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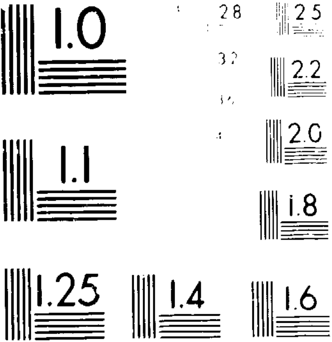

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A FACTORY CONCEPT FOR INTEGRATED CASSAVA PROCESSING OPERATIONS

US/INT/80/006

THE RAW MATERIAL CASSAVA CHIPS,

Production Systems, Quality Criteria and Techno-economic Factors*

Based on the work of P. B. Steghart of P-E International Operations Ltd., U.K. and Dr. D. W. Wholey of Minster Agriculture Ltd., U.K. on contract with UNIDO

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1.0 INTRODUCTION

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. Alian 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

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/km² to 11 persons/km².

In a densely populated region, up to 400 km² 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 km² 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

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	631
	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.

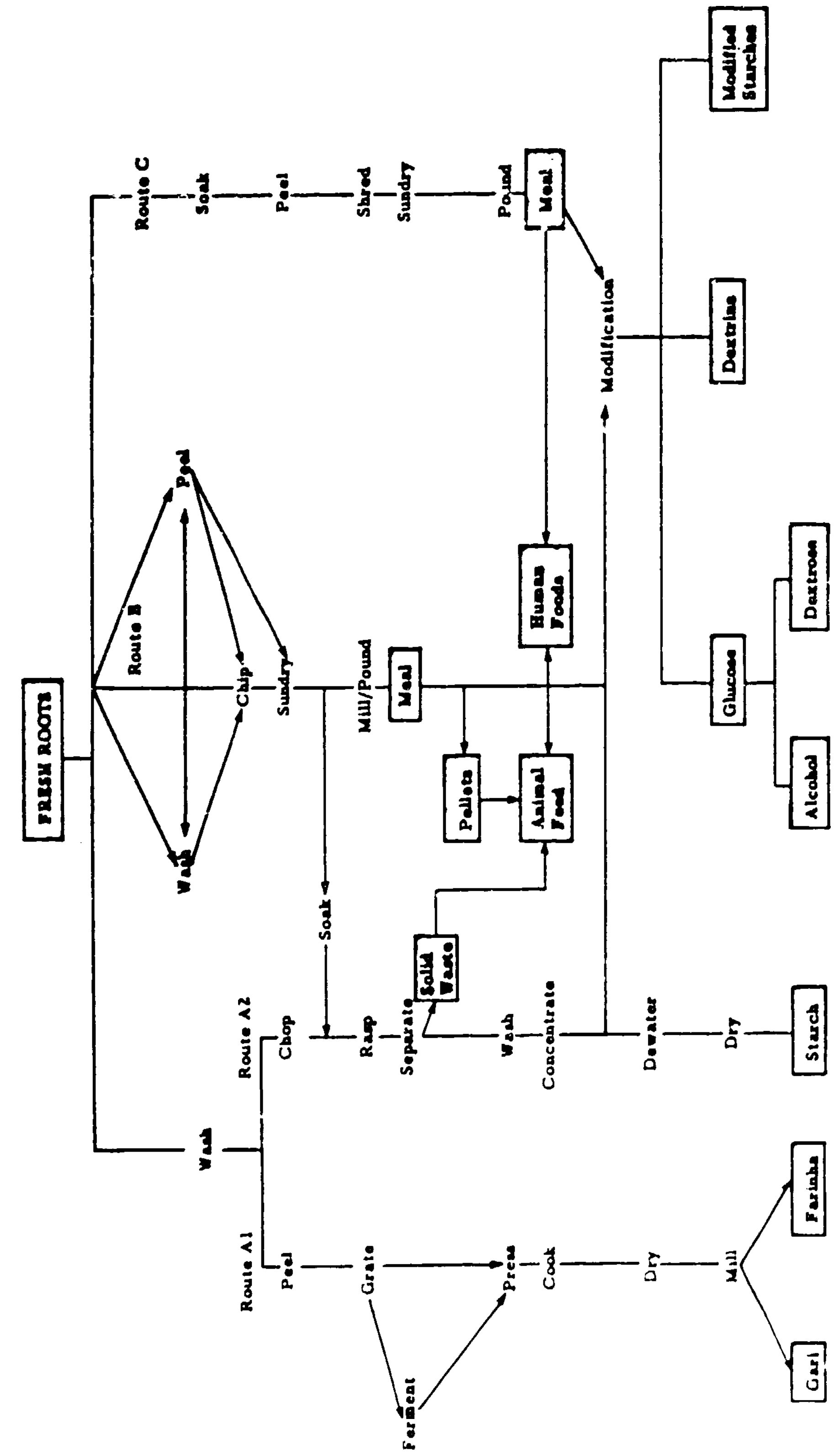
Furthermore, that report concludes that in most situations it will not be practicable for a processing factory to rely solely on fresh roots for its raw material. The logistical problems are formidable because of fresh cassava's perishability and, in any case, the transportation costs are excessive if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

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.

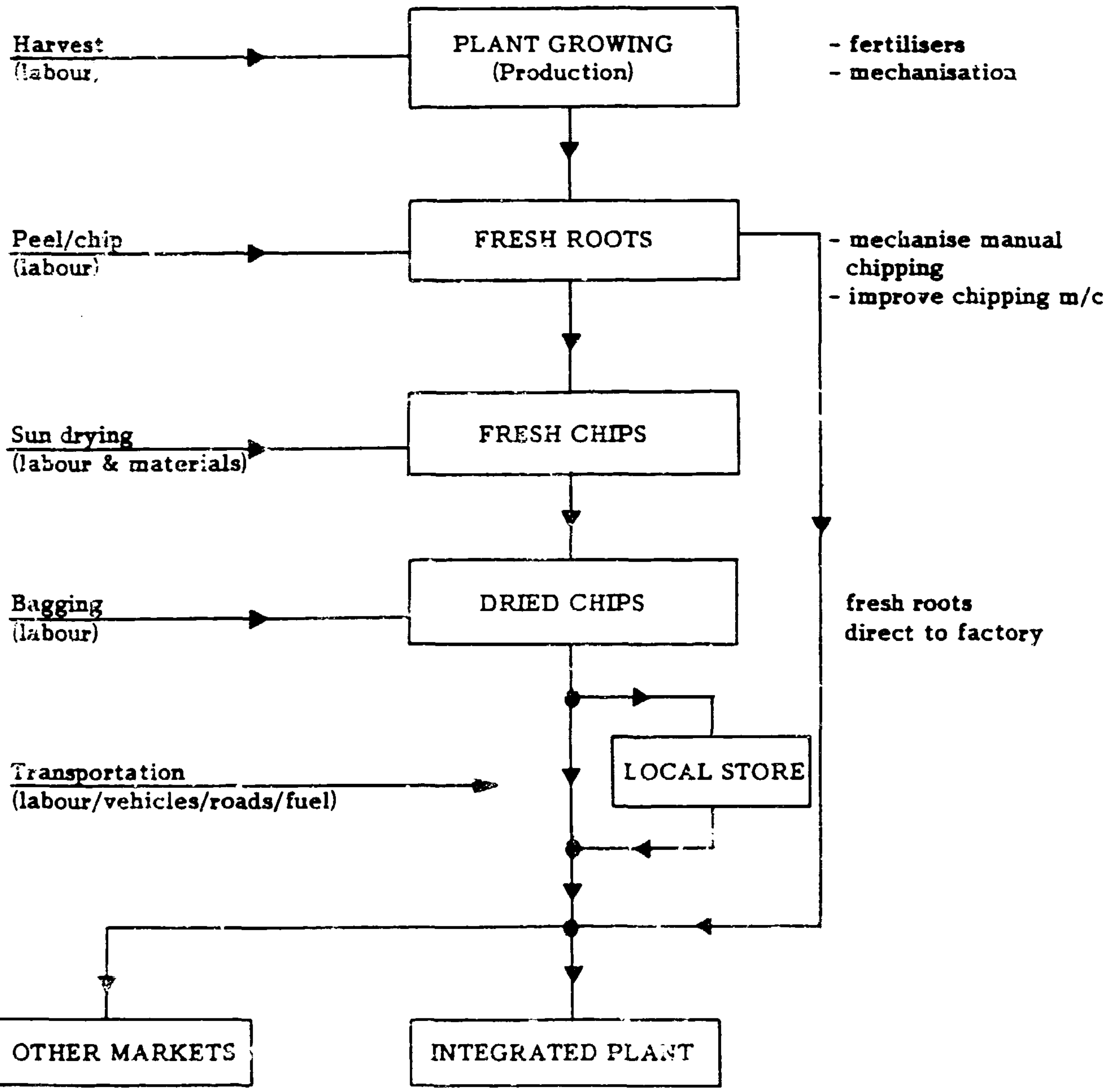
The following flow chart (Figure 4.1) shows the activities needed for the production and supply of dried chips to an integrated cassava processing plant and the main inputs to the various operations.

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 <u>The Infrastructure Needed to Ensure Continuity of Raw Material Supply</u>

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 of 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).

