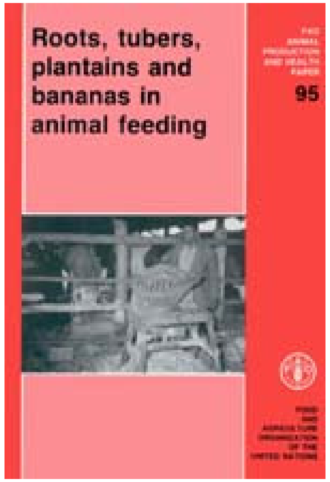

FAO ANIMAL PRODUCTION AND HEALTH PAPER 95

Roots, tubers, plantains and bananas in animal feeding

Contents

Proceedings of the FAO Expert Consultation held in CIAT, Cali, Colombia 21–25 January 1991

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Introduction

The FAO Expert Consultation on Roots, Tubers, Plantains and Bananas in Animal Feeding was held in Colombia at the Centro Internacional de Agricultura Tropical (CIAT) near Cali, from 21 to 25 January 1991.

BACKGROUND

Over the last two decades the total amount of animal feed used in developing countries has increased rapidly so that by 1988 approximately 280 million tons were produced. More than half of this feed (149 m.tons) was produced from cereals, of which more than 38 million tons were imported in the late 1980's. During the 1970's the use of cereals in animal feed in developing countries was estimated by FAO to have increased by 7.1% per annum whilst in the 1980's the rate of increase was 2.8%.

Levels of imports of this order clearly place pressure on limited foreign exchange supply, whilst the overall use of cereals and other feedstuffs, used in this way, might well be at the expense of human need.

The main purpose of such feed use is to increase the production and availability of animal protein within such countries, for which there is a clear need. In order to achieve a rapid increase in the production of such products, many developing countries have directly transferred technologies from developed, often temperate countries. Often this has involved the direct use of raw materials of temperate origin at the expense of potential local equivalents. Often such local materials outyield more conventional feedstuffs (though sometimes requiring more handling and processing) or may even be byproducts of other industries which are poorly used or discarded.

The incentives to develop appropriate livestock systems, based largely on locally produced materials, have not been sufficient in many developing countries till recent times. Now many such countries are experiencing population pressure with increased demands on both food supply and foreign exchange, difficulties in servicing foreign debts and reduced earnings from exports. As a result FAO has on various occasions been requested by developing countries to assist them to develop local substitutes for imported materials for animal feeding. Concern has been expressed on this subject in many regions of the developing world and in particular in Asia, the Near and Far East, the Pacific and Latin America.

In order to resolve this problem it is strongly felt that livestock production systems should be developed for developing countries, matching locally available resources and in particular feed resources to local needs.

PURPOSE

This Expert Consultation was aimed at establishing:

- the current availability of roots, tubers, plantains and bananas around the world for use in animal feeding and the potential that exists for greater production and use;
- the technology that is available, and that likely to be available, for harvesting, processing, preserving and storing the above materials so that they can be used as feeds for livestock;
- the nutritional value of the above products for the various livestock classes and practical ways of feeding these materials;
- the effects of using these materials to replace conventional animal feedstuffs on developing countries farming and national economies.

OPENING SESSION

The speech of welcome was delivered by Dr C. Bastanchuri, FAO Representative in Colombia. First of all he thanked the Director-General of CIAT, Dr G. Nores, and his staff for so generously welcoming the consultation and for the active participation in the preparation of the meeting.

In his speech he reminded the participants of the great needs to resolve the economic problems of developing countries through making them less dependent on exports of primary materials. He also emphasized that this consultation particularly addressed this problem and that the presence of Dr. Jaime Navas Alvarado, who is deputy director of the Instituto Colombiano de Agropecuaria, reflected the importance that the Colombian Government gave to the subject to be considered.

Dr. Alvarado then gave an address of welcome on behalf of the Colombian Government. He confirmed the great interest in his country towards becoming more self sufficient in animal feeds and agreed that the subjects under discussion would be particularly relevant to the national and regional situation. He also noted the great spread of international interest in the subjects covered which was reflected in the range of countries from which the experts were drawn. From this he concluded that major breakthroughs in the field would have particular significance in many countries undergoing development problems. In particular he hoped that the presence of such an experienced group of experts interacting with staff of CIAT and other Colombian contacts would greatly facilitate the exchange of ideas and information between countries and regions for the common good of all.

Dr. Gustavo Nores, Director-General of CIAT, gave the opening speech and welcomed all participants. He stated his pleasure in hosting the consultation because of the tremendous

importance of the event in relation to the challenges the world scientific communities will face over the coming decades to make technologies available that will link the growing numbers of small farmers to expanding markets.

In particular, he pointed out that the fastest growing demand in the developing countries is for animal products to which this particular consultation was specifically addressed. Also he noted that with cereal prices likely to drop over the next decade producers of commodities addressed in this consultation would be under greater competitive pressure. The development of more appropriate and economic technology would greatly assist such producers to compete effectively.

Prior to the introduction session a short speech was given by Dr. D.H. Machin, technical secretary of the Expert Consultation. He explained that the consultation fell within the overall framework of meetings organized by the Animal Production and Health Division of FAO in the last ten years, to review the possible feed resources present in the developing world and to promote a better utilization of these local feed resources in such countries.

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Overview of needs and justification for use of roots, tubers, plantains and bananas in animal feeding

by D.H. Machin

INTRODUCTION

Over the past twenty years many developing countries have experienced considerable difficulties in providing sufficient food to satisfy the ever increasing demands of expanding populations.

In order to meet these needs they have looked to transfer technology from developed countries. Often this technology has been developed for temperate rather than the tropical or subtropical environments common to most developing countries. Due to the close environments interaction between crops and their environment only certain aspects of temperate technology could be utilized. For this reason cropping systems that were developed had to be designed for each environment in order to function at all. However, in the case of livestock, which are less environmentally sensitive, it was possible to transfer not only technology but whole systems, including animals, building designs and feeds.

Many of the developing countries that followed this approach to resolving livestock production deficits were able to finance such activities through the export of primary products, such as oil, minerals, tea coffee, etc., or by borrowing.

Over the last decade the above practice has commonly proved to be financially unsustainable due to:

1. **escalating demands for livestock products, from expanding and increasingly urbanised**

populations, outstripping the amount of foreign exchange available to purchase the necessary inputs.

2. reduced amounts of foreign exchange available for continued importation caused by falling earnings from the export of many primary products and the need to allocate greater amounts of foreign exchange to finance earlier borrowings.

For the above reasons FAO has on various occasions been requested by developing countries to assist in seeking effective means of resolving these problems. This expert consultation constitutes part of the initiative to try to resolve this problem.

UTILIZATION OF CEREALS FOR ANIMAL FEEDING IN DEVELOPING COUNTRIES

The use of cereals for animal feeding in developing countries was recently considered at the meeting of the Intergovernmental Group on Grains (IGG), held in FAO, Rome in November 1990 (FAO, 1990). The report prepared for this meeting showed (Table 1) that of the total of 900 million tons of compound feed, in grain equivalents, used worldwide in 1988, around 280 million tons were used in developing countries (grain equivalent refers to the feed value of 1 kg of barley in terms of metabolisable energy and protein). Of this total more than half (149 million tons) consisted of cereals, including 127 million tons of coarse grains, 12 million tons of wheat and surprisingly 10 million tons of milled rice.

TABLE 1.**Estimated World utilization of livestock feed in grain equivalents**

	World			Developing countries		
	Output	Growth rate		Output	Growth rates	
	1988	1971–80	1981–88	1988	1971–80	1981–88
	(m.tons)	(percent/year)		(m.tons)	(percent/year)	

Concentrates	900	2.4	1.8	279	5.8	3.3
Cereals*	623	2.4	1.1	149	7.1	2.8
Oil meals**	119	4.8	3.3	36	4.7	4.0
Brans & by-products	110	2.3	2.1	74	3.7	2.8
Roots & tubers	32	-0.5	2.4	17	2.9	3.9
Pulses	17	-1.3	12.3	3	1.4	1.9

* ***Cereals including rice in milled form.***

** ***Includes fishmeal, tonnages are expressed in grain equivalents*.**

Source: FAO 1990.

The IGG meeting also assessed the international trade in animal feed. The briefing report showed that whilst developing countries were net exporters of grains (approximately 5 million tons) in the early 1970s they had become net importers by 1988 to the extent of about 21 million tons. It is also of particular interest to note that estimates indicate that between 75 and 80 percent of all shipments to developing countries are cereals used for animal feed production.

The replacement of these imports by local alternatives would enable developing countries to save considerable foreign exchange, which would otherwise have been needed to purchase the imported material, as well as pay related shipping and transport charges. At the same time, the development of local industries to produce substitutes for imported feedstuffs could stimulate local industrial activity and help increase local employment opportunities.

THE NEED FOR INCREASED ANIMAL PROTEIN PRODUCTION IN DEVELOPING COUNTRIES

It is predicted that the population of the world will rise to around 6.25 billion from a current estimate of 5.29 billion by the year 2000 (Table 2). As a consequence the world population will have doubled from that of 1960. Clearly more feed of every type will be required. The current systems of feed production seem to be largely unsustainable and in particularly those associated with the production of animal protein. The clearance of forests to produce land to graze animals, overgrazing of these and existing lands, together with methane and carbon dioxide produced by such activities are currently believed to be implicated in world environmental problems. It is therefore clear that more appropriate and sustainable systems of livestock production and feeding will need to be developed to meet both the current needs and future expansion.

World *per capita* protein production estimates are shown in Table 3. These show that total protein supplies in developing countries (57.6g in 1983) were around half those of developed countries (99.2g in 1983), of which approximately 20% was animal protein in developing countries but 50% in developed countries.

TABLE 2. **World Population Growth by Decade, 1950–90, with Projection to 2000.**

Year	Population (billions)	Increase by decade (millions)	Average annual increase (millions)
1950	2.515		
1960	3.019	504	50
1970	3.698	679	68
1980	4.450	752	75
1990	5.292	842	84
2000	6.251	959	96

Source: United Nations, Department of International Economics & Social Affairs, World Population Prospects 1988 (New York: 1989)

There is considerable discussion amongst human nutritionists and dieticians on the need to include protein of animal origin in human diets. It is however clear that animal protein is generally more digestible that plant protein, the amino acid balance of the animal protein more closely matches human requirements, other essential nutrients are more common in such products such as iron, calcium, phosphorus, etc. and there are generally less toxicological problems associated with the use of animal products. For these reasons, it is generally easier to obtain a balanced wholesome diet, where animal proteins provide a significant proportion of the total protein consumed.

Reference to Tables 3 and 4 indicates that in theory the amount of total protein available in developing countries should be sufficient to meet the overall populations needs. For this statement to be true it must be assumed that the protein is distributed according to the need and that the protein available is of adequate quality. Table 4 was prepared to indicate the total and variation in protein need by humans of varying age and sex. It is also particularly pertinent to note that the "Safe level of Protein Intake" referred to is based on protein having the quality and digestibil-

TABLE 3. **Per Capita Supplies of Total and Animal Protein (in grams per day)**

		Total Protein	**Total Animal Protein**	**of which from**			
				Meat	**Milk**	**Fish**	**Eggs**
World	1971–73	65.1	21.5	10.0	6.6	3.3	1.6
	1981–83	68.3	23.1	10.9	6.8	3.7	1.7

Developing	1971–73	52.7	9.2	4.1	2.5	2.1	0.5
Countries	1981–83	57.6	11.3	5.1	3.1	2.3	0.8
Developed	1971–73	96.0	52.3	24.6	16.8	6.8	4.1
Countries	1981–83	99.2	56.8	27.3	17.4	7.7	4.4

***Source: FAO Economic and Social Development Paper, No. 80, aspects of the world feed-livestock economy; Structural changes, prospects and issues (Rome, 1989)*.**

TABLE 4.**Example of Safe Protein Intake for a Family Group of Varying Age and Weight**

Family Group Member	**Age (yrs)**	**Weight (kg)**	**Safe Level of Protein Intake (g/day)***
Grandfather	60+	65	49
Grandmother	60+	50	37.5
Male	30–60	70	52.5
Female	30–60	55	41
Female (non pregnant)	18–30	55	41
" (pregnant)	18–30	55+	47
" (lactating)	18–30	55+	58.5
Children:			
Male	14–16	55.5	52
Female	14–16	52	46
Male	10–12	34.5	34
Female	10–12	36	36
Male/Female	3–5	16.5	17.5
Baby	under 1	7–10	14

** Based on protein with the quality and digestibility of milk or egg.*

Source: Data extracted from: Energy and Protein Requirements, Report of a Joint FAO/WHO/UNU Expert Consultation, Technical Report Series, No. 724, World Health Organization, Geneva, 1985 ity of milk or egg. In practice it is likely that many of the most vulnerable members of societies in developing countries will be receiving the minimum (or less) quantity of protein and this will be mostly of vegetable origin. For this reason it is likely that a large proportion of such societies will be receiving diets deficient in many of the essential nutrients of proteinaceous origin.

It would therefore appear that increasing the production and availability of animal protein in developing countries is of significant importance if the human populations of such countries are to be adequately fed.

ALTERNATIVE TECHNOLOGIES FOR REPLACING IMPORTED FEED MATERIALS AND MATERIALS FOR WHICH HUMANS COMPETE

There is a range of measures that developing countries can implement in order to alleviate the above mentioned problem. These include:

1. Maximizing the efficiency of current livestock production systems so that all existing resources, including human skills, animals, livestock facilities and feeds are used as efficiently as possible.

2. Establishing what agro-industrial byproducts, that could be used in animal feeding in a country, are currently either unused or used inefficiently and if their use is economically

viable use these to replace imported or human feeds.

3. Developing local crops that can be grown to supply the nutrients currently obtained from imports or feeds that might be better used by humans.

The particular materials to be considered in this consultation clearly fall into the latter two categories, though all points should be considered in resolving the overall problem. In particular, the first measure listed above is particularly relevant to the application of the last two. Even in developed countries with well established traditions of byproduct utilization the value of "wastes" (byproducts) or non-traditional feedstuffs has till very recently been disdainfully undervalued. In many such countries this view has now been replaced with an appreciation of their true worth, to such a point, that the profitability of many livestock industries now depends on the use of feeds largely consisting of byproducts. This change in the traditional approach to livestock feeding has now led to a more commercial approach to nutrient supply, involving the use of crops on the basis of the yields of total nutrients per unit of land and the cost of production of each nutrient. On this basis alone this should result in the utilization of less cereal and more root and tuber crops in many traditionally cereal producing areas (it is of interest to note that the Netherlands are currently using less than 15% cereal in its feed industry).

It is therefore quite clear that wholesale transfer of livestock systems from dissimilar environments is not likely to be either the most economically, nor productively efficient. Most situations, even at individual farm level, are sufficiently different to merit the development of individually designed systems, taking into account local factors and applying fundamental scientific and economic principles.

MATERIALS THAT COULD BE REPLACED BY ROOTS, TUBERS, PLANTAINS AND BANANAS

Cereals generally make up between fifty-five and eighty-five percent of most conventional compounded animal feeds, where they supply a major part of the nutrients provided. Tables 5 and 6 respectively, show a range of compositions for the most commonly produced feeds and cereals. From these it is possible to see that cereals, used at the levels indicated above, will provide not only the main part of the energy in feeds, but a significant part of the total protein, together with minerals and vitamins.

Proteins and essential fatty acids are generally supplied from oilseed cakes and meals and animal and fish protein products, many of which originate from the regions of the world in which most developing nations are located. Developing countries are in fact net exporters of these materials. Over the last two decades these exports expanded at the rate of 6.8 percent a year to reach a level of 29 million tons in the late 1980s.

Considering the above points it would appear that replacement of the cereal component of feeds is likely to offer a beneficial first step towards alleviating animal feed supply problems. The second step should then be to increase the supply of feedstuffs so that animal production can be increased and greater amounts of meat and livestock products made available to all.

TABLE 5.**Compositions of a range of typical compounded animal feed**

Feed	Protein %	Energy MJ/kg*	Oil %	Fibre %	Calcium %	Phosphorus %
Broiler Starter	23.0	12.7	3.0	3.0	1.0	0.7
Broiler Finisher	19.0	13.1	3.0	3.0	1.0	0.6
Layer	17.0	11.7	2.0	3.0	3.5	0.6
Pig Breeder	15.0	12.7	3.0	5.0	0.8	0.6
Pig Fattener	16.0	13.0	3.0	3.0	0.8	0.6

Calf Rearer	15.0	11.0	2.0	6.0	1.0	0.7
Dairy Cow	15.0	10.7	2.0	8.0	1.0	0.6

**** Metabolisable Energy, monogastric or ruminant***

TABLE 6.**Composition of a range of cereal grains used in animal feed production**

Cereal	Protein %	Energy MJ/kg*	Oil %	Fibre %	Calcium %	Phosphorus %
Maize	9.0	14.2	4.0	3.0	0.02	0.25
Millet	11.0	12.5	3.5	8.0	0.03	0.30
Sorghum	10.0	13.8	3.0	2.5	0.04	0.25
Rice (rough)	8.0	11.2	1.5	9.0	0.10	0.32
Wheat	11.0	13.0	2.0	3.0	0.05	0.35

**** As for table 1***

TABLE 7.**Composition of a range of root, tuber, plantain and banana products (dry matters)**

Product	DM* %	Protein %	Energy * * MJ/kg	Oil %	Fibre %	Calcium %	Phosphorus %
Cassava Root (whole)	36.2	2.8	14.0	0.7	1.6	0.1	0.02
Cassava Leaf	17.8	25.4	9.9	3.7	10.2	1.5	2.4
			(9.2)				
Sweet Potato Root (whole)	59.0	5.2	13.5	1.2	2.6	0.2	0.2
Sweet Potato	10.8	19.4	5.8	3.6	12.6	1.8	0.2
Leaf			(10.0)				
Plantain Fruit (mature)	29.4	4.0	14.5	0.8	1.1	0.8	0.3

Banana Fruit (ripe)	31.0	5.4	15.2	0.9	2.2	0.2	0.1
Banana/Plantain	16.0	6.4	3.5	0.8	23.7	0.9	0.3
Plant			(9.9)				

*** DM = Dry Matter***

*** * Metabolisable Energy values for monogastrics, ruminant values in brackets***

The plant materials identified for particular consideration in this consultation, to replace cereals, are listed in table 7. This table also includes an example range of compositions of primary raw materials that may be derived from these plants. A comparison of the compositions of the cereals and the possible substitutes being considered here produces the following conclusions:

1. **That, on the basis of their composition alone, the roots, tubers and fruits of plants being considered here would appear to have considerable potential to provide a considerable amount of the nutrient at present provided by cereals in animal feeds.**

2. **Although the materials refered to in 1. would appear to be able to completely replace the energy component in livestock feeds, they would be unable to provide other nutrients as well as cereal grains. However, the use of a combination of such materials with leafy material from the same plant, although reducing the energy component, could produce a blend of nutrients that could largely substitute for cereals.**

3. **The lower protein content of possible alternatives referred to in 1. could also be compensated for by better utilization of locally produced protein sources, which are at present exported, or the use of proteinaceous agro-industrial byproducts, azolla, etc.**

Roots, tubers and plantains: recent trends in production, trade and use

by C. Calpe[1]

INTRODUCTION

Following the world food crisis in the early seventies, many countries invested in irrigation, agricultural research and fertilizer subsidies, which resulted in a strong growth in world cereal production. These factors, however, had few, if any, positive effects on the production of other staples such as roots, tuber and plantains (RTPs), which often continued to be considered as "inferior foods", being displaced from their more fertile lands by cereals. Furthermore, the expansion of the livestock and poultry sector indeveloping countries over the last two decades relied mainly on feed grain imports rather than on the exploitation of the potential of domestically produced RTPs for feed use. Section II of this paper reviews the changes in production, utilization and trade of RTPs over the last decade or so, and, because the scope of this Workshop is mainly to assess the potential for these products as feeds, special attention is placed on this aspects. Section III focuses on cassava, which unlike other RTPs, developed as an important feed ingredient traded internationally. The special conditions which made this development possible are examined.

STATISTICAL REVIEW

Changes in production, trade and consumption patterns, 1976–78 to 1986–88

Statistics on production, trade and utilization on RTPs are generally poor. Except for potatoes, which are mostly cultivated as a cash crop, estimates for the other RTPs are often difficult to obtain as they are mostly “subsistence crops” and are little marketed outside their immediate areas of cultivation. This section relies on FAO Food Balance Sheets, which despite some shortcomings (particularly regarding trade statistics), are the only source providing complete country coverage on supply/ utilization for these products. Because the information on “minor” roots such as taro and yam is even more limited and as they are important only in particular regions, this paper mainly deals with potatoes, sweet potatoes, cassava and plantains.

[1] Presented by S. Nyvold.

World production of *roots and tubers* stagnated over the last decade reaching 580 million tons in 1986–88 compared with 571 million tons a decade earlier (Table 1). Similarly the production of *plantains* remained virtually unchanged around 24 million tons. These poor production performances contrasted with a relatively high growth in cereal production estimated at close to 2 percent per annum over the same period. International trade in fresh RTPs is small mainly because of their bulkiness and perishability, but in the processed form it has developed, with the opening of new markets for feed especially for cassava products. In addition, border trade in RTPs may be important in regions such as Africa and Latin America but is often not officially recorded. International trade statistics are thus likely to underestimate the actual volume of trade in those products.

Among roots and tubers, the largest at the global level is potatoes. World *potato* output was stable between 1976–78 and 1986–88 at around 282 million tons: there was a significant expansion in developing countries and a decline in the developed countries, which still

produced about three-quarters of the total in 1986–88. Potato production in developing countries rose by some 26 percent over the period, or by an average rate of over 2 percent per annum, from 56 million tons in 1976– 78 to close to 71 million tons in 1986–88. About 65 percent of the developing countries production was concentrated in the Far East (China alone accounting for 40 percent) where a 2 percent annual growth was recorded. Output grew fastest in the Near East (6 percent per annum) and Africa (3 percent per annum), albeit from very small production bases.

TABLE 1.**Production of cereals, roots and tubers and plantains**

	Cereals		**Roots & tubers**		**Potato**		**Sweet potato**		**Cassava**		**Plantains**	
	1976–78	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**
	Millions MT											
WORLD	1433.3	1688.9	571.2	579.6	281.9	281.3	163.3	**151.9**	**117.5**	**137.4**	**24.1**	**24.3**
Developed countries	797.9	839.9	228.7	213.4	225.9	210.6	2.3	**2.3**	**-**	**-**	**-**	**-**
North America	308.9	314.5	19.4	20.0	18.8	19.4	0.6	**0.6**	**-**	**-**	**-**	**-**
Western Europe	154.1	190.6	51.1	48.2	50.9	48.1	0.1	**0.1**	**-**	**-**	**-**	**-**
Eastern Europe	290.3	288.3	150.7	136.6	150.8	136.7	0.1	**-**	**-**	**-**	**-**	**-**
Oceania	19.8	23.2	1.0	1.3	-	-	-	**-**	**-**	**-**		
Other developed countries	24.8	23.3	6.5	7.3	4.4	5.1	1.5	**1.6**	**-**	**-**	**-**	**-**
Developing	635.4	849.0	342.6	366.2	56.0	70.8	161.0	**149.6**	**117.5**	**137.4**	**24.1**	**24.3**

Africa	44.9	59.6	80.2	97.8	2.9	4.0	26.0	**29.5**	**46.4**	**59.2**	**17.7**	**17.5**
Latin America	82.7	104.5	45.9	46.4	10.3	12.2	3.3	**3.0**	**31.6**	**30.5**	**5.4**	**5.9**
Near East	52.9	66.4	5.6	9.6	5.2	9.2	0.2	**0.2**	**-**	**-**	**-**	**-**
Far East	454.8	618.5	209.5	210.9	37.6	45.4	130.8	**116.1**	**39.3**	**47.4**	**1.0**	**0.8**
Other developing countries	-	-	1.4	1.6	-	-	0.7	**0.8**	**0.1**	**0.2**	**-**	**-**

Although trade in potato products rose considerably between the tworeference periods (from 5–6 million tons to 9–10 million tons) it continued to account in 1986–88 for only three percent of world production (compared with around 13 percent for cereals). Furthermore, it was heavily concentrated in Western Europe, which accounted for 70 percent and 74 percent of world imports and exports respectively.

As regards potato utilization, about half of the world total is estimated to be consumed as food, one quarter is fed to animals and the rest is used as planting material, processed or wasted. Feed use of potatoes is very high in China, where it was estimated to exceed 35 percent of total utilization in 1986–88. The relatively large use as feed is probably because of difficulties with inland transportation in this country which encourages considerable local and on farm use of roots and tubers. Elsewhere the quantity of potatoes fed to animals only represented a small share of supply. Thus, while potatoes are mainly used for human consumption, in certain circumstances, such as where there is low tuber quality, feedstuffs shortages or poor marketing structures, they are used as feed.

***Sweet potatoes* are mostly grown in developing countries which accounted for over 98 percent of world output, China alone producing about three quarters of the total. Between 1976–78 and 1986–88, world sweet potato production fell from 163 million tons to 158 million tons as a result**

of low output in China where land was increasingly diverted to cereal cultivation. By contrast, production rose by an overall 13 percent in Africa to some 30 million tons in 1986–88. Production in the other regions was basically unchanged over the period. The constraints to the expansion of sweet potato production vary from country to country. In many producing areas, yields have failed to improve due to varietal degeneration as some varieties are often grown for many years and even decades. In addition, there appear to be few incentives to use agricultural chemicals on sweet potatoes. Producer prices do not make their application economical, and a lack of markets has hindered the expansion of production.

International trade in sweet potatoes was practically non-existent in 1976–78, although unrecorded transactions are likely to have taken place. In the second half of the eighties, sweet potato trade was boosted by EEC import demand for feed. Since 1987 exports from China to the European Community have been regulated through a bilateral agreement which set an annual ceiling of 600 000 tons of dry sweet potato chips (about 1.5 million tons of roots), which could enter EEC member countries free of duty. This development resulted in a sharp increase in sweet potato trade which averaged about 1.4 million tons in root equivalent in 1986–88. In recent years, however, trade in sweet potatoes has fallen, mainly reflecting China's inability to fulfil its quota to the EEC. This was probably due to domestic transportation problems as well as increasing requirements in China itself. Elsewhere, the sweet potato trade has remained extremely limited.

On the utilization side, world food consumption of sweet potatoes is estimated to account for over 50% of supply while 30% is estimated to be feed and the remainder used as planting material, processed or wasted. Feed use in China is thought to be of the order of 20 percent of availability, a proportion that falls to 16 percent for developing countries as a whole. In Africa, however, only 3 percent of supply is estimated to be feed and over 20 percent wasted. This could indicate the existence of some potential in this region for larger on-farm use as feed if

waste could be cut.

***Cassava*, which is almost exclusively grown in developing countries, is the only root for which global production rose to a significant extent over the decade under review. Between 1976–78 and 1986–88 world output expanded by 17 percent from 117 million tons to 137 million tons (or 1.6 percent per annum) as a result of significant growth in Africa, where cassava is often a staple food. This reflected, to some extent, the recognition by farmers and Governments, particularly after the 1984 drought, of the role that cassava plays in food security, since it is much less sensitive to climatic conditions than most cereals and other RTPs. The adoption by certain countries (e.g. Nigeria), of policies intent on reducing cereal imports also acted as an incentive to increase cassava plantings in recent years.**

The underlying factors behind cassava growth in the Far East were of a different nature, and basically related to the development of export markets by Thailand and to a lesser extent Indonesia. In Latin America, by contrast, production stagnated or fell due to lack of production incentives and competition in demand from cereals, which was only partially compensated for by the development of new markets for feed, particularly in Colombia and Brazil.

World trade in cassava products also experienced a significant increase over the period, rising from 15–17 million tons in 1976–78 to some 27–32 million tons a decade later. This sharp increase was stimulated by the growth of the EEC markets for cassava, albeit for restricted quantities. EEC cassava imports have been regulated since the early 80s through bilateral trade agreements with major exporters. In addition, new markets have developed since the mid-eighties and particularly in the far East (see next section).

World cassava production is mainly for food consumption, which accounted for 58 percent of supply in 1984–86. About 28 percent was estimated to be fed to animals, 3 percent was

processed into industrial products and 11 percent wasted. However, wide differences existed among regions. In Africa, cassava continued to be predominantly a food crop with 80 percent of supply consumed as food and only 2 percent destined for feed use. Given the relatively poor distribution and marketing conditions in the region, about 16 percent were thought to consist of post-harvest losses, a share that may be underestimated. Feed use of cassava in Latin America was much higher - 37 percent - compared with 42 percent for direct human consumption. In the Far East, the major exporting region, food consumption accounted for 80 percent of available production. Feed was estimated to account for only 6 percent and waste for 10 percent. However, the development of cassava trade within the region is leading to a greater use of cassava in feed by non-producing countries such as Japan and the Republic of Korea, while feed use in China is increasing, absorbing around 40 percent of supply in 1986–88.

Cassava has also become an important feed ingredient in the EEC, as its use in feeds rose from 15 million tons (in root equivalent) in 1976–78 to 24 million tons in 1986–88. This has been made possible by high domestic cereal prices, which have allowed cassava to compete successfully with grains in those markets (see also Section III below).

World production of *plantains* remained at around 24 million tons between the late seventies and eighties with most regions maintaining their share of the total. World trade expanded in the late eighties, owing to larger imports by El Salvador and the USA, but still accounted for less than one percent of global output.

