can be used for small quantities of roots for the fresh market. The main concern is to avoid physical damage.

For large-scale operations only two alternatives are available:

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

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

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

5.3 METHODS OF CHIP PRODUCTION

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

5.3.1 Small-Scale Chip Production

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

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

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

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

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

Although a number of hand operated cassava graters and slicers have been designed and built, no effective hand operated cassava chipper has been encountered. There is a need for such a machine to reduce the drudgery involved in hand chipping cassava, and to assist in the production of a more uniform product of acceptable geometry from the sun drying viewpoint.

Later in this section larger chipping machines with removable adjustable blades are discussed. It is proposed that a simple hand or foot operated device which incorporates a similar blade be developed. A machine such as this would produce a chip similar in geometry to those produced by larger power driven machines. These are known to have good sun drying characteristics and the processing factory would have similar chips coming in as raw material, irrespective of the scale of producer.

It is recommended that the necessary research and design work to produce a small hand chipper for farm use be carried out as soon as possible.

5.3.2 Large-Scale Chip Production

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

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

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

The chipping machines used widely in the Malaysian state of Perak are smaller in terms of chip throughput than their Thai counterparts. However, the Malaysian machines produce thin root strips by means of a series of blades mounted on a large circular metal plate. The drying characteristics of the Malaysian chips are much superior to those produced by the Thai machines, drying in under 2 days in most circumstances.

It is recommended that a design project be implemented to develop a cassava chipping machine which combines the replaceable blade principle of the Malaysian machine with the feed hopper and rugged, transportable (on wheels) characteristics of the Thai machines. Such a project should review on-going work at CIAT where various prototype machines exist, and some progress is being made in developing the Malaysian machine.

The Malaysian machine requires the replacement of the six wavy-edged cutting blades every 4-6 weeks depending on root throughput. This compares with having to replace the entire cutting wheel on the Thai machines, an expensive operation wasteful in metal and high in costs of spare parts. A simple workshop could easily be set up for the production of wavy-edged blades for cassava chippers. The technology is so simple that a small boy can produce the blades using a pre-formed anvil and oxyacetylene torch in Malaysia.

A schematic layout of the basic Malaysian machine is shown in Appendix 4. It is recommended that the Malaysian design be set up and used immediately for a pilot project if larger scale chipping were considered appropriate for a particular project.

5.4 METHODS OF CHIP DRYING

The method used universally to dry cassava chips is by spreading them out in the sun. In Thailand and a few other places this is done in bulk on large concrete yards. Smaller scale drying is practised using a variety of methods from raised platforms and roofs to simply laying them out on the ground.

Two other forms of drying have been attempted - artificial drying, using heat input from fuel, and solar assisted drying using a solar grain collection device.

At current prices artificial drying using fossil fuels and electricity is uneconomic and no such practice was found during the study. Where cheap wood and peat occur these fuels may be considered, but it is generally accepted that sun drying of cassava is the only cost-effective method currently available.

The principles of solar drying of chips are discussed in detail in Volume II of this report. At first sight the collection of solar energy, e.g. using the 'greenhouse effect', appears attractive. Experiments on these lines are still in progress at CIAT, Colombia (see Volume 2) but have not produced an economic system so far. A solar collector (e.g. of plastic sheet), combined with thermal storage elements (e.g. stones or bricks) certainly improves thermal efficiency. In general, placing chips of the appropriate geometry on raised platforms which permit the passage of air through a layer of chips is recognised as being most efficient. Unfortunately, for large-scale chip production the practical disadvantages of having to handle a large number of relatively flimsy, expensive drying trays outweigh any advantages in terms of drying rate. Therefore, drying on cement floors is still the most convenient and cost effective for large-scale operations. The small farmer on the other hand is unlikely to find the combination of cost and significant extra handling effort attractive. However, simple raised platforms for normal direct solar drying are recommended for small-scale drying operations by individual farmers.

5.4.1 Small-Scale Chip Drying

The technique of using raised drying platforms is recommended as being the most appropriate for small-scale drying. It is suitable for the quantity of chips produced using a knife or simple hand or foot operated chipping machine proposed in Section 5.3.1.

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

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

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

5.4.2 Large-Scale Sun Drying

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

A powered chipping machine of the type proposed in Section 5.3.2 above should be capable of producing 10 tonnes of chips per day which requires a drying area of 6,000 - 8,000 m^2. This area is sufficient to dry the chips within a 2 day period (given dry weather).

The expense of setting up a drying floor is considerable (see Volume 2) and can be justified only when the cassava drying season is long and/or when other uses can be found for the drying area, e.g. drying other crops such as rice or groundnuts.

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

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

Where heavy vehicles run on the drying floor, reinforcement should be provided. A steel reinforcing mesh as used in concrete road construction is ideal. To avoid reinforcing the whole drying floor it is advisable to provide a 'hard' area for the loading and unloading of lorries, i.e. a masked 'hardstanding' for lorries and a manoeuvring zone for a front loader if the operation is large enough to justify its use. Further construction details are given in Volume 2.

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

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

5.5 HANDLING AND STORAGE OF DRY CHIPS

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

5.5.1 Transportation of Chips

The transportation requirement may vary from the bulk movement of chips over a few hundred metres to transportation over hundreds of kilometres. The economics of transportation are discussed in Section 6. However, it is necessary to recommend that transportation methods should be such that:

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

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

5.5.2 Storage of Dry Chips

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

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

Since cassava chips are hygroscopic they should be stored ideally in dry air. A storage system using solar heated convection is proposed in Section 8.2.2 of the 1983 UNIDO 'Factory Concept' Report.

6.0 QUALITY CONSIDERATIONS AND STANDARDS FOR CASSAVA CHIPS

6.0 QUALITY CONSIDERATIONS AND STANDARDS FOR CASSAVA CHIPS

This section presents a discussion of the factors which may affect the quality of sun-dried cassava chips and goes on to set out the recommended quality standards appropriate to the "Factory Concept".

6.1 QUALITY CONSIDERATIONS

The quality of a finished product following a processing activity is frequently influenced by the quality of the raw material used in the manufacture of the product. This study relates to the production of cassava chips as a raw material for processing; therefore it is relevant to discuss the various aspects of chip quality and the factors which affect it.

6.1.1 Size and Shape of Cassava Chips

The sun-drying characteristics of cassava chips are closely linked with their shape and size. Therefore, any advantages in the physical criteria of the chip must be related to a faster, more uniform drying characteristic. The results of a number of research programmes, discussed in Volume 2, show clearly that thin bars have the best drying characteristics and that the mechanisation of chip production leads to the strip being the most suitable compromise between the theoretical ideal and the practical result.

Cassava chips which are too thick in section do not dry to the inner core sufficiently quickly to prevent deterioration. Thus 'chunks' of root have discoloured moist cores made up of fermenting starchy tissue which imparts off-flavours and smells to the resulting meal.

The type of chip produced by the Malaysian blade is the one recommended in that sun drying to 12-13 percent moisture content can be achieved even under relatively humid climatic conditions in less than two days exposure to the sun. The chips are approximately 5 mm x 3 m in section and, in practice, vary in length up to 15 cm at the time of cutting. The chips break into shorter lengths during the drying process.

6.1.2 Moisture Content

As explained above this aspect of quality is linked to chip geometry. An important factor, however, is the duration of the drying period and the atmospheric conditions prevailing during the drying period.

Acceptably dry chips are those which are dried to, or below, equilibrium moisture content which is usually around 12-13 percent of chip weight. Removing the chips from the drying floor, or placing chips to dry during periods of prolonged rainy weather with extensive cloud cover, will result in inadequately dried chips. These deteriorate in storage and during transportation, resulting in discoloured chips with off-smells and flavours, and reduced starch content.

It must be clearly stated that chips with the ideal physical dimensions for sun drying cannot be converted into a good quality dried product unless the appropriate drying conditions are provided. These are discussed in Section 5.4.

6.1.3 Starch Content of Cassava Chips

The most important component of cassava roots is the starch. The normal composition of a cassava root is:

Water	65.0%
Nitrogen free extract	32.2%
Crude protein	0.6%
Ether extract	0.3%
Ash	0.8%
TOTAL	100.0%

Of the nitrogen extract the majority is starch, the balance being simple sugars and cellwall material.

Factors affecting the starch content of cassava chips can be divided into pre-harvest and post-harvest factors.

6.1.3.1 Pre-harvest Factors Affecting Starch Content

The pre-harvest factors which influence starch content of the roots and ultimately the chips are mainly agronomic, and include the following:

- the variety of cassava grown;
- the stage of maturity of the cassava roots at harvest;
- the nutrient status of the soil;
- the health of the cassava crop.

Cassava varieties exhibit a range of starch content. Some varieties have been identified as bearing roots with consistently higher starch content than the average. Where cassava processing is carried out on an organised scale there is a preference for 'high starch' varieties of cassava. In areas where cassava is eaten as a boiled vegetable the high starch types are not as palatable as the lower starch types, therefore care is required to ensure that appropriate cassava varieties for processing are available before contemplating a processing venture.

Accumulation of starch in cassava roots commences during the second month after planting and continues until the plant reaches maturity. This varies with variety but is normally within the 9-15 month range. Climatic and soil factors also affect the rate of development and therefore influence the maturity period.

Roots from immature cassava plants contain a lower percentage of starch than roots from mature plants. Over-mature cassava roots become fibrous and eventually spongy with hollow cores. The starch content of over-mature cassava can be very low, and therefore unsatisfactory for processing requirements.

The nutrient status of the soil, particularly the potassium content, influences the starch content of roots. Circumstantial evidence from Malaysia indicates that soils with high nitrogen and relatively low potassium, e.g. recently cleared forest soils, produce large yields of cassava roots which are disappointingly low in starch content.

In order to stimulate cassava to produce starch yields consistent with its genetic capability, applications of balanced fertiliser are required.

The cassava crop is affected by a large number of diseases and pests which can seriously affect both the yield and starch content of cassava roots. Many of these disease and pest problems can be overcome by using resistant varieties of cassava, selecting disease-free planting material, and following a rotation policy to avoid the build-up of pests and diseases. Recent advances with biological control mechanisms offer alternatives to chemical control of pests and should be considered in areas where large-scale cassava cultivation is carried out.

The starch content of cassava roots can be determined using a range of techniques varying from the simple to the sophisticated. The most appropriate method for a cassava chipping yard or processing factory is the specific gravity balance which determines the starch content of a sample of roots. These balances are used widely in South-East Asia and fresh cassava prices are often linked to starch content. It is recommended that cassava processors should monitor the starch content of their raw material using a specific gravity balance, and should adopt a pricing policy which favours roots with high starch content.

6.1.3.2 Post-Harvest Factors which Affect Starch Content

Post-harvest deterioration sets in soon after the roots have been separated from the cassava plant. One of the factors of deterioration is the enzymatic breakdown of starch and in order to conserve the starch content of roots it is important that they are processed as soon as practically possible after harvest.

Attempts have been made on an experimental scale to arrest the deterioration of cassava chips before drying. Common salt (NaCl) and other chemical treatments have been demonstrated to conserve wet chips for some weeks, but difficulties in feeding the dry treated chips to livestock have been reported.

Within the context of the integrated cassava processing concept it is recommended that chemical conservation of wet chips be re-examined as a method of medium-term root conservation. Should common salt prove to be a universally successful method of preservation, the removal of the salt in the preliminary washing and soaking stage of processing chips into starch should not create a difficult problem.

Loss of starch continues during the chipping and drying process through a combination of physical and bio-chemical processes.

The clouds of white dust which rise whenever chips, during drying or already dried, are disturbed represents a physical loss of starch to the processor. Losses due to wind have not been quantified.

A rapid and thorough sun-drying procedure is required to reduce the loss of starch by enzymatic action. Thorough drying prevents the development of micro-organisms which continue to attack the starch component of the chips during storage.

Dried cassava chips are exposed to attack by a range of insects during storage. The insects tunnel into the chips to exploit the starch rich cells leaving galleries and seriously reduce the volume of dried cassava, especially the starch component. Recommendations for storage of cassava chips are given in Section 5.5.2.

6.1.4 Contamination of Cassava Chips with Foreign Matter

During the normal harvesting operations soil, sand and small stones adhere to cassava roots and are transported to the chipping yard. Mutual abrasion between roots during transportation removes some of the soil, but during wet weather, especially in clay-soil areas, the quantity of soil still adhering to the roots when they are fed into the chipper can be substantial.

This contamination can be a serious problem where sun-dried chips are to be milled at a later stage. The soil/sand particles cause wear to machinery and eventually contaminate the final product.

Similarly, unless roots are trimmed properly in the field, woody peduncles and even sections of stem are transported to the chipping yard to be loaded into the chipping machine, together with the roots. Large amounts of woody material reduce the quality of the dried product by reducing its nutritional value, and rendering the resulting meal unsuitable for monogastric animals and poultry due to the high fibre content.

Pieces of wood also result in damage to chipping machinery, especially cutting edges.

The cassava chip export trade between Thailand and the EEC went through a period a few years ago when adulteration of cassava chips was a widespread practice. Pelleting the chips facilitated the practice as compressing the dry chips enabled the addition of inert material, e.g. sand, and fibrous matter (rice, husks etc.). Strict quality control checks by both the exporter and the importer, coupled with severe penalties imposed on those prosecuted, have curtailed adulteration in recent years.

