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 zero tillage 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 Phytophthora 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 (Rodríguez, 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, *Phenacoccus 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.

**Bibliography**


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.

- Microorganisms have a very fast growth rate.
- They can be easily modified genetically for growth on a particular substrate under particular cultural conditions.
- Their protein content is quite high varying from 35 to 60%.
- They can be grown in slurry or on solids.
- 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 have 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 inhibitory 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/l) was complete in around 20 h, yielding around 22.5 g/l (dry biomass) containing 41% crude protein (48 to 50% crude protein in the mycelium) and 31% true protein (7.0 g/l).

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<th>TABLE 1. Fermentation conditions for protein production from cassava mash by <em>A. fumigatus</em> 1–21 A (Gregory, 1977)</th>
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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 min, immediately after grinding, in one-half final volume | Gelatinize starch, permitting complete utilization, prevents development of antifungal activity, provides desired starting temperature after dilution to final volume

Nitrogen source = Urea (1.72 g/l) | No automatic pH control required; whereas, (NH₄)₂SO₄ results in excess acidity

Mineral supplement = KH₂PO₄ (0.25 g/l) | 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, NH₄NO₃ - 1.00, KH₂PO₄ - 1.50, MgSO₄·7H₂O - 0.25, CaCl₂ - 0.01, MnSO₄·4H₂O - 0.001, ZnSO₄ - 0.001, CuSO₄·5H₂O - 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 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, NH₄NO₃ - 1.00, KH₂PO₄ - 1.50, MgSO₄·7H₂O - 0.25, CaCl₂ - 0.01, MnSO₄·4H₂O - 0.001, ZnSO₄ - 0.001, CuSO₄·5H₂O - 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%.

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**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$_2$PO$_4$, 0.8 g MgSO$_4$ 7H$_2$O 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$_4$)$_2$SO$_4$] 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.

<p>| TABLE 2. Total protein (g/100 g DM) changes during fermentation of different mixtures of cassava flour and wastes. |
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<th>Cassava mixture flour/wastes</th>
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</tr>
</tbody>
</table>
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 occasionally 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 an 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>
<thead>
<tr>
<th>TABLE 3. Growth performance of broilers fed with SCP enriched cassava feed (Padmaja and Balagopalan, 1990)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment/Body Wt. (g)</strong></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>$T_0$ (control)</td>
</tr>
<tr>
<td>$T_1$ (50% SCP)</td>
</tr>
<tr>
<td>$T_2$ (55% SCP)</td>
</tr>
<tr>
<td>$T_3$ (60% SCP)</td>
</tr>
</tbody>
</table>

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.

**Bibliography**


**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 lotaustral. 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 - hydroxyisoleucine 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 fermentation (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 fermentation 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 microorganisms 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 sun-drying:

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 microorganisms including *Aspergillus flavus* (pathogenic), *A. fumigatus*, *A. cherahen*, *A. teirenes*, *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 sun-drying of cassava roots using inclined tray drying 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 sun drying. Bound cyanide which is less volatile can be a greater contributor to cyanide toxicity in sun dried 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>
<thead>
<tr>
<th>Cassava/Products</th>
<th>Hydrocyanic acid content (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh whole root</td>
<td>88.3–416.3</td>
</tr>
<tr>
<td>Fresh pulp</td>
<td>34.3–301.3</td>
</tr>
<tr>
<td>Fresh peel</td>
<td>364.2–814.7</td>
</tr>
<tr>
<td>Sun-dried whole root</td>
<td>23.1–41.6</td>
</tr>
<tr>
<td>Sun dried pulp</td>
<td>17.3–26.7</td>
</tr>
<tr>
<td>Sun dried peel</td>
<td>264.3–321.5</td>
</tr>
<tr>
<td>Oven-dried whole root</td>
<td>51.7–63.7</td>
</tr>
<tr>
<td>Oven-dried pulp</td>
<td>23.7–31.3</td>
</tr>
<tr>
<td>Oven-dried peel</td>
<td>666.8–1250.0</td>
</tr>
<tr>
<td>Dried cassava waste</td>
<td>240.0</td>
</tr>
<tr>
<td>(peels and discarded small</td>
<td></td>
</tr>
<tr>
<td>tubers)</td>
<td></td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Parameters</th>
<th>Corn</th>
<th>Sundried peel</th>
<th>Oven-dried peel</th>
<th>Fermented peel</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCN content (ppm) of feed</td>
<td>0</td>
<td>130.2</td>
<td>595.2</td>
<td>42.5</td>
</tr>
<tr>
<td>Daily feed Intake (g)</td>
<td>28.45b</td>
<td>27.70b</td>
<td>31.25ab</td>
<td>32.63a</td>
</tr>
<tr>
<td>Daily weight gain (g)</td>
<td>10.97a</td>
<td>9.02c</td>
<td>9.43c</td>
<td>10.30b</td>
</tr>
<tr>
<td>Daily Cyanide Intake (mg)</td>
<td>0b</td>
<td>1.80b</td>
<td>9.30a</td>
<td>0.69b</td>
</tr>
</tbody>
</table>