According to FAO Food Balance Sheets some 62 percent of world supply was destined for human consumption in 1986–88, 14 percent processed, 21 percent wasted and only 2 percent used as feed. This represented a shift in utilization patterns since 1976–78. In this period feed use accounted for 9 percent of overall supply, while availability for food (55 percent) was lower.

These changes were probably induced by the adverse production trends in Uganda - the world's largest producer - which resulted in lower feed use in Africa. Post-harvest losses, although somewhat reduced over the period (from 24 percent to 21 percent of supply), remained high relative to roots.

Feed use of roots and tubers

World feed use of roots and tubers (Table 2) rose by 12 percent to 153 million tons between 1976–78 and 1986–88, compared with 19 percent for cereals. Growth was particularly pronounced in developing countries where it rose by 35 percent over the decade to reach 68 million tons (in fresh root equivalents). However, their expanding animal product sector continued to rely predominantly on cereals, often imported, the use of which in feeds grew by 55 percent to 133 million tons in 1986–88. Most of the expansion in the use of roots and tubers (as well as cereals) in animal feeding was concentrated in the Far East, and more specifically in China, where a high growth of per capita income, continued to be recorded in the 80s. The greater feed use of roots and tubers in this region was not associated with increased production but rather with a shift in utilization patterns away from food. In the other developing regions, the feed use of roots and tubers fell, mainly as a result of poor production performance and continued substitution by feed grains. Similarly the utilization of plantains in feeds over the same decade declined, since larger requirements for food reduced the availability for feed, in the absence of significant increases in production.

CASSAVA FEED TRADE

World cassava trade expanded considerably in the seventies and eighties from less than 1.5 million tons in 1970 to a record of 12 million tons (in pellets equivalent) in 1989. This remarkable increase was largely the result of the workings of the EEC's Common Agricultural

Policy (CAP). In 1967 the EEC introduced a common variable import levy on cassava chips and pellets, at 18 percent of the barley levy. In 1968, this levy was bound to a maximum 6 percent *ad valorem* duty under the Kennedy Round of the GATT negotiations. At the same time, the application of the CAP resulted in high domestic prices of cereals in member countries which exceeded, in most years, world levels and stimulated import demand for alternative feeds. Cassava pellets which, when supplemented with protein meals, can substitute for grains in animal rations, could accordingly fetch much higher prices in the Community than those which would have resulted otherwise. Considerable increase in compound feed production in the EEC in the seventies and eighties gave an additional boost to the demand for cassava pellets (Table 3) which became the major cassava product in international trade.

TABLE 2.**Feed Use of cereals, roots and tubers and plantains**

	Cereals		**Roots & tubers**		**Potato**		**Sweet potato**		**Cassava**		**Plantains**	
	1976–78	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**	**1976–78**	**1986–88**
	Millions MT											
WORLD	520.0	617.8	135.8	152.8	80.2	68.5	26.2	44.0	29.2	40.0	2.1	0.7
Developed countries	434.1	484.4	85.3	84.6	70.1	57.9	0.4	1.5	14.8	26.0	-	-
North America	141.8	164.0	0.9	1.0	0.9	0.9	-	-	-	-	-	-
Western Europe	103.7	105.0	23.8	29.8	9.0	5.3	0.1	1.4	14.7	24.1	-	-
Eastern Europe	167.2	187.3	60.1	53.0	60.0	51.7	-	-	-	1.4	-	-
Oceania	2.7	4.0	-	-	-	-	-	-	-	-	-	-
Other developed	18.7	23.9	0.5	0.8	0.2	-	0.3	0.1	-	0.5	-	-

countries												
Developing countries	86.0	133.4	50.6	68.2	10.1	10.6	25.6	42.5	14.4	14.0	2.1	0.7
Africa	2.9	4.5	2.5	1.5	-	-	0.7	0.3	1.7	1.1	1.7	0.2
Latin America	30.5	42.9	12.1	11.9	0.5	0.3	0.5	0.4	11.1	11.2	0.5	0.5
Near East	13.6	24.6	-	0.2	-	0.2	-	-	-	-	-	-
Far East	39.0	61.4	35.9	54.5	9.6	10.0	24.6	41.8	1.7	1.7	-	-
Other developing countries	-	0.5	-	-	-	-	-	-	-	-	-	-

The resulting high prices (Table 4), however prevented cassava feed products from successfully competing with grains in non-EEC markets except in 1973–74, when prices of grains reached record levels. In an attempt to stimulate non-EEC markets, some major exporters changed their policies in 1984. Since then a dual price system developed under which prices remained high in the EEC market but were considerably lower in non-EEC countries thus stimulating a sizeable expansion of cassava imports into these markets (see below).

High export prices to the EEC in the seventies and eighties encouraged a large expansion of cassava production in Thailand, the response being much weaker in other major producing countries (Table 5). Output in Thailand, which originally produced only small quantities of cassava for its starch industry, was subject to an exceptional boost. Production in this country rose from 3.4 million tons of roots in 1970 to 24.3 million tons in 1989. The existence of virgin land in the Northeast and the development during the Vietnam war of a major road network connecting that region with southern ports led to an increased cultivation of cassava without curtailing the production of other crops. Owing to high export prices, farmers' profit margins

for cassava were also high relative to other products. Furthermore, considerable private investment in processing and port-handling facilities led to reduced marketing costs, which improved the advantages of Thailand relative to other potential exporters, particularly Indonesia.

The response of Indonesia to favourable cassava export opportunities, was much weaker than in Thailand (Table 5). Although production expanded, particularly in Lampung, the development of the pelleting industry, and shipping facilities to handle big vessels did not take place until recent years. In addition, unlike in Thailand where little cassava was consumed domestically, exporters in Indonesia had to compete for supplies with demand for food consumption, particularly in years of poor rice harvests. As a result, exports from this country, while rising, were not subject to the spectacular increase experienced by Thailand.

TABLE 3. **EEC imports of cassava chips and pellets**

		From:		
	Total	**Thailand**	**Indonesia**	**China**
		('000 Tons)		
1970	1352	926	296	15
1975	2222	1873	314	4
1980	4866	4116	372	336
1985	6336	5681	553	78
1986	5822	5098	352	270
1987	6982	5671	756	340
1988	7024	5805	834	311
1989*	6982	5224	825	170

1990*	6200	4800	825	175

* ***Preliminary***

TABLE 4. **Prices of cassava pellets, cassava/soybean meal mixture and barley in the EEC, and world maize prices**

	Cassava pellets	**Cassava/soya -bean meal[1]**	**Barley[2]**	**Maize[3]**
	(US $/ton)			
1985	104	120	136	112
1986	144	159	170	88
1987	119	167	202	76
1988	154	184	197	107
1989	144	172	175	111
1990	161[4]	171	194[5]	112[4]

1 ***80 percent cassava, 20 percent soybean meal (includes a 6% ad-valorem duty on cassava pellets).***

2 ***Selling price in Germany***

3 ***No. 2 yellow FOB US ports***

4 ***Jan-Sept average***

5 *Jan-April average*

TABLE 5. **Cassava root production and cassava chips and pellets exports in major exporting countries**

	Production[1]			Exports[2]		
	Thailand	Indonesia	China	Thailand	Indonesia	China[3]
	(000 tons)					
1970	3431	10569	1600	1172	334	15
1975	7094	12649	2100	2239	303	4
1980	16540	13574	3300	4970	386	336
1985	19263	13851	3600	6598	543	78
1986	15255	13312	3500	5878	425	270
1987	19554	14356	3300	5850	783	340
1988	22307	15471	3250	7663	1086	311
1989	24264	17091	3160	9316	1200	170
1990	22780	17064	3200	7900[4]	1000[4]	180[4]

1 *Root equivalent*

2 *Product weight*

3 *Based on EEC import statistics*

4 *Preliminary*

Shipments from other producing countries such as Tanzania and Nigeria in Africa and Brazil in Latin America were small and erratic. In these countries, the use of cassava as food as well as overvalued exchange rates pushed domestic prices too high to make exports profitable.

The large increase in shipments of non-grain feed ingredients (NGFI)[2] into the EEC during the seventies generated a wave of protests from European cereal producers particularly since large grain surpluses developed. In response, a series of negotiations were held in the late seventies with Thailand and subsequently with Indonesia and the other exporters, and a series of trade restraint agreements signed, which put a ceiling on the volume of cassava which could enter the Community at the level of 6 percent ad-valorem duty. Since the early 80s[3], imports of cassava chips and pellets into the Community have been restricted under three different types of quota, the first of which was allocated to Thailand (which was recognized as the major EEC cassava supplier), the second to other GATT countries, 85 percent of which was assigned to Indonesia, and the last to Non-GATT countries, mainly China. Cassava feed imports exceeding the pre-established ceilings were subject to much higher import duties.

The volume of EEC cassava pellets imports from Thailand for the period 1987–1990 was fixed at 21 million tons with a maximum of 5.5 million tons in any one year. For 1991–94 the same overall quantity was fixed despite requests from the Thai Government for an increase. However, the new agreement provides greater flexibility as it allows Thailand to export up to 5.75 million tons a year, with the possibility of ‘borrowing’ up to 650 000 tons during the last six months of 1994 from the next four-years quota, as a means of ensuring continuity of supplies[4]. The bilateral agreement with Indonesia for both 1987–90 and 1994–94 provide for a maximum of 825 000 tons a year. The maximum amount allowed from other GATT countries was established

at 145 590 tons. For China the volume was fixed at an annual 350 000 tons over both 1987–90 and 1991–94. Another 30 000 tons a year is reserved for other non-GATT countries (mainly Vietnam). As a result, the maximum amount of cassava pellets allowed to be imported into the EEC has been set at 6.9 million tons since 1987 (7.1 million tons in 1990), although this has not always been achieved[5]. The annual ceiling in 1991–94 has been raised to 7.1 million tons. EEC restrictions on cassava imports acted as a brake to the expansion of cassava trade. The adoption first by Thailand in 1984 and more recently by Indonesia of special policies to allocate the EEC quota among their exporters, contributed to a new expansion of trade and increased feed use by non-EEC countries.

2 Including dried cassava, molasses, milling by-products, maize gluten, dried beets, oil cakes and citrus pulp.

3 Thailand had agreed only 'informally' to limit its 1979 and 1980 cassava exports at the 1978 level.

4 In 1990 Thailand was allowed to borrow up to 750 000 tons from its 1991–94 allowance.

The allocation of the EEC quota by Thailand was originally on a 'first come, first served basis'. Since 1984 an incentive or 'bonus' quota was introduced which reserved part of the quota for export to the EEC to exporters selling to non-EEC countries. In 1989, for example, about 50 percent of the overall quota was destined to the bonus programme, the other half being distributed in proportion to stocks. The distribution of the bonus quota, was made on the basis of a pre-established 'bonus rate'. In 1989, 500 000 tons were allocated at a ratio of '1 to 1.3' (for each ton sold to third countries, exporters received 1.3 tons of the EEC quota) and the remaining part at a ratio of '1 to 1'. In 1989 the Indonesian Government decided to distribute all

its EEC quota under a similar bonus system, which was very attractive since it entitled exporters to receive 2 tons of the EEC quota for each ton sold to other markets.

These incentive export measures resulted in a dual international price system for cassava feed products. Export prices to the EEC, which continued to be linked to high domestic grain prices, were attractive to exporters, who were prepared to sell at a lower price to third countries in order to have access to part of the remunerative EEC market quota. Prices on non-EEC markets were linked to prices of world cereal and protein-rich meals and were, therefore, set at much lower levels. In 1989, for example, the prices (f.o.b.) to non-EEC countries were about one third of those obtained in the European Community. This resulted in expansion of demand for feed by non-EEC countries particularly the Republic of Korea and Japan as well as the USSR and Eastern European countries[6]. In total it rose from less than 0.5 million in 1984 to 4 million tons in 1989.

[5] In some years it has been exceeded because of delays between the issuance of import certificates by the Commission and the actual arrival of supplies in European ports.

CONCLUSIONS

The production of RTPs in developing countries, with the exception of potatoes and cassava, has grown slowly over the decade 1976–78 to 1986– 88. Potato production rose, but from a relatively small basis, and was mostly destined for human consumption, particularly in urban areas. Cassava production also increased either for food consumption (in Africa) or for export (in the Far East).

Domestic demand of RTPs for feed did not appear to be a driving force for an expansion of production in any of the developing regions, even in the Far East, where increasing volumes of

RTPs were fed. Post-harvest losses in most developing regions were estimated to account for 15 percent of supply; for plantains the waste was of the order of 20 percent. Although losses could be reduced through improved transportation and storage techniques as well as through the development of small animal production units close to the production areas, further analysis would be required to assess whether investment in related projects would be economically and financially justified. Indeed, a major constraint to investments in these crops in many developing countries continues to be the more favourable level of cereal prices.

The development of import markets for cassava feed products has been linked to the artificially high cassava prices in the EEC. Although nonEEC countries have learnt in recent years how to use cassava in feed rations, it would not pay them to continue to use it if the price of the cassava/protein rich meal were to exceed world price of feed grains. Production costs in Thailand and Indonesia still appear to be too high for an 'autonomous' expansion of these markets (i.e. without the prop of the dual-price system) particularly since world cereals prices are rather weak. The exceptional development of cassava feed use in the last decade is thus unlikely to be repeated for other RTPs. Although there is scope for major producing countries to replace feed grains with domestically produced RTPs, their prices relative to those of feed grains will continue to be the critical factor.

[6] Demand in those countries has fallen considerably in 1990 reflecting reduced feed use and shortages of hard currency.

Recent developments in cassava agronomy
by R.A. Moreno

INTRODUCTION

Cassava is produced under diverse ecological conditions and production systems. Although this diversity makes generalization difficult, this paper attempts to provide an overview of recent developments in the area of cassava agronomy. Cassava is produced mainly by small farmers in multiple purpose and complex production systems. This complexity at farm level increases the risk of generalization since agronomic practices tend to be site specific.

Only a few countries and notably Thailand, produce cassava primarily as a single crop over relatively extensive areas of land. Monocropped cassava is rare in the rest of the world.

The available information about modern cassava technology has improved considerably in recent years with the advent of international cassava information networks. Unfortunately, information from some areas of the world where cassava is an important food crop, has not kept pace with recent improvement in communications. This is particularly the case in some African and Southeast Asia countries.

Despite the diversity of physical environments in which cassava is cultivated, most of the information relevant to cassava agronomy has been generated on experimental stations, and is frequently delivered without on farm validation.

Although cassava is in a more favourable position than other roots crops fewer resources are allocated to cassava research at both national and international levels than to other crops, particularly grains (Cock, 1985). This lack of resources negatively affects technology development and transfer to farmers. Under the present economic crisis facing Third World countries, underfunding for research, development and transfer of technology for cassava, will continue to limit the development and application of better agronomic practices.

In this article a brief overview of the most important cassava based cropping systems in different ecological areas is presented, together with relevant recent research results that could lead to improvements in cassava production.

CASSAVA CROPPING SYSTEMS

In the Low Humid Tropics (0–3 mo/yr with less than 60 mm rainfall) cassava is produced year round in a multiplicity of cropping systems. Land clearing and soil preparation demand high inputs of hand labour due to the vigorous growth of native vegetation in this ecosystem, therefore, weed control is the most labour demanding cultural practice, after crop establishment. Declining soil fertility and root rots limit cassava yields when production continues on the same plot.

In the Semi arid Tropics (7–9 dry mo/yr) cassava, develops under water stress during most of the growing period. Uncertainty about the onset and end of the rainy season negatively affects hand labour planning and allocation, concentrating peaks in labour demand before and during planting. After one or two years of drought the availability of planting material becomes critical. Similarly, mite attack can be devastating in conjunction with prolonged periods of drought. Nevertheless, cassava is one of the few crops that can produce reasonable yields under these extreme conditions.

In the Seasonally Dry Tropics (4–6 dry mo/yr) cassava is usually produced in combination with several other crops. Timing of land preparation and weed control during the establishment phase of the crop are critical to achieve high yields. Marketing considerations, and particularly prices for fresh roots or dry chips, determine the level and quality of farmer management of cassava production.

In the Subtropics, cassava's growing season is defined by temperature rather than precipitation. In the Southern Hemisphere cassava stakes are cut at the onset of the winter, stored, and planted as soon as the temperature rises again. Early and late cassava varieties are commonly intercropped or relay cropped with several other species.

COMPONENTS OF IMPROVED TECHNOLOGY

Land preparation

Although one of the most energy demanding activities for cassava production, land preparation has received comparatively little research attention, and only a few practical recommendations are available.

In areas at risk from flooding, soil should be ridged before planting. However, although fresh root yields in ridged and unridged plantings in short term experiments, are not consistently different, it is generally accepted that ridging is beneficial in these types of environments (Lozano, 1987; Rodriguez, 1990).

The performance of cassava under different tillage systems is rather site specific. No-tillage, reduced tillage and conventional tillage have been tested in different ecosystems with variable results in terms of yield (Ofori, 1973). Soil preparation is more important for effective weed control than as a means to improve the microenvironment for root bulking. For example, acceptable yields are obtained by small farmers using zero-tillage, whilst no significant differences in yields have been obtained between “conventional” tillage (plough and harrow) and different forms of reduced tillage. Deep soil preparation does not result in better yields, except under very specific circumstances. The most common form of reduced tillage is the local removal of soil around the area where the cassava stake is to be planted. This practice, although rather primitive, (Okigbo and Greenland, 1976) is still widely used today in different parts of the world.

Mulch effectively increases yields when zero-tillage is used (Hulugalle and Opera-Nadi, 1987), though in semi arid zones, mulching is more important as a means to conserve water than to improve the soil condition around the root system.

Because of its ability to grow in poor soils, cassava is frequently cultivated on steep land, which because of the slow initial growth of cassava can result in soil erosion during the first three months after planting. The development of improved technology to reduce erosion is one of the most serious challenges facing cassava research today.

Contour ridges alone, or in combination with live barriers and zerotillage provide effective erosion control under experimental conditions in Latin America and Asia, though, the acceptance of this technology by farmers has not yet been evaluated (CIAT 1989, 1990).

Planting

The literature abounds with recommendations related to planting material. Cutting size, planting position, phytosanitary treatment and other topics have been widely researched around the world. Most of these results, obtained on experimental stations, are published with relatively poor descriptions of the conditions under which the experiments were conducted. The applicability of the recommendations to farm conditions is often unclear or highly site specific.

In most production systems, vigorous stakes selected from the middle portion of the basal branches of fertilized mother plants result in better yields. A basic formula for phytosanitary treatment of cuttings is available for use by farmers (CIAT, 1985). Storage of planting material for up to 4 months before planting can be achieved by placing them in the shade and burying the tips of the stakes in the soil (CIAT, 1990).

As with many other crops, planting densities and spatial arrangements currently used by farmers are determined by several factors, not necessarily related to yield. The availability of planting and land preparation implements, the practice of intercropping, weed incidence, water holding capacity of the soil, and market considerations are among the most important of these factors (Norman, 1979).

Increases in planting density normally result in higher yields of smaller roots, a greater labour requirement for weed control (during the establishment phase of the crop) and intense use of available planting material (Cock 1978).

New cultivars

Due to the American origins of cassava, more genetic diversity is present in the Neotropics. New cultivar development in the rest of the world depends heavily on the availability of germplasm obtained from Latin America.

In Latin America most small farmers generally grow more than one variety simultaneously. Some phenotypes tend to be more commonly cultivated than others in individual production zones, though in some production areas, near well-defined markets, single varieties are grown.

Brazil is by far the largest cassava producing country in Latin America, accounting for almost 70% of total production. In the Humid Wet Tropics of Northern Brazil, the cultivars IM-158, IM-

168, IM-175 and BGM-021 have been recently released due to their tolerance to *Phytopthora* and *Fusarium* spp. (Fukuda 1990; CIAT 1990). The cultivars IAC-12-829 and IAC-576-70 were released by the Instituto Agronomico de Campinas in southeast Brazil. In the South sub-tropical region, the cultivars Aipim, Pioniera and Gigante, released by national institutions, continue to be widely cultivated. No improved varieties are presently cultivated by farmers in semi-arid northeastern Brazil, the largest production area of the country, containing almost 58% of the total area planted to cassava (Fukuda, 1990).

Colombia is the second largest cassava producer in Latin America. The variety Manihoica P-12 has been released in the North Coastal area of the country, whilst varieties CG 1141-1 and CM 3306-4 are in the pipeline for release in 1991 after evaluation by 400 small farmers (Lopez *et al.*, 1987). Varieties ICA-Sebucan and ICA-Catumare were released in 1990 for the Llanos ecosystem (Rodriguez and Hershey, 1989). Other cultivars such as Manihoica P-13 (HMC-1) have been released in the Valle Department.

Cassava is very important in Cuba where the early CIAT cultivar CMC-40, of Brazilian origin, is grown together with the intermediate local selection CEMSA and the traditional late variety Señorita, to guarantee cassava availability in the market during most of the year. Recent releases such as CEMSA 5–19, CEMSA 74–6329 and Jaguey Dulce are of more restricted ecological adaptation (Rodriguez, 1990).

Paraguay is the largest *per capita* consumer of fresh cassava roots in Latin America. Among several local cultivars with excellent agronomic characteristics, Meza-i has been recently recommended by the extension service (SEAG, 1989).

The varieties Dayana in Panama (Chavez, 1990) and MCol 2205 in Ecuador (Hinostroza, 1990) are recent releases, which are just beginning to be cultivated by farmers.

The national institutions of Thailand and Indonesia release more improved cassava cultivars than other Asian countries. In Thailand, Rayong 1, probably the world most successful cassava cultivar, served as parental material for the development of Rayong 2, released in 1984, and Rayong 3. The latter has a very high dry matter content and, although only recently released, is already extensively cultivated (Sinthuprama *et al.* 1987; CIAT 1990).

In Indonesia, Adira 1 is widely cultivated by small farmers due to its low HCN content and ability to grow in intercropping systems. Adira 4, with a slightly higher HCN content (90 ppm), was released in 1986 for industrial purposes and is now cultivated on almost 20,000 ha, mainly in Sumatra (Soenarjo *et al.*, 1987; CIAT, 1990).

In the Philippines, the Philippine Root Crop Research Center released the cultivars Kalabao, Golden Yellow and Colombia in 1980. In 1986, the cultivar CM 323-52 was released under the name UC-1. The University of the Philippines at Los Banos recently released the sweet cultivar Lakan 1 and the bitter cultivars Datu 1 and Sultan 1 (Mariscal, 1987; Carpena, 1987).

In China the local selection SC 205 (South China 205) and the introduced cultivar from Colombia CM 4031-2, are widely cultivated (Lin *et al.*, 1987).

In South Vietnam, the Thai cultivars Rayong 60 and Rayong 1 outyielded local cultivars, and are in the pipeline for immediate release (CIAT, 1990).

Little information about cassava varieties recently released in India and Africa is available. Apparently five high yielding hybrids were released in India around 1987 (Nayar *et al.*, 1987).

Intercropping

Research on cassava intercropping is relatively more recent than other aspects of cassava production. Considerable research effort has been dedicated to gaining a better understanding of interactions between components of crop associations (Leihner 1983). Several publications dealing with intercropped cassava in specific environments, particularly in Asia and Africa, are available, though most of these research results are applicable only in very specific conditions.

Due to the slow initial growth of the crop, Land Equivalent Ratios values above 1 are frequently obtained when cassava is intercropped with short cycle annual crops such as common beans, cowpea or vegetables. With crops such as maize, sorghum or pigeon peas, the ability of cassava to recover a full leaf area after the harvest of the intercrop is the main reason for LER values above 1. Generally, the cultivation of cassava under tree crops does not negatively affect the yield of the trees, and therefore values for LER above 1 are frequently obtained.

Maize is probably the most common annual crop grown in association with cassava. Improved short maize cultivars intercropped with cassava tend to yield more than traditional cultivars and also result in higher cassava yields (CIAT, 1988).

Weed control

Cassava requires effective weed control, and especially during the establishment phase of the crop, for optimum yields. In traditional agriculture, weeds are controlled through cultural practices such as planting density, the use of vigorous cultivars, intercropping, reduced tillage, cover crops, use of mulches, etc. Most recent research on weed control in cassava has shown that in addition to the application of selective pre-emergence herbicides, at least one hand/hoe weeding is necessary for optimal yields. Among the most researched and recommended preemergence herbicides are fluometuron, diuron and alachlor. Paraquat has also been recommended for post emergence application as a complement to hand/hoe weeding. However, the most widely used herbicide combination for preemergence is probably a tank mix of diuron with alachlor in a variety of doses according to the soil characteristics. This mix is also effective for use with a cassava/maize intercrop when planting of the two crops is either simultaneous or only few days apart (Doll and Piedrahita, 1976; Moody, 1985).

Fertilization

Cassava is grown on a great variety of soils, but is mainly found on ultisols, oxisols and entisols. While the crops grows well with little or no fertilization, it responds well to fertilizer application in infertile soils. The high cost/benefit ratio of cassava fertilization in infertile soils was shown in a series of experiments coordinated by the FAO Fertilizer Program (FAO, 1980).

Cassava responds to P application in infertile oxisols, except in those with high mycorrhizal populations, while N response is found only in sandy soils low in organic matter content (Howeler and Cadavid, 1990).

There is also a marked positive response in root production to applications of K when cassava is grown continuously in the same field for more than 2–3 years (Howeler, 1990a).

In soils with very low levels of available P, high rates of P application are recommended for one or two years in order to increase the available P content in the tissue above the critical level. Since cassava takes up relatively small amounts of P and is highly efficient in P use subsequent P applications can be reduced (Howeler and Cadavid, 1990; Howeler, 1990b). In soils low in organic matter or available N, 50–100 kg N/ha are recommended per crop cycle. In most tropical soils with very low K supplying power, it is recommended to apply at least 100 kg K/ha annually to sustain cassava yields (Howeler and Cadavid, 1990).

Plant protection

Although cassava is frequently considered relatively tolerant to insects and pathogens, its yields are often negatively affected by pests and diseases. In fallow-based agriculture, several cultural practices such as crop rotations and the inclusion of fallow as part of the rotation scheme, help not only in the maintenance of soil fertility, but also in the control of pests, diseases and weeds.

African Cassava Mosaic Virus is considered one of the most serious diseases affecting cassava production in Africa today. It causes serious yield losses in East, West and Central Africa. This insect-transmitted disease is controlled only through the use of healthy planting material in areas where the reinfection rate is slow. The development of resistant varieties is possible by crossing *M. esculenta with M. glaziovi* but insufficient virus resistant material is currently available to farmers.

Cassava Common Mosaic Virus is an important disease with an unknown vector. The use of "clean" planting material (Lozano 1989) is consequently the only available control measure.

Bacterial Blight caused by *Xanthomonas campestris* is another disease of worldwide importance. In addition to the usual control practices cited in the literature, successful control can be obtained through inoculation of planting material with strains of *Pseudomonas fluorescens* and *P. putida* (Lozano 1986). *P. putida* can also be used for the control of *Diplodia manihotis*, a root rot pathogen (Lozano 1986 and 1988).

Among the important insects pests affecting cassava, the Cassava Hornworm (*Erinnyis ello*) can be controlled with *Trichogramma* and *Bacillus thuringiensis*, but the most promising control practice is application of the hornworm baculovirus (CIAT 1989).

Two species of cassava mealybugs, *Phenacocus manihoti* and *P. herreni*, can cause serious

yield losses. *P. manihoti* caused severe yield losses in Africa until the introduction of natural enemies from the Neotropics by IITA and CIAT. *Epidinocarsis lopezi*, a natural enemy of *P. manihoti* collected in Paraguay, was released in 1981 in Nigeria and is now established on approximately 750,000 Km^2 over a wide range of African ecological zones, helping to maintain low levels of mealybug attach (Bellotti *et al.* 1987).

The control of the Cassava Green Mite (CGM) in Africa is one of the most serious challenges facing crop protection today. Shipments of natural enemies from the Neotropics to Africa have been made regularly since 1984 as a part of a joint IITA-CIAT biological control effort. Establishment of two species, *Typhlodromalus limonicus* and *Neoseiulus idaeus*, has recently been documented in several release sites in West Africa (IITA, 1990). The success of the biological control campaign against CGM in Africa will depend on continued collaboration between international agricultural research centres and national institutions in African countries.

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Processing of cassava tuber meals and chips
by B. Ospina and C. Wheatley

PART I: TECHNICAL ASPECTS OF CASSAVA PROCESSING.

INTRODUCTION

Over the past 25 years significant market opportunities for cassava have opened up in the animal feed industry, initially in the EEC countries but more recently for the rapidly expanding animal feed industries of tropical developing countries. Cassava roots compete with other carbohydrate sources, especially maize and sorghum, on the basis of price, nutritional value, quality and availability.

Cassava has several advantages compared with other carbohydrate sources, especially other root crops. It has a high productivity under marginal climatic and soil fertility conditions, which result in a low cost raw material. Root dry matter content is higher than other root crops, at 35–40%, giving optimum conversion rates of 2.5:1 or better. Over 85% of root dry matter consists of highly digestible starch. Cassava starch has excellent agglutinant properties which make it especially suitable for shrimp and fish feed, replacing expensive artificial agglutinants.

The potential disadvantages of cassava roots are their bulk and rapid perishability, their low protein content and the presence of cyanide in all root tissues. Through simple processing, the disadvantages of bulk and perishability can be overcome: a stable product is reached when moisture content falls below 14%. Natural drying is widely used to achieve this objective.

Drying also permits the elimination of most of the cyanide from root tissues. The dried cassava product thus has only one disadvantage with respect to other carbohydrate feed sources: low protein content. This can be overcome through price competitiveness.

For export markets, where transportation over thousands of kilometres is necessary, further processing to produce high density pellets is carried out to minimize transport costs.