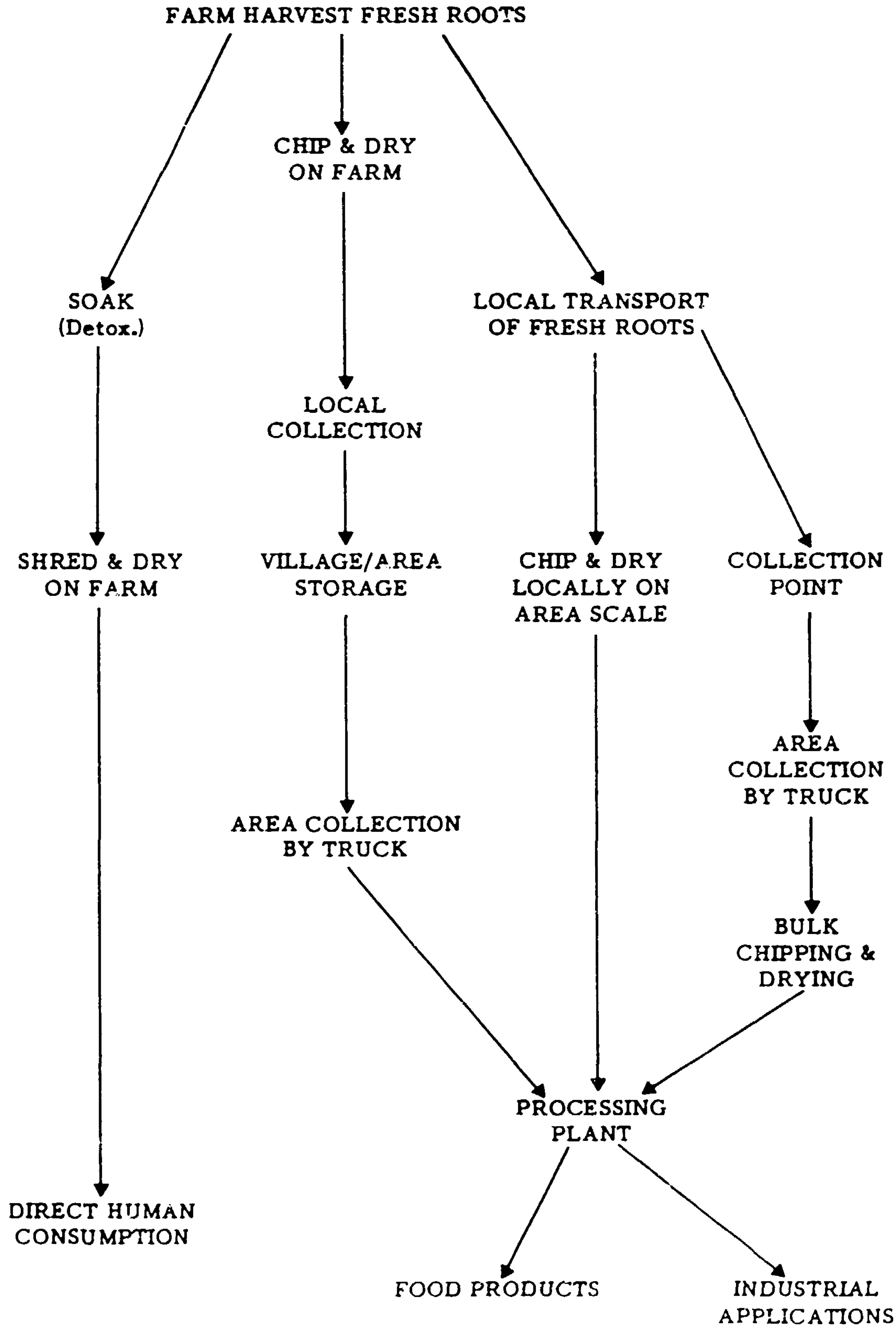
Obviously each route is applicable only in some circumstances and not in others. The three main alternatives for supplying a processing plant are discussed in turn.

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 pre-requisite 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

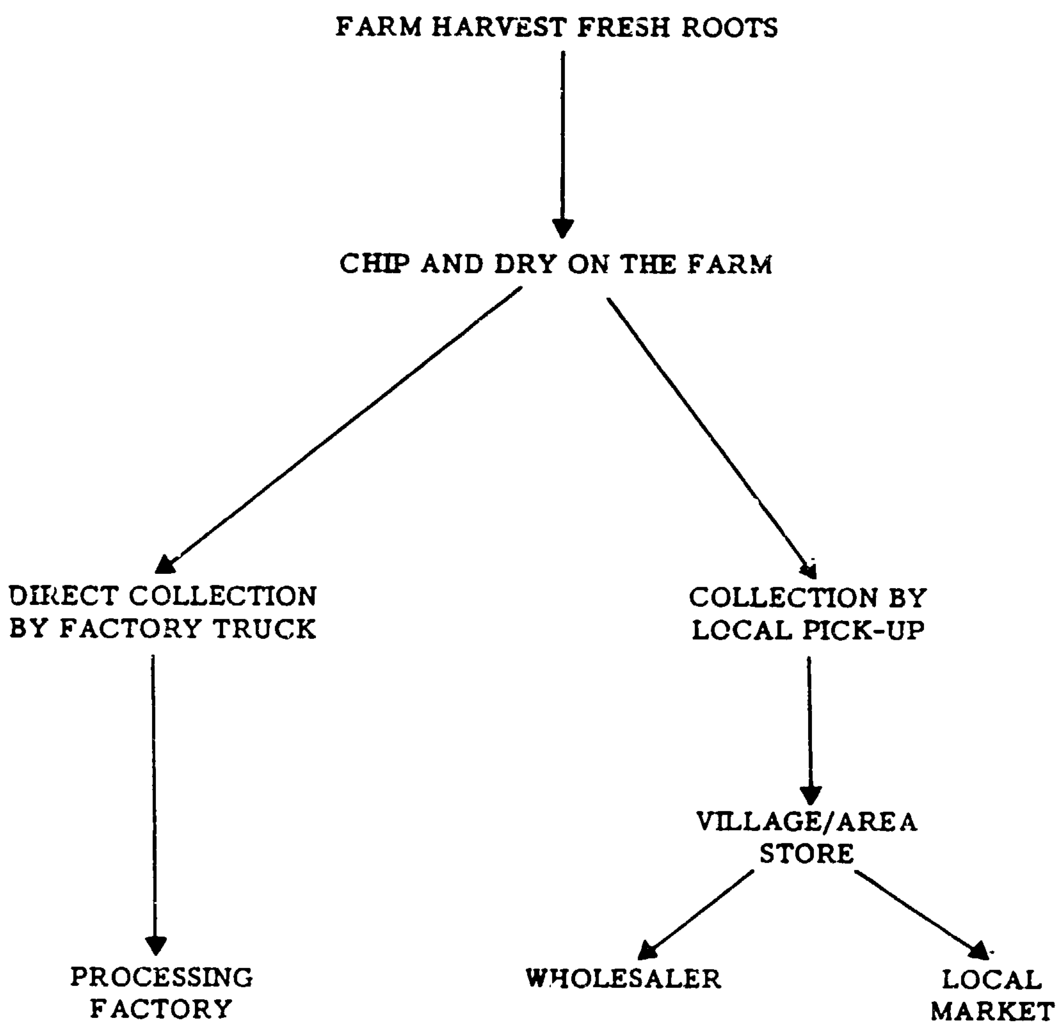


TABLE 4.1

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. · 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

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 Selection of Cassava Variety

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 ongoing 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

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 tl 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 scil/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 guaranteed 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 standar s 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