6.1.5 Microbiological Contamination

Cassava chips are rich in soluble carbohydrate, mainly starch, but also various sugar compounds. These provide a substrate upon which a diverse flora of micro-organisms flourish. As early as 1966, German laboratory tests established that imported cassava for animal feed exhibited spore counts of over 24 million per gram in 40 percent of samples taken*. Drying the chips removes the moist environment which most of the micro-organisms require to survive and multiply. Therefore rapid, uniform and thorough drying reduces the degree of microbiological infestation of cassava chips.

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* Dr. H.L. Schmidt, Pfaelz, Landw. Untersuchungs - und Forschungsanstalt, Speyer/RH.

Nevertheless the freshly chipped roots are exposed to micro-organisms, both fungi and bacteria, during the sun drying process. Debris on the drying floor from previous batches of chips and dust settling over the chips spread out to dry, are both responsible for contaminating fresh lots of chips. Chipping machine blades and the tools used to spread and turn the chips also contribute to the contamination process.

The sun drying process must therefore be viewed as a race between drying the chips to a moisture content low enough to prevent microbiological contamination and the micro-organism's ability to colonise and multiply rapidly enough to exploit the cassava chips before they dry.

The fact that chips dried within two days are white and acceptable from the point of view of smell compared with the brown musty chips dried over a 3-4 day period, indicates that the drying process should be as rapid as possible to maximise chip quality.

Some of the micro-organisms which colonise cassava chips during the drying process and subsequent storage period appear capable of surviving and multiplying on relatively dry chips. Therefore, even chips which have been dried to equilibrium moisture content will deteriorate through moulds and bacterial activity when stored for extended periods.

Because of this it may be necessary to develop methods of preventing the development of storage moulds etc. during medium to long term storage of cassava chips (should the presence of such micro-organisms be a problem to the processor/consumer). No such methods have been developed at present.

An important factor of microbiological contamination is that related to contamination of chips with animal excreta. Such organisms as E.coli, Salmonella, Shigella and Corynebacteria can pass through to be ingested, together with the processed products from cassava chips and cause serious health problems to the consumer, whether animal or human. Avoidance of faecal contamination is a major factor of the management of a cassava chip sun drying operation. Further details on microbiological contamination are given in Section 6.3.

6.1.6 HCN Toxicity of Cassava Chips

The question of cassava toxicity is often regarded as being well understood. Nevertheless, it remains a serious problem in some areas of Africa and Asia where traditional cooking methods of the root, either direct or from dried chips or sections of root, fail to remove all the toxic HCN content. This leads to goitre and cretinism.

The danger lies in the fact that these effects may not manifest themselves for a very long time - it can take up to twenty years. This problem was encountered by the study team and has been recognised by the Indonesian Government which is taking active steps to counter this long-term danger.

A major advantage of establishing an integrated cassava processing operation is that food products from such a factory can be guarantee. completely free from any toxic HCN content. This is of special relevance in those areas and countries where toxicity problems still exist, and also in countries less familiar with the crop where the dangers of incorrect food preparation are still not recognised by the rural population.

6.1.6.1 Background of Cassava Root Toxicity

Cassava roots contain cyanogenic glucosides which hydrolyse in the presence of an enzyme, also present in the roots of cassava, to liberate hydrocyanic acid (HCN). The concentration of HCN produced in cassava roots varies with variety, environmental and cultural conditions, resulting in the broadly classified bitter (high HCN) and sweet (lower HCN) varieties. However, there is no precise classification of HCN content available. Drought, soil type and level of fertilisation have been shown to influence HCN content. This means that an apparently innocuous variety can become hazardous when grown at a new site, or grown using different agronomic techniques.

There is a considerable variation in the glucoside concentration within a single root, with the concentration increasing from the core of the root outwards. Generally the HCN content of the peel is substantially higher than that of the flesh. This is almost universally understood in traditional food preparation and roots are usually peeled at an early stage. However, as explained earlier, the flesh still contains residual HCN that can produce chronic toxicity problems.

HCN as such is not present in the roots of a healthy growing plant, but is released when tissues are mechanically damaged or there is a loss of physiological integrity such as during post-harvest deterioration. Hence most traditional food preparations seek to bring about the maximum release of HCN by widespread cell rupture to bring the enzyme in contact with the glucosides. The subsequent elimination of the HCN is achieved by pressing out the liquid (and the dissolved HCN), by heating to volatilise the HCN, or in solution of washing and/or cooking water.

Surprisingly there is little published information on HCN levels in traditional cassava food products. New analytical methods which permit the measurement of both 'free' and 'bound' cyanide have been developed (Cooke 1978, 1979). It is only recently that these new techniques have highlighted the long term dangers arising, particularly from the 'bound' cyanide component.

Further work is necessary to define precisely the traditional cooking methods that are truly safe and, above all, to educate the population of the relevant areas of Africa and Asia.

6.1.6.2 The Implications of Toxicity for Cassava Chips

As explained above, cassava roots contain cyanogenic glucosides which release HCN when the plant is physically damaged. Therefore, during harvesting and chipping HCN is released in the root tissues. Much of the HCN, which is a volatile gas, escapes into the atmosphere during sun drying, and the dry chips are relatively free of 'free' HCN.

However, recent research indicates that the drying process prevents all the cyanogenic glucoside being broken down by enzyme action into HCN. Therefore, even though the dry chip may appear low in HCN, once rehydrated the enzymatic action resumes in the chip and further HCN is produced. This rehydration can occur in the alimentary system of the consuming animal or human, resulting in HCN poisoning. As much of the cyanogenic glucoside has been converted the quantities of HCN released in the alimentary tract are relatively small. Therefore acute toxicity is rare, the major danger being chronic toxicity and the failure to recognise it over the long period it takes to develop the symptoms.

It follows that special care is needed when introducing the integrated cassava processing concept to ensure that cassava chips produced for the operation are not regarded by the local population as being safe for direct food preparation without taking appropriate precautions such as washing or heating to a high temperature. The danger is that these methods are not always practical for a rural population.

On the other hand, the production of food products by a processing factory eliminates the dangers of HCN toxicity through its built in soaking and washing procedures. A clear message that only factory produced cassava products are guaranteed safe would be easy to promulgate and simple to understand. As a result, the widespread introduction of integrated cassava processing would constitute a major advance in ensuring a safe, reliable supply of food for many millions of people.

6.2 QUALITY STANDARDS FOR CASSAVA CHIPS

Traditional cassava-based food products of producer countries have not generally been standardised and their quality is very variable, although a few specifications have been suggested or adopted. In international markets, legislation for quality control is widespread and the large-scale importation of cassava chips and pellets by the EEC has stimulated the development of standards for these products. Standardisation and quality control is a major concern of the animal feed industry and, as cassava chips have been traded largely with this end use in mind, it has been a logical development that the quality standards which exist for cassava chips have been drawn up for the animal feed industry by J. Ingram, 1975. Relevant quality standards which currently apply in selected countries are presented in Appendix 3.

Recommendations for dried chip quality standards for the integrated processing concept are set out in this section covering the aspects discussed in the previous Section 6.1, as follows:

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

6.2.1 External Physical Characteristics

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

Several size standards exist. Brazilian standards specify a maximum length of 5 cm for export while specifying a thickness. Indian standards specify a maximum thickness of 2 cm for chips destined for human consumption and 1.5 cm for livestock feed. Malagasy chips are also subject to a maximum thickness of 1.5 cm.

Chip length is important where thick chips, i.e. root chunks which are difficult to break, are concerned. Mechanical handling machinery is subject to blocking and a maximum chip length of 5 cm is recognised. We recommend 5 x 3 x 10-15 mm.

6.2.2 Moisture Content

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

6.2.3 Starch Content

As starch is the most important component of cassava chips, it is desirable to create standards to maintain a high starch content. However, the different varieties and growing conditions make it impractical to lay down a single standard for all regions. The theoretical maximum is in the region of 80-85 percent but current standards require less than this value. Currently the EEC standards require a minimum of 62 percent starch for animal feed. In India, however, a theoretical standard of 82 percent exists.

It is recommended that, initially, a simple standard be developed and laid down by each processing factory in the range of 72 percent to 82 percent for local purchasing purposes. Pricing should then reflect the starch content on a basis of what is achievable in that particular region. Further information on starch quality is given in Section 6.3.2.

6.2.4 Ash Content

This reflects soil/sand and sometimes cement dust contamination from the drying process and should not exceed a maximum of 3 percent.

6.2.5 Crude Fibre Content

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

6.2.6 Cyanide Content

According to the EEC Directive 74/63/EEC, the permissible maximum limit for HCN in straight animal feedstuff is 50 mg/kg **except** in cassava products when it is 100 mg/kg of material. India and Malagasy have both laid down standards for permitted HCN content in cassava products for livestock feed. These are 300 mg and 200 mg per kg of material respectively.

These standards were set up prior to the recent developments which distinguished 'free' and 'bound' cyanide and it is strongly recommended that all HCN standards are reviewed using the most recent analytical techniques.

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

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

6.2.7 Microbiological Standards

Bacterial spore counts of moulds and fungi are not normally made for cassava chips, although microbiological contamination of cassava products is widely recognised. Recommendations have been made that spore counts should not exceed 10 million per gram of material but to date no official standards exist incorporating this advice. Until the food industry adopts unified standards for microbiological contamination, it is not possible to make specific recommendations for cassava.

For the processing factory, as stated in Section 6.1.5, the key requirement is to avoid faecal contamination which carries the danger of pathogenic organisms such as E. coli, Salmonella, Shigella and Corynebacteria.

6.2.8 Cassava Pellet Standards

Once cassava chips have been modified into pellets different standards may apply. Pelletisation has simplified transportation and handling operations and by increasing the bulk density of the product realised economies in freight costs.

The standards for cassava pellets reflect those for the animal feed industry as defined by Ingram (see Appendix 3). In addition, dust is a major factor of pellet quality. Poor quality pellets produced on crudely engineered equipment, without steam injection and proper pellet cooling, are prone to disintegration. This results in dust pollution which can reach unacceptable levels at the destination points in Europe. As a result premiums are payable for 'hard' pellets which are relatively dust free, and controls are exercised increasingly by European ports on excessive dust, normally on a visual basis at present.

6.3 RELATIONSHIP BETWEEN CHIP QUALITY AND THE PROCESSED PRODUCT

The relationship between the quality of the dry chip and the quality of the processed product depends to a large degree on the extent of the changes brought about by processing. It is highly likely that chips produced in the context of an integrated processing factory will also find application in direct food preparation by manual methods. It is necessary, therefore, to consider alternative uses for cassava chips and the impact that their quality may have on the characteristics of the final product.

There are two basic processing routes which sun-dried chips can follow:

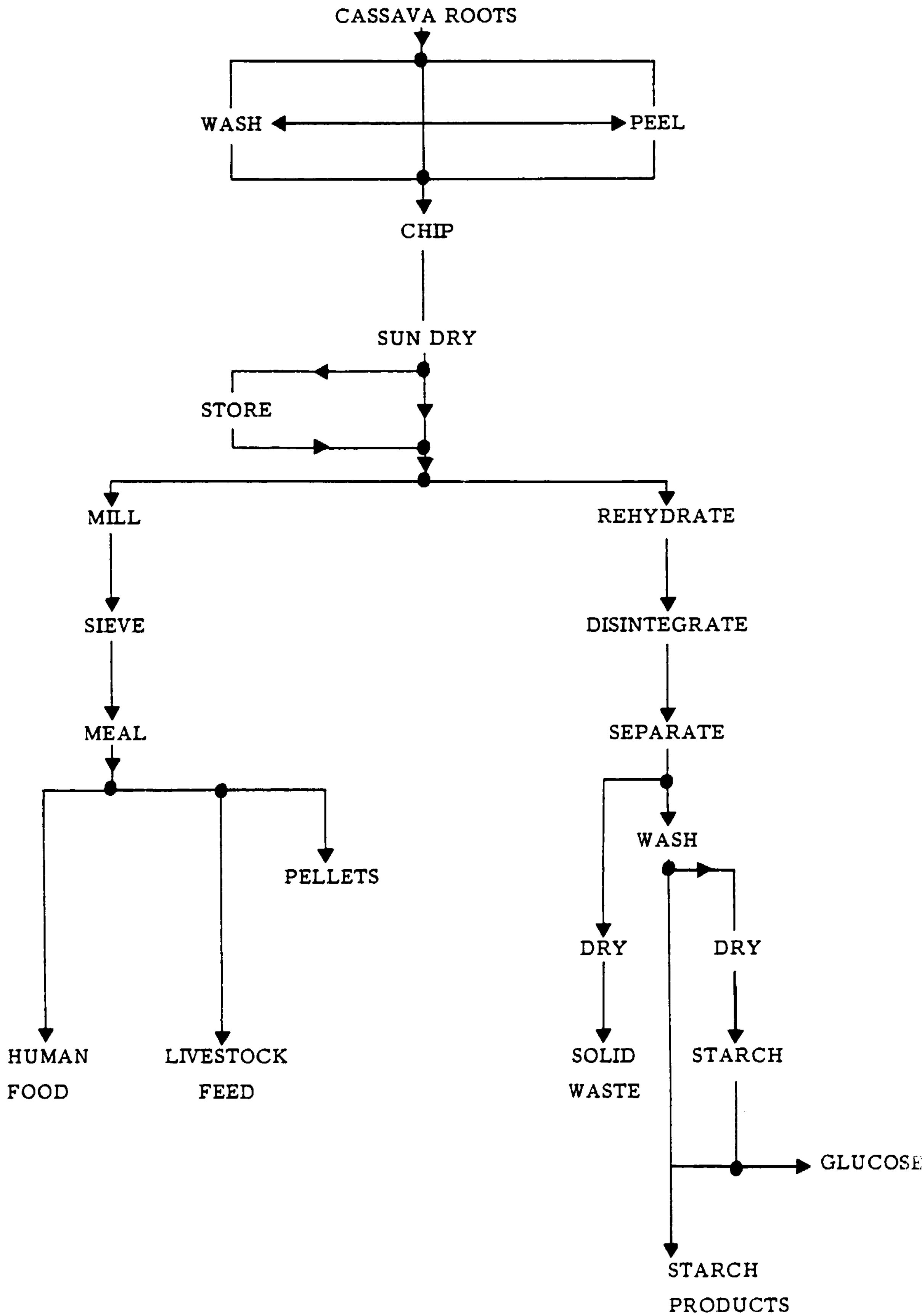
- milling into a meal;
- processing to extract starch.