PROCESS DESCRIPTION

All countries where dried cassava is produced for sale to animal feed industries use essentially similar processing technologies. Cassava roots are transported to the processing plant, where they are chipped and sundried for two-three days before being packed and stored prior to further processing or transportation to industrial clients. This process will be described in more detail, and various processing variables which affect product quality or process economics will be mentioned. Detailed, technical information on the different processes can be found in Best 1978; Thanh and Lohani 1978 and Best and Gómez, 1985.

Harvest and transport of fresh roots

Roots are usually harvested manually, and transported the same day to processing plants.

The distance from field to processing plant must be short: cassava contains 65% water and transport is not economic. The need to minimize fresh root transportation costs favours the use of many, small to medium sized processing units rather than a few large scale operations.

Rapid fresh root perishability, due to physiological deterioration which initiates 1–3 days after harvest, necessitates rapid processing of the fresh roots. Although storage times of 2–4 weeks can be achieved using a variety of methods, none are cost-effective for the purpose of

permitting the holding of stocks at the processing plant.

Processing plants must be ensured of almost daily deliveries of raw material, and can only operate during cassava harvesting periods. A positive correlation exists between physiological deterioration and root dry matter content ie. those roots which are of best quality for processing are precisely those which deteriorate fastest. Excellent links between producers and processors are necessary to ensure that freshly harvested cassava is delivered to the plant as and when required. If fresh roots are held at the plant for over 5 days before processing is initiated, the possibility of end-product contamination with aflatoxin is much increased.

Chipping

Size reduction of cassava roots shortens the drying time and ensures efficient elimination of the cyanide component present in the fresh root. roots may be chipped manually, using a knife (Indonesia, Colombia) in which case a few, large root pieces may take many days to dry and produce a poor quality product. In thailand and most of Latin America, cassava chippers baed on an original Thai design are used, powered by a7Hp motor. Roots are chipped by a rotating disc either perforated with holes with cutting edges, or provided with interchangeable corrugated blades. In Brazil, a mahine to produce rectangular chips has been designed.

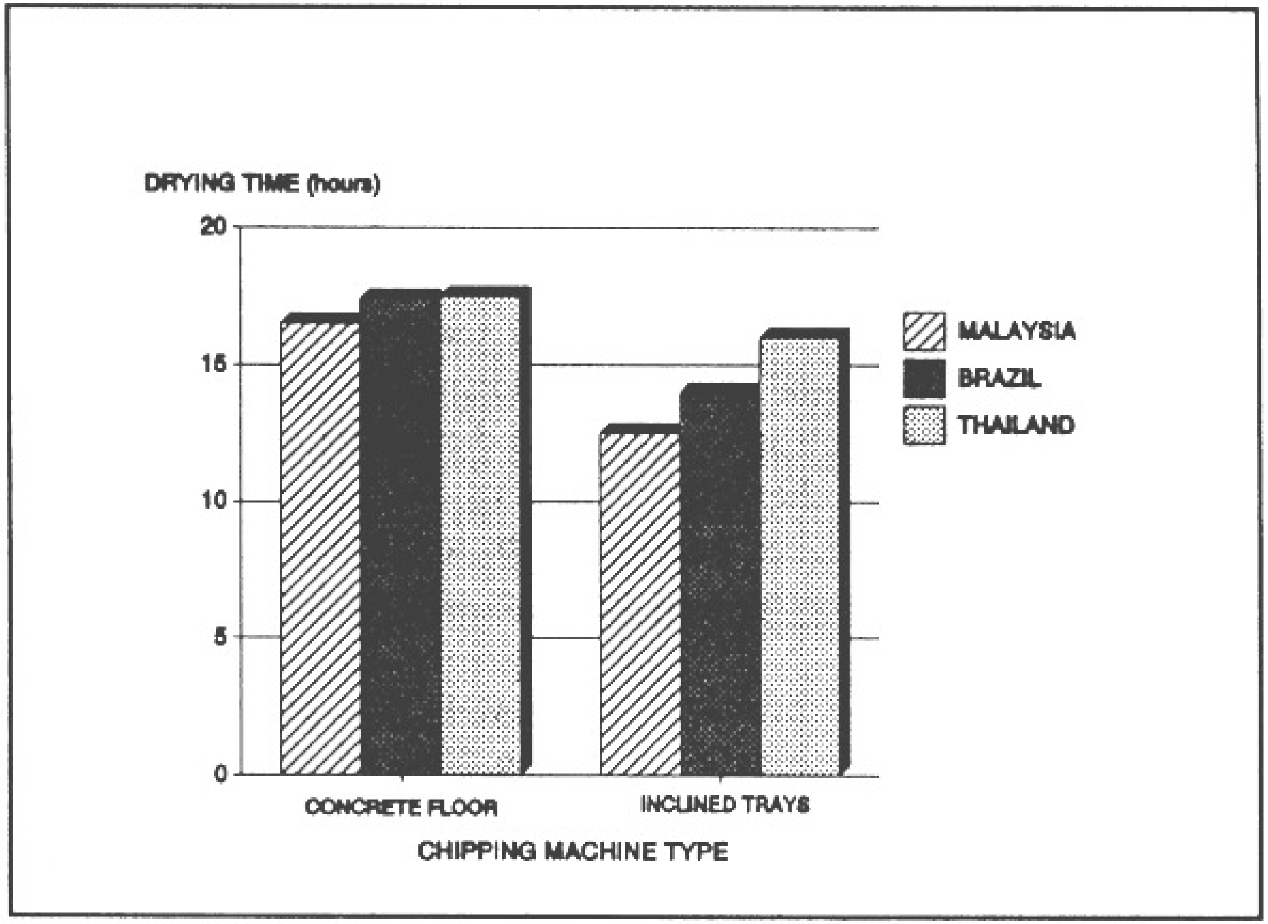
Table 1 gives the dimensions of the typical chips produced by these machines. However, in practice less than 50 % of chips actually fall within these measurements: a large percentage are broken or below size. Chip size and geometry affects the drying rate, especially when drying is conducted on inclined trays (Fig. 1). On concrete floors, Castillo and Hernández (1986) found minimal differences between these three types of machine. In Colombia, the efficiency of the basic model Thai chipper has been improved, principally through the design of

more effective cutting blades. Capacity has been increased from 3 to 12 ton/hr. Several countries have developed manual or pedal powered chippers, eg. India, Indonesia, Peru and Colombia, but in practice they have been little used date.

TABLE 1. **Differences in chip geometry: dimensions of typical chips.**

shipping machine	Dimensions (mm)			% chips with these dimensions
	Length	Width	Thickenss	
Thailand	60–80	25–30	4–7	42
Brazil	50–70	10	4–6	44
Malaysia	50–80	4–5	4–6	35

Fig.1:Effect of chip geomerty on drying time (loading rate 10kg/m^2)



Natural drying

All cassava roots processed for animal feed are dried using natural solar radiation. Drying time depends on climatic conditions and chip size and loading rate amongst other variables. In most situations, drying is carried out on concrete floors. Drying on inclined trays is a faster option (Fig. 2) but with greater initial investment and a shorter working life. Under normal conditions at CIAT and in the Atlantic Coast region of Colombia, chips produced by the Thai type chipper at a 10 kg/m^2 loading rate dry in two days to below 14% moisture. Drying times in excess of

three days can result in quality problems. Natural drying is normally confined to dry season months. However, recent experiences in Colombia suggest that processing plants can continue to operate economically and produce a good quality product even during months with significant rainfall providing that loading rates are reduced and more care is taken in plant operation.

Fig.2: Comparison of floor vs.tray drying of cassava chips (adapted from: Best, 1979)

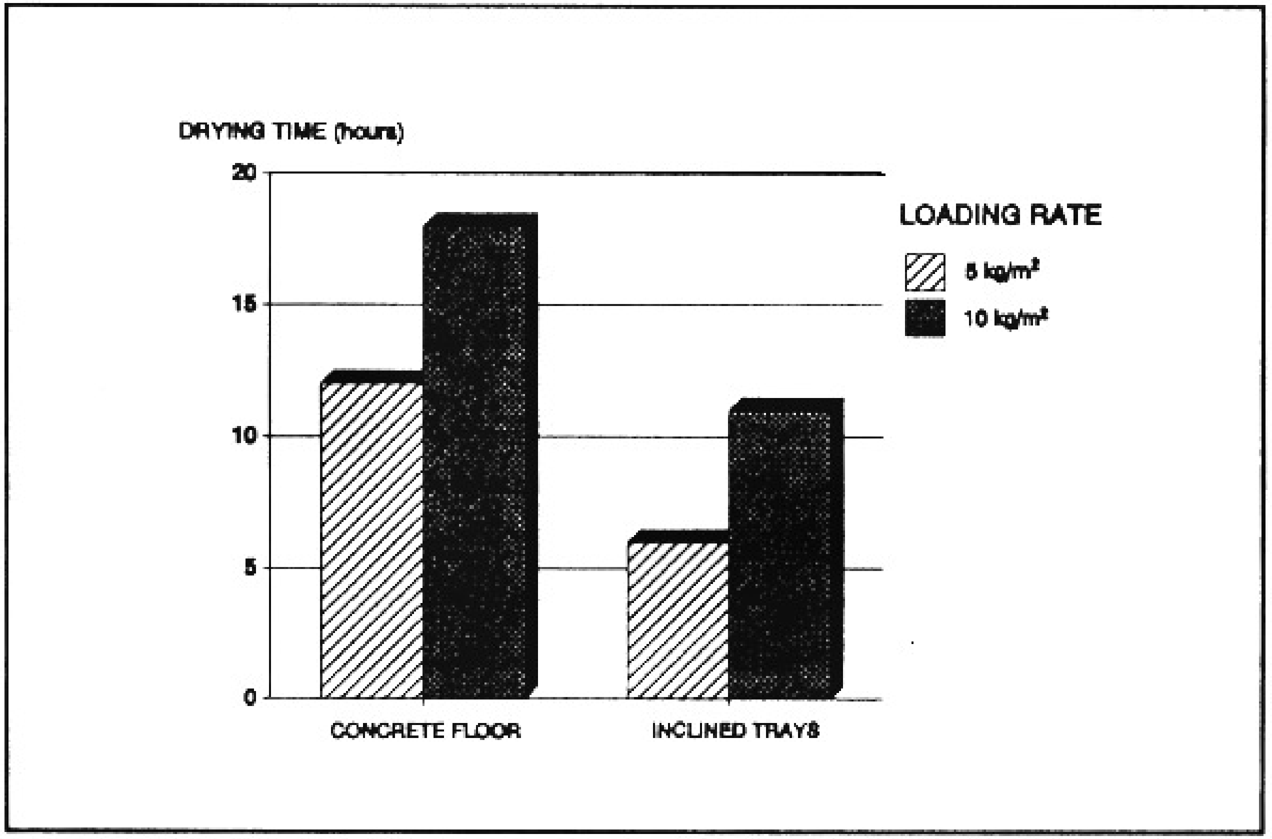
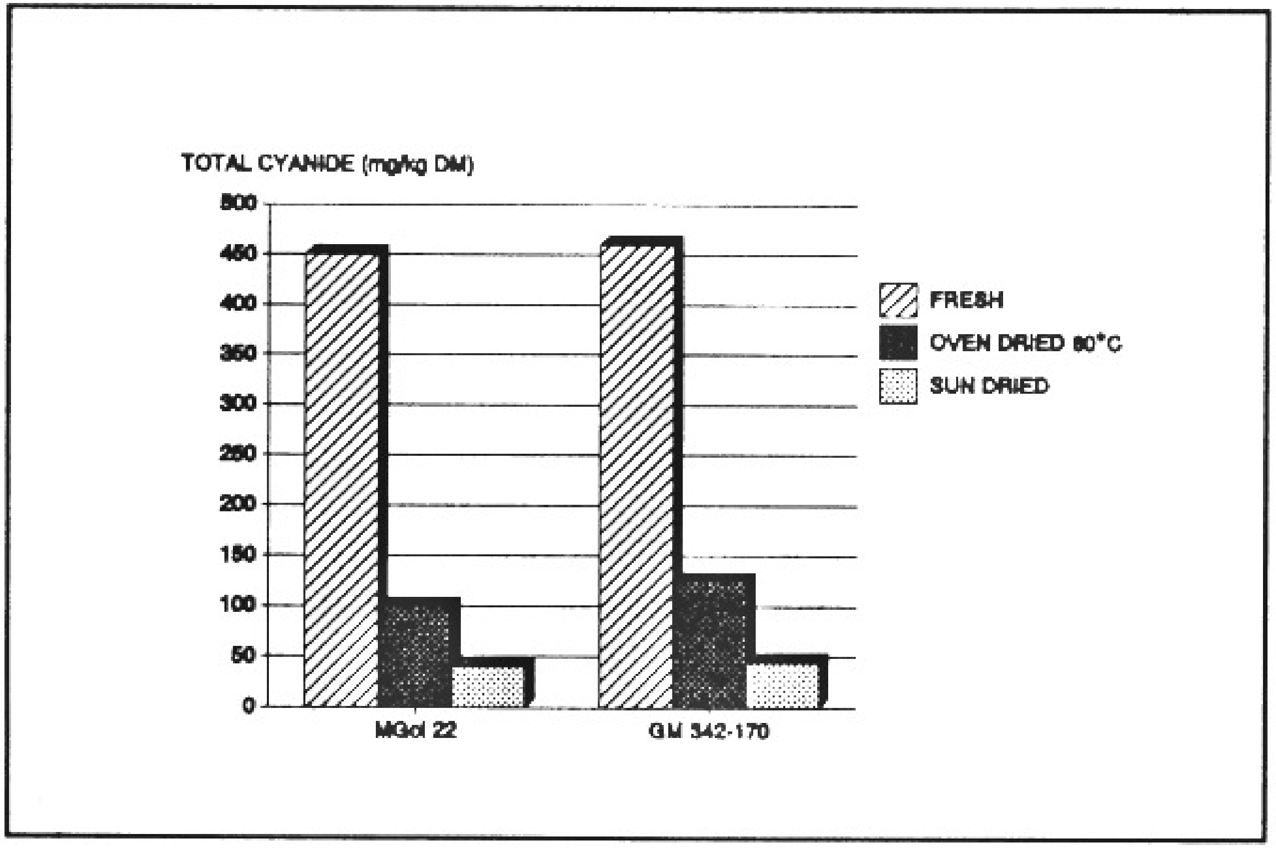


Fig.3:Elimination of cyanide from cassava chips by drying (adapted from:Gomerz & Valdviezo)



The two day period taken to reach a 14% final moisture content also allows substantial reduction in total cyanide content. Fig. 3 shows that fresh chips of MCol 1684 and CM 342-170 were highly toxic at over 1000 ppm on a dry weight basis (OVER 300 ppm, fresh weight), but fell to below 50 ppm after drying. Oven drying at 60°C, with a 8 hour time taken to reach below 14% moisture content, resulted in dried chips with unacceptably high cyanide levels, Gómez and Valdivieso (1984). Natural drying thus represents the best option for reducing potential problems with cyanide toxicity. Neither European cassava importers, nor Colombian animal feed companies using cassava, have ever expressed concern over HCN levels in the naturally dried product as commercially available.

Natural drying requires considerable drying floor areas, even for moderately sized operations. In Colombia, floor areas range from 250 m^2 to 3000 m^2, with one 5000 m^2 plant under construction. In Thailand, plants with 35,000 m^2 of drying floor, and totally mechanized operation, are common. During drying, the chips need to be turned every two hours. This can be carried out manually, using rakes, or mechanically using equipment attached to tractors. Collection of the dried product can be similarly arranged. In Latin America, the dried cassava is usually packed into 50 kg sacks when dry, and stored in warehouses at the plant. In Thailand, the loose chips are transported directly to the pellet factories. The drying operation has minimal waste: roots are chipped unpeeled, and are stored as such once dry.

Further processing

Three options exist:

a. dried chips to the animal feed industry, which mills them and carries out the subsequent mixing and formulation (eg. Colombia, Brazil).

b. Milling of dried chips, and sale of cassava flour to animal feed or other industries (eg. Ecuador).

c. Sale of chips to pellet factory, for processing into an export commodity (Thailand).

A further potential option exists, as yet unrealized: formulation and production of animal feed rations by the processing plant itself. A trial of milling cassava flour, mixing with other locally available animal feed components and the use of this feed by local livestock farmers has been successfully completed in Colombia.

PROCESS ECONOMICS

The production of dried cassava for export is an important industry in Thailand and Indonesia. Dried cassava is currently produced for local animal feed industries in Colombia, Ecuador, Brazil, Panama and Bolivia. In other countries, some use of dried cassava undoubtedly exists, but at a less commercial level. The economics of cassava vs. other sources of carbohydrate will not be considered here: only the relative importance of different costs in determining the final price of cassava chips.

In the case of Colombia (Table 2) (Ostertag, 1990), the majority of the costs (74%) are represented by the price of the raw material (the fresh roots) including the cost of transport to the plant. The conversion rate of fresh to dried cassava is thus of crucial importance to the profitability of the enterprise. The use of high dry matter content varieties is recommended.

Processing costs comprise only 17% of total costs. These are due mainly to the labour costs involved in process operations. With total costs of Col.$69,000 compared with a selling price of Col.$91,000, there is ample margin available for the enterprise, and for covering financial costs involved in the initial capital investment. These have not been included in the analysis since conditions and amount of credit vary greatly between individual plants.

TABLE 2. **Processing costs, dried cassava, Colombia 1990**

	Col.$	**%**
Variable costs		
Raw material	514000	74
Labour	69000	10
Packaging	1700	2

Fuel	1320	2
Payment to ANPPY (1%)	810	1
TOTAL	62102	89
Fixed costs		
Manager	2679	4
Treasurer	1786	2
Secretary	1190	2
General expenses	300	1
Plant maintenance	1164	2
TOTAL	7119	11
Total cost per ton	69221	100
Price per ton (less transport)	91000	

**** US$1 = Col$ 520***

Source: Adapted form Ostertag (1990).

ORGANIZATIONAL ASPECTS

In Asia, individual or family run enterprises are the usual organizational form found for initial cassava processing. In Indonesia, village cooperatives perform wholesale, milling and pelleting activities. In Latin America, cooperatives and associations of small farmers dominate the production of dried cassava, although the private sector is growing in importance (40% of production in Colombia in 1990).

For cooperatives of small farmers to function adequately in the operations of processing

cassava, and to manage the business aspects of the enterprise, substantial investment in technical assistance is required. In Colombia, Ecuador and Brazil, inter-institutional teams coordinated by rural development or extension agencies have been crucial to the growing success of the dried cassava cooperatives during the 1980's. The 1990's will see second order cassava producer/processor organizations take over some of these support functions.

NEW TECHNOLOGIES

More sophisticated drying technologies have potential for use to produce dried cassava for animal feed. Artificial or mixed drying systems result in a better quality product for all characteristics except cyanide content. Several artificial drying systems, described in Best and Gómez 1985, have been developed. However, the economic feasibility of such systems is uncertain. For animal feed, cassava must be cost competitive with maize and sorghum. Increases in processing costs due to artificial drying will not be compensated for by an increase in end product price, despite better quality, at least for animal feed uses. Improved quality will, however, allow cassava flour to enter other markets, for industrial or food use, in which higher prices will compensate for process cost increases.

Through allowing greater utilization of existing plant capacity (drying in rainy seasons) and permitting cassava drying to spread to regions where natural drying is not a feasible option, artificial or mixed systems may have potential. The economic feasibility of these technologies is currently under evaluation in Colombia at three sites (Sucre, Cordoba and Meta departments).

PART II: CASE STUDY: CEARÁ INTEGRATED CASSAVA DEVELOPMENT PROJECT.

INTRODUCTION

To be able to overcome the inherent market limitations caused by the lack of diversification in cassava markets, the process of developing a market for dry cassava chips within the animal feed industry requires key institutional interventions. The Cassava Program of CIAT has been involved during the last ten years in the implementation of these type of interventions in key target cassava producing areas of Latin America. These interventions to date have been organized around the so called Cassava Integrated Development Projects.

Since May 1989, the Cassava Program of CIAT is assisting some agricultural sector agencies of the State of CEará, Northeast Brazil in the implementation of the Ceará Integrated Cassava Development Project with financial support from the W.K. Kellogg Foundation.

This case study presents some of the main results obtained in the first two years of implementation of this project.

MACROECONOMIC ANALYSIS

Brazil is the second world's largest producer of cassava with a total production comprising almost 16 % of world production and representing near 75% of Latin American production (See Fig. 4) (Anon, 1984).

Cassava is a major source of energy in Brazil. According to IBGE data, the most important energy sources in Brazil are rice, sugar, cassava, beans and wheat, all equally important. There are however, regional differences. Cassava in the North part of Brazil represents 27% of total energy intake and in the Northeast represents the most important energy source with 23% (Anon, 1924; Anon, 1984).

The market for animal feed rations

Brazil is one of the main beef producers of the world with a cattle stock of over 135 million animals (Anon, 1989). Beef and swine production is lower in the North and Northeast areas than in the rest of Brazil. Beef as well as swine production had remained relatively stable over the last 15 years. A different situation occurs with the production of poultry meat which has presented a dynamic growth within the same time frame. Brazil is the world's third largest poultry meat producer and produces some 7% of total world market supply. From the beginning of the seventies the poultry industry has been growing at an extremely fast rate and the brazilian government has made a decisive effort to open export markets. Exportation of poultry meat rose from 3.4 thousand tons in 1975 to 280 thousand tons in 1984. Production of poultry meat in 1987 was 1.32 million tons.

Production levels of eggs in Brazil are high with a significant steady growth rate in the last 15 years. In 1987 the total production of eggs was near 25.09 billion eggs of which more than half were produced in the southeast and only 16% in the North East (see Table 3).

Demand for animal feed rations

Up to the nineteen-sixties Brazil's animal feed industry was relatively small mainly directed to dairy cattle. At the beginning of the sixties, swine production on the basis of balanced animal feed rations started to grow stimulating a fast development of the animal feed industry. The demand for balanced animal feed went from 2.4 million tons in 1971 to 10 million tons in 1985. This prompted a rapid modernization of the animal feed and meat production industry which attained similar conversion rates to those in the United States. This strong growth created an increasing demand for maize which in Brazil represents the main animal feed raw material accounting for up to 65% of the ration. Between 1971 and 1985, the consumption of maize by the animal feed industry increased from 8.4 to 15 million tons.

As a consequence of this situation Brazil which was formerly a maize exporting country had to start importing maize (between 1977 and 1980 Brazil imported more than 4 million tons). In 1986 due to adverse climatic factors, the country again had to import more than 3.5 million tons of maize.

Fig 4: Cassava Production in 1989, World and Latin America (FAO meeting jan-91)

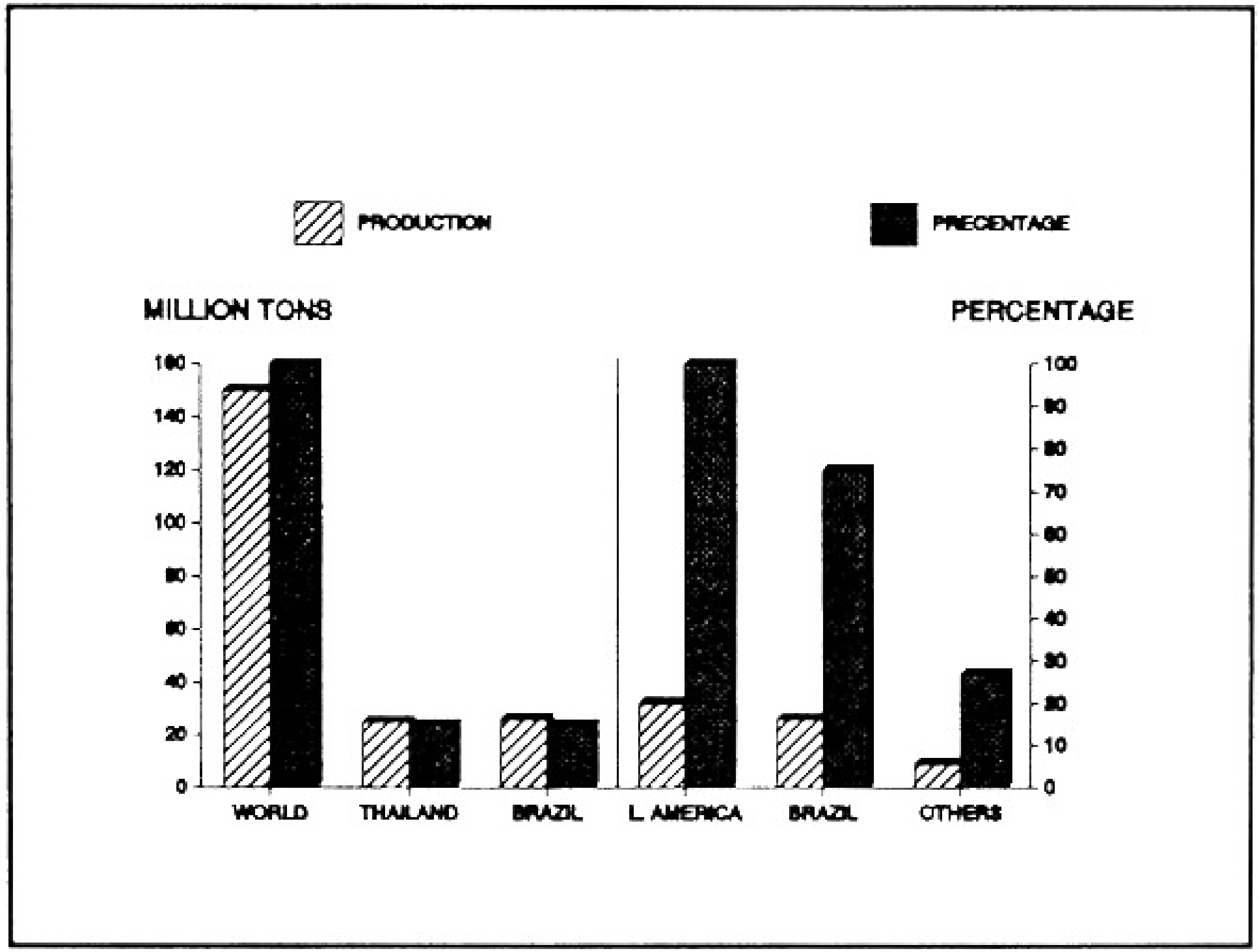


TABLE 3. **Animal Production in Brazil by Regions**

REGIONS	Cattle	Swine	Poultry meat	Eggs
	Millions of animals			Millions of dozens
Brazil	135.7	32.4	524	2.058
Northeast	24	8.8	94.8	329.2
Cear�	2.5	1.28	22.5	111.1

Source: IBGE - Anúario Estatístico 1989

Potential for use of cassava in animal feeding

In relation with the production and consumption levels of cassava, maize, animal feed, poultry, eggs and swine, Brazil presents specific characteristics whereby cassava production is concentrated in the North and Northeast, and maize and animal feed production are concentrated in the south and central west. These two regions produce a considerable surplus on top of their own needs. On the other hand, the northeast region has large deficit of maize as well as of animal feed (Table 4).

Macroeconomic analysis aimed at placing cassava in the overall development context of Brazil and of the northeast region with emphasis on the evaluation of the potential demand for cassava and cassava products, the ability of cassava to compete in the different markets and the production potential of cassava in different regions suggested that the production of dried cassava for animal feeding in the northeast could be an appropriate way to improve the region's self-sufficiency in feed grains, animal feed and animal production. Additionally, an alternative cassava market would be very welcome to widen the market perspectives for the small cassava farmer with favourable effects on small-farmer income and rural employment.

TABLE 4. **Maize, animal feed and cassava in Brazil surpluses and deficit by regions (millions of**

tons)

Regions	Maize	Animal feed	Cassava
Northeast	-0.708	-0.199	10.245
Southeast	-1.212	-0.139	1.973
South	0.6	0.343	1.138
Midwest	1.559	0.03	0.947

Source: Companhia de finaciamiento da produccion (CEP) IBGE, Anuario Estatilstico 1989.

THE SCENERY OF THE PROJECT

Northeast Brazil

Northeast Brazil is a region comprised of nine States (Maranhao, Piaui, Ceará, Rio Grande do Norte, Paraiba, Pernambuco, Alagoas, Sergipe and Bahfa) with a total area of approximately 1.5 million k2 (18% of country's total area).

The region is considered to be the area with the highest levels of poverty and underemployment of Brazil. Negative national records are hold in aspects such as absolute poverty, infant mortality rates, unemployment and underemployment, illiteracy and access to basic services. It has been estimated that by 1990, the total population of Northeast Brazil will be approximately 43 million representing 28% of the population of the country, that 42% of the "Nordestinos" will be living in rural areas and that over 50% of the total work force will be engaged in agricultural activities.

In northeast Brazil, 72% of the total number of families is considered to be living below the

poverty line*. Land distribution is characterized by a great disparity; the number of farms with less than 10 ha represent 70% of the total number of farms and occupy less than 6% of the total farm area; conversely, the number of farms with areas over 100 ha represent 6% of the total number of farms and occupy more than 40% of the total farm area (See Fig. 5).

The northeast region contribution to the total Brazilian agricultural production represents about one fifth of the total value and some of the most important agricultural commodities produced in the region (sugarcane, cotton, cassava) represent a significant share of national production.

The State of Ceará

Ceará is the fourth largest State in Northeast Brazil with a total area of about 148,000 km“2”. Population projections indicate that by 1990, the total population of Ceará will be of apparoximately 6,4 million. Of which 36 % will be living in rural areas. Agriculture is the main economic activity employing about 56 % of the State's labour force.