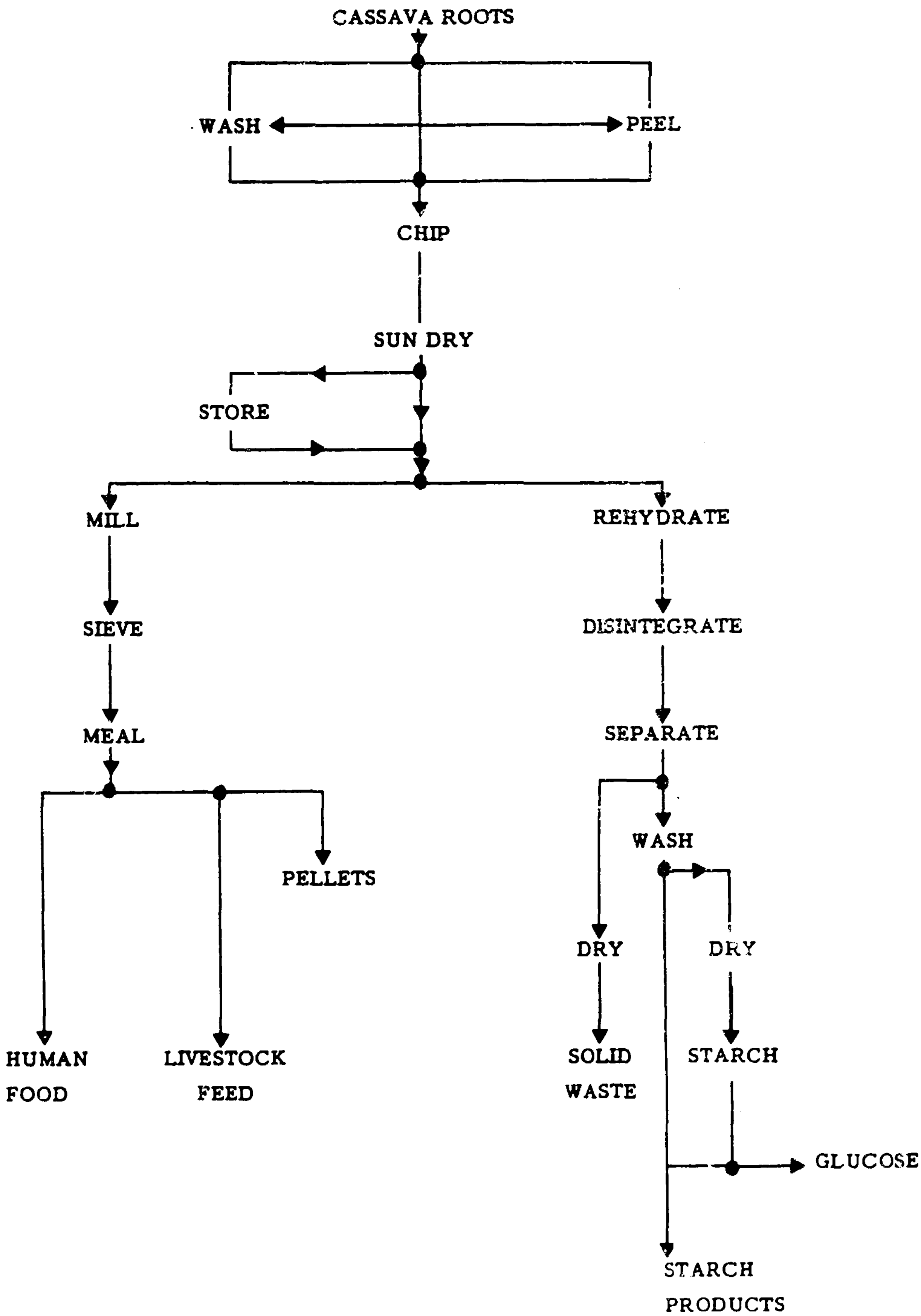
CASSAVA ROOTS
WASH
PEEL
CHIP
SUN DRY
STORE
MILL
REHYDRATE
SIEVE
DISINTEGRATE
MEAL
SEPARATE
WASH
PELLETS
DRY
DRY
HUMAN FOOD
LIVESTOCK FEED
SOLID WASTE
STARCH
GLUCOSE
STARCH PRODUCTS

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.

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.

APPENDIX 1

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
ted, pounded then baked/boiled	Boiled/soaked, pounded (Fufu)	Boiled, grated admixed with coconut (Puttu)
l, sundried, pounded into flour	Soaked, pounded, dried (Chickwangue), ground into flour (Nshima)	Steamed, fermented, baked (or raw) (Peujeum)
d, pressed, roasted (Farinha	Fermented, pounded, dried, ground into flour	
andioca) or baked (Casave)	Sliced, sundried, pounded/ground into flour (Kokonte)	Sliced, sundried (Gaplek), pound/ground into flour
xed, crushed, pressed, dried then	Grated, fermented (wet 'dough' - Fufu, Akple)	
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 liq...	

* 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

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.

$$\text{glu-0-}\underset{\displaystyle CH_3}{\overset{\displaystyle CN}{\overset{|}{\underset{|}{C}}}}\text{-}CH_3 + H_20 \xrightarrow{\text{Linamarase}} \text{glucose} + HO\text{-}\underset{\displaystyle CH_3}{\overset{\displaystyle CN}{\overset{|}{\underset{|}{C}}}}\text{-}CH_3$$

Linamarin — Cyanohydrin

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

$$HO\text{-}\underset{\displaystyle CH_3}{\overset{\displaystyle CN}{\overset{|}{\underset{|}{C}}}}\text{-}CH_3 \underset{pH<5.0}{\overset{pH>5.0}{\rightleftharpoons}} HCN + 0{=}\underset{\displaystyle CH_3}{\underset{|}{C}}\text{-}CH_3$$

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.

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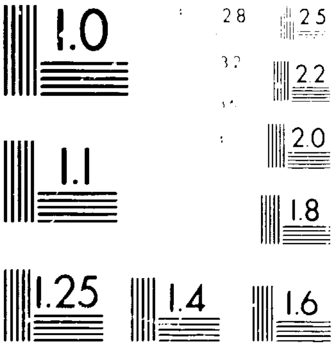


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL [illegible]

[illegible] TEST CHART [illegible]

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 fermentation 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 worm 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 minimized.

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)

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
Foreign 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

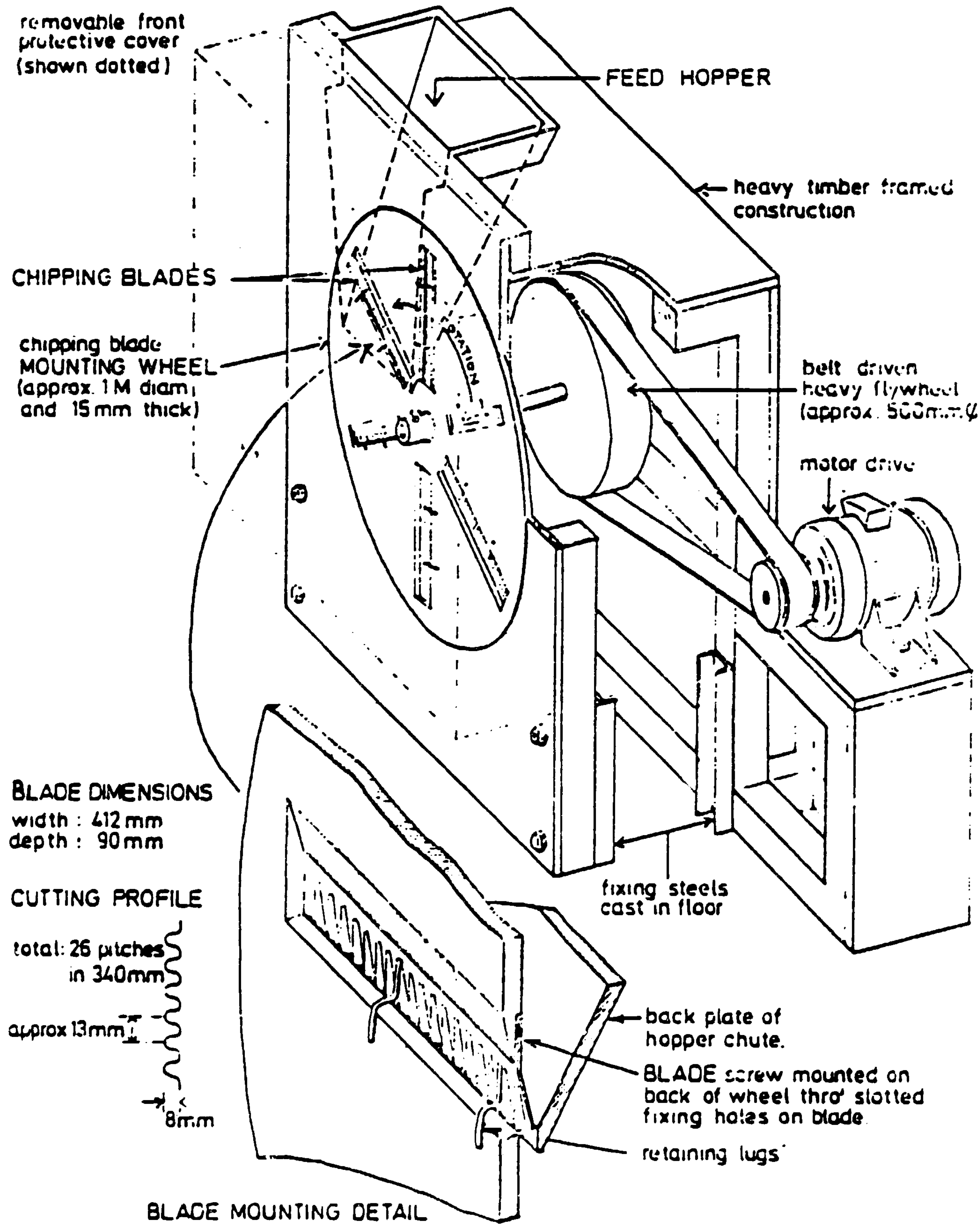
	PELLETS
Moisture (max %)	10.0
Starch (min %)	70.0
Fibre (max %)	3.5
Sand (max %)	1.0

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



CUT-AWAY ILLUSTRATION OF CHIPPING MACHINE

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

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

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

AGRONOMY, RESEARCH AND GENERAL BACKGROUND INFORMATION

ANON
The Philippines Recommends for Cassava
PHILIPPINE COUNCIL FOR AGRICULTURE AND RESOURCES RESEARCH, Philippines, 1977