Figure 6.1 shows the various steps necessary to convert sun-dried chips into meal or starch and starch products. The impact of chip quality on the characteristics of these products is discussed below.

6.3.1 The Impact of Chip Quality on the Characteristics of Meal and Meal-Products

The production of meal from sun-dried chips is a simple grinding and sieving process. Most, if not all, of the cassava chips and pellets imported into the EEC are processed in this way before being mixed into compounded animal feeds. Similarly, traditional human foods are produced by grinding or pounding cassava chips. Recently the addition of cassava meal into bread dough has been advocated, thereby partially substituting imported wheat flour with a locally produced material.

FIGURE 6.1



CASSAVA ROOTS
WASH
PEEL
CHIP
SUN DRY
STORE
MILL
REHYDRATE
SIEVE
DISINTEGRATE
MEAL
SEPARATE
WASH
PELLETS
DRY
DRY
HUMAN FOOD
LIVESTOCK FEED
SOLID WASTE
STARCH
GLUCOSE
STARCH PRODUCTS

Table 6.1 presents in summarised form the relationships between chip quality and the quality of the resulting meal. Prolonged and/or inadequate drying can result in brown-black chips, the discolouration being partly due to the development of phenolic substances during drying and partly due to the development of micro-organisms on and in the chips. Thus rapid thorough sun drying of chips is required to ensure that the meal end product is not discoloured and off-smelling.

Contamination of chips with soil and sand is a serious problem only remedied by thorough washing and/or peeling. Chips destined for animal feed are rarely washed or peeled resulting in measurable quantities of sand/soil carrying through into the meal. As stated above, quality standards exist to limit the quantity of total ash in chips but most of these standards have been drawn up with the animal feed industry in mind. Where the meal is destined for human consumption the need for washing should be seriously contemplated to reduce soil and sand passing through into doughs and breads etc.

Fibrous materials both from the cassava plant and elsewhere frequently contaminate the dry cassava chips, and pass through the milling process to contaminate the meal. Cassava root peel tends to contain more fibre than the core of the root, therefore peeled roots contain less fibre than non peeled roots. Indigestible material reduces the nutritional standard of the meal. Where the meal is to be fed to livestock, high fibre levels can result in lowered productivity especially with poultry and monogastrics which cannot digest fibrous material.

Many of the micro-organisms which infest cassava chips produce anti-enzymes and toxic substances which can pass through the milling process into the foodstuff. The predominant species of fungus contaminating cassava chips appears to be Aspergillus which is responsible for the production of such mycotoxins as aflatoxin. Analyses were carried out in Germany in 1966 identifying several types: Aspergillus flavus, fumigatus, terreus, ungius and versicolor*. It is of serious concern that such work to quantify the occurrence and significance of the presence of this dangerous substance in cassava chips and meal is so rare and not widely publicised.

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* Dr. H.L. Schmidt (see Section 6.1.5 and Reference Appendix 8.)

TABLE 6.1

RELATIONSHIPS BETWEEN QUALITY OF SUN-DRIED CASSAVA CHIPS AND THE QUALITY OF RESULTING MEAL

Quality Parameter	Chip Quality	Meal Quality
Visual appearance*	White in colour Brown in colour	Grey-white, acceptable colour Unattractive brown meal
Foreign matter	None/very low	Acceptable colour, no off-smells/flavours, digestible, wholesome
Mineral	Soil/sand contamination	Discoloured, gritty, off-smells/flavours, digestive disorders
Fibrous	Wood, rice-husk (plant residues) contamination	Discoloured, off-smells/flavours, high fibre levels, low digestibility, esp. monogastrics/poultry
Macrobiological	Insect contamination, rodents	Discoloured, off-smells/flavours, digestive disorders (?), toxins (?).
Microbiological	Fungal, bacterial contamination	Discoloured, off-smells/flavours, digestive disorders (?), toxins (?)
Faecal	Animal/human faeces	Discoloured, off-smells/flavours, digestive disorders, toxins e.g. E.coli, salmonella, shigella, corynebacteria
Toxic properties	High HCN content	Unacceptable flavours, digestive disorders, toxins, chronic health problems
Moisture*	Moist chips	Brown/discoloured, off-smells/flavours, presence of moulds/bacteria, digestive disorders (?), toxins (?)

* Note: These quality parameters are inter-related, as brown chips usually result from inadequate or protracted sun drying.

A similar situation holds for contamination from organisms which infest the chips. These organisms include insects, moulds, fungi and bacteria. The milling procedure may generate some heat, but insufficient to kill many of the microscopic organisms. Thus the meal is usually contaminated with large populations of living micro-organisms. Subsequent cooking will destroy the majority of these providing a certain threshhold temperature is reached. However, where the meal is consumed without sufficient heating, or inadequately cooked, then the micro-organisms are ingested, together with the meal.

It is worthy of note that pelletising cassava chips reduces the micro-biological population due to the high temperatures generated as the chips pass through the dies.

The presence of micro-organisms, toxins and anti-enzymes resulting from the micro-organisms, and insect bodies, eggs, faeces and detritus lead to many problems ranging from discoloration of the meal, the presence of off-smells and tastes, anti-nutritional effects, to the presence of toxic substances. Further studies to quantify the dangers of using sun-dried cassava chips for meal for human consumption are justified.

Sun-dried cassava chips contain significant quantities of HCN, especially when unpeeled roots are used. Values between 80 and 90 ppm of HCN in chip dry matter were recorded in Thailand. It is assumed that this analysis measured free HCN and ignored any 'potential' HCN which would result from the chips being ingested. Milling cassava chips into meal may result in a reduction of the free HCN if the temperature of the chips is raised during the milling process. However, the majority of the HCN passes through the milling stage and is present in the meal.

When the meal is cooked thoroughly, free HCN is driven off and the enzyme responsible for the production is denatured so that 'bound' HCN cannot be liberated at a later stage. Thus cooking renders cassava meal safe for consumption. However, tests are needed to establish precisely the temperature and length of cooking needed to ensure these changes. Boiling or steaming, as is commonly practised, is insufficient for this purpose.

Because of the dangers posed by the HCN content of cassava meal, it is recommended that the integrated cassava processing concept should be used to produce cassava-derived substitutes for wheat flour in bakery products. Further studies are suggested to test this recommendation by erecting a pilot 'concept' process in a country where wheat flour substitution would be both feasible and acceptable.

6.3.2 Impact of Chip Quality on the Integrated Cassava Processing Concept

In contrast with meal manufacture from sun-dried chips where the quality of the meal is highly dependent on the quality of the chips, chip quality has a much less dramatic effect on the end products of the integrated factory concept (i.e. starch and starch derivatives), as many of the impurities in the chips are removed during processing. The integrated processing concept makes extensive use of water as a preliminary to grating and starch separation. The soaking of the dry chips allows the physical separation of sand and soil particles which sediment out of the aqueous suspension of chips. Similarly, soluble contaminants, free-living micro-organisms and insects etc. pass into the water from which the starch granules are subsequently separated.

The major component of the dried chip, of critical importance to the processing factory, is the starch content. Chips with low starch content result in low starch yield from the process and reduced income from the venture. Factors affecting starch content of chips have been discussed earlier in Section 6.1.3. It is of the utmost importance that the cassava processor avoids the various problems which lead to reduced starch content of chips.

In addition to diluting the starch content of chips, fibrous contaminants cause problems in terms of physical abrasion and wear to the grinding machinery. This is a crucial process as individual root cells must be ruptured to release starch grains, and damage to the cutting edges of grinding machinery renders them less efficient, resulting in lower starch recovery. Therefore it is important to reduce the amount of woody peduncles and stems entering the factory from the field, and to avoid the use of over-mature, i.e. lignified roots.

Of particular importance to the processor aiming to extract starch from sun-dried chips is the enzymatic degradation of the starch which occurs before and after chipping and during and after sun drying. Starch granules which have been attacked by enzymes exhibit different properties than unaffected granules. Where the starch is to be further modified into sweeteners or alcohol, the change in properties is of little or no importance. However, where the starch is destined for food use, some users may be reluctant to purchase starch which has been degraded by enzymatic action.

There is a need for research to determine the effects of enzymatic degradation on cassava starch produced from both roots and chips. Once this information is available it should facilitate the international marketing of starch obtained from sun-dried chips. Currently the majority of the cassava starch on the world market has been extracted from fresh roots, and even though most of the starch is subsequently chemically modified, the quality standards are very high and may be more difficult to achieve following the dry chip route.

The proposal is to establish two cassava starch standards:

- standards for starch extracted from roots, i.e. high grade cassava starch;

- standards for starch extracted from chips, i.e. industrial grade cassava starch.

The prevention of enzymatic deterioration of starch is achieved by reducing the delay between harvesting and chipping the roots (to reduce endogenous enzyme action) and to sun dry the chips as thoroughly and rapidly as possible (to prevent further endogenous enzyme action and reduce the incidence of micro-biological attack during drying and storage).

The major problem posed by the presence of both free and bound HCN in cassava chips, especially unpeeled chips, is coped with adequately by the soaking, disintegration and separation process of the integrated cassava processing concept. The HCN glucoside substate and enzyme complex are all removed in the water leaving the starch separated by the process and suitable for addition into human and animal feed without danger from HCN toxicity.

6.4 RESULTS OF LABORATORY ANALYSES

During the study team's visit to South-East Asia, samples of chips were collected to enable quality comparisons with published information. Seven samples were collected during the field visit:

- one from a recently dried batch of chips from Malaysia (Sample A);
- six collected from various sources in Java, Indonesia (Samples B-G).

The Malaysian sample was of unpeeled chips destined for animal feed, whereas the Indonesian samples were of sun-dried peeled roots and root pieces 'gaplek', destined for human food. Indonesian gaplek is exported also as animal feed, mainly from Sumatra.

The following tables describe the samples, their origins and the results of the laboratory analyses.

TABLE 6.2

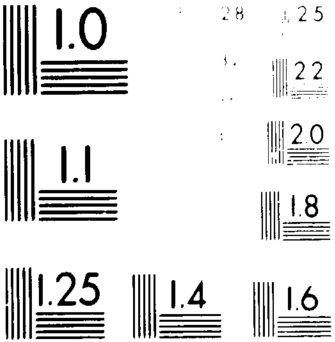
ORIGINS OF CHIPS AND NOTES MADE AT THE TIME OF COLLECTION

Sample	
A	Collected from Perak State, Malaysia. Animal feed chips.
B	Collected from chip wholesaler at Wonosari, Java. One year old chips - insect infested.
C	Fines collected from bottom of sack from which Sample B was taken.
D	'Gaplek' from Wonosari - regarded as poor quality by wholesaler.
E	Mouldy 'gaplek' from Wonosari.
F	Newly prepared 'gaplek' from farm on Gunung Kidul, Java.
G	One month old typical 'gaplek', Wonosari.

TABLE 6.3

GENERAL APPEARANCE OF CHIP SAMPLES

Sample	Prior to Grinding	After Grinding
A	Small chips appearance variable. Some very grey, others creamy white.	Creamy-grey powder.
B	Pale cream pieces, clean but evidence of severe insect infestation (holes).	Pale cream powder.
C	Chip fines, no grinding required.	Cream powder, slight greyness with some black specks.
D	Top, broad end of root severely attacked by black mould at the core. No mould at tapered end. Indicates incomplete drying at the centre of thicker region. Outside of root grey-brown.	Pale grey powder
E	Whole root except extreme tip severely affected by black mould. Unpleasant, alcoholic odour.	Dark grey, fibrous. Difficult to grind owing to moisture content.
F	Good clean root, pale cream throughout. Outside clean and well peeled.	Cream powder, no specks.
G	Variable with indication of some mould growth. Outside grey-brown. Some insect infestation.	Pale grey powder.



MICROCOPY RESOLUTION TEST CHART

TABLE 6.4

RESULTS OF COMPONENT ANALYSIS

Sample Ref	Moisture (%)	Ash (%)	Acid Insol. Ash (%)	Crude Fibre (%)	Starch (%) (Dry Basis)
A	9.74	5.07	1.90	4.44	71
B	10.71	1.99	N.D*	1.91	81
C	15.13	2.25	0.05	2.54	71
D	15.77	1.76	N.D*	5.36	56
E	32.8	2.23	0.09	6.62	49
F	11.74	1.17	N.D*	2.73	63
G	14.66	1.68	N.D*	2.68	65

* Since total ash was already below (2%) for acid insoluble ash, it was not considered useful to carry out this determination.