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


<table>
<thead>
<tr>
<th>Parameters</th>
<th>0%</th>
<th>0.25%</th>
<th>0.50%</th>
<th>0.75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed/gain ratio</td>
<td>2.59b</td>
<td>3.07b</td>
<td>3.32a</td>
<td>3.18a</td>
</tr>
<tr>
<td>Protein Efficiency</td>
<td>1.90a</td>
<td>1.64b</td>
<td>1.53b</td>
<td>1.58b</td>
</tr>
<tr>
<td>Nitrogen Retention %</td>
<td>70.63a</td>
<td>64.50a</td>
<td>56.09a</td>
<td>55.97b</td>
</tr>
<tr>
<td>Serum total protein</td>
<td>6.12</td>
<td>6.00</td>
<td>5.97</td>
<td>5.97</td>
</tr>
<tr>
<td>Serum Urea (g. 100ml⁻¹)</td>
<td>92.18b</td>
<td>1.53a</td>
<td>114.65a</td>
<td>97.12b</td>
</tr>
<tr>
<td>Serum thiocyanate (mg. 100ml⁻¹)</td>
<td>1.09b</td>
<td>1.19b</td>
<td>1.65a</td>
<td>1.24b</td>
</tr>
<tr>
<td>Urinary thiocyanate (mg. 100g⁻¹ feed intake)</td>
<td>2.47c</td>
<td>5.69b</td>
<td>10.91a</td>
<td>5.99b</td>
</tr>
<tr>
<td>Liver thiocyanate (mg.g⁻¹ fresh weight)</td>
<td>0.41b</td>
<td>0.39b</td>
<td>1.18a</td>
<td>0.39b</td>
</tr>
</tbody>
</table>

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


<table>
<thead>
<tr>
<th>Parameters</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total HCN (ppm)</td>
<td>0</td>
<td>96</td>
<td>400</td>
</tr>
<tr>
<td>Protein level %</td>
<td>20.19</td>
<td>20.42</td>
<td>20.12</td>
</tr>
<tr>
<td>Serum thyroxine (T₄) (mg/dl)</td>
<td>4.47a</td>
<td>3.63b</td>
<td>3.32b</td>
</tr>
<tr>
<td>Serum total protein (g/dl)</td>
<td>6.9</td>
<td>6.9</td>
<td>6.9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Dietary HCN level (ppm)</th>
<th>0</th>
<th>250</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestating gilts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum thiocyanate (mg/100 ml)</td>
<td>2.01</td>
<td>2.15</td>
<td>2.29</td>
</tr>
<tr>
<td>Serum protein bound iodine (mg/100ml)</td>
<td>3.1</td>
<td>3.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Amniotic fluid thiocyanate (mg/100ml)</td>
<td>0.90</td>
<td>0.45</td>
<td>1.18</td>
</tr>
<tr>
<td>Thyroid (g/100 g body weight)</td>
<td>5.52</td>
<td>7.44</td>
<td>7.98</td>
</tr>
<tr>
<td>Fetuses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thyroid (g/kg body weight)</td>
<td>0.54a</td>
<td>0.36b</td>
<td>0.52a</td>
</tr>
<tr>
<td>Serum thiocyanate</td>
<td>0.85b</td>
<td>0.87ab</td>
<td>1.02a</td>
</tr>
</tbody>
</table>
### Lactating sows