ASHER, C.J. et al
Desórdenes Nutricionales de la Yuca
CIAT, Colombia, 1980

ATKINSON, D.R., WHOLEY, D.W., JARMAN, T.R.W. and TURNBULL, J.
A factory concept for integrated cassava operations
UNIDO, Vienna, 1982

BREKELBAUM, T. et al (eds.)
Proceedings Cassava Protection Workshop
CIAT, Cali, Colombia, 1977
CIAT, Colombia, 1979

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)
Abstracts on Cassava Vols. 1 - IX
CIAT, Colombia, 1975-83

CIAT
Annual Reports 1971, 1972, 1980, 1982
CIAT, Colombia, 1971, 1972, 1980 and 1982

CIAT
Cassava Programme, Annual Reports 1975-1981
CIAT, Colombia, 1975-1981

CHUNG CHEE YOKE
Commercial Tapioca Production by Smallholders on Different Soil Types in the Kinta District, Perak
MIN. AG., Malaysia, Farm Management Information Series, Malaysia, 1976

COCK, J. et al (eds.)
Proceedings of the 4th Symposium of the Int. Society for Tropical Root Crops, Cali, Colombia, 1976
IDRC, Canada, 1977

COULSON, A.C.
Crop Priorities for the Lowlands of Tanga Region
TANZANIA NOTES AND RECORDS no. 81/82 43-53, Tanzania, 1977

COURS, G.
Le Manioc à Madagascar, In Mémoirs de l'Institut Scientifique de Madagascar, Tome III, Serie B
MADAGASCAR, 1951

DOMINGUEZ, C.E. (comp.)
Yuca: Investigación, Producción y Utilizacion
CIAT, Colombia, (1982)

HOWELER, R.H.
Mineral Nutrition and Fertilisation of Cassava
CIAT, Colombia, 1981

HUNT, L.A. et al
Growth Physiology of Cassava
COMMONWEALTH BUREAU OF PASTURES AND FIELD CROPS, UK, 1977

KONG KEONG, AW YONG and MOOI SOONG WOOI
Cultivation and Production of Tapioca in Perak
JABATAN PERTANIAN - KEMENTERIAN PERTANIAN DAN PERIKANEN, Kuala Lumpur, 1973

NATIONAL CASSAVA POLICY COMMITTEE
International Seminar on Cassava and Cassava Products, Bangkok, 1981
Bangkok, 1981

NOJIMA, K and HIROSE, S.
An Outline of Bibliographical Studies on Cassava - A Guide to Cultivation of Cassava
LAMPUNG (Thailand) AGRIC. DEVT. PROJECT. JAPAN INT. COOP AG., Japan, 1977

ODIGBOH, E.U.
A Two-row Automatic Cassava Cuttings Planter: Development, Design and Prototype Construction.
J. AGRIC. ENGINEERING RES. 23, 109-116, 1978

ONWUEME, I.C.
The Tropical Tuber Crops: Yams, Cassava, Sweet Potato, Cocoyams
JOHN WILEY & SONS, UK

PLUCKNETT, D.L. (ed.)
Tropical Root and Tuber Crops Tomorrow, Vols. 1 & 2 - proc. of 2nd Int. Symposium on Tropical Root and Tuber Crops, Hawaii, 1970
COLLEGE OF TROP. AG., UNIVERSITY OF HAWAII, 1970

ROCA, W.M., HERSHEY, C.D. and MALAMUD, O.S.
Primer Taller Latinoamericano Sobre Intercambio de Germoplasma de Papa y Yuca. Memorias
CIAT, Colombia, 1982

SELVADURAI, S.
Tapioca. Agriculture in Peninsular Malaysia
Bulletin No. 148, pp 155-162
MINISTRY OF AGRICULTURE, Kuala Lumpur, Malaysia, 1978

TAI, E.A. et al (eds.)
Proceedings of the International Symposium on Tropical Root Crops
UNIVERSITY OF THE WEST INDIES, St. Augustine, Trinidad, 1967

TERRY, E.R. et al (eds.)
Tropical Root Crops: Research Strategies for the 1980s - proc. 1st Triennial Root Crops Symposium of Int. Soc. for Tropical Root Crops - Africa Branch - Nigeria, 1980
IDRC, Canada, 1981

TORO, J.C. and ATLEE, C.B.
Practicas Agronomicas para la Producción de Yuca: (Una Revision de la Literatura)
CIAT, Colombia, 1981

WHOLEY, D.W. and COCK, J.H.
Rooted Shoots for Physiological Experiments with Cassava
Tropical Agriculture (Trin.) 52,2, 187-189, 1975

WHOLEY, D.W. and BOOTH, R.H.
A comparison of simple methods for estimating starch content of cassava roots. J. Sci. Food and Agric., 30, 158-164, 1979.

PRODUCTION OF CHIPS AND PELLETS

ANON
Assim se Fabricam...... (Manufacturing of Cassava Starch, Chips and Flour)
AGRICULTURA E PECUARIA No. 533: 52-55, 1968

ANON
Casas de Farinha
Empresa Brasileira de Assistenicia Técnica e Extensao Rural
BRAZIL, 1982

ANON
Cultura e Industrializacao de Mandioca (Cultivation and Industrialisation of Cassava)
LAVOURA 14: 12-21, 1942

ANON
Estudio de Factibilidad Agricola e Industrial Para el Establecimiento de una Planta "Chips" Secos de Yuca en San Carlos (Feasibility Study of an Agro-economic Enterprise for Processing Dry Cassava Chips in San Carlos)
MINISTERIO DE AGRICULTURA Y GANADERIA, San Jose, Costa Rica, 1974

ANON
Fabricação da Raspa de Mandioca

ANON
Fabrication Artisanale de Fécule de Manioc (Cassava Flour Processing as a Rural Industry)
CAHIERS D'AGRICULTURE PRACTIQUE DES PAYS CHAUDS 26 (1) 51-54, 1971

ANON
Farinha de Mandioca (Cassava Flour)
BOLETIM DE COMISSAO DE PLANEJAMENTO ECONOMICO (5 (1): 13-17, 1959

ANON
Les Ressources Naturelles (Natural Resources and Their Processing)
MARCHEES TROPICAUX ET MEDITERANEENS No. 1308: 3487-3493, 1970

ANON
Notes on the Preparation of "Gaplek" from Cassava (Tapioca) Roots
NEW GUINEA AGRICULTURAL GAZETTE 7 (1): 38, New Guinea, 1941

ANON
Preparation du Manioc pour l'Exportation (Cassava Processing for Exportation)
J. D'AGRIC TROPICALE No. 93: 79-80, 1909

ANON
Producción de Chips en los Paises Clásicos de Exportación de Tapioca, relacionado con las Distintas Posibilidades de Secamiento (Extract)
1973

AGRO INDUSTRIAL MONAGAS, C.A.
Agroinmuca: Planta Deshidratadora de Yuca (Agroinmoca, a Cassava Dehydrating Plant)
JUSEPIN, MONAGAS, VENEZUELA, 1975

AKHTAR, J.
Drying of Cassava Chips with Heated Air
MAG. Sc. Thesis Bangkok, Thailand
ASIAN INSTITUTE OF TECHNOLOGY, 1978

ANDRADE, A.M. des, ROCHA, B.V. DA and CORREA, Armazenamento de Raizes da Mandioca (Cassava Root StorageINFORME AGROPECUARIO 5 (59/60): 94-96, Brazil, 1979

ARAULLO, E.V., NESTEL, B. and CAMPBELL, M. (eds.Cassava Processing and Storage - Proceedings of an Interdisciplinary Workshop, Patlaya, ThailanIDRC, Canada, 1974

ATKINSON, D.R. et al
A Factory Concept for Integrated Cassava Processing Operations: The Cassava Processing Concept
UNIDO/10.534, Vienna, 1983

ATKINSON, D.R. et al
The Concept for an Integrated Cassava Processing Factory for Establishment in Zambia
UNIDO/10/R.51, Vienna, 1983

BEST, R.
Cassava Drying
CIAT, 1979

BEST, R.
Solar Drying Information - Private Communication

BEST, R., ALONSO, L. and VELEZ, C.
The Development of a Through Circulation Solar Heated Air Drier for Cassava Chips
6th Symposium Int. Society for Tropical Root Crops
ISTRIC, Lima, Peru, 1983

BOOTH, R.H.
Cassava Storage
CIAT, 1975

BOOTH, R.H.
Storage of Fresh Cassava, II. Simple Storage Techniques
EXPERIMENTAL AGRICULTURE 13 (2): 119-128, 1977

BOOTH, R.H. and DHIAUDDIN, M.N.
Storage of Fresh Cassava: II Preserving Chipped Roots Before and During Sun Drying
EXPERIMENTAL AGRICULTURE 15: 135-144, 1979

BOOTH, R.H. et al
Changes in Quality of Cassava Roots During Storage
J. FOOD TECH. 11 (3): 245-264, UK, 1976

CHIEPPE, K. et al
Secagem Ambiental... (Natural and Artificial Drying of Cassava)
PESQUISA AGROPECUARIA BRASILEIRA 17 (4): 583-597, Brazil, 1982

CHIRIFE, J. and CACHERO, R.A. (1970)
Through Circulation Drying of Tapioca Root
J. Food Sci. 35; 364-8