TABLE 6.5

MICROBIOLOGICAL EXAMINATION

Sample Ref	Total Viable Count	Yeast	Moulds
A	2.0×10^6/g	10/g	10/g
B	2.9×10^6/g	10/g	10/g
C	5.0×10^7/g	10/g	10/g
F	1.25×10^7/g	10/g	1.2×10^6/g
D, E, G	Too badly contaminated with moulds to obtain meaningful useful counts).		

The results of the various tests demonstrate a number of important factors relating to chip quality.

The Malaysian chips were of excellent quality in terms of moisture content (under 10 percent) because of the good drying characteristics of the chip. However, the unwashed, unpeeled roots resulted in an ash content exceeding 5 percent which is unacceptable.

The Indonesian 'gaplek' chips were made from peeled roots which resulted in low ash and in some cases low fibre content. However, the large chunks, in many cases whole, thin roots and half-roots, resulted in inadequate drying. This is reflected by the high moisture content of many of the samples. Sample E was selected because of its mouldiness. This sample was inadequately dried with a moisture content exceeding 32 percent, similarly the starch content was lowest, presumably due to the action of the moulds and yeasts infesting the sample.

The starch content of some of the Indonesian 'gaplek' samples was low, possibly because of the poor soil conditions of the Gunung Kidul area in which the crop was grown. In general the roots observed were thin.

All samples were heavily infested with moulds and yeasts, some so heavily that population counting was not possible.

APPENDICES

APPENDIX 1

TRADITIONAL METHODS OF PROCESSING AND PREPARATION OF CASSAVA

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TRADITIONAL METHODS OF PROCESSING AND PREPARATION OF CASSAVA

Tropical America	Africa	Asia
Roasted/boiled/stewed (Sancocho)/fried	Boiled/steamed/roasted/fried	Boiled/baked/roasted/fried
Grated, pounded then baked/boiled	Boiled/soaked, pounded (Fufu)	Boiled, grated admixed with coconut (Puttu)
Sliced, sundried, pounded into flour	Soaked, pounded, dried (Chickwangue), ground into flour (Nshima)	Steamed, fermented, baked (or raw) (Peujeum)
Grated, pressed, roasted (Farinha	Fermented, pounded, dried, ground into flour	
da Mandioca) or baked (Casave)	Sliced, sundried, pounded/ground into flour (Kokonte)	Sliced, sundried (Gaplek), pound/ground into
Soaked, crushed, pressed, dried then	Grated, fermented (wet 'dough' - Fufu, Akple)	flour
ground into flour (Farinha d'Agua)	Grated, fermented, roasted (gari)	Grated, pressed, 'pelletised', dried (Landang)
<u>By Products</u>	<u>By Products</u>	
Starch from press liquid	Starch from press liquid	

* Note: This list is prepared from a comprehensive review of the subject published by Lancaster et al (1982). Local names in the above table are indicative, and include only wider used terms.

APPENDIX 2

CASSAVA TOXICITY, PROCESSING AND PUBLIC HEALTH ISSUES

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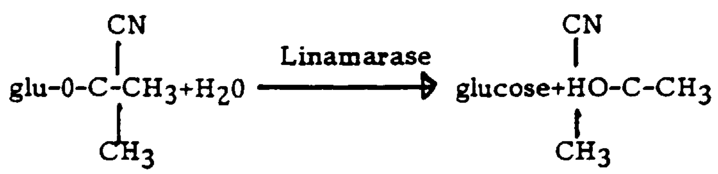
CASSAVA TOXICITY, PROCESSING AND PUBLIC HEALTH ISSUES

Cassava's capacity to produce acute cyanide poisoning in humans and animals has been well known to man since prehistory. Knowledge of its toxic nature has undoubtedly contributed to the wide range of methods used to prepare cassava roots for human consumption. Despite this toxicity cassava has become a major food crop on a pan-tropical scale and it is estimated to be an important source of daily carbohydrate for 300-500 million people in the tropical regions.

2.1 THE NATURE OF CASSAVA'S TOXICITY

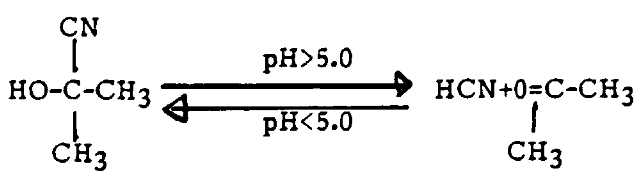
The tissues of the cassava plant contain cyanogenic glucosides principally linamarin with some lotaustralin. When damage is caused to the tissues, an endogenous enzyme linamarase hydrolyses the glucosides releasing hydrogen cyanide.

The first stage in the breakdown of linamarin is hydrolysis to glucose and cyanohydrin.



Linamarin Cyanohydrin

The cyanohydrin breaks down further into acetone and hydrocyanic acid (HCN)



Cyanohydrin Acetone

Cyanohydrin is relatively unstable at pH values greater than 5.0. As the pH of freshly grated cassava pulp is around 6.0 the reaction proceeds to the right resulting in the liberation of HCN. At low pH values, eg when bacterial fermentation occurs, cyanide is retained in the form of cyanohydrin precluding HCN release.

Whilst cassava toxicity is a well recognised problem, assessment of this toxicity has been oversimplified. The toxicity of cassava and cassava products was, until recently, assumed to be associated with the presence, and therefore concentration, of free cyanide. The lethal dose of free cyanide for an adult male is quoted at 50-60mg (Cooke 1983).

Recent research however has shown that the hydrolysis of the cyanogenic glucosides is frequently interrupted during processing, food preparation, or cooking and that the non-hydrolysed glucosides pose a serious threat to the consumer as the unreleased cyanide may be liberated after cooking, before and after ingestion. Thus the terminology 'free' and 'bound' cyanide has been developed:

'Free' cyanide - hydrogen cyanide in the liberated form (HCN).

'Bound' cyanide - cyanide locked-up in the form of glucoside of cyanohydrin which can still be released by hydrolysis.

It was previously thought that bound cyanide as glucoside could be released by the appropriate hydrolysing enzyme, and that deactivation of the enzyme was sufficient to render the foodstuff innocuous. However recent studies have shown that hydrolysis can occur in the alimentary tract. This can be due to continued hydrolysis by the enzyme which becomes reactivated following rehydration in the alimentary canal. Alternatively if leafy foods or other substances containing B-glucosidase are ingested, enzymatic hydrolysis occurs liberating hydrocyanic acid in the gut.

2.2 FACTORS AFFECTING GLUCOSIDE CONTENT OF CASSAVA

The other form of bound cyanide, cyanohydrin breaks down to release free HCN once the pH has increased above a value of 5.0. Therefore acid cassava products containing cyanohydrin can release free HCN if the pH is increased during food preparation or cooking.

Cassava varieties or cultivars are frequently referred to as 'bitter' or 'sweet' according to the cyanide content of their roots. However this is an oversimplification of the actual situation. A wide range of cyanide concentrations occur among cassava varieties. Similarly the cyanide content of root tissues has been shown to be influenced by several factors including the age of the plant, soil conditions and climate.

The root cortex or peel contains higher cyanide concentration with values ranging from 407 to 4229 mg/kg (measured on a dry matter basis) of cyanide in the peel and 49 to 825 mg/kg in the flesh of the root. Ratios between total cyanide content of peel and flesh were calculated, and these ranged from values of 2 (relatively low peel to high flesh HCN), to 48 (relatively high peel to low flesh HCH).

A continuous range of root HCN levels from 2mg/kg to more than 600 mg/kg (fresh weight basis) has been reported.

So far no cyanide-free variety has been developed. However reports from work carried out in Indonesia before World War II indicate that a cyanide-free variety was identified only to be lost during hostilities.

In spite of early reports, recent trials with large numbers of varieties have shown no clear relationship between yield and HCN content of roots. This clears the way for plant breeders to develop a high yielding low HCN variety. Studies on the activity of the enzyme linamarase responsible for releasing the HCN, have shown that the enzyme may be more potent in some varieties.

In addition to the large differences in cyanide content between peel and flesh, longitudinal and radial HCN gradients have been shown in peeled roots. The outermost layers of flesh in some cases contained ten times the cyanide concentration of the central core. Similarly considerable variation in cyanide content from individual roots on the some plant has been shown.

Studies on the effect of plant age on the cyanide content of roots have shown that whereas the HCN content of the flesh remains relatively unchanged between 9 and 12 months of age, the HCN content of peel decreased over the same period. However it has been pointed out that such changes may be related to changes in rainfall over the period.

It is generally accepted that the glucoside content of roots can vary greatly due to differences in soil and climatic conditions. Conflicting reports occur in the literature, possibly mainly due to the use of outdated HCN analytic methods, but variations in soil nutrient status and rainfall pattern probably play an important role. It is generally agreed amongst research workers that high levels of nitrogen fertilisation increase glucoside concentration in cassava roots. Similarly a number of authors refer to increased cyanogenesis in soils with low potassium status. Whereas severe drought has been shown to increase glucoside content, increases have also been detected at the onset of the rainy season.

2.3 THE EFFECTS OF PROCESSING ON CYANIDE CONTENT OF CASSAVA PRODUCTS

Cassava roots are traditionally processed by a wide range of methods to reduce their toxicity, improve their palatability and convert the highly perishable fresh roots into stable products. Traditional processing methods include single-step and multi-step processes involving peeling, drying, soaking, fermenting, boiling, frying, steaming or roasting. Many of these processes decrease the total cyanide content of the roots.

The toxicity of cassava and cassava products was, until recently, assumed to be associated with its content of free cyanide. However recent developments in terms of quantifying the 'bound' cyanide in cassava foodstuffs has led to a re-evaluation of the toxicity situation.

Many traditional methods of preparation have been developed to reduce a large proportion of the glucoside in the root by removing the glucoside-rich peel, and then to create conditions which promote contact between substrate (linamarin) and enzyme (linamarase) thereby releasing HCN.

This latter condition is achieved by gross damage to root tissue by grating or rasping. Alternatively maintaining roots in reducing conditions by soaking in water over a period of days is used as a means of reducing HCN content. Finally heat is used to dry the product, gelatinise the starch and drive-off free HCN.

The individual processing steps used individually or in combination to convert fresh roots into a consumable product are discussed individually below.

2.4 SUN-DRYING

It is a matter of concern that there are conflicting reports about the effects of sun drying on HCN content of cassava roots. Gomez (in Delange and Ahluwalia, 1983) states that "drying whole-root chips is very effective in reducing the cyanide content of cassava roots considerably".

Sun drying on concrete floors led to a reduction in total cyanide content to between 20 and 30 percent of the levels present in the fresh chips.

Nevertheless the author quoted results of experiments carried out at CIAT which showed that sun-drying on floors or trays did not reduce the cyanide content of chips, made using roots from high HCN varieties, to below the EEC ceiling value of 100 mg/kg on a dry matter basis.

Conflicting evidence is quoted by Bourdoux etal (1983) (in Delange and Ahluwalia, 1983) quoting results from experiments in Zaire where peeled roots were chipped and sun-dried before incorporation with maize to produce fufu. This research revealed that HCN content (on a fresh weight basis) increased after sun drying, the drying process apparently concentrating the HCN in the chips.

The comparison between unpeeled and peeled roots (the former containing larger quantities of cyanide due to the presence of the peel), and the differences in expressing total cyanide in terms of dry weight (Gomez) and fresh weight (Bourdoux et al), render direct comparison difficult.

It is considered necessary to clarify these apparent discrepancies by further research. However it is clear from a paper presented by Cooke (1982) (in Delange and Ahluwalia, 1983), that slower drying rates achieved through sun drying produce greater losses of bound cyanide.

2.5 ARTIFICIAL DRYING

As the production of HCN in cassava roots occurs as a result of a chemical reaction it is important to record the critical temperatures for the various organic compounds involved.

The cyanogenic glucoside linamarin is degraded at 150° C, a temperature rarely reached in traditional methods of food preparation.

The enzyme responsible for the release of HCN linamarase is degraded at 72° C, a temperature easily achieved in traditional processing methods.

The importance of these two critical temperatures is discussed below. The main feature however is that cooking frequently denatures the enzyme which releases the HCN but rarely denatures the glucoside substrate.

Thus, under the appropriate conditions HCN production can continue even after cooking.

Oven drying both unpeeled and peeled chips at 100° C has been shown to be less effective in reducing total HCN as the enzyme linamarase is deactivated at around 72° C, resulting in large amounts of residual 'bound' cyanide in the chips.

Drying peeled chips in forced air drying ovens has been shown to reduce total cyanide, but not as much was removed as in the case of unpeeled chips. Drying at 60° C removed 25 percent of the bound cyanide, in comparison to 30 percent removed by drying at 47° C. The longer drying period required by the lower temperature permitted extended enzyme activity, converting slightly more bound cyanide, in comparison to 30 percent removed by drying at 47° C. The longer drying period required by the lower temperature permitted extended enzyme activity, converting slightly more bound cyanide into free HCN. Corresponding losses in free cyanide were 80 percent at 47° C and 85 percent at 60° C. At higher temperatures over 95 percent of the free cyanide was removed.

From these results it appears that artificial drying is more efficient at removing free cyanide than bound cyanide. For efficient removal of both forms of cyanide ie total cyanide a combination of sun drying to reduce bound cyanide, followed by artificial drying to remove the free cyanide produced could be contemplated. As HCN is volatile at 25° C-30° C the need to artificially dry at high temperatures can be avoided.