Fig 5: LAND DISTRIBUTION IN BRAZIL NORTH EAST & CEARA (Comite Mandioca Ceara)

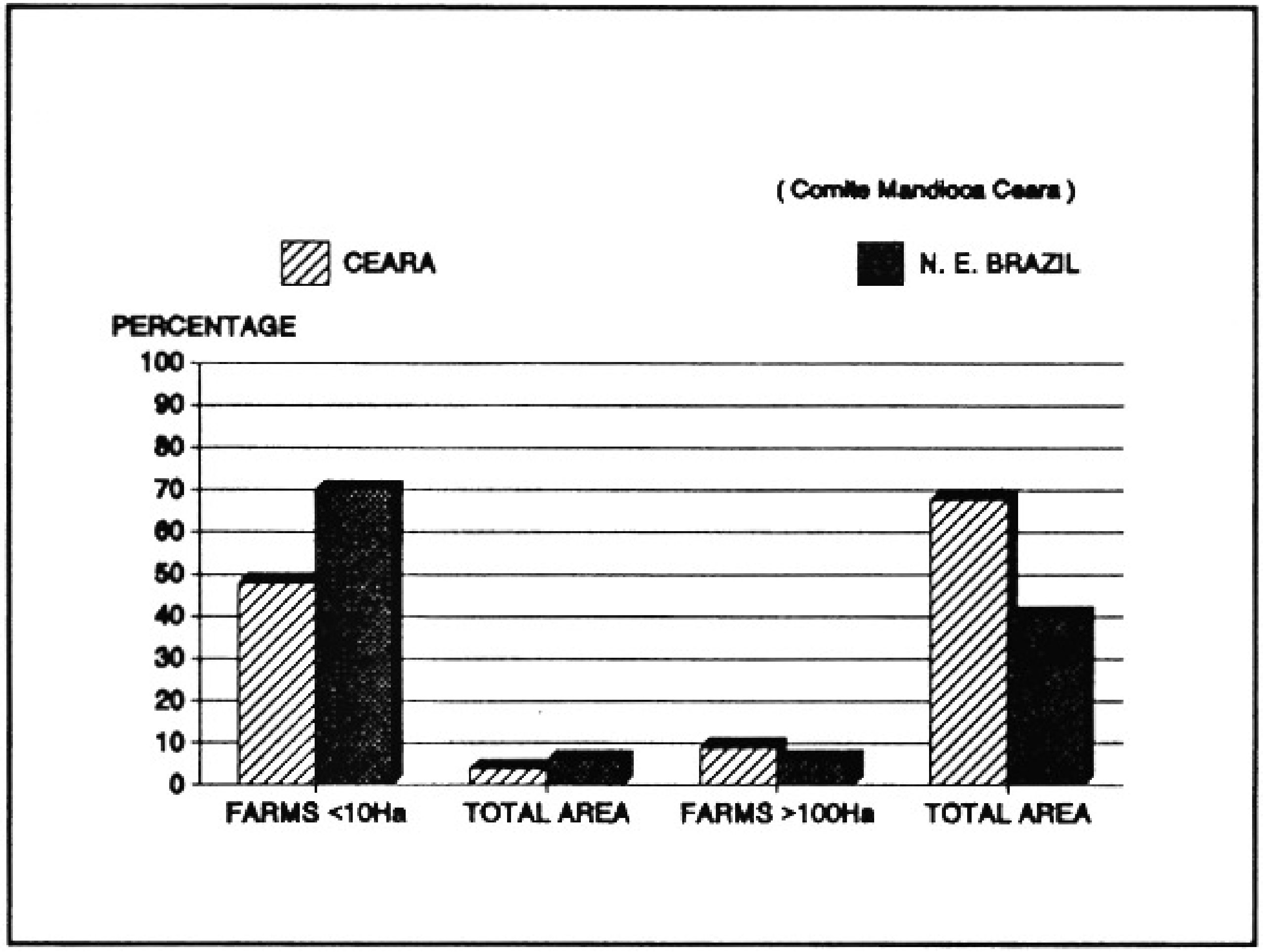


TABLE 5. **Cassava production and consumption in Brazil 1989**

	Cassava Production (thousand hectares)	***Per capita* Consumption**	
		Fresh cassava	**Cassava flour**
Brazil	1.903	6.1	17.6
Northeast	1.092	4.3	43.7
Cear�	112	3.2	55

Source: FAO - *Perspectivas Alimentarias 1990 IBGE - 1989*

Average *per capita* income in rural areas of Ceará is one of the lowest in the Northeast of Brazil. The income distribution pattern is extremely unfair with 50 % of the population (the poorest of the poor) earning less than a minimum salary (US$ 65 in January 91) and participating with only 15 % of the total rent of the state. High rates of infant mortality (25 per 1,000), malnutrition and illiteracy are common major socio-economic problems in Ceará.

Land distribution in Ceará, as in the rest of Northeast Brazil, presents a highly skewed pattern whereby the number of farms with less than 10 ha represent 48 % of the total number of farms and occupy only 3,9% of the total farm area. On the contrary, the number of farms with areas over 100 ha represent only 9 % of the total number of farms and occupy 68 % of the total area available. Some 60 % of the total number of rural producers are classified as non-owners and of those considered as owners, about 40 % have no legal little to their land (see Fig. 5).

CASSAVA PRODUCTION AND IMPORTANCE

Brazil

Cassava is grown in all states of Brazil. According to FAO figures, in 1989 the area planted was 1.9 million ha with a total production of 23.2 million t and an average productivity of 12.5 t per ha. Brazil used to be the most important producer of the world but lately this position has been lost to Thailand. On a country basis, cassava holds eight place as regards to total crop area planted and seventh place regarding monetary value. 8/.

The consumption of cassava in Brazil is highest in the rural areas and is consumed in two principal forms. First, as farinha (a toasted flour) and second, as aipim or fresh cassava. Per capita consumption of farinha on a country basis is 17.6 kg/year and of aipim is 6.1 kg/year.

Consumption of farinha in North and Northeast Brazil is greater at about 45 kg/year than in the south at 3.5–6 kg/year. The consumption of farinha in Brazil as a per-capita basis has declined over the last 15 years, partially due to the urbanization process since urban consumption is significantly lower than rural consumption (see Table 5).

Northeast region

Cassava is produced in the northeast region mainly by small farmers. The climatic conditions is this area are much harsher than those of other cassava growing areas of the country and, consequently, yields are lower. Data available indicates that in 1989 a total of 1.09 million ha of cassava were planted with a total production of 11.7 million tonne and an average productivity of 10.7 tonne per ha.

Most of the cassava harvested in the region is used for production of “farinha de mandioca” with smaller amounts sold as fresh cassava for human consumption and minimal quantities used for animal feeding.

The State of Ceará

Production of cassava in the State of Ceará represents one of the main agricultural activities. During the period 1985–87, the average annual production of cassava was of 113,035 ha with a productivity level of 9.6 tonne per ha. This production represented state wide, the fifth place in terms of total crop area planted and second place in terms of total monetary value.

Consumption of “farinha” in Ceará is done mainly in the form of farinha (64 %), animal feeding at farm level (25 %) and minimal quantities are used in fresh form for human consumption.

PROJECT DESCRIPTION

Project objectives and expected outcome

The project is intended to improve the welfare of the rural poor involved in cassava production in communities throughout the State of Ceará, Northeast Brazil. This general objective is to be achieved through the introduction and adoption of improved cassava production, processing and marketing technology. The outcome expected of the project:

1. Generation and testing of a small scale cassava-based agroindustrial development model.

2. Institution building through the utilization of a participative management approach for the implementation of the project at the various levels and stages. Emphasis has been placed on developing and strengthening community-based organizations.

3. Welfare improvement through the stimulation of economic development and generation of employment opportunities in rural communities in the project area.

Project activities

Implementation of the work plan has involved the following activities:

1. Selection of site for developing a pilot project.

2. Identification of local institutional capacity to carry out the implementation of the project, as well as identification of local sources of financial support.

3. The design and establishment of the pilot project.

4. Observation of the operation of the pilot project and in situ modification of the modus

operandum to accommodate it to local conditions.

5. Monitoring of project performance and modification of project design.

6. Expansion phase to semi-commercial and commercial-scale production.

PROGRESS TOWARDS PROJECT OUTCOMES

Following is a report on the progress made during the first two years of implementation of project's activities.

Selection of site for developing a pilot project

The selection of the State of Ceará as the site for the pilot project was strongly influenced by prior involvement of some agricultural institutions of Ceará, especially the Technical Assistance and Rural Extension Agency (EMATERCE), in the promotion of activities related to small scale cassava farming and processing.

The concept of cassava-based, small scale agro-industries for the production of dry cassava chips for animal feeding was tested out between 1981 and 1987 with rather disappointing results. Among the reasons for this failure could be mentioned the extensive drought that hit the area between 1979to 1983, the agro-industrial model chosen which relied on large producer cooperatives (400–500members) and the poor selection of areas and farmers group.

In 1988, the Ceará State Cassava Committee was formed and in 1989, with the approval of the Kellogg Foundation founded project for Ceará, the coordinating activities by the cassava committee in support of the cassava crop in the state were strengthened and during this period (1988– 1990) a total of 33 groups of cassava producers have been organized for the installation and administration of dry-cassava processing agro-industries.

The involvement and the commitment of some agricultural sector agencies in support of cassava production and processing activities during the period 1981–88 served indeed as a foundation of both experience and organizational infrastructure on which the Kellogg financed project started to be built.

Identification of local institutional capacity and local sources of financial support

The identification of local institutional capacity and the building of local institutional support is being pursued at four different levels: State, Regional, Municipal and Community level (see figure 6).

The Design and establishment of the pilot project

The establishment of the pilot phase of the project has involved activities in the following areas: production technology, processing technology, commercialization, organization and training.

During the first year (1989–1990) with 12 farmer groups, the total output was 702 t of fresh cassava processed and 265 t of dry cassava chips produced. In the second year (1990–1991) with participation of 32 groups the total output was 3.315 t of fresh cassava and 1.254 t of dry cassava chips. This production represented an increment of 370% in relation with the first year. A conversion rate of 2.64 was satisfactory.

Most of the dried cassava produced in Ceará has been sold directly to dairy farmers in the vicinity of the drying plants. Of the 115 consumers of the dry cassava processed in 1989, only 6 were high volume consumers although they purchased 30.4% of total output. For 1990 season the tendency appears to be the same with a large number of low volume consumers (223) purchasing 24.7% of the total output and a small number of high volume consumers (10) purchasing 75.3% of the dry cassava produced. This situation may be due to the fact that animal feed manufacturers are usually high volume consumers over prolonged periods and the project is not yet sufficiently developed to stimulate the interest of these buyers (See table 6).

Monitoring and evaluation

Tracking progress towards achieving project specific objectives is being done through an evaluation strategy which includes the following activities:

i. Monitoring the daily running of the project in the area of cassava processing.

ii. Monitoring the impact of the project in relation to cassava production and productivity in Ceará and,

iii. Monitoring the distribution of the benefits of the project among intended beneficiaries.

RESULTS OF THE FIRST TWO PROCESSING SEASON (1989–1990)

The following information has been collected during the first two years of processing activities in relation with the benefits of the project and its distribution among beneficiaries.

Cassava sales

During the first processing season (July-December 1989) 53% of the cassava roots processed was coming from non -members around the processing units and 47% from the members. During 1990, partial information available at this point indicates that 56% of the raw material

processed was coming from non-members and 44% from members.

Fig6: CEARA INTEGRATED CASSAVA DEVELOPMENT PROJECT ORGANISATIONAL STRUCTURE

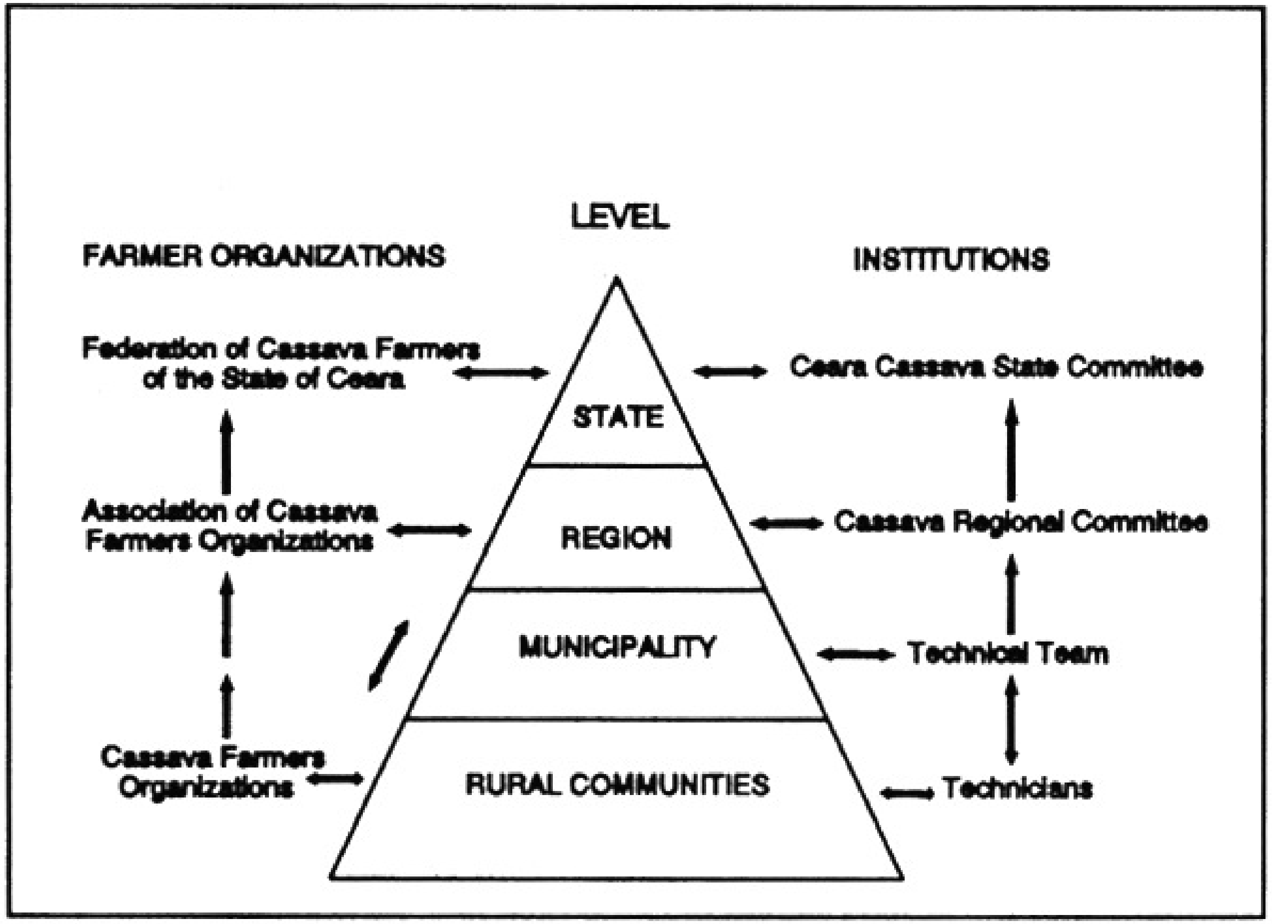


TABLE 6. **Commercialization of dry cassava in Cear� 1989/90**

Year	Number of organizations	Total output	Conversion rate	Total number consumers	Consumers per ton bought	% of total production sold to high volume consumers

		Fresh roots Dry chipston				<1 1–10 >10			
1989	12	702	2654	2.64	115	68	41	6	30.4
1990	32	3315	1254	2.64	151	86	86	10	75.3

In relation with the land tenure status of the farmers, during the first year 69% of the cassava roots sold to the processing units were coming from small holders, 22% from renters and 9% from share-croppers. Information about 1990 processing season indicates that 66% of the raw material sold to the drying plants was coming from small holders, 30% from renters and only 4% from share-croppers.

Cassava processing wages

Besides the selling of cassava roots another form of benefit gained by the farmer members of the cassava agro-industries is represented by the wages paid at the cassava drying plants during the processing activities.

During the first cassava drying season (1989) the wages benefiting the farmers were distributed as follows: 52% were gained by small holders, 35% were gained by renters and 13% were distributed among sharecroppers.

Data for the second cassava drying season (1990) were only partially available and the results obtained show that 26% of the wages paid at the cassava processing plants were gained by small holders, 53% was gained by renters and 21% was distributed among share-croppers.

Total incomes

Benefits gained by farmer groups who participate in dry-cassava processing activities include cassava sales, wages and the sharing of annual profits among members. During the first processing season, 58% of the total income earned by the processing groups went to small holders, 32% to renters and 10% to share-croppers. Total information about the second processing season is not yet available because some of the agro-industries will be processing dry cassava until January 1991. Preliminary information indicates that of the total incomes gained by the beneficiaries of the project, 53% went to renters, 25% to small holders and 22% to share-croppers.

Additionally, the distribution of this total income according to the size of cassava plots planted in 1989 shows than more than 70% of the total income went to those farmers whose area planted was between 1.0 and 2.0 hectares of cassava and that those farmers with more than 3.0 hectares received less than 10% of total income. In 1990, with partial information the results show that 94% of the total income went to those farmers with cassava areas of up to 2.0 hectares and that those farmers with more than 2.0 hectares of cassava received less than 10% of total income.

Prices of dry cassava and cassava flour

Throughout the 1990 cassava processing season (July-December) the prices for dry cassava chips have been consistently more profitable than those for cassava flour.

This situation is reducing the drastic fluctuations on cassava prices at the farm level. During this season, the incipient dry-cassava market has been acting as a floor price in the main cassava growing areas of the State of Ceará (See table 7).

TABLE 7. **Dry cassava and cassava flour prices in Cear� (Average 1990 Processing Season)**

	Dry cassava	Cassava flour

	Cr$/kg	%	Cr$/kg	%
Raw material	6.53	52.5	10.89	64.4
Processing costs	0.83	6.7	6.32	37.4
Fixed costs	1.20	9.7	2.40	14.2
Selling price	12.44	=	16.91	=
Profits	3.88	31.1	-2.70	-16.0

SUMMARY AND CONCLUSIONS

The experiences accumulated to date in Colombia, Ecuador, Brazil and other countries indicate that an integrated approach towards the development of the cassava crop leads to country wide benefits in terms of import substitution and the creation of employment in rural areas.

The main strategy in the implementation of cassava-based development projects lies in the transition of cassava from a basic staple food into a multiuse carbohydrate source, a process in which it is necessary to link the small-scale farmer to expanding alternative markets thus offering the possibility of generating income and employment opportunities to the small farm sector, generally responsible for cassava production in Latin America.

The abilities of the cassava crop to substitute for feed grain imports, to supply calories to the poorest sector of the society, to increase incomes for small farmers with marginal land resources and to provide employment in processing activities convert the cassava crop into an efficiently agricultural policy instrument.

In Northeast Brazil the development of a dried cassava industry for animal feed purposes has great potential for diminishing the need to import maize, stabilize cassava on-farm prices and

greatly expand the market size for the crop.

The initial results obtained in the Ceará Cassava Project are showing that linking small-scale cassava farmers usually producing in marginal agro-climatic zones to a growth market such as the one that exists for dried cassava, could yield significant increased income to this farming sector traditionally left out from the development process.

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Quality aspects of tradeable cassava products including problems of adulteration by J.F. Wood

CASSAVA TRADE TO THE EEC FOR FEED USE

The utilization of cassava as a primary energy source for livestock (particularly pig feeds) within Europe is now well established and provides valuable foreign exchange to cassava producing countries, most of which are third world /LDCs. Within Germany for example, cassava with a 65% starch content is 25–30 % cheaper than maize. Although cassava requires mixing with soya bean meal in the approximate ratio of 4:1 to form a “cereal replacer” its inclusion in feeds has resulted in a drop in maize imports into the EEC from around 15 million tonnes in the mid-1970's to below 2 million tonnes. The main world producers of cassava are

Brazil and Thailand. Thailand's exports have increased from about 2 million tonnes in the 1960's, mainly to the EEC, to 9.2 million tonnes in 1988. Under a self limiting agreement (quota) only 5.25 million tonnes can be sent to the EEC each year, the remainder going to the USSR, Japan, the Korean Republic and Turkey. The EEC has similar "voluntary" agreements with Indonesia, China and Vietnam (Schumacher, 1990).

Table 1 summarises imports of cassava into the EEC for the period 1983–89. Import quotas for 1990 are given in Table 2.

It is interesting to note that exports of cassava from the ACP countries in 1988 and 1989 were well short of the 146,000 tonne quota for the year at only 58 000 and 35 000 tonnes respectively. This suggests an increasing use of cassava within the countries of origin as both a food and feed source, rather than a decline in production level.

When considering the subject of the quality of tradeable cassava it is important to place it in the context in which the cassava will be used. This can be demonstrated by comparing typical usage patterns of cassava in livestock feeds between the Netherlands (a high cassava user), and the UK (a high cereal user) both of which are within the EEC (Table 3). The difference in tapioca usage pattern is predominantly a function of distance from the raw material source within the EEC and the proportionate transport costs.

TABLE 1.**Importation of cassava into the EEC 1983–89 ('000 tonnes)**

Year	GATT countries		Non-GATT countries	Totals
	Thailand	Indonesia and others (ACP)	China and others	
1983	4396	181	54	4631
1984	5355	398	64	5817

1985	4555	507	115	5177
1986	4679	417	300	5396
1987	5510	954	372	6836
1988	5487	883	353	6723
1989	5482	862	218	6562
1990	3119	811	184	4114
Jan-Oct				

TABLE 2.**Import Quotas for cassava into the EEC at 1990 ('000 tonnes)**

Thailand	5250
Indonesia	825
PR China	350
Other GATT countries*	146
Non GATT countries**	30
PR China (sweet potatoes)	600

* ***ACP countries e.g. Brazil, Tanzania and Philippines***

** **Vietnam**

Source: Data from COCERAL (1990) and Schumaker (1990)

TABLE 3. **Typical raw material inclusion levels in livestock feeds (%)**

	pig finisher		layer		broiler	
	Holland	UK	Holland	UK	Holland	UK
Cereals	-	54.0	7.0	60.0	22.0	69.0
Cereal by-products	18.0	9.0	15.0	7.0	-	1.0
Vegetable protein	28.0	24.0	35.0	17.0	39.5	14.0
Animal protein	8.5	7.0	7.0	5.0	8.5	11.0
Cassava	37.0	-	24.5	-	20.5	-
Oil and fat	2.5	2.0	3.0	1.0	7.5	4.0
Others	6.0	4.0	8.5	10.0	2.0	1.0

Source: Data from Nijweide 1987

PRE- AND POST-HARVEST MANAGEMENT OF THE CROP

The trade in cassava into the EEC works through the following chain: farmer, chipper, dryer, pelleter, country of origin export broker, EEC import broker, feed compounder. Some of the larger companies have responsibilities within each of these roles with the exception of feed compounding. In other cases cassava chip and pellet production will be through individual local companies. These smaller producers deal with the export brokers whose responsibilities will be to ensure capacity loadings for shipment. Shipments may therefore be of cassava of mixed origins and quality.

The methodology of cassava chip and pellet production has been well documented. In particular the Proceedings of the IDRC interdisciplinary workshop Pattaya Thailand April 1974 on Cassava Processing and Storage. This Workshop highlighted the manufacturing problems within the cassava chip/pellet industries in Thailand.

ADULTERATION

At the 1974 IDRC cassava conference, Thanh (1974) and others listed the main criticisms from European customers of cassava pellets from Thailand as being:

i. nutrient quality: minimum starch content was not achieved (minimum 62 %); maximum sand and foreign matter limits were exceeded (maximum 7% raw cellulose and 3% sand); maximum moisture content was exceeded (maximum 14 % moisture).

ii. physical quality: pellets were of poor friable consistency causing excessive dustiness and high meal content with pellets. Bacteria and mould contents were too high.

These criticisms were particularly addressed to “native” products, i.e. those processed by Thai factories using locally manufactured equipment rather than the higher quality “branded” pellets processed by companies using imported pelleting equipment.

In addition, Mathot (1974) indicated that the financial returns to the pelleting companies were sufficiently low to encourage excessively short drying times, absence or non-use of sand sieves, a great deal of mixing in of foreign matter such as ground corn cobs, tapioca wood, tapioca waste (offal of the starch industry), rice bran and other cheap materials of high crude fibre content.

In contrast cassava chips from Indonesia were found to be of good quality being white, well peeled washed and dried.

Since 1974, the regulations on cassava quality within the EEC have been revised, notably to reduce the maximum moisture content from 14 % to 13 %, and to increase the minimum starch content from 62 % to 63 %. The current EEC quality requirements for cassava products (EEC

1979) are presented in Table 4.

TABLE 4. **Current EEC quality requirements for cassava products**

Feedstuff	**Description**	**Composition requirement**	
Manioc meal	Dried and if necessary washed and peeled	Starch moisture	min 75% max 13 %
Chips or roots	Manioc roots; also products obtained by crushing and grinding	Crude fibre Crude ash Ash insoluble in HCI	max 5.2 % max 5.5 % max 3.3 %
Manioc type 55 meal	Unpeeled manioc roots, dried and if necessary washed	Starch Moisture Crude fibre	min 63 % max 13 % max 9 %
Flakes roots	products obtained by crushing and grinding	Crude aash Ash insoluble HCI	max 6 % max 4 %

Aflatoxin in straight feedstuffs: 0.05 mg/kg.
Hydrocyanic acid in manioc products: 100 mg/kg (maximum content in mg/kg of feeding stuff referred to a moisture content of 12 %) (EEC 1974).

The present state of cassava quality is now considered under the perspectives of the cassava exporter, the import broker and the feed compounder.

CASSAVA EXPORT BROKER

For these data I have relied heavily on literature from Krohn and Co, one of the major German cassava traders and refers to activities in Thailand (Krohn and Co., 1990).

The basic process adopted by the pellet producers is as follows:

1. Chip whole roots to 1–2cm thickness x 2–5cm length
2. Sun dry 2–3 days with turning to moisture level of 15–18% which is acceptable for pelleting.
3. Screen chips to remove fine meal and sand.
4. Pellet with preconditioning at 80–85°C with dry steam at 10 bar for 15–20 seconds.
5. Cool pellets and reduce moisture to 13–14%.
6. Screen for fines.
7. Spray 0.1–0.5% rice bran or coconut oil to reduce dusting.
8. Bulk store on godown floor.
9. Barge from port godown to seagoing ship by lighter.
10. Voyage Thailand to Rotterdam. Approx 30 days via Suez Canal or 42 days via Cape of Good Hope.

If desired the company can arrange for fumigation to be carried out (eg by SGS at 1–2 kg/1000 cuft methyl bromide gas applied for 24–48 hours).

QUALITY STANDARD AND CONTROL PRIOR TO EXPORT

i. *TISI quality standard.* The quality standard of Thailand cassava hard pellets has been set by the Thai Industrial Standard Institute of the Ministry of Industries (TISI) whose inspectors control the quality standard of cassava products through regular visits to the factories and drawing random samples from production.

ii. *Pre-Pelleting.* Prior to reception at a pelleting plant chips receive a visual check for general appearance, normal colour, odour and mould. After this a sample is drawn and analyzed in the laboratory for sand and moisture content.

iii. *Production control.* At intervals of 2 hours a sample is drawn from the raw material that goes to production, and the finished product. These samples will be analyzed for sand and moisture, and the pellets additionally for meal and hardness.

   A daily average sample is collected by the private independent surveyor, e.g. Société Générale de Surveillance (SGS) for analysis to full TISI standard analysis.

iv. *Export control.* The sampling and subsequent analysis are carried out by the Office of Commodity Standard of the Ministry of Economic Affairs. The product is checked twice, upon application for an export licence (pre-loading control) and during export loading (loading control). Depending upon the sales contract a second private control organisation licensed by the OCS may be employed.

Although quality control prócedures for centrally controlled processing operations would appear to be more than adequate, such control is not practicable at smaller units where the products of drying and chipping are passed to independent pelleters and brokers who will be handling material from a variety of sources.

EEC IMPORT BROKER

Trade quality limits in themselves do not give us a picture of the state of products entering the EEC. For this we need analytical data on cassava imports.

Examination of data from an independent UK laboratory (Moulder, 1990) of cassava samples tested during 1985–90 indicated some important trends in cassava quality parameters (Table 5). The samples were primarily from shippers/import brokers and represent the range in product quality of cassava entering the EEC from Thailand and Indonesia in particular.

i) CHIPS: Indonesia and Java

TABLE 5. **Analytical data for chips and pellets 1985 and 1990**

	1985			1990		
	No tests	**Mean**	**Range**	**No tests**	**Mean**	**Range**
Moisture	152	13.5	10.9–15.9	224	11.7	9.6–14.7
Starch	216	65.5	62.5–74.5	225	72.1	66.2–75.5
C Fibre	136	3.1	2.2–4.9	228	3.2	2.1–4.2
Sand	73	1.3	0.2–9.5	157	0.5	0.1–4.2

ii) PELLETS: Indonesia and Thailand

	1985			1990		
	No tests	**Mean**	**Range**	**No tests**	**Mean**	**Range**
Moisture	4226	12.7	9.4–17.1	1469	10.9	8.7–16.2
Starch	3924	66.0	57.5–74.5	2164	65.5	56.5–74.5
C Fibre	3692	3.9	2.0–10.7	2003	4.3	2.6–9.2

Sand	2979	2.9	0.2–7.2	1676	3.1	0.2–5.7

From approximately 9000 samples of cassava analyzed over the period 1985–1990 in the ratio 1:8 chips: pellets, equal importance was apparently given to the results for moisture, starch and fibre. The clients requests for sand and /or silica were approx 80% as for the other analyses.