CHONG, P.K. and WEBB, B.H.
Tapioca Pelleting Studies
MALAYSIAN AGRIC. RES. BULL. 4 (1): 77-89, 1975

CHYE, K.O. and LOH, W.Y.
The Tapioca Processing Industry in Perak
MINISTRY OF AGRICULTURE AND LANDS, FED. AGRIC. MARKETING AUTHORITY, Malaysia, 1974

DANTAS, J.L.L. and CUNHA, M.A.P. DA
A Colheita ... (Harvest and Post Harvest of Cassava in Brazil: A Case Study)
CENTRO NACIONAL DE PESQUISA DE MANDIOCA E FRUTICULTURA, Documentos 1, Brazil, 1981

DHIAUDDIN, M.N. and BOOTH, R.H.
Cassava Storage and Processing Research, 1976-78
LAPURAN MARDI REPORT No. 64, Malaysia, 1979

DORR-OLIVER, B.V., CARANSA, A
Proposal for a Cassava Starch Plant, Paper on Cassava Starch and Reference Lists of Systems
Netherlands, 1983

FRAPPA, C.
Les Insectes Nuisibles au Manioc sur Pied et aux Tubercules de Manioc en Magasin a Madagascar. II: Insectes Nuisibles au Manioc en Magasin (Insects Injurious to Cassava Plants and to Stored Cassava Tubers in Madagascar. II: Insects Injurious to Stored Cassava
REVUE DE BOTANIQUE APPLIQUEE ET D'AGRICULTURE TROPICALE 18: 104-109, 1938

GEH, S.H. and AZHAR, A.K.
Feasibility Study of the Planting of Tapioca and Production of Pellets in the State of Kelantan
MALAYSIAN FED. IND. DEVT. AUTHORITY, IND. STUDIES AND SURVEYS UNIT, 1972

GONCALVES, J.C.
Aspectos Industriais de Mandioca (Cassava Industrialisation)
CRUZ DAS ALMAS, Brasil, CENTRO NACIONAL DE PESQUISA DE MANDIOCA E FRUCTICULTURA, 1976

GRACE, M.R.
Cassava Processing
FAO PLANT PRODUCTION AND PROTECTION, SERIES No. 3, Rome, 1977

GRACE, Dr. M
Processing of Cassava
FAO, Rome, 1981 (Agricultural Services Bulletin No. 8)

HACHERO, L.
A Cottage Cassava Slicer
PHILIPPINE J. AGRIC. 22 (1-4): 81-88, Philippines, 1957

HATUM, L DO C
Mandioca.... (Cassava, a Machine to Make Chips)
Empresa Brasileira de Assistência Técnica et Extensão Rural -Serie Técnica para Produção Vegetal
EMBRATER T. 106, Brazil, 1981

HERRERA, C.A. et al
Guia para la Construccion de una Trozadora de Yuca (with plans)
CIAT, Colombia, nd

HOLLEMAN, L.W.J. et al
A Simple Remilling Process for Tapioca
J. SC. RES. 1 (5): 130-134, 1952

INGRAM, J. and HUMPHRIES, J.R.Cassava Storage: A Review
TROP. SC. 14 (2) 131-148 UK 1972

JUSTE JUNIOR, E.S.G.
Produtos e Subprodutos da Mandioca (Cassava Products and By-Products)
INFORME AGROPECUARIO 5 (59/60): 89-93, Brazil, 1979

KERR, A.J. (comp)
The Storage of Native Food Crops in Uganda
E. AFRICAN AG. J 7 (2): 75-76, 1941

LANCASTER, P.A. et al
Traditional Cassava-based Foods: Survey of Processing Techniques
ECONOMIC BOTANY 36 (1): 12-45, USA, 1982

LAVIGNE, R.
Etude sur le Séchage du Manioc
BULL. MADAGASCAR 240: 442-466, Madagascar, 1966

MAHMUD, Z. and THANH, N.C.
Tapioca Chips and Pellets; an improved technology
Agric. Mech. in Asia 8 (2): 25-30, 1977

MAINI, S.B. et al
Cassava Chips Industry in Kerala
INDIAN FARMING 30 (5): 13-14, India, 1981

MALAYSIA DEPT. AGRIC., FARM MECH. BRANCH
Construction and Operation of a Simple Cassava Chipper
Malaysia, 1974

MANIMEGALAI, G. and NEELAKANTAN, S
Post-Harvest Processing and Utilisation of Tapioca. In Nat. Sem. on Tuber Crops Prod. Tech., Coimbatore, India
PROC. TAMIL NADU AGRIC. UNIVERSITY, India, 1980

MARRIOTT, J., BEEN, B.O. and PERKINS, C.
Storage of Fresh Cassava Roots in Moist Coir Dust
MIN. IND., Kingston, Jamaica, 1974

MEUSER, F. et al
Extraction of Tapioca Starch from Roots, Chips and Pellets on Laboratory Scale
INSTITUT FUR LEBENSMITTEL TECHNOLOGIE, Germany, 1978

NAVAS, G. andf NAVARRETE, C.
Estudio del Secado de Yuca ... (Study on Drying Cassava as a Method of Conservation for the Ecuatorian Oriente)
UNIVERSIDAD TECNICA DE AMBATO, Ecuador, 1979

NIETO, M.S, GARCIA, R.A. and RODRIGUEZ, G.A.
Construccion de Máquina ... (Construction of a Malaysian-type Cassava Chipper Based on the Design by TPI)
INSTIT. NAC. DE INVESTIGACIONES AGR., Mexico, 1979

NOBRE, A.
Tecnologia dos Productos Tradicionais da Mandioca (Cassava Products) In Curso Intensivo Nacional de Mandioca, lo, Cruz das Almas, Brasil, Empresa Brasileira de Pesquisa Agropecuária
CENTO NACIONAL DE PESQUISA DE MANDIOCA ET FRUTICULTURA, 1976, 1, 64-75

NORMANHA, E.S. and LOZENZI, J.O.
Mandioca: Secagem de Raspas ... (Cassava: Sundrying Cassava Chips for the Production of Power Alcohol and Rations)
EMPRESA DE BRASILEIRA DE ASSISTENCIA TECNICA E EXTENSAO RURAL, Serie Informative Mandioquero No. 37, 1980

NUCCI, T.A. de and LORENZI, J.O.
Raspas de ... (Sun Dried Cassava Chips)
CASA DA AGRICULTURA 2 (2): 12-14, Brazil, 1980

NUSBAUM, S.J.
The Application of Modern Technology to the Multiple Uses of Cassava
Journal Article - no source

ODIGBOH, E.U.
Cassava Chips Processing and Drying. A Cassava Chipping Machine. Plucknett, D.L. ed. Workshop on Small-scale Processing and Storage of Tropical Root Crops, Hawaii 1979
PROC. WESTVIEW PRESS, (Trop. Ag. S No. 1), USA, 1979

ONG, H.H.
Investigation into Pelleting of Tapioca
MALAYSIAN AGRIC. J. 49 (4): 442-454, Malaysia, 1974

OSPINIA, J.E., ROCHA, J.L.V.
Comparacão de Três Formes... (Comparison of Three Forms of Drying Cassava in Solar Bins. Congresso Brasileiro de Pesquisa Agropecuaria
DEPT. INF. AND DOC., Portugal, 1979

OUDIT, D.D.
Polythene Bags Keep Cassava Tubers Fresh for Several Weeks at Ambient Temperatures
J. AGRIC. SOC. TRIN. & TOB. 76 (1): 63-66, 1976

PAPACOSTAS, C.P. and RAMIREZ, V.A.
Determinación de Método.... (Determining the Optimum Method of Natural Drying of Cassava)
CHAPINGO 13/14: 15-20, Colombia, 1978

PARKER, B.L. et al
Arthropods Infesting Stored Cassava in Peninsular Malaysia
PROTECTION ECOLOGY 3: 141-156, 1981

PARKER, B.L. and BOOTH, R.H.
Storage of Cassava Chips: Insect Infestation and Damage
EXPERIMENTAL AGRICULTURE 15 (2): 145-152, 1979

PATINO, B.O.
Informe de Activades en la Planta Pilato de Secado Natural de Yuca san Juan de Betulia - Sucre
CIAT, Colombia, 1982

PINGALE, S.LV. et al
Insect Pests of Stored Tapioca Chips and Their Control
BULL. CENTRAL FOOD TECH. RES. INST. 5 (6): 134-136, India, 1956

PIZZINATTO, A. et al
Comportamento de Cinco Cultivares.... (Pellet Production of Five Cassava Cultivars from the Macapa Region) In Congresso Brazileiro de Mandioca
Brazil, 1979

PLUCKNETT, D.L. (Small-scale Processing and Storage of Tropical Root Crops
WESTVIEW PRESS (Westview Tropical Agriculture Series No. 1), USA, 1979

ROA, G.
Natural Drying of Cassava (PhD Thesis)
MICHIGAN STATE UNIVERSITY, USA, 1974

ROA, G. et al
Drying of Cassava (paper presented at Annual Mting. of Am. Soc. Agric. Eng. 1974
CIAT, Colombia, 1974