2.6 PEELING

As discussed above the largest amount of cyanide in the cassava root is concentrated in the peel portion. It has been calculated that for a root which is composed of 15 percent peel, with a total cyanide content of 950 mg/kg (fresh weight basis) in the peel and 35 mg/kg in the flesh, 83 percent of the total cyanide is removed by peeling the root. This shows in stark terms the value of peeling roots as a first stage in food preparation.

Most peeling is currently done by hand, a long tedious activity. There is an important need to develop mechanical peeling machines which can cope with the wide range of cassava root shapes, sizes and dimensions.

2.7 BOILING

The free cyanide content of fresh cassava roots is rapidly reduced in boiling water. Up to 90 percent can be removed within 15 minutes. In contrast the bound cyanide decreases at a much slower rate and approximately half remains even after boiling for 25 minutes.

Many earlier reports quoting results of HCN analysis after boiling cannot be relied upon as the enzymatic assay test to assess 'bound' cyanide was not available and therefore the results probably reflect on the free cyanide.

2.8 STEEPING (LEACHING IN WATER)

This term is used to describe short term immersion of cassava roots in water. Experiments have shown that steeping roots in warm or agitated water removed up to 90 percent of the free cyanide from roots, most of which could be accounted for in the water. In spite of this, negligible amounts of bound cyanide were removed by steeping.

Stirring cassava chips in water at ambient temperatures overnight for 18 hours caused a marked decrease in bound cyanide but a drop in pH and sour smell indicated that an 18 hour period is too long to be regarded as 'steeping' as some fermentation had occurred.

2.9 SOAKING (FERMENTING) IN WATER

When cassava roots are immersed in water for longer than around 12 hours fermentation begins, and micro-organisms produce enzymes which complement the activities of endogenous enzymes in the cassava root to hydrolyse the glucoside to produce HCN. It has been suggested that different rates of fermentation between varieties of cassava are linked to the amount of free sugars in the root. The addition of glucose in the fermentation liquid has been shown to increase the rate of enzyme activity probably by providing energy to the micro-organisms involved in the fermentation. Therefore the link between the presence of sugar and detoxification rate can be linked.

Experiments in Nigeria quantified the removal of HCN from soaking roots. Peeled roots of six varieties ranging in total cyanide content from 44.5 to 117.5 mg/kg (fresh weight basis) were allowed to ferment whilst soaked in water for 3 days. At the end of the period the total cyanide content ranged from 1.3 to 6.0 mg/kg and nearly 90 percent of the total cyanide in the fresh roots was hydrolised and diffused into the water.

During the three day soaking period the free cyanide content of the roots actually increased due to the activity of the hydrolysing enzymes but by the third day most of the HCN had diffused into the water and free cyanide levels in the cassava root flesh ranged from only 0.01 to 0.03 mg/kg.

Recent work in Zaire (Delange et al 1983) demonstrates the beneficial effect on the HCN content of soaking peeled cassava roots.

TABLE 2.1

EFFECTS OF SOAKING ON THE HCN CONTENT OF 'BITTER' CASSAVA ROOTS

Soaking Period (Days)	HCN Content mg/kg	% of Initial HCN
0	108.2 ± 48.8	100.0
1	59.5 ± 40.7	55.0
2	45.8 ± 35.8	42.3
3	20.6 ± 18.7	19.0
4	11.8 ± 17.2	10.9
5	2.9 ± 3.3	2.7

Soaking beyond 5 days resulted in the disintegration of the cassava roots.

The addition of further linamarase enzyme to roots soaked for 5 days showed that no linamarin glucoside remained, demonstrating that the HCN system has 'exhausted' itself. In certain parts of Zambia cassava roots are soaked for a number of days before peeling. The peel is removed at the end of the soaking period. No information is available to show the effects of soaking on unpeeled roots.

2.10 RASPING OR GRATING

Two major foodstuffs produced from cassava include rasping in the process. Farinha de Mandioca in Brazil and the similar (but fermented) product known as gari in West Africa are both prepared from rasped roots.

Rasping the roots into a coarse pulp produces conditions which favour maximum contact between linamarin substrate and the enzyme linamarase which is released after tissue wounding. Thus rasping accelerates the release of HCN.

Normally peeled roots are used to produce gari, but it has been pointed out that as peel is rich in enzyme, rasping the whole root so that large quantities of enzyme are liberated to work on the linamarin may result in accelerated HCN release. Data presented by Hahn (Delang and Ahluwalia, 1983) indicates that the grating process for gari production results in the total cyanide content being reduced by half and the free cyanide content increasing fourfold.

Data presented by Cooke 1983 (In Delange and Ahluwalia) show total cyanide content of roots decreasing from 40.9 mg/kg in fresh roots to 35.4 mg/kg after rasping. The proportion of HCN in the free form however had increased from only 14 percent in the fresh roots to 81 percent in the rasped material.

This demonstrates clearly that rasping, whether it be done as a preliminary for gari or farinha production or as the first stage in starch extraction, is a very efficient method of converting bound cyanide into the free form.

An alternative method of soaking cassava roots to promote fermentation is practised in parts of Zaire and elsewhere, to produce fufu. Peeled cassava roots are soaked for 2 days until the fermentation process has softened the roots sufficiently to permit sieving the fibres from the flesh. The resulting soft pulpy mass is transferred to a bag where excess water is drained off, before placing in a container with excess water. To keep the material fresh the water is changed daily until required. Fufu is cooked in water over a fire to produce a sticky dough.

In other parts of Africa roots which have been fermented by soaking, are sun-dried or dried/smoked over a woodfire. After pounding, the resulting floury meal is cooked with water as a stiff porridge.

2.11 FERMENTING GRATED CASSAVA

In the production of gari, which is widely consumed in West Africa especially Ghana and Nigeria, the pulpy material which results from grating is fermented. In the traditional process, pulp from peeled roots is placed in jute sacks and left for a period of 3-5 days. Stones and logs are placed on the sacks to squeeze out the moisture, in which are dissolved large quantities of cyanogenic glucoside and free HCN. This latter process is referred to as dewatering. During the fermentation process micro-organisms bring about chemical changes in the dewatered pulp. Fermentation occurs in two stages.

During the first day Corynebacterium manihoc attacks the starch in the pulp producing organic acids which lower the pH of the pulp. The acid conditions promote hydrolysis of linamarin yielding HCN. As by this stage most of the free water has been pressed out, much of the HCN is in the gaseous form.

The second stage of fermentation begins with the development of a fungus (Geotrichum candida) in the pulp (G. candida has a preference for acid media). The fungus produces aldehydes and esters as it develops in the moist pulp. These compounds impart the characteristic 'fermented' flavour to gari.

Fermentation of cassava root pulp can be carried out on a large scale. Large plastic vats of pulp are 'inoculated' with the appropriate organisms and after a period of 3-5 days (depending on whether a mild or strong flavour is desired) the fermented pulp is mechanically dewatered in a motor driven press.

Intermediate scale production methods are available permitting the mechanisation of village scale production. Various pieces of equipment are manufactured in Nigeria and other W. African nations.

After fermenting, the pulp is fried to gelatinise the starch (which imparts the swelling characteristics of gari), and dried so that the finished gari can be stored over the medium term.

The fermentation of grated cassava has been shown to be an effective method of reducing the total HCN content of the roots. Data presented by Hahn, (in Delange and Ahluwalia 1983), indicate that total HCN can be reduced by as much as 25 percent of the quantity present in the fresh roots of some high HCN varieties. Most of this reduction is due to the conversion of bound HCN to the free form. In spite of this, the fermentation process has little effect on the amount of free HCN in the pulp. Hahn reported between 3 and 4 mg/kg as present throughout and at the end of the fermentation process.

The traditional fermen`ation process is therefore less efficient at detoxifying cassava roots than the soaking method, and fermented cassava pulp required further detoxification during the frying and drying processes.

Recent developments in gari processing carried out by Meuser and Smolnik are reported by Oke (in Delange and Ahluwalia 1983). By allowing the fermentation period to proceed for a longer duration (5 days), 'fruit water' can be expressed from the fermenting pulp carrying with it both bound and free cyanide. By washing the fermented pulp with water and draining the wash water, the residual HCN content of the gari (after gelatinising and drying) was reduced to below 10ppm. Many of the 'flavour compounds' are washed from the gari, together with 50 percent of the protein and 40-70 percent of the minerals resulting in a product very similar in composition to Brazilian 'Farinha Amazonia'.

2.12 FRYING OR HEATING

The critical temperatures involved in cassava detoxification were discussed above in the section on artificial drying. Frying is generally a secondary process following boiling, or fermentation of the fresh roots. However roots of low-cyanide types of cassava are often deep-fired in oil after only peeling. Where raw roots are fried the slices are usually very thin (2-3 min) and a fine product resembling potato 'crisps' is produced, which is eaten as a snack. No published information of the effects of deep-fat frying on fresh cassava are available. This probably reflects the fact that only a minute portion of the world's cassava is deep-fat fried. Again this probably reflects the relative scarcity of large quantities of oil in the kitchens of poorer families of the tropical regions.

Heating the dewatered pulp of cassava roots is common to both Farinha de Mandioca and gari production processes. The pulp is 'fried' and dried in one continuous process in iron pans at temperatures in the range of 80-85° C, (sufficient to gelatinise the starch but insufficient to caramelise it). The dried product is free-flowing and granular in consistency. Fine quality products may be sieved to remove fibres and then milled to a finer consistency. The quality of gari depends on its ability to swell to 3-4 times its volume when boiling water is added.

Data presented by Hahn (in Delange and Ahluwalia, 1983) shows that total HCN was reduced from around 60mg/kg to 20-50mg/kg after frying. Drying reduced the total HCN content to less than 10mg/kg as most of the remaining cyanide was in the free-form and therefore very volatile.

In Nigeria and other W. African nations, yellow gari is produced by the addition of a small quantity of vegetable oil (typically palm oil) to the fermented pulp at the time of frying. Oke (in Delange and Ahluwalia, 1983) reports that yellow gari appears not to contain any residual cyanide in contrast with the 5-20 ppm found in gari prepared without palm oil. The effects of palm oil on cyanogenesis and detoxification of cassava is currently being investigated.

In order to scale up the frying and drying process to enable large-scale mechanised production, various types of machines have been tested. Large horizontal rotating-drum driers are favoured by the Newell-Dunford process used in many large scale gari factories in West Africa.

Trials with freeze-drying and flash drying have shown that only free HCN is removed. In contrast roller drying resulted in very little HCN removal. Drying in a warm stream of air has been shown to be a more thorough method of removing both bound and free HCN (Oke).

2.13 WET MILLING FOR STARCH EXTRACTION

Cassava starch is traditionally extracted by wet-milling washed roots, and washing the starch from the resulting pulp. The starch-rich wash water is run into tanks where it separates by sedimentation. After running off the water, the wet starch is spread to sun dry or dried on heated floors.

The process results in large scale hydrolysis of linamarin followed by the removal of the HCN in the wash water. The wet milling process favours maximum contact between enzyme and glucoside, and the large volumes of water required to wash out the starch granules from the pulp also removes the soluble cyanide. Finally sedimentation under water leads to some fermentation and this, followed by extended drying, leads to the release of tiny residual amounts of HCN in the starch. The following table traces the HCN loss at the various stages in the starch extraction process.

TABLE 2.2

	HCN Concentration mg/kg (dry basis)	Proportion as Free HCN (%)	Extraction Index*
Fresh roots	409	14	100%
Milled roots	354	81	87%
Pulpy residue	132	87	9
Wash water	2,294	100	67
Wet starch	14	96	3
Dry starch	4	59	1

* where 100% is the quantity of total HCN in the fresh roots entering the process.

It is worthy of note that of the residual one percent HCN more than half of this is in the free form and will most likely be driven-off during cooking.

The key step in the detoxification process is the wet-milling of the roots. It is possible that by holding the milled pulp for a period of time, a substantial proportion of the bound cyanide will be converted into the free form. This is largely removed in the separation/wash stages of the process and any residue is removed by heating during the cooking process. Fortunately eating raw starch causes severe digestive discomfort so the miniscule dangers of free HCN in dry starch is thus minimised.

2.14 PUBLIC HEALTH ISSUES - ACUTE TOXICITY

The acute toxicity of cassava is a phenomenon likely to have been well understood since pre-historic times. The many different individual processes used either singly or in combination demonstrate human ingenuity in trying to convert the starch rich yet poisonous roots into wholesome food.

The widely known toxic nature of fresh cassava roots prevents large-scale problems of acute poisoning. Where these do occur they are usually the result of ignorance or lack of experience with preparation techniques. Hungry children left alone fall victim to eating raw unpeeled cassava roots which they have seen being prepared by their mother. In times of famine, hungry people too anxious to eat rather than follow a protracted, often elaborate traditional method of preparation, also fall victim to acute cassava poisoning.

Fortunately the incidence of acute toxicity is low. It is the recent discoveries in the field of chronic toxicity of cassava which is creating cause for concern.

2.15 CHRONIC CASSAVA TOXICITY

Studies carried out during the past decade into the incidence of endemic goitre in areas of Zaire have shown conclusively that the cassava-based diet of the afflicted people is a major factor. Not only the fact that cassava is the staple food, but also the method of preparation into food features importantly amongst the findings of the study (Ermans et al; in Delange and Ahluwalia, 1983).