The following additional tests on cassava were requested by clients:

aflatoxin	1
salmonella	1
purity	1
insects	11
hydrocyanic acid	nil

Data for the intervening years 1986–89 followed a similar pattern to the above and have therefore not been presented. The most important factors emerging from this data are:

1. **There has been a marked reduction in the mean moisture levels of both cassava chips and pellets to a level which is safely below the 13 % maximum set by the EEC legislation. This will no doubt have resulted in lower levels of microbiological and fungal contamination. Regrettably I have no data to substantiate this proposition.**

2. **Almost all samples were above the 63 % minimum starch level.**

3. **All samples of chips and a high proportion of pellets were well below the maximum limits for crude fibre and sand of 9 % and 5.5 % respectively.**

These figures therefore suggest that there has been a gradual improvement in the quality of cassava chips and pellets since the mid 1970's at least in relation to the EEC requirements. Adulteration of cassava pellets with corn cobs, tapioca wood, sand, etc. would appear to be less common occurrences, such practices having been controlled at the point of origin.

However, results for starch fibre and sand ranged widely from the means and clearly indicate that some shipments could result in potentially costly imbalances of nutrient levels in feed formulations if such variability was not accounted for at the formulation stage.

HYDROGEN CYANIDE

The apparent absence of requests for HCN by shippers indicates that high cyanide levels are unlikely to be found in commercial cassava chips or pellets for use as an animal feedstuff.

This position is confirmed by the findings of Gomez *et al.* (1984) in studies on cyanide content of cassava during tray drying. These workers found that chopping of whole cassava allowed a very rapid hydrolysis of the cyanogenic glucoside, leading to a fast rise of the volatile free cyanide portion. Within the dried chips, 60–80% of the total cyanide was present as free cyanide. In this trial, the total cyanide level of 50% of the varieties was below the 100 mg/kg level desired by the EEC. These levels would almost certainly have been lowered further had the chips been exposed to the rigours of pelleting.

AFLATOXIN

Aflatoxin B1 when extracted from feed materials shows intense fluorescence under ultra violet (UV) light. Studies to determine the extent of aflatoxin contamination in cassava from the Colombian feed industry initially revealed important levels of contamination due to the fluorescence noted under UV light. However, previous research at CIAT had shown that

cassava post harvest physiological deterioration involves the synthesis of scopoletin, an innocuous natural resin which also fluoresces under UV light. In subsequent studies CIAT reported that the fluorescence in all samples of feed grade cassava chips was due to scopoletin and not to aflatoxin (CIAT 1990).

Furthermore, for over a period of 8 years of cassava use in animal feed in Colombia, only two samples showed traces of aflatoxin and these were negligible. This was considered to be the result from good drying practices since aflatoxin producing mould are unable to grow on chips dried to less than 14% moisture content.

Similar results were obtained by Sajise and Ilag (1987). Their observations suggested that cassava was not a good substrate for aflatoxin production. Cassava chips at 8.6–15.5 moisture served as a substrate for *A. flavus*, but the conditions did not promote aflatoxin formation. In contrast, Wheatley (1984) found that in a survey of cassava in the Philippines, 100% of samples were contaminated with aflatoxin with a mean of 468 ug/kg, though these figures were qualified by saying that high incidence was not always "real" and depended on the analytical method used.

Moulder (1990) has also confirmed the fluorescence from cassava extracts which would at first appearance seem to be due to aflatoxin, but in fact are due to other compounds.

The possibility of aflatoxin being mistakenly measured by fluorescence techniques therefore suggests that further work is needed on this subject.

FEED COMPOUNDER

The data from the shippers analyst is representative of the material selected by the broker for examination. From the feed compounders point of view the results are biassed in the shippers

favour and may not necessarily reflect the findings of the end user at the feed mill. The standards set by the EEC are not considered to be buying standards since these will be agreed between shipper (broker) and feed compounder following negotiations between the two parties. Price negotiation after delivery is considered by some cassava users as an undesirable but necessary step, since there is often considerable variation in apparent quality between the results of the shippers analysis and the more detailed analysis of the feed compounder. Starch content, fibre and sand and silica content are of particular importance in price negotiation.

From a users perspective the problems with cassava may be summarised.

1. **Inconsistent physical and nutritional quality**
2. **Excessive dust on handling and trans-shipment**
3. **Product contamination with sand an similar materials**
4. **Presence of undesirable matter such as sacks, string, insecticide envelopes, etc.**
5. **Excessive hardness of some grades of pellets causing jamming of intake augers, fractures of machinery bearings etc.**

HCN is not considered to be a problem if cassava is bought with a fibre level of less than about 3.5% where HCN levels may be 10–20 ppm (mg/kg). Fibre levels above 5.5% are often associated with undesirable HCN levels of 80–150mg/kg.

Some feed compounders would prefer to buy cassava of the quality consistency of Chinese sweet potato. This material is traded as dried slices and may be sold as Chinese cassava.

The contamination of feed grade cassava with mycotoxin does not appear to be a major problem. Nevertheless, aflatoxin contamination in cassava for food use has been found at up to 1000 ppb (Rensburg *et al*., 1979) and appropriate precautions against contamination of feed cassava is highly desirable. Bacterial contamination will, to some degree be reduced during cassava pelleting.

These findings indicate that many of the problems of feed grade cassava summarised in 1974 are still prevalent in 1990. For the feed compounder where cassava is included at high levels in the diet, the variability in the starch content of cassava shipments from 65 to 70% will demand reformulations and adjustments within the mill which he may prefer not to make. In spite of these problems the European feed industry has adapted to handling this material without seemingly applying excessive pressure on the importers to improve the physical quality of the product, and above all, provide a product of consistent quality.

POTENTIAL FOR IMPROVING MARKETING OF CASSAVA

When searching for new opportunities for the marketing of cassava it is essential to remember that cassava, as an internationally traded commodity finds its place in the market because of its competitive nutritional value/price structure relative to cereals. To ensure a continued growth in the utilisation of cassava within the feed industry, it must be priced in relation to world market or local cereal prices, while recognising that cassava is not in itself a cereal replacer, but may be considered as such when blended with a supplementary protein source such as soya.

It would be inadvisable for countries which may be considering the expansion of dried cassava production for export to assume that the EEC is waiting to absorb such production under the present pricing structure. In addition, the cassava trade position may be significantly

influenced by possible developments from future GATT negotiations.

Improvements in the quality consistency of cassava must be seen to benefit both cassava producer and compounder alike and the costs of improvements in the quality of cassava must result in a concomitant improvement in livestock productivity.

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Detoxification of cassava products and effects of residual toxins on consuming animals by O.O. Tewe

INTRODUCTION

The use of cassava in livestock feeding has been limited. Reasons include the presence of toxic cyanogenic glucosides, deficiency in nutrients other than energy, dustiness of the dried products, mouldiness during processing and the high fibre and ash content of the peel, which limits the selection of other ingredients which are high in these components. Nevertheless, the development of cassava products which meet minimum requirements for incorporation into commercial livestock feed production, in cassava producing areas, would certainly relieve the pressure on demand for available cereal grains. Additionally it would help guarantee the supply of energy for livestock feeding, in these regions, that are perennially acutely short of animal feed ingredients and due to unfavourable trade balances are unable to make up deficiencies with imports.

As the presence of cyanogenic glucosides constitute a major limitation to the use of cassava in both human and animal foods there is the need to review current findings for the elimination of the toxic glucoside in cassava products and also to examine the implications of feeding cassava and its products on livestock production.

Nature of Cassava toxin

Cassava is fed to livestock in the fresh or processed form. In the whole unbruised plant the cyanogenic glucoside remains intact in the form of linamarin and lotaustralin. When the cellular structure is disrupted, the intracellular glucoside becomes exposed to the extracellular enzyme linamarase. Hydrocyanic acid (HCN) is then produced. The reaction has been shown to

proceed in two steps by Nartey, (1978) viz:

i. **Cyanogenic glucoside is degraded to sugar and cyanohydrin (x - hydroxynitrile);**

ii. **Cyanohydrin then dissociates to ketone and hydrocyanic acid. Thus, for linamarin the glucoside is first hydrolysed by linamarase to produce B-D-glucopyranose and 2 - hydroxyisolentyronotrite or acetone - cyanohydrin, after which the latter is degraded to acetone and HCN. Cyanohydrin produced as a result of linamarin activity is stable only under moderately acidic condition (pH 4.0); in neutral or alkaline condition it undergoes spontaneous hydrolysis to yield HCN (Cooke *et al.* 1985).**

In spite of the relative instability of cyanohydrin it coexists with intact glucoside and HCN in differently processed cassava products. It is therefore clear that the cyanide in cassava products exists in three forms: (i) the glucosides (linamarin and lotaustralin), (ii) the cyanohydrin and (iii) the free hydrocyanic acid (HCN).

However, the quantitative estimation of cyanide by various methods has produced incomparable results, and in many cases a gross underestimation, emanating from quantification of free HCN alone in the reports of earlier investigators. The harmonization of current analytical and presentation methods is therefore suggested.

EFFECT OF CASSAVA PROCESSING ON CYANIDE LEVEL

Cassava tubers are traditionally processed by a wide range of methods, which reduce their toxicity, improve palatability and convert the perishable fresh root into stable products. These methods consist of different combinations of peeling, chopping, grating, soaking, drying, boiling and fermenting. While all these methods reduce the cyanide level, the reported loss in cyanide content differs considerably due to analytical methods, the combination of methods

and extent to which the process(es) is(are) carried out.

The specific effects of various processing techniques on the cyanide content of cassava are discussed below:

Peeling

Many methods of processing cassava roots commence with the peeling of the tubers. Generally the cassava peel contains higher cyanide content than the pulp. Removal of the peels therefore reduces the cyanogenic glucoside content considerably. In studies carried out by the author, the peel of the "bitter" cassava variety was shown to contain on average 650 ppm and the pulp to contain 310 ppm total cyanide; the corresponding values for "sweet" varieties were 200 ppm and 38 ppm respectively. The above classification is conveniently based on the cyanide content; with the sweet varieties having most cyanide in the cortex and skin and little or no cyanide in the pulp, whereas the bitter varieties, more or less, have an even distribution of cyanide throughout the tuber. For these reasons the former can be eaten boiled while the latter has to be processed before it can be consumed.

Peeling, therefore, can be an effective way to reduce the cyanide content by at least 50% in cassava tubers. However, it should be noted that while the peel contains a high glucoside content relative to the pulp, the glucosidase level is higher in the latter.

Grating

This process takes place after peeling and is sometimes applied to whole tubers. Grating of the whole tuber ensures the even distribution of the cyanide in the product, and will also make the nutrients contained in the peel available for use. In the grated product, the concentration of cyanide depends on the time during which the glucoside and the glucosidase interact in an

aqueous medium.

Grating also, obviously, provides a greater surface area for fermentation to take place.

Soaking

Soaking of cassava roots normally precedes cooking or fermentation. It provides a suitably larger medium for fermentation and allows for greater extraction of the soluble cyanide into the soaking water. The process removes about 20% of the free cyanide in fresh root chips after 4 hours, although bound cyanide is only negligibly reduced. Bound cyanide begins to decrease only after the onset of fermentaion (Cooke and Maduagwu, 1978). A very significant reduction in total cyanide is achieved if the soaking water is routinely changed over a period of 3–5 days.

A variation to the soaking technique known as retting, was described by Ayenor (1985). This process involves prolonged soaking of cassava roots in water to effect the breakdown of tissue and extraction of the starchy mass. A simulation of the technique, followed by sundrying showed a reduction of cyanide of about 98.6% of the initial content in the roots.

Boiling/Cooking

As with soaking, the free cyanide of cassava chips is rapidly lost in boiling water. About 90% of free cyanide is removed within 15 minutes of boiling fresh cassava chips, compared to a 55% reduction in bound cyanide after 25 minutes (Cooke and Maduagwu, 1978). Cooking destroys the enzyme linamarase at about 72°C thus leaving a considerable portion of the glucoside intact.

Fermentation

Microbial fermentations have traditionally played important roles in food processing for thousands of years. Most marketed cassava products like "garri", "fufu", "pupuru", "apu" etc., in Africa are obtained through fermentation. The importance of fermentation in cassava processing is based on its ability to reduce the cyanogenic glucosides to relatively insignificant levels. Unlike alcoholic fermentation, the biochemistry and microbiology is only superficially understood, but it is believed that some cyanidrophilic/cyanide tolerant microorganisms effect breakdown of the cyanogenic glucoside. It has been shown that the higher the retention of starch in grated cassava the better the detoxification process. This could be attributed to the fermentative substrate provided by the starch. Also, the longer the fermentaion process the lower the residual cyanide content.

In Nigeria, investigation of the effect of fermentation period on the residual cassava toxins is currently being carried out. As a preliminary stage, the use of starter cultures recovered from fermentation effluents is being tested to increase the conversion of substrate to product and reduce fermentation time.

However, Cooke and his co-workers using irradiated cassava found that mircroorganisms are not necessarily involved in the breakdown of cyanogenic glucosides. It is therefore clear that the effect of the microorganisms on cyanide detoxification requires further investigation.

Generally, fermented cassava products store better and often are low in residual cyanide content. Onabowale (1988) developed a combined acid hydrolysis and fermentation process at FIIRO (Federal Institute for Industrial Research, Oshodi, Nigeria) and achieved a 98% (approx.) reduction in total cyanide after dehydration of the cassava flour for use in the feeding of chickens.

A process, which can be described as "dry fermentation",is believed to occur in cassava

peelings which are usually heaped for days, in many parts of Africa, before feeding to ruminants. The process generates heat and mould growth is common. However, the measurement of HCN losses during such a process has not been documented.

Ensiling

The ensiling process causes the disintegration of the intact glucoside via marked cell disruption, drop in pH of ensiled medium and intense heat generation.

Ensiled cassava roots have been used for livestock feeding. Gomez and Valdivieso (1988) reported that ensiling cassava chips reduced the cyanide content to 36% of the initial value after an ensiling period of 26 weeks. We have also found that about 98% of the free cyanide was lost by ensiling cassava roots with poultry litter for 8 weeks.

Drying

Since cassava root contains about 61% water, coupled with the solubility of its cyanogenic glucoside component, the dehydration (dewatering) process results in a substantial reduction in the content of this toxin in the pressed pulp. Drying is carried out using solar radiation (sundrying) or Driers (electric or fuel) depending on economic viability. The process is achieved at varying temperature.

Work by the author has shown that sundrying:

i. **Results in a greater loss of total cyanide compared to laboratory oven-drying at 60°C for 48 hours. Oven-drying apparently affects the stability of linamarase which decomposes at 72°C.**

ii. **Tends to produce greater loss of bound cyanide due to slower drying rate relative to oven drying.**

iii. **Allows a longer contact period between the glucosidase and the glucoside in the aqueous medium. The effectiveness of enzyme/ substrate interaction will, however, be dependent on the particle size and environmental factors such as ambient temperature, insulation, relative humidity and wind velocity. Thus proper sundrying is achieved in between 1–3 days in the dry season and in up to 8 days during the rainy season.**

iv. **Facilitates the continuation of the fermentation process.**

v. **Is cost effective, but slow and often encourages the growth of mould and other micro organisms including *Aspergillus flavus* (pathogenic), *A. fumigatus; A. cherahen; A. teirenus; A. flaripes; A. japonicus; A. niger; A. ochracuss;* and *Penicillium rubrum* (Clerk and Caurie 1968; Oke, 1978). This microbial growth can expose the consuming animal to aflatoxicosis and/or mycotoxic infection.**

Because of the poor microbiological properties of sundried cassava products, there is a need for quicker drying methods which will reduce or eliminate microbial proliferation and ensure optimal cyanide detoxification.

An improvement in sundrying of cassava roots using inclined traydrying instead of drying on concrete floors was reported by Gomez *et al.* (1984). The residual total cyanide content was 10–30% of the fresh sample, with about 60–80% of the cyanide in the dried chips occurring as free cyanide. The comparative advantage of this method could be due to good conductivity of the tray. Gomez *et al.* (1984) indicated that more than 86% of HCN present in cassava was lost during sundrying. Bound cyanide which is less volatile can be a greater contributor to cyanide

toxicity in sundried products than free HCN which vaporizes at about 28°C. yet the former is frequently unestimated though potentially toxic.

Table 1 shows the hydrocyanic acid content of cassava and its products used for livestock feeding.

TABLE 1. **Hydrocyanic acid content of Nigerian cassava and some products used for animal feeding (air dry basis)**

Cassava/Products	Hydrocyanic acid content (ppm)
Fresh whole root	88.3–416.3
Fresh pulp	34.3–301.3
Fresh peel	364.2–814.7
Sundried whole root	23.1–41.6
Sundried pulp	17.3–26.7
Sundried peel	264.3–321.5
Oven-dried whole root	51.7–63.7
Oven-dried pulp	23.7–31.3
Oven-dried peel	666.8–1250.0
Dried cassava waste	240.0
(peels and discarded small	
tubers)	

Source: Tewe and Iyayi (1989)

EFFECTS OF RESIDUAL TOXINS

Cassava toxicity

The cyanogenic glucosides were initially thought to be of little consequence to mammals as long as the cassava hydrolytic enzyme had been inactivated. However, the ingestion of high concentrations of cyanogenic glucosides from fresh cassava roots and leaves have been reported to be lethal in numerous species of animals. This was because the possibility of hydrolysis during digestion was not adequately understood, despite early reports that oral doses of pure linamarin produced physiological and biochemical changes in rats and chick embryos even in the absence of linamarase activity (Philbrick *et al.* 1977; Maduagwu and Umoh 1988).

The subject is now better understood. On excess consumption of unprocessed cassava there is the enzymatic breakdown of the glucoside releasing HCN and thereby causing poisoning.

Cassava toxicity may be acute and/or chronic. Acute toxicity results from ingestion of a lethal dose and death is caused by the inhibition of cytochrome oxidase of the respiratory chain by cyanide. This has been reported in goats ingesting cassava leaves (Obioha, 1972), and also in non-ruminants, like pigs, when fed fresh uncooked tubers.

The level of total HCN varies widely in cassava tubers, and death has been more common with the “bitter” varieties containing levels of HCN higher than 500ppm (Tewe and Iyayi, 1989). Where sub-lethal doses of cyanide are consumed, the inhibition of cellular respiration can be reversed by the removal of HCN by respiratory exchange or the detoxification process. The latter proceeds via many pathways, though probably the most important is the reaction of cyanide with thiosulphate to form thiocyanate and sulphite. The cyanide is initially trapped in the erythrocyte fraction of the blood and later converted to the less toxic thiocyanate.

Chronic cyanide toxicity on animals can affect both the growth and reproductive phases of development, each of which will be considered later.

It should be pointed out that, while the lethal dose has been estimated at between 0.5 and 3.5 mg/kg body weight or 30 and 210 mg for 60 kg adult human, the lethal dosage for various animal species has not been established. Bolhuis (1954) classified the toxicity of cassava cultivars as follows:

i. **Innocuous: less than 50ppm fresh peeled tuber;**

ii. **Moderately poisonous: 50–100ppm fresh peeled tuber;**

iii. **Dangerously poisonous: more than 100ppm fresh peeled tuber.**

A reclassification should take into consideration the potentially releasable, bound cyanide, and so correct the deficiency of that of Bolhuis, which assumed that all cyanide was available as free HCN.

Effect of chronic Cassava toxicity on the growth phase

The ingestion of fresh or processed cassava based diets causes reduced growth rates in rats, pigs, African giant rats, sheep and goats (Tewe *et al*., 1977; Tewe and Maner, 1981; Tewe, 1983). The animals also have increased serum and urinary levels of thiocyanate, which is a continuous cause of depletion of sulphur containing amino acids (Tables 2 and 3). The thiocyanate also inhibits the intra-thyroidal uptake of iodine, causes an increase in secretion of thyroid stimulating hormone (TSH) and causes a reduction in thyroxine level which is necessary for growth. It is thus a goitrogenic factor, which was demonstrated by Tewe *et al.* (1984), who reported a significant reduction in serum thyroxine levels in growing pigs fed

cassava peel diets containing 96 ppm total cyanide (Table 4).

In rats and pigs consuming inadequate amounts of protein and sulphur amino acids, the serum thiocyanate concentration becomes lower as the animals become unable to adequately detoxify cyanide. Additionally, this condition can also aggravate deficiencies in selenium, zinc, copper and vitamin A. Even with sufficient protein intake, consumption of cassava flour based rations can result in parakeratosis in pigs, attributable to zinc deficiency, aggravated by the cyanide in cassava diets. Other features include paralysis of the hind limbs and muscular weakness.

TABLE 2. **Performance and metabolic changes in African giant rats fed corn or processed cassava peel diets**

Parameters	Corn	Sundried peel	Oven-dried peel	Fermented peel
HCN content (ppm) of feed	0	130.2	595.2	42.5
Daily feed Intake (g)	28.45b	27.70b	31.25ab	32.63a
Daily weight gain (g)	10.97a	9.02c	9.43c	10.30b
Daily Cyanide Intake (mg)	0b	1.80b	9.30a	0.69b
Feed/gain ratio	2.59b	3.07b	3.32a	3.18a
Protein Efficiency	1.90a	1.64b	1.53b	1.58b
Ratio				
Nitrogen Retention %	70.63a	64.50a	56.09a	55.97b
Serum total protein	6.12	6.00	5.97	5.97
(g. $100m^{-1}$)				
Serum Urea	92.18b	1.53a	114.65a	97.12b
(mg. $100ml^{-1}$)				

Serum thiocyanate	1.09[b]	1.19[b]	1.65[a]	1.24[b]
(mg. 100ml^{-1})				
Urinary thiocyanate	2.47[c]	5.69[b]	10.91[a]	5.99[b]
(mg. 100g^{-1} feed				
intake)				
Liver thiocyanate	0.41[b]	0.39[b]	1.18[a]	0.39[b]
(mg.g^{-1} fresh weight)				

a,b,c: means with different superscripts in horizontal rows are significantly different P<0.01).

Source: Tewe and Kasali, (1986).

TABLE 3. **Performance and metabolic changes in sheep and goats fed cassava/urea based rations containing varying elemental sulphur**

	% Dietary sulphur			
Parameters:	**0%**	**0.25%**	**0.50%**	**0.75%**
HCN (mg/kg)	247.0	246.0	248.0	247.0
Body Weight Change (%)	-75.0	-25.0	83.34	68.34
Ruminal NH_3N (mg/100ml)	2.45[a]	2.40[a]	0.75[a]	1.05[b]
Blood Urea (mg/100ml)	3.0	2.89[a]	2.49[ab]	1.91[b]
Urinary Thiocyanate	0.03	0.026	0.026	0.024
(mg/100ml)				
Serum Thiocyanate	0.035[a]	0.073[b]	0.060[b]	0.073[b]
(mg/100ml)				

Ruminal Thiocyanate	4.01	3.10	3.60	2.80
(mg/100ml)				

a,b,c *Means without common superscript in horizontal rows are significantly different (P<0.05)*

TABLE 4 **Metabolic changes in pigs fed cassava peel based diets containing varying cyanide levels**

	Dietary variables		
	1	**2**	**3**
Total HCN (ppm)	0	96	400
Protein level %	20.19	20.42	20.12
Parameters:			
Serum thyroxine (T_4) (mg/dl)	4.47[a]	3.63[b]	3.32[b]
Serum total protein (g/dl)	6.9	6.9	6.9
Serum urea (mg/dl	24.0[a]	42.0[b]	47.0[b]

[a, b] means without common superscripts in horizontal rows are significantly different (P<0.05).

Source: Tewe et al., 1984

In poultry, there are scant reports of toxicity due to cassava cyanide. However, depression in growth rates of broilers consuming cassava diets is common, and especially when a significant amount of the grain is replaced without proper protein supplementation. This observation is ascribed to a lower protein content in cassava and the extra need for sulphur amino acids. The author has shown, however, that the performance of poultry on cassava diets is satisfactory

as long as the total HCN content in the final ration does not exceed 100 ppm. Such rations must however be nutritionally balanced, and in particular contain sufficient sulphur containing amino acids.

Effect of cassava chronic toxicity in the reproductive phase

Chronic cyanide toxicity appears to pose more problems with breeding stock as they remain on farms longer than growing animals. However, very few studies have been conducted in this area.

Studies carried out with gestating pigs (Tewe and Maner, 1981), showed that, when fed fresh cassava containing 0, 250 and 500 ppm cyanide, maternal and foetal serum thiocyanate levels only increased in those receiving the 500 ppm CN diet (Table 5). In this study a slight increase in the thyroid weight, with increasing levels of cyanide, was only observed, in pigs fed the two lower levels of CN, with definite pathological changes noted in the thyroids of those fed the 500 ppm CN diet.

Although the consumption of the cassava diet during gestation did not affect performance during lactation, milk thiocyanate and colostrum iodine concentrations were significantly higher (P>0.05) in the animals fed diets containing the highest level of cyanide. Otherwise, the size of litters and weights of the young produced from pregnant rats and pigs fed on the various cassava diets were essentially normal.

Maner (1972) reported that a fresh cassava based diet had an identical nutritional value to a corn based diet fed gestating pigs. However, in this study the cassava fed sows, also maintained on pasture, had an increased still-birth rate and slightly inferior weight gains in post-lactation.

TABLE 5. **Influence of cassava-based rations fed during gestation, on metabolites and thyroid weight in gilts, fetuses, and suckling pigs**

	Dietary HCN level (ppm)		
	0	**250**	**500**
Gestating gilts			
Serum thiocyanate (mg/100 ml)	2.01	2.15	2.29
Serum protein bound iodine (mg/100ml)	3.1	3.2	3.1
Amniotic fluid thiocyanate (mg/100ml)	0.90	0.45	1.18
Thyroid (g/100 g body weight)	5.52	7.44	7.98
Fetuses			
Thyroid (g/kg body weight)	0.54a	0.36b	0.52a
Serum thiocyanate	0.85b	0.87ab	1.02a
Lactating sows			
Serum thiocyanate (mg/100ml)	0.74ab	0.58b	0.78a
Serum protein bound iodine (mg/100 ml)	3.2	3.6	3.7
Colostrum thiocyanate (mg/100 ml)	1.32	1.19	1.41
Milk thiocyanate (mg/100 ml)	1.15b	1.15b	1.35a
Colostrum iodine (mg/100 ml)	4.9b	6.0b	15.2a
Milk iodine (mg/100 ml)	0.7	1.0	0.07
Suckling pigs			
Serum thiocyanate (mg/100 ml)	0.63	0.50	0.78
Serum protein (g/100 ml)	6.61	6.38	5.86
Serum protein bound iodine (mg/100 ml)	4.7	4.9	4.9

Source: Tewe, 1983

Means followed by different superscripts, in horizontal rows, are significantly different(P>0.05)

Studies have also been carried out at Obafemi Awolowo University, IleIfe, Nigeria on the reproductive performance of rabbits fed cassava based diets. These were carried out over three breeding periods and showed that the performance of pregnant and lactating does, were insignificantly different, from those receiving non cassava diets, in terms of litter size and birth and weaning weight of offspring (Omole and Onwudike 1982).

SUPPLEMENTAL VALUE OF NUTRIENTS

Protein and amino acids

The quantity and quality of protein supplementation in cassava based diets is critical, and especially with regard to the content of sulphur containing amino acids. Elemental sulphur as well as methionine supplementation have been reported to significantly improve protein utilization in pigs (Job, 1975). The requirement for sulphur-containing amino acid is for use in the rhodanase detoxification pathway.

Iodine and other dietary minerals

There are little or no reports of specific extra-requirements for other minerals in the diets of animals consuming cassava products. However, as already discussed, since thiocyanate resulting from cyanide detoxification competitively inhibits iodine uptake, there is a need for iodine supplementation to avoid the thyroid malfunctioning. Cyanide aggravation of selenium, zinc, and copper deficiencies also calls for the supplementation of cassava diets with these

minerals.

Palm Oil

The use of palm oil has been shown to be of benefit when feeding cassava based diets. Omole and Onwudike (1982) found that when rabbits fed diets containing up to 50% of cassava peel meal, were supplemented with palm oil, their serum thiocyanate levels remained unaltered. The improved performance with feeding the palm oil was attributed to the increased calorie intake of the animals. Formunyan *et al.* (1981) also reported that the rate of hydrolisis of cyanogenic glucosides in cassava, to produce the toxic hydrogen cyanide, is greatly reduced in the presence of palm oil. They suggested that this occurs because the supplemental oil delays the decomposition and therefore prevents the absorption of the cyanogenic glucosides.

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Ensilage of cassava products and their use as animal feed
by R.L. Limon

INTRODUCTION

There is a great deal of information on the potential use of alternate feedstuffs. However, the majority of the materials studied are either produced in limited quantities (i.e. to satisfy only local demand), or are only available during limited periods of the year. Some agricultural products have important agronomical limitations and others may not satisfy the quality standards of the feed industry. For these reason the major share of alternate feed sources

utilization takes place in small, poorly organized units of limited importance to the feed industry. In peasant animal production, the lack of technological knowledge, regarding the economic use of alternative feedstuffs seems to be the main limiting factor that discourages new or continued utilization.

Cassava root is an alternate feed that, based on extensive research, shows considerable potential for use in the Mexican tropics. In this area more than 450,000 ha of land have been identified with the characteristics to support cassava production without displacing other crops. If the maximum level of cassava crop yield, calculated as 80 ton/ha, were achieved, the production of cassava starch, using the land available, would be sufficient to totally satisfy Mexico's animal feed energy demand. However, the actual yield of cassava in Mexico averages only 12 tonnes/ha, and the land dedicated to cassava production is around 40,000 ha per year.