ROA, G. and COCK, J.H.
Natural Drying of Cassava,
CIAT, Palmira, Colombia, 1973

RODRIGUEZ, U.F.
Desarrollo de Tecnologia Apropiada para el Procesamiento de la Yuca en las Areas Rurales Colombianas (Dev. of Appropriate Cassava Processing Technology in Colombian Rural Areas)
BOGOTA UNIVERSIDAD DE LOS ANDES. CENTRO DE ESTUDIAS E INVESTIGACION, Serie Investigaciones 1-2, 1982

ROMERO, T.R. and MOSCOSO, S.W.
Pérdidas Postcosecha en Yuca (Postharvest Losses in Cassava)
INSTITUTO SUPERIOR DE AGRICULTURA, Dominica, 1979

SILVEIRA, A.H. DA
Industrialização de Mandioca na Fazenda (Cassava Industrialisation on Farms)
REVISTA DE QUIMICA INDUSTRIAL 18:24, 1949

SINICIO, R and ROA, G.
Secador Rural de Café... (Farm Drier for Coffee, Cacao, Cassava and Other Farm Products Using Solar Energy)
CENTRO NACIONAL DE TREINAMENTOERN ARMAZENAGEM, Serie Centreinar No. 1, Brazil, 1980

THANH, N.C. and LOHANI, B.N.
Cassava Chipping and Pelleting in Thailand (paper)
ENVIRONMENTAL ENGINEERING DIVISION, ASIAN INSTITUTE OF TECHNOLOGY, Thailand, 1978

THANH, N.C., MUTTAMARA, S. and LOHANI, B.N.
Drying Techniques for Improvement of Cassava Chips in Thailand
TH. J. AG. SC. 11:45-55, 1978

THANH, N.C., MUTTAMARA, S. and LOHANI, Technological Improvement of Thai Tapioca Pellets
THAI J. AGRIC. SC. 11 (2): 75-86

THANH, Dr. N.C., PESCOD, Prof. M.B. and MUTTAMARA, S.
Final Report on Technological Improvement of Tapioca Chips and Pellets Produced in Thailand
ASIAN INSTITUTE OF TECHNOLOGY (Research Report No. 57) IDRC, Canada, 1976

THANH, N.C. et al
Field Studies of Thai Tapioca Chips and Pellets
THAI J. AGRIC. SC. 11: 139-148, 1978

THANH, N.C. et al
Optimization of Drying and Pelleting Techniques for Tapioca Roots
ASIAN INST. OF TECH., Bangkok, Thailand, 1979

TORO, J.C.
Secamiento de la Yuca (Methods of Drying Cassava). Curso Sobre Producción de Yuca
MEDELLIN, INSTITUTO COLOMBIANO AGROPECUARIO, Regional 4, 1975

TROPICAL PRODUCTS INSTITUTE
The Industrial Manufacture of Cassava Products: An Economic Study
TPI (Report No. G.88), UK

VALENZUELAS, G. et al
Sistemas de Manejo... (Handling, Storage and Transportation Systems for Exporting Perishable Refrigerated Food Products
IIT Technologia 14 (79): 33-34

VITTI, P.
Industrialisation of Cassava - Production of Starch, Chips and Flour
BOLETIM DE CENTRO TROPICAL DE PESQUISAS E TECNOLOGIA DOS ALIMENTOS, No. 6, Brazil, 1966

VITTI, P.
Obtenção de Produto... (A Substitute for Cassava Chips)
COLETANEO DO INSTITUTO DE TECHNOLOGIA DE ALIMENTOS 3: 201-215, Brazil, 1970

WEBB, B.H. and GILL, K.S.
Artificial Heat Drying of Tapioca Chips
MALAYSIAN AG. RES. 3:67-76, 1974

WEBER, E.J., et al (ed Cassava Harvesting and Processing - Proceedings of a Workshop Held at CIAT, Colombia, 1978
IDRC, Canada, 1978

WEGMANN, K.
Untersuchungen über die Lagerfähigkeit von Manioc-Mehl (Investigations of the Storability of Cassava Flour)
Brot und Gebäck 24 (1): 16-18, 1970

WILLIAMS, C.N. et al
A Solar Heat Drier for Crops and Other Products
TROPICAL AGRICULTURE (TRINIDAD) 46 (1): 47-54, Trinidad, 1969

WILLIAMS, C.E.
Cassava Processing Problems in Nigeria
UNIVERSITY OF IBADAN, FAC. AGRIC. AND FOR., Nigeria, 1979

ZAPATA, L.E. and RIVEROS, S.H.
Preservation de la Yuca Fresca (Conserving Fresh Cassava)
IIT TECNOLOGIA No. 115: 9-20, 1978

ANON
Conservacao da Mandioca et do Milho (Cassava and Maize Storage)
CHOCARAS E QUINTAIS 113 (5): 474-475, 1966

CHEMICAL ASPECTS, QUALITY CONTROL, NUTRITION

ACENA, B. and PUNC, G.D.
A Study on the Use of Cassava in the Beer Industry
PHILIPPINE J. AGRIC. 20 (1-2): 1-13, Philippines, 1955

ADRIAENS, E.L.
Note sur la Toxicité et la Préparation du Manioc du Congo Belge
BULLETIN AGRICOLE DU CONGO BELGE 33 (3): 312-351, Congo, 1942

ANON
Adulteration, the Bugbear of the Tapioca Industry
INVESTER 10 (1): 29-32, 1978

ANON
Methodes et Procédés Spéciaux... (Special Methods and Procedures Used to Determine the Quality of Cassava Flours)
ETUDES D'OUTRE MER 38: 106, 1955

ANON
Productos de Yuca... (Cassava Products for Compound Feedstuffs)
AGRO 7 (58): 4-5, 1978

BALAGOPAL, C., DEVI, S.B. and PILLAI, K.B.
Microflora of Cassava Chips
AG. RES. J. OF KERALA 12 (1): 80-81, India

BALAGOPAL, C. and NAIR, P.G.
Studies on the Microflora of Market Cassava Chips of Kerala
J. ROOT CROPS 2 (2): 57-58, 1976

BANCO DO BRASIL: CARTEIRA DO COMERCIO EXTERIOR
Cassava Flour and Starchy Products
RIO DE JANEIRO - G.B., Brazil, 1971

BEST, R. and GOMEZ, G.
Procesamiento de las Raices de Yuca para la Alimentacion Animal. Centro Internacional de Agricultura Tropical
PROGRAM DE YUCA, YUCA: INVESTICAGION, PRODUCCION Y UTILIZACION, Colombia, 1982

CHAVES J.M. and ATUCH, S.A.
Sedimentacao de Graos de Amodo de Raspa de Mandioca (Sedimentation of Starch Grains from Ground Cassava Chips)
REVISTA DE QUIMICA INDUSTRIAL (BRAZIL) 13 (148): 18-19, 1944

COOKE, R.D.
Enzymatic Assay for Determining the Cyanide Content of Cassava and Cassava Products
CIAT, Colombia, 1979

COOKE, R.D. and COURSEY, D.G.
Cassava: A Major Cyanide - Containing Food Crop
TPI, UK

COOKE, R.D. and MADUAGWU, E.N.
The Effects of Simple Processing on the Cyanide Content of Cassava Chips
J. FOOD TECH. 13: 229-306, UK, 1978

DELANGE, F. and AHLUWALIA, R.
Cassava Toxicity and Thyroid: Research and Public Health Issues. Proc. Workshop, Ottawa, Canada, 1982
IDRC, Canada, 1982

DELANGE, F. ITEKE, F.B. and ERMANS, A.M. (edNutritional Factors Involved in the Goitrogenic Action of Cassava
IDRC, Canada, 1982

EERLEY, R.W.
Utilization of Cassava as a Livestock Feed. Hendershott, C.H. et al - A Literature Review and Research Recommendations on Cassava
UNIVERSITY OF GEORGIA, USA, 1972

FAVIER, J.C. et al
Les Amylaces du Cameroun... (The Starch Crops of Cameroon; II Processing of Cassava. The Effect on Nutritive Value)
CENTRE DE L'OFFICE DE LA RECHERCHE SCIENTIFIQUE ET TECHNIQUE D'OUTRE-MER, Cameroon, 1969

GARROS, M.
Standardisation et... (Standardisation and Processing of Dry Cassava and Regulations Regarding Tapicoa) In Congrès du Manioc et de Plantes Féculentes Tropicales, Marseille, 1949
INSTITUT COLONIAL, Marseilles, France, 1949.