Goitre, a result of thyroid inadequacy, is prevalent in areas of dietary iodine deficiency. When cassava is taken as the staple carbohydrate, especially in a form which has not been adequately detoxified, goitre develops in some of the population.

The anti-thyroid activity of cassava is related to the ingestion of the cyanogenic glucoside linamarin in the food. Linamarin, which represents 'bound HCN' is acted upon in the body of the consumer by the enzyme rhodanese to produce thiocyanate. (Acute cyanide poisoning occurs when the rhodanese detoxification process is 'swamped' by excess HCN). The thiocyanate compounds require iodine and sulphur, the latter usually from sulphur-bearing amino-acids. Removal of serum iodine to detoxify the HCN affects the iodine metabolism of the thyroid gland. In areas where dietary iodine is low, (eg because of geological reasons - low iodine-bearing rocks) there is competition for iodine between the thiocyanate HCN-detoxification process and the thyroid gland. As a result thyroid insufficiency results.

Thyroid insufficiency results in the development of goitre in adults, and when the period of insufficiency coincides with a critical period of brain development ie during foetal life and first few years of infancy, cretinism can also occur. Endemic cretinism is defined as an association of mental deficiency with a neurological syndrome consisting of deficiencies in hearing and speech, disorders in stance and gait, and hypothyroidism and stunted growth.

Thiocyanate production in the body can be monitored easily as the thiocyanate is excreted in the urine. Similarly iodine levels in the body can be monitored by urine sampling techniques. The results of the work in Zaire show that urinary thiocyanate levels increased following the consumption of poorly processed cassava.

Critical relationships between urinary iodine and urinary thiocyanate have been developed from the Zaire work.

- Under normal conditions the urinary iodine: thiocyanate ratio exceeds 7.

- Endemic goitre develops when this ratio reaches a critical threshold of about 3.

- Hyper-endemic goitre complicated by endemic cretinism occurs when the ratio falls below 2.

The four critical factors involved in chronic cassava toxicity are;

- Level of iodine in the diet.
- HCN content of cassava roots (and leaves) grown.
- Efficiency of detoxification processes used in the preparation of food from cassava
- Frequency and quantity of cassava-based foodstuffs in the diet.

An important fact to emerge is that the long term consumption of large quantities of cassava does not necessarily result in the development of endemic goitre.

These disturbing facts suggest that in areas with low iodine, consumption of marginally inadequately detoxified cassava can result in endemic goitre. Similarly in the same low-iodine areas grossly inadequately detoxified cassava (ie non-soaked, low temperature cooking), can result in both endemic goitre and cretinism.

As discussed above the sulphur required in the detoxification of bound HCN into thiocyanate is normally obtained by breakdown of sulphur-amino-acids. In people subsisting on a low protein diet, especially if the protein is inadequate in terms of sulphur-bearing amino-acids, this removal of amino-acids essential for proper growth and development can result in serious nutritional imbalances.

This information is of practical importance to the health and development of millions of people in developing countries where the staple diet is cassava. It is recommended that the various UN agencies support the various studies required to elucidate awareness of the problems associated with cassava diet, and where possible take action to combat the problem posed by chronic cassava toxicity.

2.16 CASSAVA TOXICITY IN ANIMALS

During 1981 the EEC countries imported approx 6.5 million tonnes of cassava mainly in the form of pelletised sun-dried chips. Nevertheless little research has been done on the possible effects of the 'bound' cyanide that chips are known to contain on the health of the animals that consume this cassava.

Increased urinary thiocyanate levels following consumption of cassava products containing bound cyanide have been reported for pigs and rats. This indicates that a similar detoxification process occurs in animals as in humans. The presence of thiocyanate indicates that under appropriate conditions of low iodine intake the development of goitre may be expected. This occurred when pigs were fed iodine-deficient cassava rations.

Experiments with Giant African Rats show that increased levels of thiocyanate can be found in the meat from animals raised on cassava-based diets. In this context the effect of heat on thiocyanate requires investigation because it is necessary to be sure that this goitrogenic substance is eliminated from the meat of cassava fed animals before it is consumed.

Experimental results indicate that cassava toxicity in animals can be aggravated when they consume nutritionally unbalanced diets. Protein deficiency, notably the sulphur-bearing amino-acids such as tyrosine may complicate goitre development in animals.

In summary the relatively short life of animals reared for meat may preclude serious goitre-related problems. However the effect of long-term feeding of cassava-based rations to breeding stock is required to determine the possible interactions of iodine, protein and essential amino-acid deficiencies; and their effects on foetal development, young animals and their mothers. Some preliminary results already indicate that cassava diets might have deleterious effects on the overall productivity of animals when consumed over long periods of time.

APPENDIX 3

INTERNATIONAL STANDARDS FOR CASSAVA CHIPS

Source: Ingram (1975)

APPENDIX 3

INTERNATIONAL STANDARDS FOR CASSAVA CHIPS

Source: Ingram (1975)

BRAZIL

	CHIPS		CHIPS	FLOUR
Grade	I	II	I	II
Starch (min %)	75.0	70.0	71.0	70.0
Size (% through 0.16 mm)	-	-	99.0	99.0
Moisture (max %)	13.0	14.0	13.0	14.0
Acidity (ml % in N/I NaOH sol)	2.0	2.5	2.0	2.5
Ash (max %)	2.0	3.0	2.0	2.0
Foreigh impurities (max %)	1.0	2.0	0.5	1.0
Length (cm)	5.0	5.0	-	-

THAILAND

	CHIPS
Moisture (max %)	14.0
Fibre	5.0
Sand	3.0
Starch	

INDIA

	CHIPS	FLOUR	CHIPS
	(for livestock feed)		(human food)
Moisture (max %)	10	10	13
Starch (min %)	82	82	-
Total ash (max %)	2.5	2.5	1.80
Acid-insol ash (max %)	1.0	1.0	0.10
Crude fibre (max %)	2.5	2.5	0.10
HCN (max %)	0.03	0.03	-
pH of aqueous extract	-	-	17.70
Cold water solubles (max %)	-	-	11.0

TANZANIA

	CHIPS
Starch (min %)	75
Fibre (%)	2-3
Ash (max %)	1
Moisture	-

MALAYSIA

	PELLETS
Moisture (max %)	10.0
Starch (min %)	70.0
Fibre (max %)	3.5
Sand (max %)	1.0

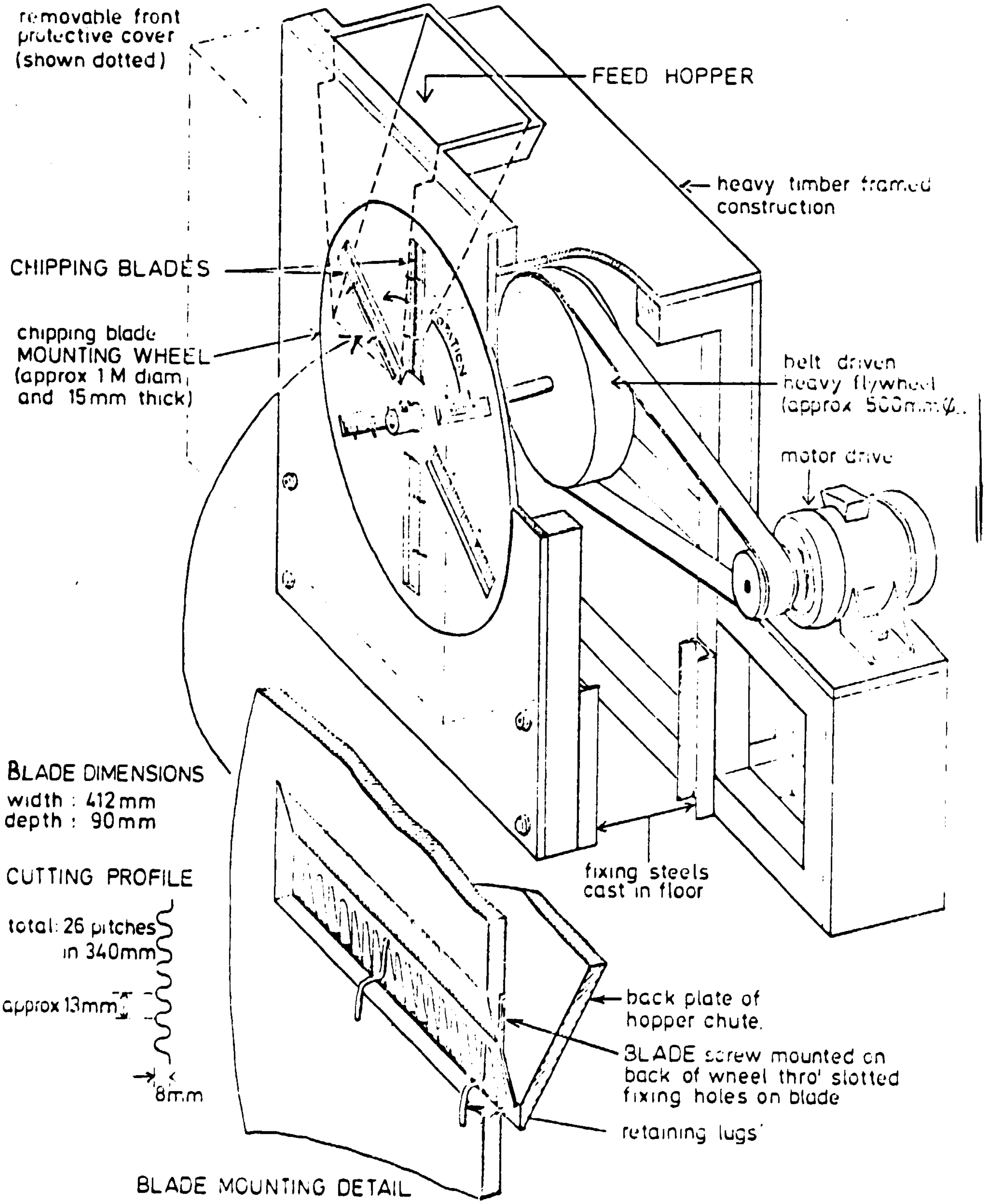
MALAGASY

	VARIOUS CHIPS		CRUSHED/COMPRESSED CHIPS	
Grade	I	II	I	II
Dust/loose bark (max %)	1.0	4.0	-	-
Foreign matter (max %)	nil	1.0	none	none
Mouldy (max %)	nil	15.0	none	traces
Insect infested (max %)	none	none	none	none
HCN (max %)	0.02	0.02	-	-

APPENDIX 4

ILLUSTRATION OF CHIPPING MACHINE

APPENDIX 4



CUT-AWAY ILLUSTRATION OF CHIPPING MACHINE

APPENDIX 5

FACTORS AFFECTING THE COST AND AVAILABILITY OF CASSAVA RAW MATERIAL

APPENDIX 5

FACTORS AFFECTING THE COST AND AVAILABILITY OF CASSAVA RAW MATERIAL

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

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

APPENDIX 6

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

APPENDIX 6

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

MEAL OR FLOUR

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

STARCH

Baked goods
Desserts - puddings, pie fillings (sago)
Infant foods
Confections (moulding of cast sweets)
Thickening agents (synthetic jellies)
Bodying agents (caramels)
Dusting agents (chewing gum)
Fermented beverages (beer)
Textile sizing and strengthening
Laundry starch
Paper sizing and bonding
Gums (envelopes, postage stamps, gummed tapes)
Dextrins (bonding pigment to paper; preventing glass checking)
Adhesives (cardboard, plywood and veneer)
Glues and pastes

Blended with peanut flour, nonfat milk solids, vitamins

Enriched with LPC, soy, corn, rice (pasta)

Alcohol

Acetone

Glucose

Oil well drilling

MODIFIED STARCHES

Pre-cooked soluble starches - "instant" puddings

Thin - boiling starches (confectionery manufacture)

Oxidised starches

Improved starches (ex: added glyceryl monostearate as a binding agent)

Source: Minster Agriculture Limited

APPENDIX 7

CROPLAND IN RELATION TO AGRICULTURAL POPULATION

IN SELECTED DEVELOPING COUNTRIES

APPENDIX 7

CROPLAND IN RELATION TO AGRICULTURAL POPULATION IN SELECTED DEVELOPING COUNTRIES

Country	Cropland (1) (000 ha)	Agric. Population (2) (000)	1 ÷ 2 ha/head	Ha/family of 6 persons
Africa				
Ghana	2,835	4,840	0.59	3.54
Nigeria	21,795	45,423	0.48	2.88
Uganda	4,888	7,342	0.67	4.02
Zaire	7,200	13,701	0.53	3.18
Asia				
India	164,610	372,605	0.44	2.64
Indonesia	18,000	83,230	0.22	1.32
Philippines	8,977	26,752	0.34	2.04
Thailand	11,415	27,398	0.42	2.52
Latin America				
Brazil	29,760	40,869	0.73	4.38
Colombia	5,258	9,541	0.55	3.30
Guatemala	1,498	3,246	0.46	2.76
Mexico	23,817	23,617	1.01	

Source: Land Reform, Sector Policy Paper, World Bank 1975

APPENDIX 8

BIBLIOGRAPHY OF KEY PUBLICATIONS ON CASSAVA CHIPS AND RELATED TOPICS

APPENDIX 8

BIBLIOGRAPHY OF KEY PUBLICATIONS ON CASSAVA CHIPS AND RELATED TOPICS

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

INTEGRATED CASSAVA PROCESSING FACTORY. CONCEPT EVALUATION OF CASSAVA CHIP PRODUCTION

(Project Reference P83/05 - US/INT/80/006)