Most cassava is grown on very small peasant farms with well defined harvesting periods, and the major part of the cassava root produced is destined for human consumption or occasionally industrial processing. It is only occasionally used as an animal feed, partly because cassava producers are rarely involved in formal animal production. Further, if it is intended for animal consumption, cassava must be viewed either as a cash crop or as a part of a production system; neither of these options are currently applied in the field.

Animal feeding requires a constant supply of ingredients; and hence longterm economic considerations must be taken into account including; predictability of price and availability and quality of ingredients. Cassava root meal or pellets can be fully integrated into commercial animal feed production since they can be stored and handled mechanically like other conventional ingredients. In Mexico the main problems relate to the processing of cassava, since it is mostly produced in the humid tropics (50% of the total in Tabasco State, to the south of the Gulf of Mexico) with an average rainfall of more than 2,500 mm and mean temperature of

29°c.

In the humid tropics sun drying is difficult and may result in the production of a low quality product with severe *Aspergillus* and related aflatoxin contamination. Artificial drying significantly increases the cost which makes the use of the rootmeal non-competitive with cereal grains (of interest it has been calculated that dry cassava root cannot be economically utilized with a price above 70% of that of cereal grains). Therefore the only viable means by which it can be used as animal feed in these areas is either in the fresh or ensiled form.

Feeding fresh cassava reduces the efficiency of land use, since it results in an extended harvesting period which also diminishes the nutritional quality of the product. It was therefore concluded that ensiling represents the most attractive alternative, but that in both cases, the use of the cassava must take place near the site of cassava production, since the fresh material has a high water content which increases transportation problems and cost. If fresh and ensiled cassava are compared, the main advantage in favour of the latter will be the advantage of storage and extended use, which in turn leads to a programmable and more efficient utilization.

SOME CHARACTERISTICS OF CASSAVA SILAGE

Cassava ensilation is very similar to that of fresh forages. However the high water content of the root and its loss during processing require that special considerations in silo construction nead to be taken into account. Firstly, solid, non-absorbant flooring should be provided in order to prevent excessive liquid losses. Secondly drainage should be provided to avoid excessive water accumulation and alcoholic fermentation and /or putrefaction occuring. As with forages, water content, ensiling time and quality of the initial product are critical in the production of a good quality preserved product. If the fermentation conditions are altered the

final product will not be as required, resulting at best in a reduced animal intake.

In the construction of field silos any of the established technologies developed for forages can be used; the only constraining condition is to ensure an anaerobic environment. Careful planning should take place before starting processing, including estimating the amount to be harvested and distance from the field to the silo, as these may affect processing. Consideration should also be given to ways of compacting the harvested mass (to reduce air spaces), the covering to be used to seal the surface, as well as on the number of animals to be fed and the rate of extraction from the silo in order to calculate its size.

The objective of the ensiling process is to preserve the root's nutritional value, by means of a lactic acid fermentation, with a resulting pH of 5 or less. Production of lactic acid occurs initially at the expense of reducing sugars, therefore, if the nitrogen free extract of cassava is below 73%, then addition of a source of soluble carbohydrates (e.g. 3% final cane molasses) should ensure a proper initiation of the fermentation process and prevent alcohol production.

Hydrocyanates (HCN) that are found in the plant limit the use of fresh cassava. Sun drying of roots diminishes the content of HCN and in the case of silage it is reduced by washing and of greater importance, by fermentation. At times this is capable of producing an HCN-free product, which gives added value to this process.

FEEDING AND NUTRITIONAL CONSIDERATIONS

Similar considerations must be taken into account when using ensiled cassava, as part of an animal's diet, as when feeding fresh roots. In particular the high water content of the material may prevent animals consuming sufficient feed to satisfy their daily energy needs. Protein consumption may also be inadequate, and in particular in nonruminants, since the protein content is extremely low and of low quality (the protein is almost lacking in sulfur amino acids, which is worsened by the use of these amino acids in the metabolic detoxification of HCN) and as much as 60% could be non protein nitrogen. These two constraints are responsible for the following recommendations concerning the feeding of ensiled cassava.

Recommendations for the feeding of ensiled cassava

Although this material is palatable and animals consume it without problem the feeder should ensure that the animals consume sufficient dry matter to meet their requirements. Due to its low nutrient density, animals, and in particular young animals may not be able to consume sufficient to meet their needs. Also, unlike many other materials, such as cane molasses etc. the rate of passage of the ingesta is not proportionally increased with intake when this material is fed. As the age of swine and ruminants increase, and in particular as they approach puberty, their ingestion potential increases and even progressive gut hypertrophia occurs, and the animals are better able to satisfy their maintenance and production energy needs. Lactating animals are probably the exception to this effect, due to their high nutrient demand during this phase. The application of this material therefore seems particularly suited to use by gestating and finishing animals.

Ad libitum systems are probably the most appropriate means of feeding ensiled cassava, but average daily dry matter intake should be closely monitored and wastage prevented by appropriate feeder design and regular feeding. If the observed animal's intake exceed the desired amounts, restricted feeding is recommended to prevent excessive fatness.

Dietary supplementation is an important aspect of cassava utilization; protein, vitamins and minerals must be added either in the form of supplements and (or) additives in the silage. With regard to the latter, De Uriarte *et al.* (1971) (Table 1) observed no improvement in silage quality

from silage enrichment with maize or soya bean meal, except that dry matter content showed a concomitant increase. When these materials were fed the greatest daily intake was obtained from the silage made without any of these “additives”; and in fact soyabean meal reduced the quality and performance of animals fed that silage. It was concluded therefore that dry feedstuffs are better utilized in the formulation of supplements for the animals fed the silage.

TABLE 1.**Productive response off finishing pigs fed with cassava silage**

	AVG.DAILY WT.GAIN (g)	**INTAKE SILAGE**	**(KG) SUPPLEMENT**
CASSAVA	622	3.8	0.8
CASSAVA + CORN	546	3.6	0.9
CASSAVA + SOY BEAN MEAL	42	1.6	1.0
CASSAVA + CORN + SOYA	33	1.6	0.4
BEAN MEAL			

Source: De Uriarte et al., 1971

Due to the low protein content of cassava, several concentrates have been evaluated as supplements, the final decision on their use relates to the complementary composition of the sources available and their respective prices. In certain circumstances the cost of protein supplements may overide the benefits of cassava feeding. Rodriguez (1989) studied the now common practice of supplementing growing pigs, fed ensiled cassava, with commercially supplied protein supplements (36% crude protein), which were originally intended for mixing with cereal grains. Protein supplementation followed the general recommendations made with regard to body weight (mostly based on calculations of daily protein requirements, similar to those given by NRC). The animal evaluation was carried out on communal commercial farms (Ejido Tierra Nueva and Colonia Jose Maria Pino Suarez, Tabasco State), using pigs (256

heads) fed from approximately 15 to 95 Kg. In the study ensiled cassava was fed *ad libitum* with a restrict fed protein concentrate, to pigs in a trial in which their individual weights and the costs of production were recorded. Mean ensiled cassava consumption was of 3.75 kg/day (1.50 Kg of dry matter) and intake of the protein concentrate an average of 0.830 Kg/day (i.e. a mean of 14% crude protein was provided). Mean daily gain during the observed period was 0.610 Kg/day which resulted in a feed efficiency (gain/feed) of 0.26; and an economic return (from feed and feeding related expenditures, others fixed) of 16.58 %.

Data from Lopez *et al*. (1988) in Table 2 show the response to feeding locally produced meat and bone meal as the main ingredient in a protein concentrate (35 % crude protein) used to complement ensiled cassava in sow feeds. From mating to day 70 of gestation 3.0 Kg. of cassava ensilage were offered each day with 400 g/day supplement to provide an average daily intake of about 1.4 kg dry matter and 140 g protein. From 70 days the same amount of ensilage was offered, but the protein concentrate was fed at 600 g/day to provide a daily dry matter intake of 1.6 Kg. and 210 g of crude protein). During lactation, cassava root meal based diets were formulated (as it was previously shown that lactating sows were unable to satisfy their energy needs using silage) to provide feeds with 13.6, 15.8 and 18 % crude protein. The response to this feeding regimen was good during gestation, but during lactation good results were only obtained at the higher protein levels, suggesting that the supply of amino acids from the meat and bone meal was limiting.

Observations like these are common in the literature, indicating that the amino acid availability and balance in the protein source should be quite different to those normally used for diets based on cereal grains, since cassava provides almost no protein and therefore most of the protein must be provided from the supplement. Further research is needed, including careful evaluation of amino acid supply to optimize animal response and to identify appropriate, locally available, protein supplements.

In ruminants the task seems to be simpler, as non-protein nitrogen and lower quality protein can be used. Ensiling cassava with the low grade protein gives the added advantage of improved utilization of these sources of nitrogen, as during fermentation crude protein quality may be increased from nitrogen incorporation into bacterial protein.

TABLE 2.**Performance of pregnant and lactating sows fed with cassava silage**

	GESTATION
	FED 3Kg Cassava Silage + Conc.
Mena Daily Liveweight Gain (Kg)	47.6
Live Piglets Born	10.2
Mean Piglest Weight (Kg)	1.4

	LACTATION		
	FED Cassava Root Meal Feed with 3 different levels of protein		
Protein in Feed%	13.6	15.9	18.0
Weight Change (Kg) (During lactation)	-21.6	21.14	-15.9
Feed Intake (Kg/day)	3.8	4.1	4.0
Weaning-Oestrus Period (days)	6.8	5.7	5.5
No. Pigs Weaned	9.1	8.4	9.0
Piglet Weaning Wt. (kg)	5.3	6.3	5.7

Source: Lopez et al., 1988

Source: Lopez et al., 1988

Recently Cruz and Cruz (1990) ensiled fresh cassava root with Taiwan grass (*Pennisetum purpureum* × *P. typhoides*) and 10% poultry litter. Cassava was included to replace grass at four levels, resulting in 4 silages containing 0, 20, 40 and 60 % of cassava and the corresponding 90, 70, 50 and 30% of Taiwan grass. In total 6 tonnes of each were ensiled. After 56 days the silos were open, samples were taken for laboratory analysis and the silages fed to Pelibuey rams (18 Kg initial weight). Dry and organic matter content linearly increased as cassava inclusion increased, while pH lowered quadratically, reaching a plateau (pH 4.4) at a break point estimated at about 45% cassava inclusion. Also of interest was that ammonia diminished linearly as the cassava inclusion increased in the following way:

Y (g/100 g of N) = 49.90 - (0.63 ± 0.042)(X), r = 0.93

In this study the sheeps performance (daily gain and feed efficiency) (Figure 1) improved quadratically, as the level of cassava in the diet increased, with daily gain reaching its maximum at about 43 % cassava inclusion, whilst feed efficiency peaked at 29% inclusion.

The source of nitrogen ensiled with cassava is an important consideration and needs further investigation: indications are that urea gives results similar to those described above, but swine faeces are apparently better utilized than poultry litter, i.e., the nitrogen digestibility is lower, but absorbable nitrogen, as true protein is of better quality (Cruz *et al*., 1990).

The carbohydrate content of cassava can also be utilized to preserve other feed sources by means of lactic acid produced during fermentation. This was used to preserve waste by-catch fish from shrimp fishing, where the fermentable carbohydrate was fresh cassava root and cane molasses (Loeza *et al*., 1980). Several mixtures of the ingredients were tested and the conclusion was that the best proportions of each, on a dry matter basis, were 45% fish (finely

chopped), 40% cassava root, 10% molasses and 5% of a culture of acidifying bacteria in a cabbage solution (Tables 3, 4 and 5.). The resulting silage had stabilized pH of 4.31 (Figure 2) and a protein content of 33% of dry matter, which was of similar quality to fish meal, as measured by chemically available lysine determination.

Other organic materials could be added to ensiling cassava, to either preserve them or to improve the nutritional value of the resulting silage, eg., cassava fodder, fruits and other food byproducts, etc.

Fig 1: Pellbuey sheep performance in response to increasing enslled cassav leveles (Cruz and Cruz 1990)

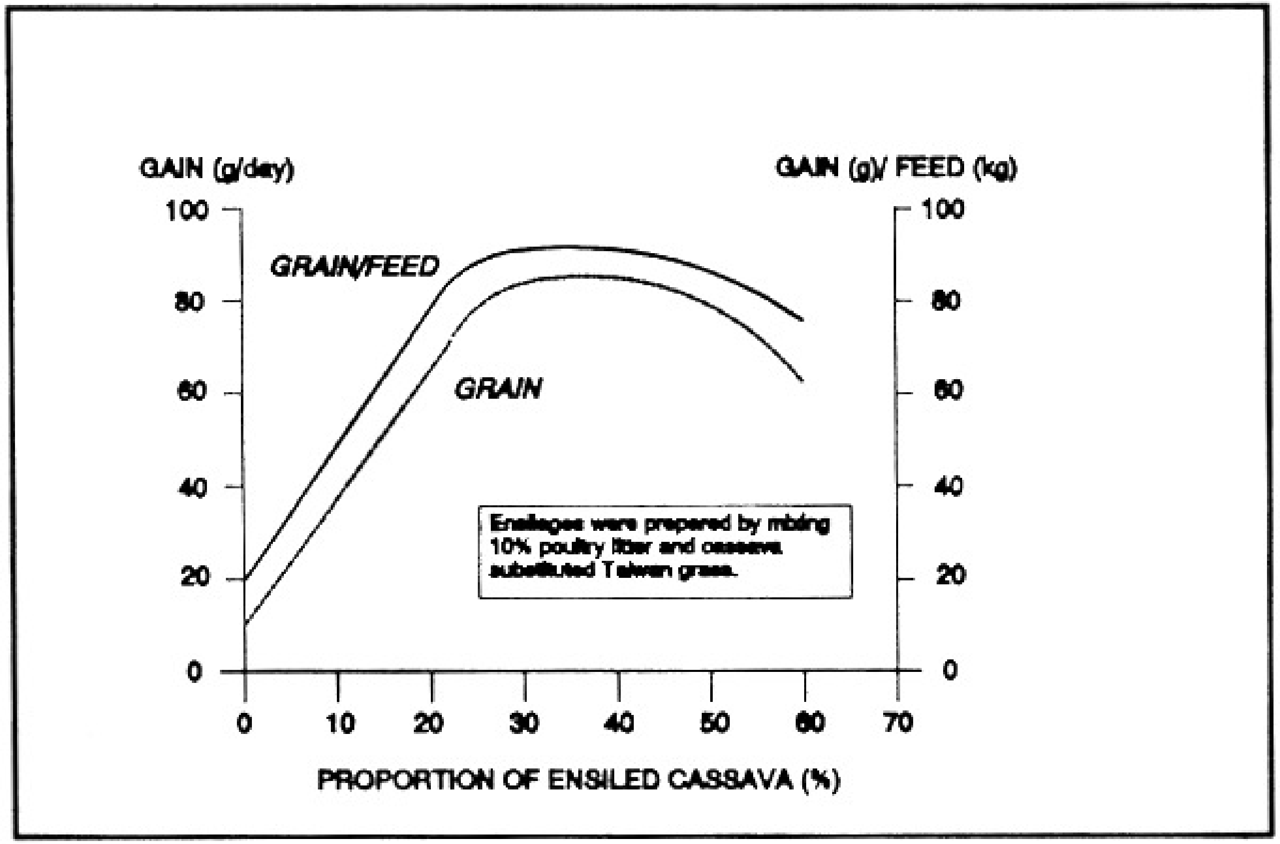

Fig 2: Fish-cassava ensilage, response in p^H as a function of time.

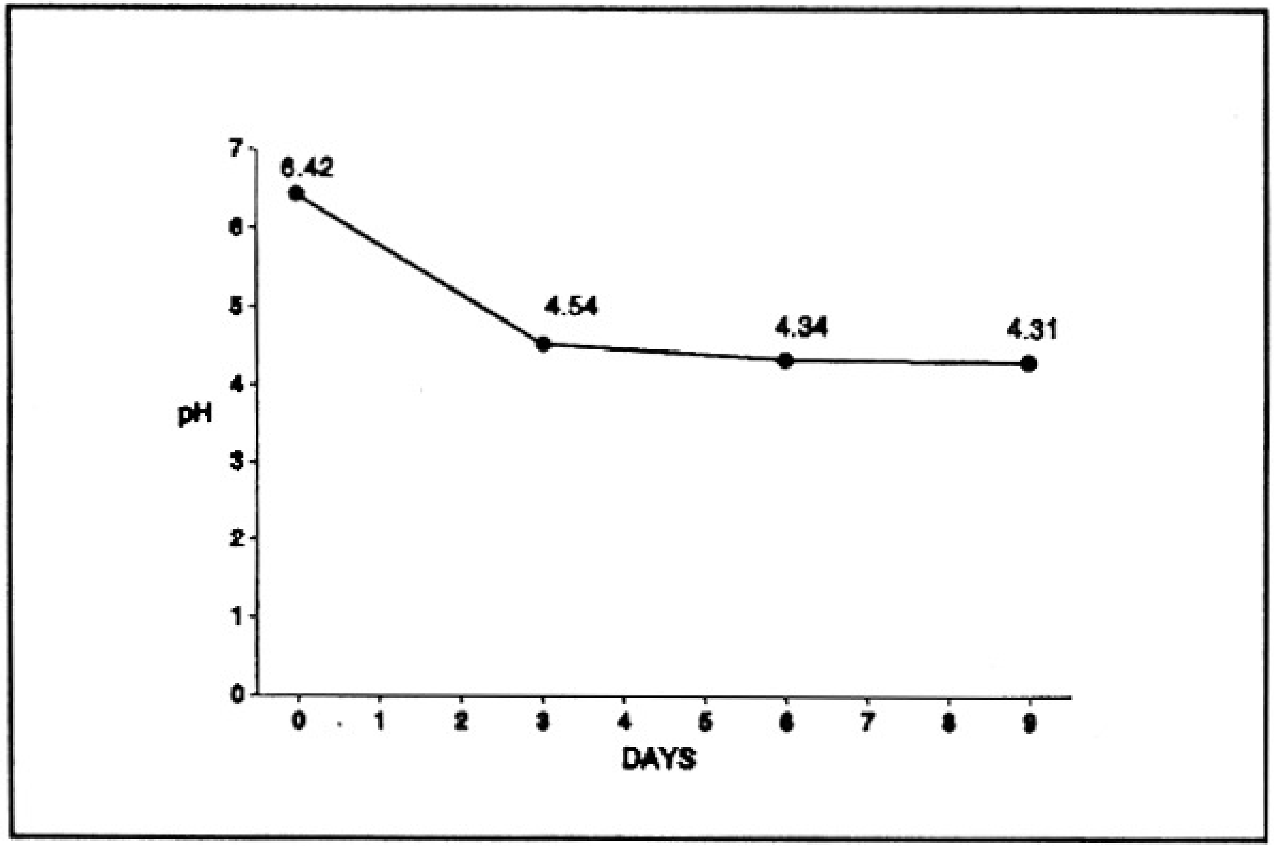

TABLE 3.**Proximate composition of waste fish from shrimp by catch (WF)**

	%
Crude Protein (N � 6.25)	66.4 � 0.78
Ether Extract	5.3�0.08
Ash	4.2�0.02
Nitrogen free extract	<25%
Dry matter	41.0�0.42

Source: Loeza et al., 1980

TABLE 4. **Ingredient content of fish silage**

	Dry Matter (%)
Waste fish	45
Cassava	40
Cane molasses	10
Lactobacillus	5

Source: Loeza et al., 1980

TABLE 5. **Fish silage composition (after 30 days)**

Crude protein (N � 6.25)	33.0 � 0.8
pH	4.5 � 0.23
NH_3 ppm	31 � 2.24
***Lactobacillus*spp. � 10^3**	3.7� 1.8
***Salmonella* spp. � 10^3**	-

***Source: Loeza et al*., 1980**

CONCLUSION

Cassava silage is an alternative means of preserving the nutritive value of cassava root, as well as a means of increasing land use. It can also be used as a means of preserving other feed materials or food byproducts, by mixing them with fermenting cassava in silos. This may result in improving their nutritional quality, though it may be more effective to use the other ingredients as supplements rather than additives.

Cassava ensilage is a technology that could be used as a means to assist the development of animal production, but also as an alternative means of encouraging the utilization of this crop, by offering market options in tropical environments, where processing for export is limited, or other markets are non existant.

However, further research is needed on the amino acid profile required for optimal supplementation of cassava silage, taking into consideration environmental contraints. Although cassava silage can be shown to have the potential to be a major ingredient, practical commercial feeding systems must be developed to take advantage of its potential. In order to achieve this a better knowledge of other available feed resources and their nutritional complementation value must be established. Further research is also needed on means of improving the nutritional value of cassava silage by the use of appropriate microbial enrichment.

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Preparation of cassava leaf products and their use as animal feeds
by V. Ravindran

INTRODUCTION

The high protein content and nutritive value of cassava leaves are well documented. Cassava leaf yields amounting to as much as 4.60 tonnes dry matter per hectare may be produced as a by-product at root harvest (Ravindran and Rajaguru, 1988). The current practice, in most instances, is to return this valuable feed resource to the soil as a green manure. It is the intent of the present paper to review the available literature on the use of cassava leaves in animal feeding and, to examine their potential usefulness in animal production systems in the tropics. Fresh cassava forage, including tender stems, could be utilized directly for ruminant feeding. For monogastric animals, however, the leaves should be processed into a dehydrated leaf

meal. The review will also discuss methods of processing cassava leaves, with emphasis on the letoxification of hydrocyanic acid.

NUTRIENT COMPOSITION

Cassava leaves contain an average of 21% crude protein, but values ranging from 16.7 to 39.9% have been reported (Table 1). This wide variability is related to differences in cultivars, stage of maturity, sampling procedure, soil fertility and climate. Almost 85% of the crude protein fraction is true protein (Eggum, 1970).

The genetic variability that exists between cultivars in leaf protein content is suggestive of the potential response to selection and this appears to be a fruitful area for further research. Optimization of cultural pactices such as fertilizer application may offer another means of increasing the protein content of cassava leaves.

Although cassava leaves are rich in protein, factors such as high crude fire may limit its nutritive value for monogastric animals (Table 1). Stage of maturity is the major factor contributing to the variability in fibre content, but environmental and cultivar effects are also implicated (Rogers and Milner 1963).

TABLE 1.**Proximate composition and metabolizable energy values of cassava leaf meal and alfalfa meal**

	Cassava leaf meal	**Alfalfa meal**[a]
Dry matter, %	93.0	93.1
Crude protein, %	21.0 (16.7–39.9)[b]	20.0
Crude fat, %	5.5 (3.8–10.5)	3.5

Crude fibre, %	20.0 (4.8–29.0)	20.0
Ash, %	8.5 (5.7–12.5)	10.5
Metabolizable energy (Kcal/kg) Poultry	1.80 (1.56–1.94)	1.63
Swine	2.16	2.03

a ***Allen (1984)***

b ***Values in parentheses refer to ranges reported in the literature***

TABLE 2. **Mineral contents of cassava leaf meal and alfalfa meal**

	CLM[a]	**Alfalfa meal**[b]
Macromineral, %		
Potassium	1.28	2.50
Calcium	1.45	1.50
Magnesium	0.42	0.32
Phosphorus	0.45	0.25
Sodium	0.02	0.08
Microminerals, mg/kg		
Zinc	149	19
Manganese	52	34
Iron	259	281
Copper	12	9

[a] *Ravindran and Ravindran (1988)*

[b] *Allen (1984)*

Cassava leaves are good sources of minerals. They are particularly rich in Ca, Mg, Fe, Mn and Zn (Table 2). Cassava leaves are also rich in ascorbic acid and vitamin A, and contain significant amounts of riboflavin. But considerable losses of vitamins, particularly of ascorbic acid, occur during processing.

AMINO ACID COMPOSITION

Cassava leaf protein is deficient in methionine, possibly marginal in tryphtophan, but rich in lysine (Eggum 1970; Rogers and Milner 1963). Some variation in the amino acid content of leaves has been reported and may be attributed to differences in stage of leaf maturity, sampling procedures, analytical methods and ecological conditions. Yeoh and Chew (1976) observed that variation among cultivars grown under identical conditions was insignificant suggesting little, if any, genotypic variation with respect to amino acid content.

The changes in amino acid composition in relation to maturity of leaves has been studied by Ravindran and Ravindran (1988). As the leaves matured, the general trend was for the amino acid concentrations to decrease. Of the essential amino acids, lysine and histidine showed the greatest decrease. The essential amino acid profile of cassava leaf meal compares favourably with that of alfalfa meal (Table 3).

PROTEIN QUALITY

Eggum (1970), using rat bioassays, studied the nutritional availability of individual amino acids

in cassava leaves. The availability of amino acids varied widely ranging from 55% for valine and isoleucine to 84% for serine. Only 59% of the methionine was biologically available, resulting in a low biological value of 49 to 57%. Supplementation with methionine improved the biological value to 80%. The low protein utilization values may be attributed to the high fibre content and the presence of condensed tannins in cassava leaves. Tannins are known to lower the protein digestibility and amino acid availability by forming indigestible tannin-protein complexes with dietary proteins and/or by inhibiting digestive enzymes.

TABLE 3. **Essential amino acid profile of cassava leaf meal and alfalfa meal (g/16 gN)**

	CLM[a]	Alfalfa meal[b]
Arginine	5.3 (4.0–5.7)[c]	4.9
Lysine	5.9 (3.8–7.5)	4.4
Methionine	1.9(1.3–2.0)	1.7
Cystine	1.4 (0.7–1.4)	1.2
Total sulphur amino acids	3.3 (2.0–3.3)	2.9
Tryptophan	2.0	2.3
Histidine	2.3 (1.1–2.5)	2.1
Isoleucine	4.5 (3.9–5.0)	4.9
Leucine	8.2 (7.2–8.9)	7.5
Phenylalanine	5.4 (5.3–5.4)	5.2
Threonine	4.4 (3.2–5.0)	4.4
Valine	5.6 (5.1–5.7)	6.0

[a] ***Eggum (1970)***

[b] *Allen (1984)*

[c] *Values in parentheses refer to ranges reported in the literature*

PRODUCTIVITY OF CASSAVA LEAVES

The potential yield of cassava leaves varies considerably, depending on cultivar, age of plant, plant density, soil fertility, harvesting frequency and climate. Ahmad (1973), investigating the leaf DM productivity of two 12-month cultivars, reported yields of up to 7.5 t/ha. In this study, five leaf harvests were made at intervals of six weeks starting from three months after planting. Leaf harvesting, however, lowered the root crop yields by almost one-half of the normal. Normanha (1962) harvested 9.0 t DM/ha in two harvests over a two-year period and obtained less than a 30% reduction of the normal yield of roots.

The leaf DM yields are generally lower, if cassava leaves are to be obtained as a by-product at root harvest. Gomez and Valdivieso (1984), evaluating two 12-month cultivars, reported the leaf DM yields at root maturity to be only 1.2 – 1.8 t/ha. In contrast, Ravindran and Rajaguru (1988) obtained a much higher leaf DM yields of 4.64 t/ha. The higher yields in the latter study may be related to agronomic, climatic and soil fertility differences.

Leaf production can be enhanced by harvesting cassava leaves during the growing season, but this would adversely affect root yields. However, several studies now have demonstrated that it is possible to harvest cassava leaves while maintaining acceptable yields of roots. Ravindran and Rajaguru (1988) harvested 6.75 tonnes kg DM/ha by defoliating once during a seven-month growing season and obtained within 86% of the normal yields of roots. Dahniya *et al.* (1981) recommended a harvesting frequency of two to three months, starting from 4 months, for best all-round yields in 12-month cultivars. However, the variation that appears to exist among

cultivars in their tolerance to defoliation needs be taken into consideration before making any recommendation of harvesting frequency.

When the cultivation of cassava is exclusively aimed towards leaf production, the plant density could be increased and the harvesting frequency can be shorter. Foliage can be harvested from 4 months of age in a cycle of 60–75 days. With adequate irrigation and fertilization, cassava plants can withstand this defoliation for several years (Montaldo 1977). Under such conditions, annual leaf DM yields of over 21 tonnes per hectare can be obtained. This corresponds to a possible production of about 4 tonnes of protein per hectare per year.

CYANOGENIC GLUCOSIDES

The cyanide content of cassava leaves has been extensively studied. The normal range of cyanide content is from 20 to 80 mg HCN per 100 g fresh leaf weight, but samples containing as low as 8 mg/100 g or over 400 mg/100 g have also been reported. On a dry basis (assuming 25% DM in fresh leaves), the normal range of HCN content would correspond to 800 to 3200 mg/kg. These levels are substantially higher than the normal range of HCN reported for fresh cassava roots.

The wide variations observed in leaf cyanide levels may be attributed to genetic, physiological, edaphic and climatic differences, but have been exaggerated by problems associated with methodology of cyanide assay. Stage of leaf maturity is perhaps a major factor causing variations in the cyanide content. As in other cyanogenic plants, the glucoside concentration in cassava leaves decrease with age. Cyanide levels in the leaves are also influenced by the nutritional status of the plant. De Bruijn (1973) reported that leaf cyanide levels were increased by fertilizer nitrogen, whereas potassium and farmyard manure had the opposite effect.

TANNINS

The presence of condensed tannins in cassava leaves presents ground for some concern (Reed *et al.* 1982). They are capable of forming indigestible complexes with protein, thus increasing the amino acid requirements of animals fed diets containing cassava leaf meal. The reported values for tannins in cassava leaves, however, are similar or lower to those of most plant leaves, including alfalfa, and are within safe limits if judiciously used for animal feeding.