HORKAWAJ, S. et al
The Effect of Microbial Contamination on the Nutritive Value of Cassava Root Products. In Khon Kaen Univ. Fac. Agric. Cassava/Nutrition Project. Annual Report, 1979
Thailand, 1979

HOUSTON, R.C.
Dietary Nitroloside and Sickle Cell Anaemia in Africa
Letter to Editor, unidentified journal, 1976

IKEDIOBI, C.O. et al
A Rapid and Inexpensive Enzymatic Assay for Total Cyanide in Cassava and Cassava Products
AGRIC. AND BIOL. CHEMISTRY 44 (12): 2803-2809, Japan, 1980

INDONESIA DEPT. INDUSTRY
Muto dar Cara uji Tepung Gaplek (Quality and Methods for Analysis of Gaplek Flour)
Indonesia

INGRAM, J.S.
Standards, Specifications and Quality Requirements for Processed Cassava Products
TPI (Report No. G.102), UK, 1975

JANSZ, E.R. et al
Cyonogenic Glucoside Content of Manioc. II Detoxification of Manioc Chips and Flour
J. NAT. SC. COUN. SRI LANKA 2 (2): 129, 134, Sri Lanka, 1974

JOHNSTON, T.D. and MADRIGAL, L.G.
Metodoligia para el Estudio del Punto.... (Methodology in the Study of the Equilibrium Point of a Cassava Chip and Flour Factory in San Carlos de Alajuela, Costa Rica
CENTRO AGRONOMICO TROPICAL DE INVESTIGACION Y EN ENSENANZA, Costa Rica, 1977

KHAJARERN, J. et al
A Preliminary Study on Cyanide Toxicity in Broilers. Khon Kaen University Fac. Agric. Cassava/Nutrition Project Annual Report 1978, Thailand, 1978

KHAJARERN, J. et al
Biological Titration of Thai Cassava Root Products of Various Quality Grades with Broiler Chicks. In Khon Kaen Univ. Faculty of Agric. Cassava/Nutrition Project, Annual Report 1977
Thailand, 1978

KHAJARERN, J. et al
Determinationof Basic Chemical Parameters of Cassava Root Products of Different Origin, Processing Technology and Quality. Khon Kaen Univ. Fac. Agric. Cassava/Nutrition Project: Annual Report 1975-76
Thailand, 1977

KHAJARERN, J.M.
Determination of Basic Chemical Parameters of Cassava Root Products of Different Origin, Processing Technology and Quality. Khon Kaen. Univ. Faculty of Agric. Cassava/Nutrition Project: Annual Report 1977
Thailand, 1978

KHAJARERN, J.M.
Determination of Basic Chemical Parameters of Cassava Root Products of Different Origin, Processing Technology and Quality. Khon Kaen. Univ. Faculty of Agric. Cassava/Nutrition Project: Annual Report 1978
Thailand, 1979

KHAJARERN, J.
The Maximum Economic Replacement of Maize by Cassava Root Chips in Broiler Diets. Khon Kaen Univ. Faculty of Agric. Cassava/Nutrition Project: Annual Report 1975/76
Thailand, 1977

KHAJARERN, S.et al
Effect of Delayed Drying on Some Chemical Components of Cassava Root. A Preliminary Study. Khon Kaen Univ. Faculty of Agric. Cassava/Nutrition Project: Annual Report 1979
Thailand, 1979

KHAJARERN, S. et al
Substitution of Cassava Root Products for Cereals in Livestock and Poultry Feeds
ASIAN PACIFIC COUNCIL FOOD AND FERTILISER TECHNOLOGY CENTRE, EXTENSION BULLETIN No. 122, 1979

MADUAGWU, E.N. and ADEWALE, A.K.
Loss of Hydrocyanic Acid and its Derivatives During Sun Drying of Cassava. Terry, E.R. et al eds. Trien. Root Crops Symp. of Int. Soc. for Trop. Root Crops: Research Strategies for 1980s.
PROC. IDRC, Canada, 1981

MAINI, S.B.
Cassava: A Protein-rich Animal Feed
INDIAN FARMING 30 (11): 27, 29-30, India, 1981

MAINI, S.B.
Quality Aspects of Cassava. Hrishi, N. and Gopinathan Nair, R. (eds.) Cassava Production Technology
CENTRAL TUBER CROPS RESEARCH INSTITUTE, India, 1978

MEUSER, F. et al
Comparison of Starch Extraction from Tapioca Chips, Pellets and Roots
STARKE 30 (9): 299-306, Germany, 1978

MULLER, Z., CHOU, K.C. and NAH, K.C.
Cassava as a Total Substitute for Cereals in Livestock and Poultry Rations
WORLD ANIMAL REVIEW 12: 19-24, UK, 1974

NAIR, P.G. et al
Studies on the Physiochemical and Microbiological Characteristics of Market Chips of Tapioca
J. ROOT CROPS 4 (1): 25-30, 1978

NEMOTO, Y.
Estudo Sôbre a Toxidez... (Study on Toxicity of Bread Made from Cassava Chips Containing HCN)
REVISTA Alimentar 4 (33): 5-7, Brazil, 1940

NESTEL, B. and GRAHAM, M.
Cassava as Animal Feed - Proceedings of a Workshop Held at the Univ. of Guelph, 1977
IDRC, Canada, 1977

NESTEL, B. and MACINTYRE, R.
Chronic Cassava Toxicity - Proceedings of an Interdisciplinary Workshop, London, England, 1973
IDRC, Canada, 1973

OBIOHA, Dr. F.C.
Forms and Quality of Root Crops Products in Livestock Feeds. (Proc. 1st Nat. Seminar on Root and Tuber Crops, Umudike, March 1977)
NAT. ROOT CROPS RES. INST., Umudike, Nigeria, 1977

OBICHA, F.C.
Utilization of Cassava as a Human Food. In Hendershott, C.H. et al, A Literature Review and Research Recommendations on Cassava
UNIV. OF GEORGIA, Athens, USA, 1972

PIERIS, N. et al
Cyanogenic Glucoside Content of Manioc. An Enzymic Method of Determination Applied to Processed Manioc.
J. NAT. SC. CO. SRI LANKA 2 (1): 67-76, Sri Lanka, 1974

PIERIS, N. and JANSZ, E.LR.
Cyanogenic Glucoside Content of Manioc III. Fate of Bound Cyanide on Processing and Cooking
J. NAT. SCL COUN., SRI LANKA 3 (1): 41-50, Sri Lanka 1975

PILLAI, K.S.
Susceptibility of Cassava Chips to Araeceras fasciculatus. Symposium of the Int. Soc. for Trop. Root Crops, 4th, Cali, Colombia
IDRC, Canada, 1977

RAJAGURU, A.S.B.
Elimination of Hydrocyanic Acid from Processed Manioc Chips
J. NAT. AGRIC. SOC. CEYLON 9/10: 53-62, 1972-73

RAJAGURU, A.S.B.
Problem of HCN in Cassava
PEREDENIYA UNIVERSITY OF SRI LANKA, FACULTY OF AGRICULTURE, Paper no. 75-7, 1975

RICHARDS, D.
Growth of Cassava Use as Feedgrain Substitute Not Without Problems
FOREIGN AGRICULTURE 16 (51): 6-8, 1978

ROSSI, S.J. et al
Curvas de teor... (Moisture Level Equilibrium Curves and Latent Heat of Vaporization for Cashew Nuts and Cassava
REVISTA BRASILEIRA DE ARMAZENAMENTO 6 (2): 5-10, Brazil, 1981

SAIF, S.M.H.
Thermal Properties of Cassava Roots and Chips
MAG. SC. THESIS, ASIAN INSTITUTE OF TECHNOLOGY, Bangkok, Thailand, 1978

SCHMIDT, Dr. H.L.
Die Mikroflora der Maniok futtermittel (Microbiological Infestation of Cassava Animal Feed)
GETREIDE UND MEHL, Issue October 1966, pages 105-110.

SCHMIDT, H.L.
Die Mikroflora der Maniokafuttermittel (Microflora of Cassava Food Products)
GETREIDE UND MEHL 16 (10): 105-110, 1966

THAILAND MIN. ECON. AFFAIRS
Standards for Tapioca Chips
Bangkok, 1963

TILLON, J.P.
Utilisation du Manioc dans l'Alimentation des Porcs: Le Point de Vue du Pathologiste (Cassava in Swine Feeding: A Pathologist's Point of View)
ELEVEUR DE PORCS No. 97: 35-37, 1978

TPI (ANON)
Report on an Investigation into the Relationship Between Atmospheric Humidity, Temperature and the Equilibrium Water Content of Cassava Chips
TPI, UK, 1965

US DEPT. HEALTH, EDUCATION AND WELFARE/FAO et al
Food Composition Table for Use in East Asia
1972

VITTI, P. et al
Comparação de raspas... (Comparison of Cassava Chips made by Two Processes, and Use of Their Flours in Breadmaking)
BOLETIM DO INSTITUTO DE TECNOLOGIA DE ALIMENTOS 59: 89-98, Brazil, 1978

VITTI, P. et al
Estudo Sobre Tecnologia de Mandioca... (Technology for Cassava to be Used for Food)
INSTITUTO DE TECNOLOGIA DE ALIMENTOS, PROJETO ITAL, 41.2/75, Brazil, 1975

YEONE, S.W. et al
The Effect of Cassava Chip Quality on Their Use in Poultry Feeds
MARDI RESEARCH BULLETIN 6 (2): 180-185, Malaysia, 1978

MANAGEMENT, ORGANISATION AND INFRASTRUCTURE

ANON
Progress and Further Development of the Cooperatives in Indonesia
MINISTRY FOR COOPERATIVES, Jakarta, Indonesia, 1982

BARBERIS, C.
Aspetti della Cooperazione... (Co-operative Project for Producing Cassava Chips in Togo)
RIVISTA DI AGRICOLTURA SUBTROPICALE TROPICALE 70: 67-75, Italy, 1976