VOLUME 2

ASSESSMENT OF CURRENT PRACTICES

FINAL REPORT

Prepared By:

Minster Agriculture Limited
13 Upper High Street
Thame
Oxfordshire
OX9 3HL
England

and

P-E International Operations Limited
Park House
Egham
Surrey
TW20 OHW
England

CONTENTS

APPENDICES

1.0 INTRODUCTION

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

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 mov_ng 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. gaplek, 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 will 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 cassav . 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 Large Scale Mechanical Chip Production Techniques

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-bladed 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

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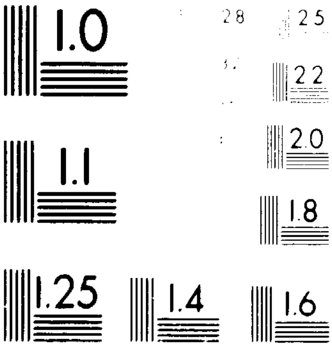

MICROCOPY RESOLUTION TEST CHART

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 moisture 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. The 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

3.0 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

FARMER	CHIPPING YARD	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 2 Baht/T	%	Yard 3 Baht/T	%
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	44[illegible]		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	Plant 1		Plant 2		Plant 3	
(1981 prices)	Baht/T	%	Baht/T	%	Baht/T	%
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	28,955	
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	- collect	- buy and sell gaplek	- consume
- harvesting	- transport	- further drying	- pelletise
- peeling	- (produce gaplek)	- storage	- export
- splitting roots			
- sun drying			

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

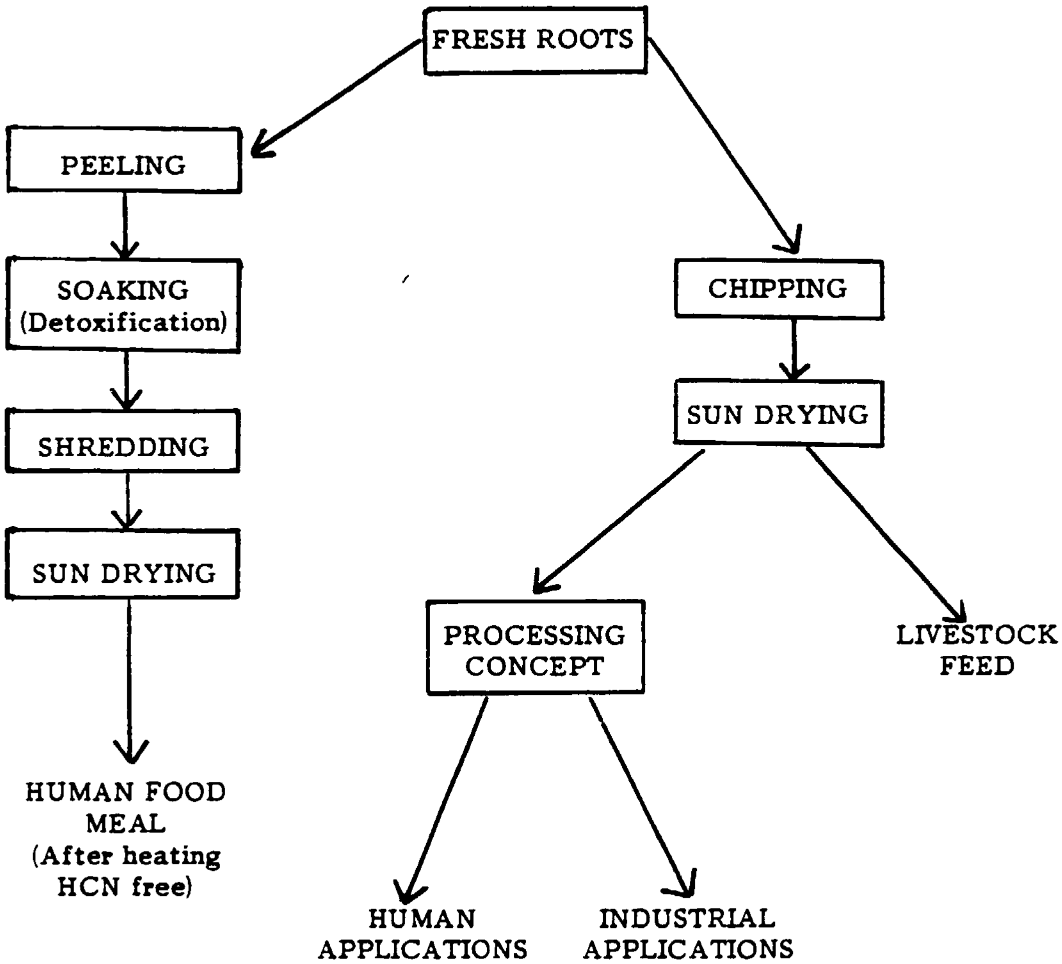
A recent paper published by the International Development Research Centre, Ottawa (Cassava Products: HCN Content and Detoxification Processes by Ermans et al) sets out the conditions for adequate detoxification of cassava roots for human consumption. The full text of the paper is reproduced in Appendix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

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:

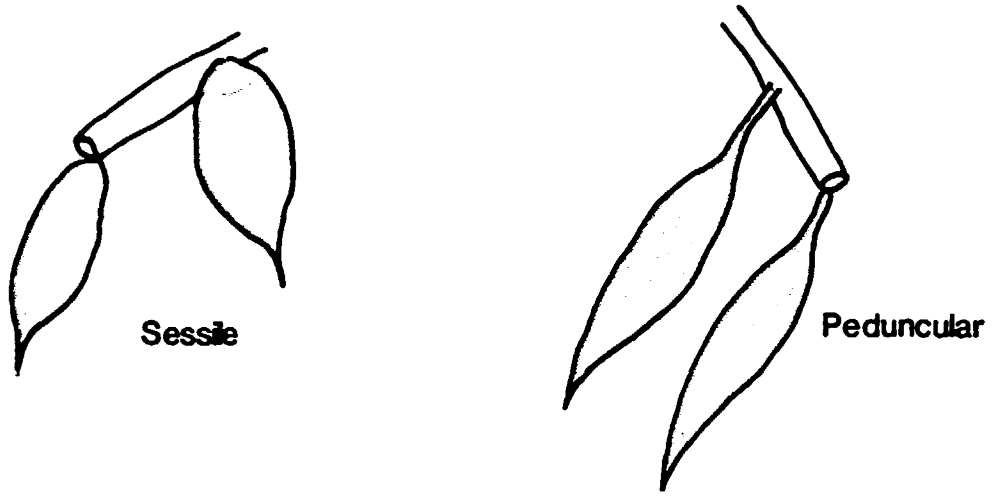
- Conical: generally sessile.

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

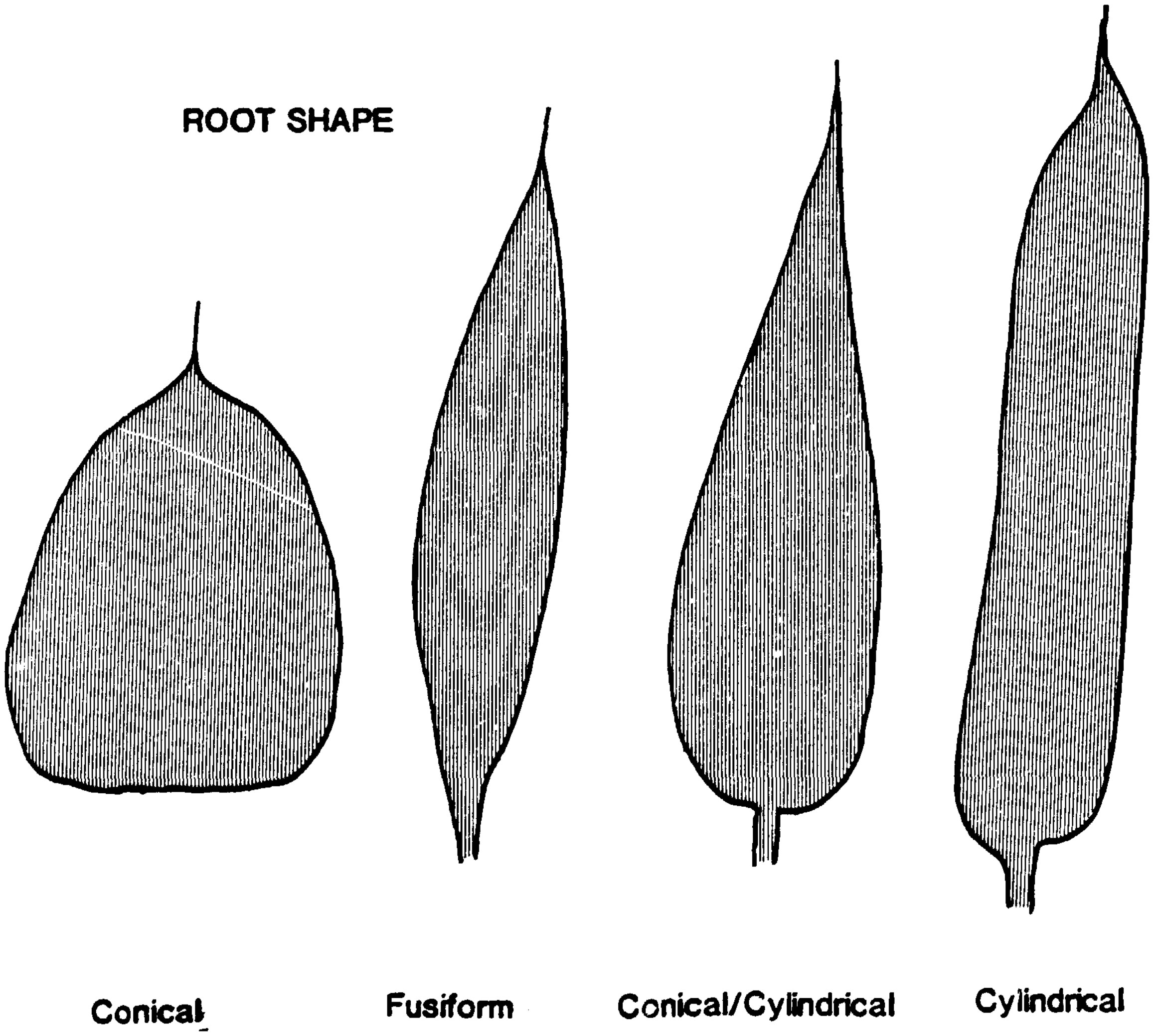
- Conical/cylindrical: maximum diameter at the proximal end, tapering towards the distal end.

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

FIGURE A.1 ROOT CLASSIFICATION



ROOT SHAPE



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

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 deterioration 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

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:

Circular (2 variants)	-	Diameter 4.5 cm Thickness to 0.5 and 1.0 cm
Rectangular (4 variants)	-	Length 8.0 cm Width 2.5 and 5.0 cm Thickness 0.5 and 1.0 cm
Cubic (2 variants)	-	1.0 x 1.0 x 1.0 cm 2.0 x 2.0 x 2.0 cm
Strips (1 variant)	-	Length 6.0 cm Width 0.5 cm Thickness 0.1 and 0.2 cm
Slices (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 $kg/h\text{-}m^2$ 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 6$\frac{1}{3}$C (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/m²) AT DIFFERENT LOCATIONS IN COLOMBIA