HARVESTING

The appropriate harvesting method under the current practice of smallscale cassava production is to manually harvest the foliage by stempruning. The foliage, including tender stems, could be wilted, greenchopped and used directly for ruminant feeding. Alternatively, the leaves could be stripped, dried and ground into a meal. However, if large scale foliage production is envisaged, development of a mechanical harvesting device would be desirable.

PROCESSING

The existence of cyanogenic glucosides has made some form of processing a pre-requisitive for the use of cassava leaves in animal feeding. Several studies have demonstrated that it is possible to produce cassava leaf meal (CLM) with low cyanide levels (Gomez and Valdivieso 1985; Ravindran *et al.* 1987a). Simple sun-drying alone eliminates almost 90% of the initial cyanide content. When combined with chopping and wilting, cyanide in the dried meal was reduced to levels which are safer for monogastric animals (Table 4). This reduction is due to the action of endogenous linamarase on glucosides following loss of cell integrity (wilting) or tissue damage (chopping). The free tannin contents of cassava leaves are also considerably lowered during drying.

TABLE 4.**Hydrocyanic acid content (mg/kg dry matter) of cassava leaf meal as influenced by processing methods**[a]

Wilting (days)	**Sun-drying**	
	Full leaves[b]	**Chopped leaves**[c]
0	173 (88.0)[d]	109 (92.4)
1	141 (90.2)	88 (93.4)
2	114 (92.1)	72 (95.0)
3	93 (93.5)	53 (96.3)

[a] ***Ravindran et al. (1987a)***

[b] ***Freshly harvested cassava leaves contained an average of 1436 mg HCN/kg dry matter***

[c] ***Freshly harvested cassava leaves contained an average of 1045 mg HCN/kg dry matter***

[d] ***Values in parentheses represent the reduction in HCN as a percentage of initial level in freshlyharvested leaves***

From a practical point of view, sun-drying would be the method of choice in the developing countries of the tropics. Since sun-drying is entirely dependent on the weather, the duration of drying will vary considerably. In general, cassava leaves dry easily and drying is completed, to about 10–12% moisture content, in two days during dry, sunny weather. In a large scale operation, artificial heat-drying would be attractive. This will enable scheduling of drying independent of weather, but the capitol investment will be higher. However, artificial drying appears to be less effective in eliminating the cyanide than sundrying. A simple procedure of processing cassava leaf meal is outlined below.

1. **Chopping - Leaves can be chopped manually or by means of a mechanical chopper. Leaves may also be bruised instead of chopping. Chopping not only increases cyanide elimination, but also shortens the drying time.**

2. **Wilting - Leaves need be wilted by spreading out in shade or in a room with cross-ventilation. Duration of wilting may vary from few hours to few days. Leaves must be turned over regularly to avoid fermentation and mould formation.**

3. **Drying - Wilted leaves should be uniformly distributed in the drying floor and turned over as necessary. Once 12% moisture level is reached, the dry leaves can be preserved either in the form of leaf meal or pellets. Processing has little influence on the crude protein content of the leaf meal (Ravindran *et al.*, 1987a).**

STORAGE

Preliminary investigations indicate that CLM has excellent storage qualities. There was no moulding or insect infestation even after 8 - months of storage. Interestingly, the cyanide content declines during storage, but a gradual decline in the crude protein content was also observed (Ravindran *et al.* 1987a).

FEEDING VALUE FOR POULTRY

At low levels of inclusion, the feeding value of CLM for poultry is similar to that of dehydrated alfalfa meal. Ravindran *et al.* (1983) compared the performance of quails fed iso-nitrogenous diets containing 0, 2.5, 5.0, 7.5 and 10.0% levels of either CLM or dehydrated alfalfa meal. Gains were not significantly influenced by leaf meal inclusion, but feed intake and feed/gain were increased as the leaf meals were incorporated above 5% level. The performance of birds fed CLM and dehydrated alfalfa meal were similar.

Ross and Enriquez (1969), in a series of trials, investigated the possible use of CLM in corn-soybean meal diets for chicks. Progressive depression in performance was observed with increasing levels of CLM. However, supplementation of diets containing 20% CLM with methionine and energy resulted in performance comparable to the control.

Montilla *et al.* (1976) reported depression in gains and feed efficiency when CLM was included at 10, 20 or 30% levels in broiler rations. Cassava leaf meal was used to replace parts of the cottonseed meal, sesame meal and corn in the basal ration. The depressing effects were largely overcome by pelleting. Montilla (1977) concluded that CLM could be incorporated up to 20% level in pelleted broiler rations.

Wyllie and Chamanga (1979) found CLM to be a superior substitute for cottonseed meal in broiler rations. Replacement of cottonseed meal with 5 and 10% CLM resulted in significant improvements in gains. However, when CLM was substituted for sesame meal and sunflower meal the performance of broilers was poorer.

Ravindran *et al.* (1986) evaluated CLM as a substitute for coconut meal and concluded that up to 15% level can be used with satisfactory results. Broiler performance was depressed at higher levels. The reported values of metabolizable energy of cassava leaf meal for poultry (Table 1) are higher than those reported for alfalfa leaf meal and Leucaena leaf meal.

The available literature suggest that poultry producers in the tropics could benefit economically by incorporating low levels of CLM. It can play useful role as a source of protein, minerals, xanthophylls and unidentified growth factors for poultry. The unfavourable effects of high dietary levels of CLM are due to bulkiness, reduced energy intake and methionine deficiency. The roles of methionine as a methyl donor in tannin detoxification and as a source of labile sulphur in cyanide detoxification further aggravates its inherent deficiency in CLM. At

high levels of inclusion, bulkiness is probably the major limiting factor and, in this context, pelleting may prove beneficial.

FEEDING VALUE FOR SWINE

Limiting published information exist regarding the use of CLM in swine feeding. Early studies of feeding fresh cassava leaves showed that palatability was depressed and growth performance was lowered with increasing proportions of leaves in swine rations (Mahendranathan, 1971). The adverse effects were evidently due to the high hydrocyanic acid levels in fresh leaves, since supplemental methionine and thiosulphate improved performance. Sarwat *et al.* (1988) found that inclusion of 15% fresh cassava leaves had no adverse effects on the performance of growing — finishing swine.

Ravindran *et al.* (1987b) evaluated CLM as a substitute for coconut meal. The results showed that CLM can replace up to 66 percent of coconut meal (26 percent of the total diet) in growing swine diets without adverse effects on performance. Most efficient gains were obtained at 33 percent replacement (13 percent of the total diet), suggesting that use of low levels of CLM feed formulations will permit greater savings in feed cost compared to higher levels.

Attempts to utilize CLM as a replacement for other protein supplements in swine diets have been less encouraging. Alhassan and Odoi (1982) reported depressions in gains and feed efficiency when CLM included at 20 and 30% levels in diets for growing — finishing swine. Cassava leaf meal was used to replace part of peanut meal, fish meal and corn in the basal ration.

Ravindran (1990) substituted 10, 20 and 30% CLM for a corn-soybean meal basal diet, and reported that the gains and feed efficiency of growing pigs were lowered linearly with

increasing levels of leaf meal. The performance of pigs on diets containing 10% CLM was improved by methionine and energy supplementation.

There is unexplored potential for the use of CLM as a source of protein in breeder diets. Evidence suggest that energy in fibrous feedstuffs, such as alfalfa meal, are well utilized by sows.

USE OF CASSAVA FORAGE IN RUMINANT FEEDING

The low nutritive value of tropical grasses and roughages, commonly available for use in ruminant production systems for the tropics, highlights the need for low-cost supplementation to improve animal productivity. In this context, tree legumes such as Leucaena, Gliricidia and Sesbania are being promoted as protein supplements for livestock. Surprisingly, despite its availability and high protein content, there was little interest until recently to utilize fresh cassava forage in ruminant feeding. This reluctance is probably related to possibilities of cyanide toxicity. Today it is no longer necessary to make a case for the supplemental protein value of cassava foliage. An abundance of published data is available on this aspect.

Fresh cassava foliage is a satisfactory protein supplement, but it should be wilted before feeding and prudently used for good results. Wilting not only lowers potential cyanide toxicity, but also reduces the free tannin levels and improves its acceptability to animals. The supplementation value of cassava foliage is comparable to those reported for tropical tree legumes (Johnson and Djajanegara 1989). No adverse effects on performance have been reported even when higher levels of wilted cassava foliage were offered to goats and sheep. Cassava foliage could also be satisfactorily preserved as a silage and could be used as a dry season feed.

CASSAVA LEAF PROTEIN CONCENTRATE

Although the potential for the use of cassava leaves in the feeding of monogastric animals is great, factors such as high fibre and cyanide limit their use as a major source of protein. These limitations could be largely overcome if the protein is separated from the fibre and a protein concentrate is prepared by a juice extraction step and steam coagulation. Though cassava leaf protein concentrate contains a high level of crude protein (over 45%), good amino acid content and low resuidal cyanide, nutritional evaluation has shown poor animal performance. Clearly further research is needed to exploit this potential.

CONCLUSIONS

The most immediate prospects for the use of cassava leaf products are in the following areas:

1. **Low level (5 – 10%) inclusion of cassava leaf meal in poultry and swine formulations. The type of ingredients generally used in tropical countries are very diverse and CLM could be easily accepted into this diversity. A commercial-scale process for the preparation of CLM has been outlined by Muller (1977). With experience, the possible use of moderately high levels of CLM may be considered particularly in layer and swine rations. Due to overpigmentation of carcasses, use of higher levels in broiler rations is not recommended.**

2. **Cassava forage as a supplement to low-quality roughages in ruminant feeding. It can be stated that today's knowledge of cassava leaves is equivalent to what was known about the alfalfa about 60 years ago. Many, if not most, of the advances made with regard to alfalfa utilization may have similar applications to cassava leaves. The task ahead is to solve the limitations, both biological and economical, that will allow the development of an acceptable system of cassava leaf production and utilization. In this context, the following**

research needs are emphasized:

i. **breeding or selection of cassava varieties which can be grown specifically for foliage production. The characters to be considered inter alia are forage yields, protein content, cyanide content, tannin content and ease of harvesting,**
ii. **developement of suitable agronomic practices to obtain high yields of forage with better nutritive value,**
iii. **development of appropriate technology for the processing of CLM and pellets,**
iv. **study effects of processing on the feeding value of CLM,**
v. **study the possibility of using cassava leaf products in combination with the energy-rich roots,**
vi. **study the economics of cassava grown only for leaf production and for production of cassava root/leaf combination, and**
vii. **study market prospects for cassava leaf products.**

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Improving the nutritional value of cassava products using microbial techniques by C.Balagopalan,G.Padmaja and M.George

INTRODUCTION

The significant increase in demand for livestock products in recent years in developing countries has required an increase in animal feed supply. In this context the role of cassava as a cheap carbohydrate source capable of supplying adequate calories to livestock is very significant. However, due to its low protein, vitamin and mineral content and lack of the sulphur containing amino acids such as methionine, it is often considered as inferior to maize or wheat. The crude protein content of whole cassava roots is around 3.5% dry weight and 40–60% of the total nitrogen is non-protein nitrogen. Careful formulation of the cassava diet is important to nutritionally balance the feed. Fermentation has been identified as one of the less expensive means of increasing the protein quality of cassava.

The use of microorganisms to convert carbohydrates, lignocelluloses and other industrial wastes into foodstuffs rich in protein is possible due to the following characteristics of microorganisms.

a. Microorganisms have a very fast growth rate.

b. They can be easily modified genetically for growth on a particular substrate under particular cultural conditions.

c. Their protein content is quite high varying from 35 to 60%.

d. They can be grown in slurry or on solids.

e. Their nutritional values are as good as other conventional foods rich in protein.

NEED FOR PROTEIN ENRICHMENT OF CASSAVA USING MICROBIAL TECHNIQUES

The economic feasibility of using cassava based rations for animals depends mainly on the price of cassava in relation to alternate energy sources and the price of the supplementary protein sources to be added to balance the protein requirements of animals to be fed. Because of the very low protein content of the cassava tubers, any substitution of cassava for cereals in compounded feeds necessitates the inclusion of a considerable amount of supplementary protein. Experimental studies conducted by Gomez *et al*. (1976) showed that a swine feeding programme based on cassava meal required approximately 60 to 65% more protein supplement than a similar feeding programme using maize as an energy sources. Therefore, in developing countries the potential for cassava use as animal feed depends mainly on the availability of cheap protein sources. An alternate approach is to enrich cassava flour with microbial protein. The microbial enrichment process is relatively cheap and the enriched product can increase the potential of cassava as a feed.

MICROBIAL TECHNIQUES FOR PROTEIN ENRICHMENT OF CASSAVA Following the successful experiments of Brook *et al*.(1969), Stanton and Wallbridge (1969), and Gray and Abou-El-Seoud (1966), attempts hav been made in many laboratories to develop fermentation techniques to produce microbial proteins using either cassava flour/cassava wastes or enriching cassava flour/cassava wastes.

Submerged fermentation of cassava

In the submerged fermentation system water is always in a free state and carbon, nitrogen, phosphorous and other nutrients are in a suspended or dissolved state. Simple aseptic inoculation of microorganisms under such conditions might convert some of the non-protein nitrogen into protein, but submerged fermentation is only economically worthwhile when done on an industrial scale, using processes that require a strict control of fermentation and which take place in a sterile environment.

Gray and Abou-El-Seoud (1966) studied the protein production efficiency of several filamentous fungi by growing them on ground cassava roots supplemented with ammonium chloride and corn steep liquor. They found that *Cladosporium eladosporoides* gave good mycelial yield and produced products containing 13–24% crude protein. strasser *et al*. (1970) described a process in which the yeast *Candida utilis* was used to produce a product containing 35% crude protein on a dry weight basis. However, it is important to note that: 1) prior to fermentation with yeasts, enzymatic or acid treatment of starch is necessary; 2) the entire fermentation has to be carried out under aseptic conditions; and 3) since the yeast takes time to settle or remains in a suspended form in the medium recovery of cell mass from such a fermentation system can be tedious. In order to avoid this, centrifugation or ultrafiltration can be used to achieve separation.

Extensive studies on the use of cassava based submerged fermentation systems have been carried out at the University of Guelph, Ontario, Canada. These reported the advantages of using thermotolerant filamentous fungi for the production of protein rich animal feeds from cassava (Reade and Gregory, 1975; Gregory, 1977 and Gregory *et al*., 1977). Screening of suitable organisms was carried out using a low pH (3.5) and a temperature in excess of 45°C, since only a few thermotolerant fungi will grow under these conditions and contaminating

bacteria, fungi and other organisms could be eliminated.

After rat feeding experiments to test pathogenicity, three cultures which gave protein efficiency ratios of 2.3 or more were selected. The fermentation conditions for protein production from cassava mash by *Aspergillus fumigatus* are given in Table 1. However, due to safety considerations, this culture was not recommended for practical application.

The use of *Cephalosporium eichhorniae* 512 (ATCC38255) which is capable of protein production from cassava carbohydrate for use as animal feed was also studied (Mikami *et al*.,1982). This strain is a true thermophile showing maximum growth at 45 to 47°C and achieving maximum protein yield at 45°C and no growth at 25°C. It has an optimum pH of about 3.8 and is an obligate acidophil, being unable to sustain growth at pH 6.0 in a liquid medium and above pH 7.0 on solid media. The optimum growth conditions for this fungus, (pH 3.8 and temperature 45°C) were strongly inhibitive to the potential contaminants. This fungus rapidly hydrolyzed cassava starch and did not utilize sucrose, but around 16% of the sucrose components of cassava were chemically hydrolyzed during the process. Fungal growth with cassava meal (50 g/1) was complete in around 20 h, yielding around 22.5 g/1 (dry biomass) containing 41% crude protein (48 to 50% crude protein in the mycelium) and 31% true protein (7.0 g/1).

TABLE 1. **Fermentation conditions for protein production from cassava mash by *A. fumigatus* 1–21 A (Gregory, 1977)**

CONDITION	REASON FOR SELECTION
Carbohydrate concentration = 4% (approx. 15% fresh cassava)	**Fermentation is completed in 20 h from a 6.7% inoculum, permitting a daily production schedule. Higher concentrations take longer, lower concentrations give lower yields.**
Mash heated to 70�C for 10	**Gelatinize starch, permitting complete utiliz- ation, prevents**

min, immediately after grinding, in one- half final volume	**development of antifungal activity, provides desired starting tempera- ture after dilution to final volume**
Nitrogen source = Urea (1.72 g/1)	**No automatic pH control required; whereas, $(NH_4)_2SO_4$ results in excess acidity**
Mineral supplement = KH_2PO_4(0.25 g/1)	**Assures sufficient phosphorous even with cassava roots which are low in P. All other mineral requirements except "S" are supplied by cassava roots.**
Initial pH adjustment with sulphuric acid	**Supplies sulfur requirement as well as acidity**
pH 3.5	**Optimum for protein production**
Temperature = 45�C	**Inhibits bacterial and yeast growth, thus permitting use of nonaseptic conditions (although optimum temperature for the fungus is 37–40�C)**
Vigorous agitation and aeration during growth	**Provides rapid oxygen transfer to growing cells**

Muindi and Hanssen (1981a,b) described a fermentation procedure to increase the protein content of cassava root meal (CRM) with *Trichoderma harzianum*. The organism was grown in a 4% CRM medium containing inorganic nitrogen. The growth medium had the following composition (g litre $^{-1}$) CRM - 40.0, NH_4NO_3 - 1.00, KH_2PO_4 - 1.50, $MgSO_4.7H_2O$ - 0.25, $CaCl_2$ - 0.01, $MnSO_4.4H_2O$ - 0.001,$ZnSo_4$ - 0.001, $CuSO_45H_2O$ - 0.0001. The fungal biomass with the remaining CRM was collected by filtration at the end of fermentation. Satisfactory results were obtained using a temperature of 23°C, a pH of 4.0 - 4.2 and a fermentation time of 60 h. The estimated efficiency of conversion of the CRM into CRM/biomass was shown to be 30%.

The submerged cultivation of *T. harzianum* resulted in a substantial improvement in the protein content and quality of CRM. However, the metabolizable energy content of enriched cassava root meal was found to be about 9.1 MJ kg^{-1} dry matter (DM), which was significantly lower ($P<0.05$) than that of non-enriched CRM (12.2 MJ Kg^{-1} DM). The CP content of the enriched CRM product used was 37.6% on dry matter basis, compared with the 2.4% CP of the untreated CRM. The nonprotein nitrogen content accounted for about 30% of the total CP value. The mean apparent digestibility coefficient of the total CP was about 66% whereas that of amino acid was about 81%. Data from this study indicate that fungal enriched CRM could be used in chicken diets.

Protein enrichment of cassava by solid state fermentation

Generally solid-state fermentation is characterized by water addition limited to the saturation of the solid without allowing the separation of the liquid from the solid phase. Besides the reduction in the fermenter volume the advantages include: simplicity, ease of adaptation to rural conditions, elimination of foaming and a reduced cost of a final product which contains up to 20% protein (Brook *et al.*, 1969).

Several organisms and fermentation methods have been tried to increase the protein content of cassava and cassava wastes using solid state fermentation. Some of the techniques developed are reported here.

The effect of substituting corn with fermented cassava in broiler rations was investigated by Varghese *et al*. (1976). They first evaluated the role of natural nitrogenous supplements like chicken manure, pineapple bran, groundnut, etc., in enhancing the fermentation of cassava. Direct fermentation of cassava, alone, with *Aspergillus, Neurospora* and *Rhizopus* elevated the protein values by 3% using nitrogenous supplements, e.g., 25% pineapple bran increased the

protein from 4 to 5%, whilst a mixture of 12.5% pineapple bran and 12.5% chicken manure increased the protein to 7%. Soyabean and groundnut were found to be even better additives to facilitate protein enrichment.

The possibility of using fungal strains isolated from Mexican, African and Oriental traditional foods to upgrade the protein content of cassava by solid state fermentation was investigated by Raimbault *et al*. (1985). The protein content of cooked enriched cassava varied from 10.9 to 16.5 percent and the residual sugar content from 28.2 to 45.2 percent. In this process milled dry cassava roots were supplemented with a mineral salt solution of high ionic strength and fermented with *Sporotrichum pulverulentum* in solid state culture. The fungus produced 30.4 g high quality protein/100 g dry cassava in 48 h at 45°C in an aerated bench scale tray fermenter.

An artisanal static process for protein enrichment of cassava by solidstate fermentation tested in pilot units in Burundi (Central Africa) produced enriched cassava containing 10.7% of dry matter protein compared with 1% before fermentation (Daubresse *et al*., 1987). In this process cassava chips which had been processed into pellets of 2–4 mm diameter, were moistened (40% water content) and steamed. After cooling to 40°C, the cassava was mixed with a nutrient solution containing the inoculum (*Rhizopus oryzae* strain MUCL 28627) and 3.4 g urea, 1.5 g KH_2PO_4, 0.8 g $MgSO_4 . 7H_2O$ and 22.7 g citric acid per 100 g dry matter. During the fermentation, the cassava, which had a moisture content of around 60% and a pH of 3.5, was spread in a thin layer (2–3 cm thick) on perforated trays and placed in an aerated humidified enclosure for 65 h incubation. The production of protein enriched cassava was 3.26 kg dry matter/m^2 per tray.

Several levels of urea were used in experiments relating to this fermentation. The study showed that after the 65 h fermentation, there was little loss of nitrogen when the 2.2 and 4.5 g doses of urea were mixed with each 100 g of cassava, though acidity increased to pH 5 during

fermentation. Using 6.8 g urea, a rapid increase in pH to 5.5 was observed accompanied by a loss of nitrogen. When the dose of urea was doubled from 2.2 to 4.5 g/100 g cassava the protein content of the final product increased by 29% from 8.81 to 11.37 of total real nitrogenous dry matter. However, the non—protein fraction of the fermentate was higher (38.41%) with the incorportion of 4.5 g urea than 2.2 g (24.25%). Tripling the urea dose gave poor results.

Balagopalan and Padmaja (1988) developed a solid state fermentation process for the protein enrichment of cassava flour and cassava starch factory wastes using the fungus *Trichoderma pseudokoningii* Rifai. The various treatments studied and results obtained are given in Table 2. The results showed that using this process it was possible to convert the substrate, using the minimum of nutrients [0.15% $(NH_4)_2SO_4$] to a protein enriched animal feed. The highest increase in protein content was observed, i.e., 14.32 g/100 g dry matter (DM) from an initial 1.28 g/100 g dry matter, where cassava flour was the sole ingredient. Overall, although protein production took place using both substrates, it was greatest where cassava flour was present and reduced as the level of cassava starch factory wastes increased. Increased amylolytic activity and the subsequent reduction in starch content during the solid state fermentation also indicated the ability of the organism to carry out bioconversion of starch to protein.

TABLE 2. **Total protein (g/100 g DM) changes during fermentation of different mixtures of cassava flour and wastes**.

	Fermentation period (days)				
Cassava mixture flour/wastes	**0**	**6**	**12**	**18**	**24**
0/100	1.26	4.06	4.45	5.09	6.18
25/75	1.34	4.38	6.88	6.00	6.60
50/50	1.32	7.75	8.50	5.57	7.48

75/25	1.30	8.01	8.84	10.82	10.67
100/0	1.28	7.68	9.55	14.32	13.10

Source: Balagopalan and Padmaja, 1988

The laboratory technology was evaluated with regard to its potential use in the large scale production of SCP enriched poultry feed at the Central Tuber Crops Research Institute, Trivandrum. In this study a mixture of cassava flour and starch factory wastes were prepared in the ratio 50:50. The moisture content was adjusted to 15 percent and 0.2 percent urea was included. The mixture was then boiled using steam for 60 min. and then allowed to cool to ambient temperature. A one week old inoculum of *Trichoderma pseudokoningii*, prepared using a cassava flour-waste mixture, in the ratio of one Kg of inoculum to 10 kg substrate, was thoroughly mixed with the substrate. The inoculated substrate was then spread over a cemente floor at a thickness of 2–3". The substrate was frequently turned to release heat generated during the fermentation. Since moisture was lost from the substrate, water was sprinkled ocasionally over the fermentate. The solid state fermentation, which was developed to suit village conditions, was terminated at the end of six days incubation and the protein content estimated.

Contamination only occurred in cases where excess moisture and high temperatures develop. In order to obtain continuity in the production of the enriched feed, paralles batches were maintained. The enriched feed was then dried and stored in gunny bags for further feeding trials with poultry. The results obtained are discussed later in the section on animal experiments.

PROTEINS FROM WASTES

A study was undertaken by Manilal *et al*. (1987) to utilize starch factory wastes by means of a solid state fermentation process. The waste consisted of a concentrated, dried primary effluent collected from a starch factory. Experiments were carried out on samples with and without nutrient enrichment. In both cases the moisture content was adjusted to 60%. Spores of a one week old culture of *Aspergillus niger* were used in the studies and the samples were incubated at 30°C for 120 h.

Initial biomass protein in the material was 1.60% (w/w). A stepped increase in the protein content was observed during the first three days, so that the material contained 7.0% protein by the third day. During the next two days of incubation the protein content only increased by and additional 0.7%. In the case of non-enriched samples the initial protein content was 1.0% which increased to a maximum level of 3.7% on the third day of incubation. No further increase in the protein content occurred during the fourth and fifth day of incubation.

ANIMAL EXPERIMENTS

Feeding experiments carried out with pigs and sheep fed microbial protein enriched cassava root meal showed promising results (Paraksa and Saeow, 1987 and Adeyanju, 1979).

Padmaja and Balagopalan (1990) studied *Trichoderma pseudokoningii* enriched cassava waste: flour mix (50:50) as an energy source in broiler rations, using three levels of feed inclusion viz. 50, 55 and 60 percent. The calculated metabolizable energy values for the various test diets ranged from 2360 to 2450 Kcal/Kg and the crude protein (g/Kg) ranged from 200 to 233.

Growth performance and percentage carcass yields showed that use of up to 60% of the enriched material did not adversely affect the birds performance. A further evaluation trial was conducted using 60% enriched feed in a starter rations and 65% in finisher rations. The

performance of the birds was compared with those fed on a non-enriched mix (50:50). The performance of birds fed the non-enriched ration was similar to those fed with SCP feed. However, the cumulative feed intake was less for the test birds which led to a reduction in overall feed use. This study clearly shows the potential that exists for commercial broiler farming to switch over to a cassava waste based feed, from the conventional feeds (Table 3).

TABLE 3.**Growth performance of broilers fed with SCP enriched cassava feed (Padmaja and Balagopalan, 1990)**

Treatment/Body Wt. (g)	Age in weeks (Starter Stage)				Finisher stage		
	2	**3**	**4**	**5**	**6**	**7**	**8**
T_0 (control)	210	380	888	1092	1320	1680	1920
	�35	�65	�17	�20	�40	�42	�40
T_1 (50% SCP)	233	420	894	1118	1420	1720	1850
	�40	�38	�20	�18	�63	�30	�40
T_2 (55% SCP)	254	430	895	1120	1380	1690	1990
	�28	�75	�39	�30	�75	�50	�28
T_3 (60% SCP)	248	415	912	1163	1395	1705	1915
	�52	�70	�58	�40	�60	�45	�45

CONCLUSIONS

In view of anticipated world protein shortages, microorganisms offer a variety of possibilities for increased protein production. However, microbial proteins have a high nucleic acid content, though from the studies presented here it would suggest that their use in animal feeds will not cause problems. Single cell proteins by virtue of their rich amino acids composition, high vitamin B and digestible nutrient content can be used to totally or partially replace conventional

vegetable and animal proteinaceous feedstuffs. Screening of safe microorganisms for high protein production and the use of asporogenous mutants is a positive development in the utilization of cassava for SCP production. The application of biotechnological techniques to produce better strains of microorganisms is also suggested as a future approach.

In the application of *in situ* utilization of cassava as an animal feed, the already developed cassava fermentation techniques offer the advantage of being simple and low cost and can be transferred to rural areas through trained extension services. In particular the solid state fermentation technology seems to be the most appropriate in rural areas since it requires little environmental control and equipment.

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Use of cassava products in poultry feeding
by S.Khajarern and J.M. Khajarern

INTRODUCTION

Shortage of cereals has recently been a serious issue in several regions of the world; in many of these the use of cereal products as livestock feeds is increasingly unjustified in economic terms. Nonruminants like poultry are markedly affected by such a trend. Therefore, there is a need to exploit cheaper energy sources, to replace expensive cereals for livestock production, to relieve the food-feed competition in the future.

Cassava is very appropriate for this purpose. Substantial efforts have been made, in the past few decades, to replace cereals with cassava in poultry feeding. The results, in terms of its feeding value, nutritional problems encountered, biological responses and productive performances of chickens fed cassava products, have exhibited wide variability. Available reports in the literature have showed variation and conflicting results regarding, what products can be used, how they can be fed and how much cassava can successfully be fed to each poultry type.

It is the intention of this paper to review and re-assess the present state of knowledge concerning the use of cassava products in poultry feeding and to evaluate what is still needed

to help establish reliable and practical guidelines by which more efficient utilization of cassava as poultry feed can be accomplished.

NUTRITIVE VALUE OF CASSAVA FEED PRODUCTS

Kind of cassava feed

The most common type of feedstuff produced from cassava roots are, root chips and pellets. Chips are the dried (normally in the sun), shredded root and are of variable size, shape and quality depending on rate of drying and contamination during the processing. The chip can then either be directly ground and used in feed mixing or pelleted. The root pellet is a uniform cylindrical product of about 0.5 to 0.8 cm diameter and 1.0 to 2.0 cm long. Pelleting is done to reduce storing space and dust problems and thus eases transportation.