BULOG
The National Food Grain Authority of Indonesia, A Short Introduction
BULOG, Indonesia, 1982

BULOG (The National Logistics Agency)
Food/Rice Price Stabilization in Indonesia. Annual Reports 1979/80, 1981/82, 1982/83
BULOG, Indonesia, 1980-83

ESCOTO, R.
Rural Industrialisation in Costa Rica. Case Study of the Co-operative Union URCOZON in the San Carlos Region
UNIDO, Industry and Development No. 4: 68-85, Vienna, 1979

TITAPIWATANAKUN, B.
Regional Co-operative Activities in Tapioca Products
UNDP (UN Economic and Social Commission for Asia and the Pacific) (Trade Co-operation Group Project RAS/79/010), 1981

ECONOMICS

ANON
Estudio Agro-Económico del Procesamiento de la Yuca on le Región Non-oriental de Barlovento
1976

ANON
Figures Relating to Demand and Price Structures of Thai Tapioca Market (2 sheets)

ANON
Latin America. Trends Highlights, on Beans, Cassava, Beef, Corn, Rice, Swine and Fertilisers
CIAT, Colombia, 1978

ANON
Mandioca, Produtos Tem Custo Elevado (High Costs of Cassava Products)
DIRIGENTE RURAL 19 (9/10): 52-53, 1977

ANON
Subsidios para Fixação de Preços.... (Subsidies for Setting Minimum Prices for Cassava Meal in the State of Amazonas)
ASSOCIACAO DE CREDITO E ASSISTENCIA RURAL DO AMAZONAS - SECRETARIA DO ESTADO DE PRODUCAO RURAL, 1975

ANON
Table - Price Spread of One Candy (480 lb) of Tapioca Chips in the Travoncore-Cochin States

ANON
The Chips are Down and the Stakes are High
INVESTOR 1974: 73-74, UK, 1974

AYRES, J.C.
Manioc: The Potential Exists for Increased Use of This Tropical Plant and its Products
FOOD TECHNOLOGY 26 (4): 128-132, 134, 136, 138, UK, 1972

BAKER, J.C.
Structure and Outlook: Tapioca Processing Industry in Thailand.
PLANTER (Malaysia) 57 (666): 500-505, 1981

BONOMI, A. and BRANCO, J.R.C.
Etanol de Mandioca... (Cassava Ethanol: Technoeconomic Evaluation). In Congresso Brasileiro de Mandioca 1.
Brazil, 1979

BRANNEN, S.J.
Economics of Cassava Production and Marketing. Hendershot, C.E. et al. A Literature Review and Research Recommendations on Cassava
AID CONTRACT No. csd/2497, pp 222-254 Athens, Univ. Georgia, USA, 1972.

CAMARGO FILHO, V.P. de
Mandioca.... (CassavA Production, Economic Importance and Marketing
COORDENADORIA DE ASSISTENCIA TECNICA INTEGRAL, Sao Paulo, Brazil, 1977

CHECCHI and COMPANY, WASHINGTON
Prospects for a Tapioca Starch Industry in Guinea
Washington, USA, 1964

CROWN, F.
White Elephant Tales: Venezuela's Cassava Processing Plants
AGRIBUSINESS WORLDWIDE 2 (1): 24-29, 1981

FALCON, W.P., DIXON, J.A. et al
Cassava on Java: Policy and Economics (draft report)
UK, 1982

FAO/ICP
Joint ICP/FAO Bankers Programme Reconnaissance Mission to Colombia, Report 1974
Rome, 1974

FLINN, J.C.
Possibilities for Economic Research into Cassava Production Systems in Africa. In Terry, MacIntyre eds. The Int. Exchange and Testing of Cassava Germplasm in Africa - Workshop Proc., Ibadan, Nigeria, 1975
IDRC, Canada, 1976

HONE, A.
The Importance of Tapioca as a Foodstuff, Feeding Material and Industrial Raw Material in India: With Particular Reference to Kerala State
INST. COMM. STUDIES, Oxon, UK, 1973

LOHANI, B.N. and THANH, N.C.
Statistical Modelling of Tapioca Drying in Thailand. Agricultural Mechanisation in Asia 9:75-80, 1978

LYNAM, J.K. and PACHICO, D.
Cassava in Latin America: Current Status and Future Prospects
1982

McCANN, D.J. and SADDLER, H.D.W.
A Cassava-based Agro-industrial Complex. I. Financial Considerations, II. Technological Considerations.
PROCESS AND CHEMICAL ENG. 28 (4): 23-27, 1975

MINSTER AGRICULTURE LIMITED
The Role of Cassava in Kenya - A Discussion Document
MINSTER AGRICULTURE LIMITED, UK, 1980

NELSON, G.C.
Implications of Developed Country Policies for Developing Countries: The Case of Cassava (PhD Thesis)
STANFORD UNIVERSITY, California, USA, 1982

PHILLIPS, T.P.
A Study of Mandioca as a Raw Material for Alcohol Production in the Northeast
UNIVERSITY OF GUELPH, Ontario, Canada, 1979

SUPERINTENDENCIA DO DESENVOLVIMENTO DO NORDESTE (Brasil)
Estrutura dos Custos... (Agro-industrial Cost Structure for Cassava Flour
RECIFE, Brazil, 1967

TITAPIWATANAKUN, B.
Cassava Industry in Thailand (Thesis)
THAMMASAT UNIV., Bangkok, Thailand, 1974

TITAPIWATANAKEN, B.
Production Cost of Tapioca Products in Thailand
Thailand, 1981

TRUJILLO, C.F.A.
Industrialización de la Yuca en Colombia:... (Industrialisation of Cassava in Colombia: Financial Analysis of the Production of Chips)
INST. CENTROAMERICANO DE AMINISTRACION DE EMPRESAS, TESIS MAG. SC., Managua, Nicaragua, 1976

USDA Foreign Agricultural Service
Attache Report, Thailand: Annual Agricultural Situation and Policy Report
USDA, USA, 1983

VALDES, S.H.
The Importance of Cassava Processing in the Economy of Colombia. 4th Symp. of Int. Soc. Tr. Root Crops, Cali, Colombia, 1976
PROC. IDRC, Canada, 1977

WALTERS, P.
Manioc Poised for Major UK Compound Role?
AGRITRADE 1978: 20-23, 62, 1978

MARKETING AND TRADE

ANON
Manioc - Asian Exports to European Countries Could Reach 1.1M Tons by 1970
FAR EAST TRADE AND DEVELOPMENT 24 (4): 238-239, 1969

ANON
O Problema Internacional do Pellet da Mandioca (The Cassava Pelletizing Industry in Brazil and its Marketing Perspectives)
PAVON ENGENHAVIA E INDUSTRIA, Brazil, 1973

DIAZ, R.O. et al
Aspectos del Mercadeo de la Yuca (Aspects of Marketing Cassava)
CIAT, Colombia, 1977

HENNINGSEN, M.F. and BALINT, A.B.
Notas Sobre las... (Notes on the Possibilities of Exporting Dried Cassava Chips and Slices)
INSTITUTO NACIONAL AGRARIO, Honduras, 1970

INTERNATIONAL TRADE CENTRE/UNCTAD/GATT
Cassava Export Potential and Market Requirement
ITC, Geneva, 1977

JONES, S.F.
The World Market for Starch and Starch Products with Particular Reference to Cassava (Tapioca) Starch
TROPICAL DEVELOPMENT AND RESEARCH INSTITUTE (Report No. G 173), UK, 1983

PHILLIPS, T.P.
Cassava Utilization and Potential Markets
IDRC, Canada, 1974

PHILLIPS, T.P.
Prospects for Processing and Marketing Cassava Products as Animal Feed
World Animal Review No. 31: 36-40, UK, 1979

PINHEIRO, A.A.
Mandioca (Cassava)
GUIA DA COMERCIALIZACAO RURAL 1970: 166-170, Brazil, 1970

SERE, C. et al
Trends in CIAT Commodities
CIAT, Internal Documents - Economics, 1-8, Colombia, March, 1983

THAI TRAPIOCA TRADE ASSOCIATION
Regular Issues of Statistics - Tapioca Products Market Review (monthly), Tapioca Chips, Pellets and Hard Pellets Expert Figures
Thailand, 1983

TITAPIWATANAKUN, B.
Changes in Agricultural Wholesale Marketing in Thailand: A Case of Maize and Cassava
DEPT. AGRIC. ECON., KASETSART UNIV., Bangkok. Staff Paper No. 39, Thailand, 1980

TITAPIWATANAKUN, Maize and Cassava Marketing in Thailand
KASETSART UNIV. EXTENSION BULLETIN (ASPAC/FFTC) No. 153: 10-19, Thailand, 1980

TITAPIWATANAKUN, B.
The Role of Transnational Corporation in Tapioca Trade
DEPT. AGRIC. ECON. KASETSART UNIV., Bangkok, Staff Paper No. 47, Thailand, 1982

UNNEVEHR, L.J.
Cassava Marketing and Price Behaviour on Java (PhD Thesis)
STANFORD UNIV. California, USA, 1982

UNNEVEHR, L.
Cassava Marketing on Java
STANFORD UNIV. CASSAVA PROJECT, USA, 1979