	Temp (°C)	Humidity (%)	Windspeed (m/sec)	Solar Rad cal/cm²/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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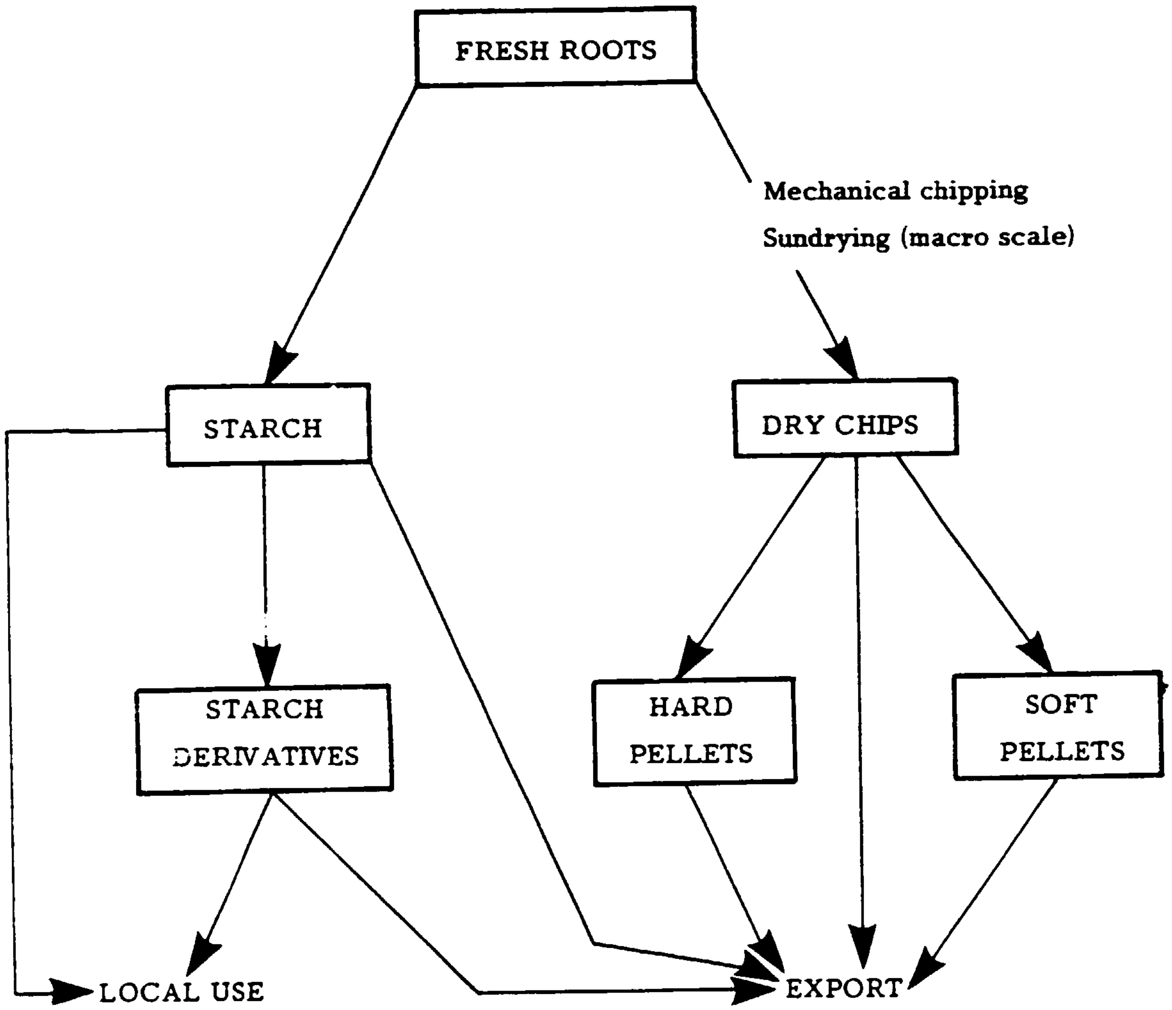
* In Weber E.J. et al (1978).

APPENDIX 4

PROCESSING CHANNELS: THAI CASSAVA INDUSTRY

APPENDIX 4

PROCESSING CHANNELS: THAI CASSAVA INDUSTRY



APPENDIX 5

CHIP PRODUCTION COSTS - THAILAND 1981

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
Transport to customer	304			-			-			27	-	-	.6	-	-
Sub-total	1,393			753			294			124	251	184	7.3	18	13
Depreciation	90			139			52			8	46	33	.5	3.3	2.3
Interest	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=1.12 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

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

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					
Fuel Vehicle	480			Energy	5.0	
Oil	200					
Wages Fixed	80			Labour		
Wages 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%

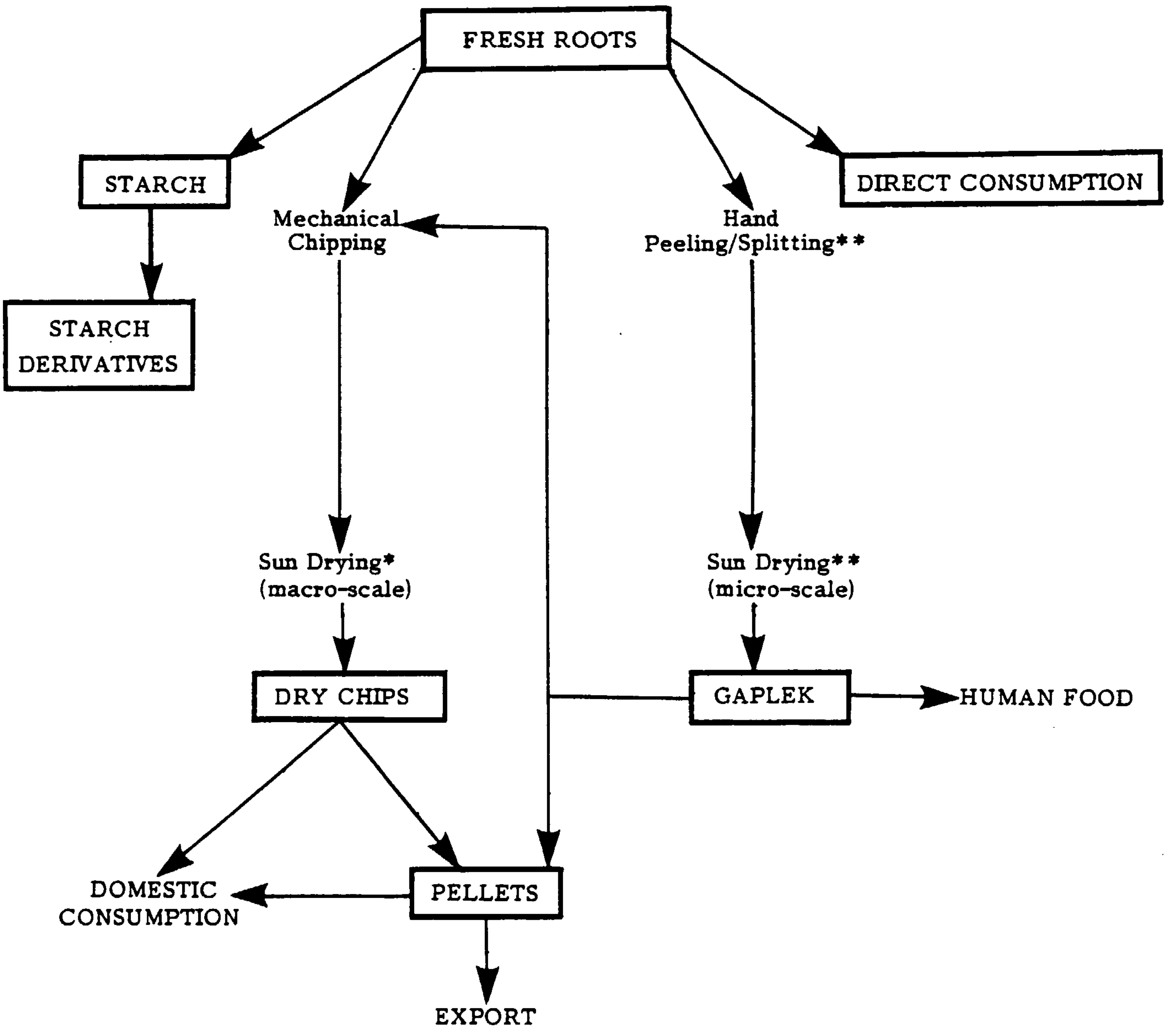
APPENDIX 8

INDONESIAN CASSAVA PROCESSING ROUTES

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.

APPENDIX 9

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

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.

Editors:

F.B. Iteke, Head, Institute of Scientific Research (IRS), Zaire.

A.M. Ermans, MD, PhD, Head, Department of Radiosotopes, St. Pierre Hospital, University of Brussels, Belgium; Director, Goitre Program IRS-CEMUBAC, Zaire.*

F. Delange, MD, PhD, Departments of Pediatrics and Radiosotopes, St. Pierre Hospital, University of Brussels, Belgium; Codirector of the Goitre Program IRS-CEMUBAC, Zaire.*

* Also co-authors

Chapter 5

Cassava Products: HCN Content and Detoxification Processes

P. BOURDOUX, P. SEGHERS, M. MAFUTA, J. VANDERPAS, M. VANDERPAS-RIVERA, F. DELANGE, AND A.M. ERMANS

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 apparaît 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.

Area	HCN content (mg/kg)		
	<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 products 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	1.9 – 10.8
Ubangi			
Fuku	89	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)	Remaining HCN: %
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
Fufu (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 *mpondu* 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 ± 35.8	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

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

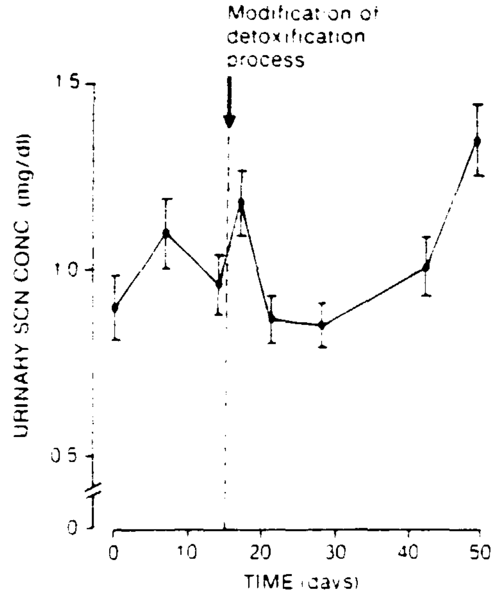


Fig. 11. *Changes with time in urinary SCN concentrations (mean ± SEM) in 29 persons in the village of Bokuda (Ubangi) during a trial of nutrition education.*

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

BIBLIOGRAPHY OF KEY PUBLICATIONS ON CASSAVA CHIPS AND RELATED TOPICS

APPENDIX 10

BIBLIOGRAPHY OF KEY PUBLICATIONS ON CASSAVA CHIPS AND RELATED TOPICS

AGRONOMY, RESEARCH AND GENERAL BACKGROUND INFORMATION

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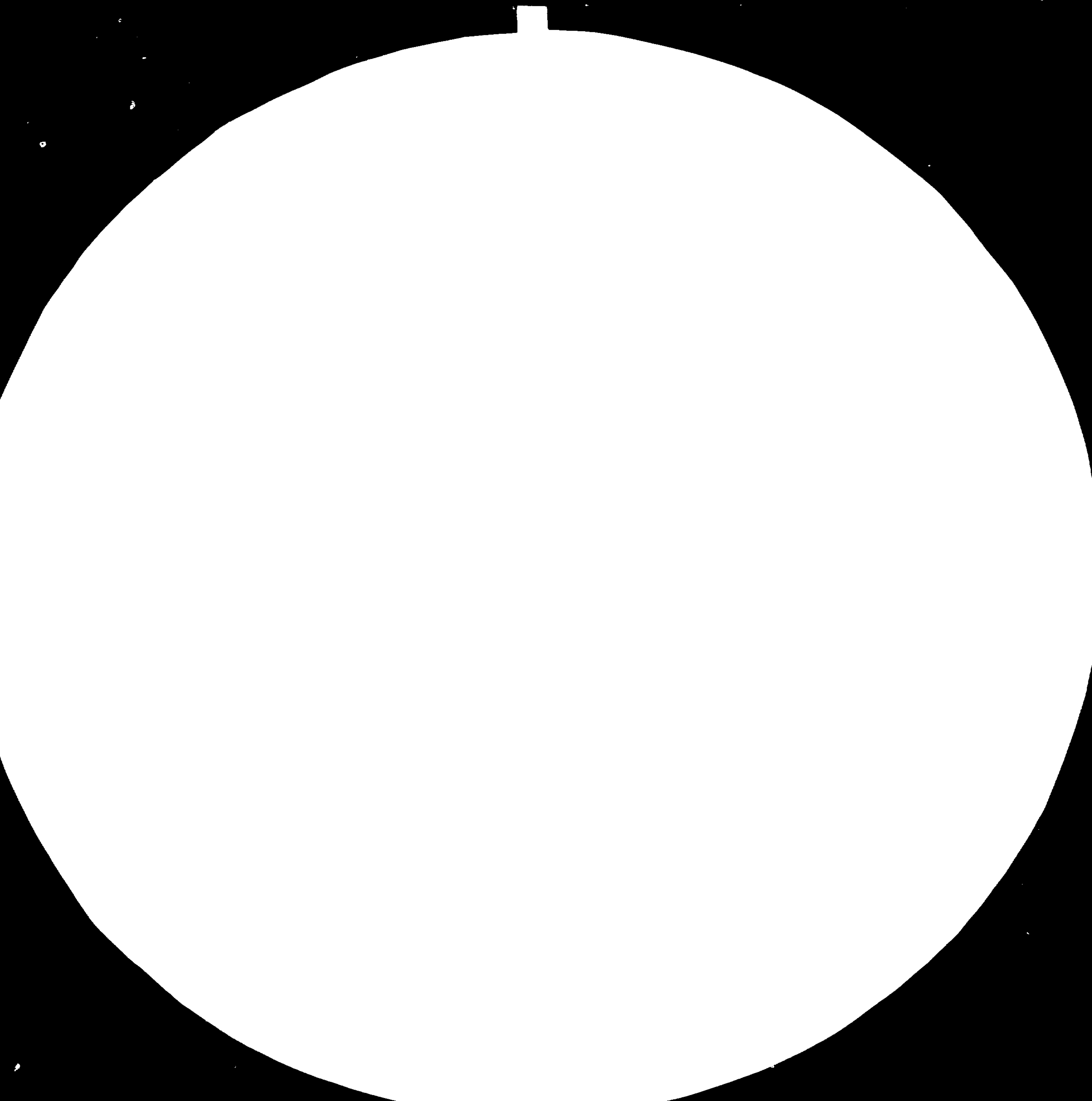

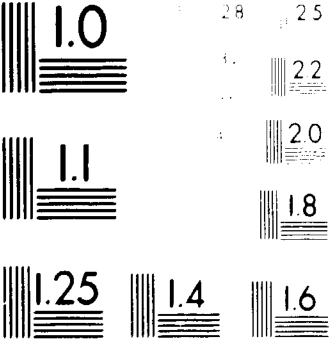

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