Cassava leaf is another potential feed source for poultry. The leaf blade accounts for 10 to 40% by weight of the plants aerial part, depending upon the age and ecological condition of the plant. Leaves can be harvested within 4 to 5 months of planting, without adversely affecting root production, yielding up to 10 tonnes of dry foliage per hectare. After drying, the leaf or foliage can be ground into meal which is a good source of protein and carotene for poultry.

Other feed products from cassava are of limited significance and not normally used in feeding due to their high labour requirements and high costs in processing. These include the dried products from the fermented or ensiled root carried out to detoxify it or to increase its protein content, dried cassava waste from starch factories and cassava peel meal. Data on their use in poultry feeding are limited.

Nutritive profile

It is widely known that cassava root products are rich in carbohydrates but low in protein, amino acids and all other nutrients and thus are used mainly as sources of energy. In using cassava root products as cereal substitutes, approximately 15 to 20% extra protein source is needed (Table 1). Cassava leaf (CLM) and foliage meal (CFM) contain moderate levels of crude protein and amino acids, mineral, vitamins and carotene but are rather high in crude fibre making them only fair sources of protein for nonruminants.

Both root and leaf products contain widely ranging levels of cyanogenetic glycosides, namely linamarin and lotaustralin. Upon enzymatic hydrolysis during practical processing, hydrocyanic acid (HCN) is liberated from these, rendering the dried products safe feeds for all classes of livestock and poultry. However, the residual glycosides in the products can still cause some degree of deleterious effects on the performances of cassava-fed animals. Enriquez and Ross (1967) demonstrated that supplementation of methionine at 0.15 to 0.20% of diets could help overcome the HCN toxicity and restore chick performances to normal levels.

TABLE 1. **Chemical composition of cassava products as compared to maize, soyabean meal and their mixture**

		Composition, % of dry matter			
Constituent:	**Cassava root[1] meal (CRM)**	**Maize[2]**	**Soyabean[2] meal (SBM)**	**Mixture of[1] 85 CRM + 15 SBM**	**Cassava[3] meal (CLM)**
Crude protein	2.50	8.50	49.40	8.88	23.20
Ether extract	0.30	3.80	0.90	0.40	4.80
Crude fibre	3.50	2.00	9.20	3.64	21.90
Ash	3.80	1.10	3.50	3.40	7.80
WFE	89.90	84.60	37.00	83.68	42.20

Minerals Calcium	0.18	0.03	0.32	0.20	0.37
Phosphorus	0.09	0.27	0.73	0.18	0.58
Amino acids					
Lysine	0.04	0.25	6.32	0.47	7.11[1]
Methionine and cystine	0.02	0.25	3.04	0.23	2.53[1]
Threonine	0.05	0.36	4.14	0.33	4.70[1]
Tryptophan	0.01	0.05	1.30	0.10	1.09[1]
Metabolizable energy poutry	3,145	3,524	2,606	3,047	1.59[4]
ME Kcal/kg					

1 ***Adapted from Muller et al., 1974***

2 ***US, NRC., 1984***

3 ***Devendra, 1977***

4 ***Hutagalung et al., 1974***

The literature on the nutritive value of cassava products contains a wide variation in the published values, especially where these were obtained by biologically testing. This was mainly caused by inaccurate definition of the tested products. Evidence clearly shows that cassava products from different origins, with regard to varieties, ages at harvest, ecological conditions of plant growth and processing methods contain widely varying levels of nutrients, energetic values and HCN. Data on the energetic value of the products (Table 2) are good examples of such a variation. It was, therefore, agreed among scientists attending the workshop on the

utilization of cassava as feed at the Guelph University in 1977 that all researchers should exactly define, in scientific reports, the feed products being used in their studies to enable realistic comparisons to occur.

VALUE OF CASSAVA PRODUCTS IN POULTRY FEEDING

Cassava root meal

Cassava root meals contain a range of metabolizable energy values for poultry from 2.87 to 4.27 kcal ME/g of dry matter. They also contain very low levels of protein (2.5% of DM) and are deficient in all other nutrients. In formulating a balanced poultry ration, there is therefore need to supplement the root products with protein, amino acids, fat, minerals and vitamins at higher levels than when using cereal-based diets. Earlier attempts to replace cassava root products for cereals in poultry rations resulted in generally depressed performances of cassava-fed chickens (Tobayayong, 1935; McMillan and Dudley, 1941; Vogt, 1966). This was probably due to variations in HCN levels in the cassava used and the composition and make-up of diets. In their classical study, Enriquez and Ross (1967) overcame the growth depression by supplementing methionine at 0.15 and 0.20% of 50% cassava diets.

They concluded that a part of the methionine was needed to make up for nutrient deficiencies, as soyabean meal was used as the main source of protein, and the rest was for HCN detoxification. They also noted that the addition of soyabean oil at 3.7% of the methionine supplemented diets further improved chick performances, suggesting that energy was a second limiting factor. A similar response was reported by Olson *et al.* (1969a) who subsequently (Olson *et al*., 1969b) showed that the supplementation of cystine at 0.40% of a 45% cassava diet gave comparable results to the 0.20% supplemented methionine.

TABLE 2. **Energetic value of cassava products in poultry rations**

Poultry type Age (wks)		Energetic value			Source
		CRM		CLM	
		ME, kcal/g	Note	ME, kcal/g	
Broiler		3.76	=	=	**Olson *et al*., 1969b**
Leghorn	2–4	4.31	=	=	**Maust *et al*., 1972**
Broiler	2–4	3.23	=	1.5	**Hutagalung *et al*.,1974**
Poultry	=	3.65	=	=	**Muller *et al*., 1975**
Leghorn	2–4	3.78	(40% diet)	=	**Fetuga and Oluyemi,**
	2–4	3.88	=		**1976**
Broiler	=	2.87	(92% of maize)	=	**Stevenson and Jackson, 1981**
Poultry	=	=	=	1.87	**Rajaguru and Ravindran, 1983**
Broiler cock	10–13	4.27	Prewashed chip 98.9% diet Conventional chip		**Khajarern *et al*., 1982**
		3.66	98.8% diet Oven dried chip 98.9% diet		
		4.02	Precooked chip 98.9% diet Hard pellet 98.9% diet		
		3.56			
		3.98			
Leghorn	4	=	67% TDN—10% diet		**Yoshida, 1970**
Broiler	=	=	98.6% Dig. MFB		**Szylit *et al*., 1977**

Broiler			94,3% of DM was available Energy		**Agudu and Thomas, 1982**

Works subsequent to this period was carried out to establish the optimum levels of inclusion and types and levels of supplementation of cassava-based rations to make them precisely meet the nutritional needs of poultry at the most economical cost. Maximum possible levels of inclusion in various types of poultry rations have been reported (Table 3). The data again shows variations in the reported levels. The variations, apart from being caused by the varying origins of the tested cassava, are due to differences in the chicken breeds, types, kinds and levels of production. In addition, the form, make-up and composition of diets, levels and types of supplementation, and plane of nutrition are additional factors contributing to these variations. Results from these trials lead to the following general conclusions concerning feeding cassava root to poultry:

a. **Cassava root products can be successfully used as substitutes for cereals in nutritionally balanced rations for almost all classes of poultry. However, it should be noted that broilers tend to tolerate diets containing high levels of cassava better than layers, where egg production and quality are particularly susceptible to the type of imbalances commonly found in high cassava diets. Also, partial substitution of cassava for cereals tends to support better chick performance than the control diets or where total substitution occurs. At high level of substitution, efficiency of feed utilization tends to be depressed before growth reduction is noticed.**

b. **t is important to assure that cassava based rations are balanced for all nutrients and in particular energy, sulphur containing amino acids, phosphorous, zinc, iodine and vitamin B_{12} (Hutagalung, 1977). The normal methionine supplementation of high cassava based diets is 0.2 to 0.3%. It has been questioned, however, whether the extra methionine is**

really needed for HCN detoxification (Adegbola, 1977). According to him, the depressed reduction of urinary thiocyanate in rats does not support the hypothesis. In addition, Gomez *et al*. (1984) observed no benefit from 0.2 to 0.3% methionine supplementation of high cassava (65%) diets fed to all classes of pig. They also showed that when least cost rations containing 3% fish meal and low cassava inclusion, were used in pig diets (30% in breeder, 40% in starter and 20–30% in growerfinisher), no supplemental methionine was needed. For poultry, no such comparable data is available.

TABLE 3. **Maximum possible inclusion levels of cassava products in poultry rations**

Type:	Diets	Maximum cassava levels, % of ration					Source:
		Starter	Grower	Finisher	Developer	Layer	
Root meal Broiler	P	58.0	=	58.0	=	=	Chou and Muller, 1972
	NS	60.0	=	60.0	=	=	Christensen *et al*., 1977
	P	57.5	=	57.5	=	=	Khajarern *et al*., 1979
	P	50.0	=	50.0	=	=	Stevenson & Jackson, 1981
LayerHeavy	P	40.0	60.0	=	60.0	50.0	Khajarern *et al*., 1979
Leghorn	M	15.0	30.0	=	40.0	40.0	Eshiett and Ademosun, 1976
Heavy	M	=	=	=	=	60.0	Hamid and Jalaludin, 1972

Leghorn	M	=	=	=	=	50.0	**Enriquez and Ross, 1972**
Foliage and leaf meal Broiler							
CFM	M	2.50	=	2.50	=	=	**Montilla *et al*., 1973**
CFM	P	20.0	=	20.0	=	=	**Montilla *et al*., 1976**
CFM	M	10.0	=	10.0	=	=	**Siriwadene & Ranaweera, 1974**
CLM	NS	20.0	=	20.0 (+3% SBO +0.25%Met)			**Ravindran *et al*., 1986**
Layer	NS	20.0	Male	20.0 (+3% maize			**Ross and Enriquez,1969**
CLM			Leghorn	oil + 0.5% Met)			
CLM	P	=	16.5	=	16.5(Heavy breeds)		**Khajarern *et al*., 1980**

Note: P = Pellet diet;
M = Mash diet;
NS = Not specified;
SBO = Soybean oil;
Heavy = Heavy layer breeds

c. **Palatability of cassava-based ration is an important factor limiting feed intake of poultry. Physical properties such as dustiness and bulkiness are closely related to palatability and limit feed intake. Further processing of cassava-based diets including pelleting, the** addition of molasses or fat to eliminate dust and improve texture of the diets, supported significantly better chick performance than the use of mash diets.

Apart from improving the palatability of feeds, fat supplementation has also been reported to supply essential fatty acids needed for normal egg size as well as provide additional energy to allow the diets to meet the requirements of chickens. Improved body weight and feed efficiency are normal responses to the addition of fats to cassava-based diets. However, Gomez *et al*. (1987) showed that a 5% increase in ME, using supplemental vegetable oil or tallow, had no beneficial effect on body weight of broilers fed mash diets containing 20–30% cassava meal (Table 4). Although the feed efficiency of the fat supplemented chicks was significantly better than the unsupplemented ones, the use of fat supplementation could not be economically justified.

d. Cassava root products are deficient in carotene and other carotenoids. Consequently, supplementation of cassava-based diets with these compounds is needed for the maintainance of normal egg yolk and broiler skin pigmentation.

TABLE 4. **Effects of added vegetable oil and tallow to cassava-based diets on broiler performances[1] (Gomez *et al*., 1987)**

		Treatments					
	Cassava level, %	0	0	20	20	30	30
Performance	Relative ME, %	100	105	100	105	100	105
Vegetable oil							
Starter (0–4 wk)	BW gain,g Feed/gain	768[b]	714[b]	793[b]	811[b]	799[b]	795[b]
		1.76[b]	1.81[b]	1.68[b]	1.61[b]	1.63[b]	1.62[b]

Final BWgain,g (0–8 wk)	**2,068 Feed/gain**	2,048 2.28[b]	2,153 2.29[b]	2,167 2.27[b]	2,077 2.22[b]	2,141 2.27[b]	2.21[b]
Tallow							
Starter (0–4 wk)	**BW gain, g Feed/ gain**	717[ab]	744	733	749	689	717
		1.81[b]	1.70[b]	170[b]	1.67[b]	1.76[b]	1.59[b]
Final (0–8 wk) Feed/gain	**BW gain, g**	2,010[b]	2,037	2,078	2,096	1,974	2,020
		2.34[b]	2.28[b]	2.33[b]	2.25[b]	2.36[b]	2.29[b]

1 Each value represents mean of 36 chicks
a-c Means in the same row bearing different superscripts are significantly different (P<0.05).

Fermented or ensiled root meal (FRM)

Dried products, from roots which have been fermented or ensiled, to detoxify the HCN or to increase their protein content, are other ways of root processing. Data on the substitution of the FRM for cereals in poultry rations is limited. In Nigeria, Pido *et al.* (1979) replaced FRM (lafunized roots) for maize at the rates of 0, 25.0, 37.5 and 50% of broiler rations. Bird body weight at 9 weeks was similar for all treatments, whereas, feed conversion ratios slightly increasing as the FRM levels increased. In this study groundnut meal was used as the cassava supplementary protein source and fish meal was fixed at 8% of the diets.

More recently, Khajarern *et al*. (1982) added dried layer manure to fresh cassava chips in the proportion of 1:9, on a dry basis, prior to ensiling the mixture for 24 days. The FRM, containing 5.5% crude protein, was then used to replace; cereals (maize + rice products); 10, 20, 30, 40% cassava; or 50% of a layer diet containing 10% fish meal. The feeds were fed for 270—days egg production and showed that the FRM could successfully replace cereals or cassava in the layer

diets. However, a slight reduction in hen-day production and feed conversion was noticed when the FRM inclusion levels were higher than 40% of the ration. This should be expected since the diets were fed in mash form. The initially conclusions are that the FRM can successfully be substituted for other conventional energy sources in poultry feeding, at up to 50% of the ration, providing that the supplementation and form of the feed was similar to that used for cassava root meal. However the economical value of this feed processing method needs to be carefully assessed.

Cassava leaf meal

Limited data on cassava leaf (CLM) and foliage meal (CFM) indicate that these products might be used, at low levels, as pigmenting agents, or, at higher levels, as partial substitutes for the conventional protein sources in poultry rations. Data in Table 3 indicates that the CLM could be included at up to 20% in broiler rations whereas the inclusion levels of CFM were slightly lower. This is natural as CFM contains higher level of crude fibre than CLM. For replacement pullets, the maximum possible inclusion level was 16.5% of pelleted rations, whereas with layers, where it was used as carotenoid source, a maximum level of 5% is recommended (Khajarern *et al*., 1980). The limiting nutritional factors with CLM and CFM are the HCN content, its low energy, bulkiness and possibly their tannin content (Ravindran *et al*., 1986). Normal supplementation of high CLM and CFM inclusion rations are 0.15 to 0.25% methionine and 3.0% fat.

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded from the available evidence that cassava products in various forms, root meal, fermented roots, leaf and foliage meals can successfully be used as substitutes for the conventional feedstuffs in poultry rations, provided that the high cassava-based rations are duly balanced for all nutrients, properly supplemented to correct nutritional problems and are

fed in the appropriate forms to assure an adequate feed intake. The following are the key considerations to be taken into account in the incorporation of cassava in the animal diets.

a. **It is important to correctly balance cassava-based diets for all nutrient to appropriately satisfy the needs of each class of poultry, plane of nutrition, production intensity, climatic condition and physical nature of diets.**

b. **HCN depresses chick performance and feed intake due to palatability problems. Care should be taken to use the products with the lowest possible HCN content and to supplement the diets with an adequate amount of methionine, sulphur containing amino acids and nutritional factors supporting methionine and sulphur metabolism.**

c. **Physical properties of cassava-based diets are important factors limiting feed intake. Thus cassava-based diets should be fed to poultry in pellet forms or after the addition of fat or molasses to eliminate dust and improve texture. Added fat may also be important in increasing the supply of available energy and essential fatty acids needed for normal egg size.**

d. **Carotenoid substances are needed for the provision of normal egg yolk and broiler skin pigments. They should thus be adequately supplemented preferably by CLM or CFM.**

e. **It is not possible to define precisely what are the optimum levels of inclusion of cassava products in poultry rations due to inaccuracies in definition of product types and test conditions in the available reports. However, they should be somewhere below the maximum possible inclusion levels given in Table 3. with broilers tending to be able to accept higher cassava levels in their diets than layers. One should take advantage of the maximum economic gains obtained by the complimentary responses of chickens fed diets**

containing the partially substituting levels of cassava products. Such a substitution also offers opportunities of avoiding the unnecessary supplementation of diets with the expensive imported feed ingredients such as amino acids and carotenoid substances.

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Use of cassava products in pig feeding
by G.G. Gomez

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is widely grown in the tropical regions. It is estimated that most (65 percent) of the cassava crop is used for human consumption while the remainder is used for animal feed, starch, and industrial applications. Some European countries are using cassava pellets, imported mainly from Thailand, in animal feeds, particularly for swine. Although the commercial production of dried cassava chips and pellets in most tropical countries is still insignificant, there is a considerable potential to expand the use of cassava in local animal feed markets.

The purpose of this paper is to review the most relevant information on the use of cassava products, mainly fresh, ensiled, and dried root chips or cassava meal, in swine feeding programmes. Most of the data herein reported has been obtained with, either; whole roots of 10- to 12-months-old plants, of cassava cultivars grown at CIAT or cassava pellets imported to Hawaii from Thailand.

NUTRITIONALCHARACTERISTICS OF CASSAVA ROOT PRODUCTS

Whole fresh cassava roots contain approximately 65 percent water and have to be dried or processed to extend their shelf life or to preserve them. Contents, expressed as percentages in parentheses, of crude protein (1–2), ether extract (0.2–0.5), crude fibre (0.8–1.0), and ash (1–2) are generally low in the fresh roots, with the nitrogen-free extract (30–35) or total soluble carbohydrates as the second most important chemical constituent after water (Gomez 1979).

Cassava whole-root chips can also be safely stored in airtight silos, and the resulting biomass has a chemical composition similar to that of fresh roots (Gomez *et al*. 1988).

If cassava is not consumed fresh or stored in silos, the roots can be converted into stable

dried products such as chips or pellets that can be subsequently used for industrial purposes or in composite animal feeds. Although all chemical constituents are concentrated in the dried cassava product, the most important component is starch, which accounts for 70 to 80 percent of its composition (Gomez 1979).

Dried cassava chips have less than half the protein content, and consequently lower amino acid contents than feed grains. The low concentration of sulfur amino acids and the relatively high content of arginine are common features of all cassava products analyzed (leaves, foliage, and whole-root chips), (Gomez and Noma 1986).

Of major concern with the use of cassava products, as animal feed, are their cyanide content. Most of the cassava cyanide is found in the form of a cyanogenic glucoside known as linamarin. A wide range of total cyanide concentrations (140 to 890 ppm dry matter basis) have been found in the fresh whole-root chips of several cassava cultivars (Gomez et al., 1984b), though most of them have a cyanide content below 300 ppm. Processing of cassava roots (sun-drying, oven-drying, ensiling) reduces the cyanide content in the final products to levels lower than the permissible maximum amount of hydrocyanic acid (100 ppm) set by the Council of the European Community (Ingram 1975). For example, cassava pellets imported from Thailand have a low cyanide content. No major problems have been encountered in feeding fresh, ensiled, or dried cassava roots to pigs in Latin America, because most of the cassava cultivars grown in this region have a low cyanide content.

FRESH CASSAVA ROOTS IN SWINE FEEDING PROGRAMMES

Fresh whole-root chips have been fed, *ad libitum*, either separately or mixed with a protein supplement. The basic difference in the different feed use was that a certain amount of protein supplement was saved when it was mixed directly with the fresh chips (Buitrago 1964); though,

the extra labour required to do the mixing could outweigh the advantage of this method.

Experimental information obtained at the Centro International de Agricultura Tropical (CIAT) and the Instituto Colombiano Agropecuario (ICA) in Colombia has shown that fresh cassava can be used successfully throughout all the periods of the swine life cycle. However, sows fed fresh cassava during gestation and lactation had a slightly inferior breeding performance than sows fed a corn-soyabean meal-based diet (Maner 1972).

The consumption of chopped fresh cassava by growing-finishing pigs varies according to the protein content of the supplement. The daily intake of cassava throughout the growing-finishing period was greater when the protein supplement (fed free choice) had a higher protein level (Table 1). At the same time the intake of the supplement decreased (Job 1975), though a tendency to overconsume protein was observed as the protein content of the supplement increased (Table 1).

TABLE 1. **Performance of growing-finisher pigs fed fresh cassava roots and a protein supplement (PS) free choice**

	control diet	**Fresh cassava +**		
Parameter		**20% PS**	**30% PS**	**40% PS**
Daily gain (kg)	0.63	0.70	0.67	0.65
Daily feed intake (kg)				
Fresh cassava		1.78	2.74	3.32
Protein supplement		1.39	1.00	0.75
Total feed (90% DM)	2.08	2.08	2.07	2.04
Feed/gain	3.30	2.97	3.09	3.14
Protein in diet (%)	14.3	14.6	16.6	17.3

Pigs do not readily consume fresh bitter roots. When a protein supplement was supplied *ad libitum* with fresh, chopped, bitter roots, the pigs consumed an excess of the supplement to compensate for a reduced intake of the bitter roots. When fresh bitter roots were mixed with the supplement, pigs did not consume enough feed and lost weight during the experimental period (Gomez *et al*. 1976).

The management of feeding programmes based on fresh cassava roots is an important aspect to be considered. For example, pigs more readily consume chips produced using a chipping machine (such as the Malaysian model), which cuts the roots into relatively regular chips, and reduces the loss of starch in the chipping process, than ground fresh roots. Also, self-feeding systems based on, free choice-*ad libitum* consumption of fresh chopped roots and protein supplement, usually lead to an excess intake of the supplement. A proportioned supply of chopped cassava mixed with the protein supplement would restrict the excess protein consumed to normal levels, though the additional labour required must be taken into account in an economic evaluation.

Experimental results obtained during the different periods of the swine life cycle suggest that fresh cassava roots are an excellent source of energy for swine feeding when properly supplemented with protein, minerals, and vitamins.

CASSAVA ROOT SILAGE AS A SWINE FEED

Little information is available on the ensiling process and on the nutritive quality of the stored product. Work at CIAT has shown that cassava whole-root chips can be safely stored in airtight silos for at least six months. The ensiling process is an efficient means of reducing the cyanide content and the resulting biomass can be fed to pigs (Gomez and Valdivieso 1988).

Pigs fed cassava whole-root silage with a protein supplement, either premixed or separately, performed similarly to pigs fed a control sorghum-based diet (Gomez *et al.* 1988). Furthermore, any of three protein supplements evaluated (soybean meal-cottonseed meal, soybean meal-fish meal, and cottonseed meal-fish meal (Table 2) proved to be effectivly used when fed in combination with cassava whole-root silage.

Limited data available on the use of ensiled cassava chips for gestating and lactating sows as well as for growing-finishing pigs indicated that results were comparable to those obtained with chopped fresh cassava roots (Maner 1972).

TABLE 2. **Composition (%) of protein supplement**

Ingredient	**SBM—CSM**	**SBM—FM**	**CSM—FM**
Sorghum	1.0	16.2	12.0
Soybean meal (SBM)	43.5	40.4	0.0
Cottonseed meal (CSM)	43.5	0.0	42.5
Fish meal (FM)	0.0	40.4	42.5
Bone meal	9.0	0.0	0.0
Salt, iodized	2.0	2.0	2.0
Mineral-vitamin premix	1.0	1.0	1.0
Calculated analysis (%)			
Crude protein	39.3	40.0	40.0
Lysine	2.01	3.24	2.25
Methionine	0.52	1.05	1.02
Calcium	2.25	2.14	2.20
Phosphorus	1.72	1.32	1.53

Ensiling of cassava whole—root chips could be a relatively inexpensive solution to the postharvest deterioration of the roots, particularly in humid tropical areas where drying of root chips would not be always feasible. Furthermore, storage of cassava root chips in silos would ensure a continuous supply of cassava for on-farm animal feeding programmes. However, more research on the ensiling of cassava root chips is needed to find the most appropriate silage method to preserve and enhance the high quality of cassava starch.

USE OF CASSAVA MEAL IN SWINE FEEDING PROGRAMMES

The most convenient and practical way of handling cassava is to dry the whole—root chips and grind them into a meal, which can be easily incorporated into composite diets. Dried cassava chips, pellets, and meal can be stored in a well-ventilated area for a long time without deterioration in their nutritive value. Cassava meal is an excellent energy source because of its highly digestible carbohydrates (70–80 percent), mainly in the form of starch; however, its protein content (2–4 percent) is low.

Experimental research at CIAT was conducted to study the effects of a cassava meal-soybean meal-feeding programme throughout the life cycle of the pig, with emphasis on the gestation and lactation periods. The results showed a consistent trend of the cassava feeding programme to produce lower reproductive performance and number of pigs farrowed (8.4 vs. 10.0) and weaned (6.6 vs. 9.4) than the control, yellow cornsoybean meal diets (Maner 1972, Gomez *et al.* 1976, Gomez 1977). The factors responsible for the lower reproductive performance of gilts fed the cassava meal-based diets were not clear, but a shortage of methionine was suspected to be one of the responsible factors.

The effect of methionine supplementation in cassava-based diets both for gestating and

lactating gilts as well as for growing-finishing pigs was subsequently ascertained (Gomez *et al.* 1984a). The experimental results showed that the extra amount of methionine (0.3 percent) added to the cassava meal-based diets did not improve gilt or litter performance (Table 3).

TABLE 3. **Effect of methionine (Met) supplementation in diets based on cassava meal for gestating-lactating gilts**

Parameter	Corn + SBM	Cassava meal + 0.0% Met	Soyben meal + 0.3% Met
No. gilts farrowed	14	10	10
Data at farrpwomg			
No. pigs/litter	8.5	9.1	9.4
Avg. pig weight (kg)	1.09	1.06	1.07
Data at weaning (56 days)			
No. pigs/litter	7.1	8.2	8.0
Avg. pig weight (kg)	16.7	16.2	16.5
Total litter weight (kg)	117.0	128.5	132.0

A comparison of previous experimental conditions with those of the latter experiment suggested that handling of the feed supply during the gestation period could explain the difference in the results. Previously (Maner 1972, Gomez *et al.* 1976), the amount of daily feed (1.8 kg diet/gilt) required for each experimental group was spread on a concrete platform in the shaded area of a pasture lot, but the amount consumed per gilt could not be controlled, and consequently feed intake may not have been uniform.

Although the same group-feeding system was used with the control diet (corn-soybean meal), it appeared that with this diet the feed intake per gilt was more uniform than with the cassava-based diet. Diets containing high levels of cassava meal have a more dusty or floury texture

and lower density than the corn-based diets. Feeding management, therefore, appears to be an important factor that may affect the performance of gestating and lactating gilts or sows fed diets containing high levels of cassava meal.

Although cassava meal can be satisfactorily used as the main energysupplying ingredient, especially when combined with soybean meal, leastcost diet formulation will take into consideration the nutrient supply as well as the cost of available feedstuffs. Under practical conditions, cassava meal would be between 20 and 40 percent of the diets at a price equivalent to approximately 80 percent of the current price of corn or sorghum. Performance of gestating and lactating gilts, their litters, and growing-finishing pigs fed least-cost diets containing cassava meal were also similar to that obtained with practical commercial diets based on sorghum (Gomez *et al.* 1984a).

Because of the physico-chemical characteristics of cassava starch (a small-diameter granule, a low amylose content, and an X-ray diffraction pattern of the A-type) (Szylit *et al.* 1977), which facilitate an efficient amylolytic degradation of the starch, cassava-based diets appear to be highly digestible and particularly suitable for baby pig feeding. A palatability test with baby pigs fed diets containing different levels of cassava meal (0, 20, and 40 percent) throughout the lactation (42 days) and post-weaning (42 to 56 days) periods, using the free choice method, clearly showed a definite preference for the diet containing the highest level of cassava meal throughout the entire experimental period (Table 4) (Gomez and Valdivieso 1983). However, there was no significant difference between the cassava- and sorghum-based diets when they were compared by the single feed method.

TABLE 4. **Baby pig preference for diets containing cassava meal in free choice test**

	% Cassava meal in diets			
	0	20	40	

Feed intake	Kilograms of feed consumed			Total
Per litter				
14–42 days	1.83	3.00	12.35	17.17
42–56 days	14.65	26.23	39.11	79.99
Total	16.48	29.23	151.45	97.16
% of total	17	30	53	

Data from recent experimental studies with nursery pigs (from weaning to 20–25 kg liveweight) at the University of Hawali have shown the following: a) diets containing 20 to 30 percent cassava meal produced pig performances similer to or slightly better than taht of pigs fed a control diet based on corn-soybean meal, b) diets containing 30 percent cassava meal in combination with either 10, 15, or 20 percent dried whey produced results similar to those obtained with a control diet based on corn with 20 pecent dried whey, c) a combination of 30 percent cassava meal with soyabean meal and fish meal led to better nursery pig performance than that obtained with either soybean meal alone or in combination with meat and bone meal or a combination of all three protein feeds, and d) the physical form (meal, crumbled, pelleted) of a diet based on 30 percent cassava meal in combination with soyabean meal and fish meal did not significantly affect pig performance (Gomez, unpunlished results).

Because of its low protein content, cassava meal-based diets require higher amounts of protein-supplying ingredients such as soybean meal to obtain an adequate balance of protein and amino acids. Therefore, the economic feasibility of using cassava as a substitute for conventional energy sources would depend not only on the relative price of cassava but also on the price of protein supplements needed to balance cassava-based diets.

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