<table>
<thead>
<tr>
<th></th>
<th>Serum thiocyanate (mg/100ml)</th>
<th>Serum protein bound iodine (mg/100 ml)</th>
<th>Colostrum thiocyanate (mg/100 ml)</th>
<th>Milk thiocyanate (mg/100 ml)</th>
<th>Colostrum iodine (mg/100 ml)</th>
<th>Milk iodine (mg/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.74(^{ab})</td>
<td>3.2</td>
<td>1.32</td>
<td>1.15(^{b})</td>
<td>4.9(^{b})</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>0.58(^{b})</td>
<td>3.6</td>
<td>1.19</td>
<td>1.15(^{b})</td>
<td>6.0(^{b})</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>0.78(^{a})</td>
<td>3.7</td>
<td>1.41</td>
<td>1.35(^{a})</td>
<td>15.2(^{a})</td>
<td>0.07</td>
</tr>
</tbody>
</table>

### Suckling pigs

<table>
<thead>
<tr>
<th></th>
<th>Serum thiocyanate (mg/100 ml)</th>
<th>Serum protein (g/100 ml)</th>
<th>Serum protein bound iodine (mg/100 ml)</th>
<th>Colostrum iodine (mg/100 ml)</th>
<th>Milk iodine (mg/100 ml)</th>
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<tr>
<td></td>
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<td>6.0</td>
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<tr>
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<td>0.78</td>
<td>5.86</td>
<td>4.9</td>
<td>15.2</td>
<td>0.07</td>
</tr>
</tbody>
</table>

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, Ile-Ife, 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-requisites 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 hydrolysis 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.

Bibliography


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**Cassava**

Common name for any of several related plants native to tropical regions in the Americas. Cassava is the West Indian name; manioc, or mandioc, is the Brazilian name; and juca, or yucca, is used in other parts of South America. The plant grows in a bushy form, up to 2.4 m (8 ft) tall, with greenish-yellow flowers. The roots are up to 8 cm (3 in) thick and 91 cm (36 in) long. The roots contain from 20 to 32% of starch in ½ to 1½ year old plants.
Two varieties of the cassava are of economic value: the bitter, or poisonous; and the sweet, or non-poisonous. Because the volatile poison can be destroyed by heat in the process of preparation, both varieties yield a wholesome food. Cassava is the chief source of tapioca, and in South America a sauce and an intoxicating beverage are prepared from the juice.

The root in powder form is used to prepare farinha, a meal used to make thin cakes sometimes called cassava bread. The starch of cassava yields a product called Brazilian arrowroot. In Florida, where sweet cassava is grown, the roots are eaten as food, fed to stock, or used in the manufacture of starch and glucose. In Africa Gari is a popular food preparation. Tapioca, easily digested starchy foodstuff extracted from the root of the cassava plant. Tapioca is often used in pudding. The term "tapioca" is used to designate products made from cassava like starch, dried chips etc. Tapioca is also replacing mung bean starch - the prime material for making clear starch noodles, however, tapioca starch need modification to produce a gel with the same strenght as mung bean starch, which is very high in amylose.

Scientific classification: Cassavas belong to the family **Euphorbiaceae**. Both bitter and sweet cassava are classified as **Manihot esculenta** or **Manihot utilissima** or **Manihot Aipi**

**Chips.** This is the most common form in which dried cassava roots are marketed and most exporting countries produce them. The chips are dried irregular slices of roots which vary in size but should not exceed 5 cm in length, so that they can be stored in silos. They are produced extensively in Thailand, Malaysia, Indonesia and some parts of Africa.

**Process.** The present method of processing chips is very simple, consisting in mechanically slicing the cassava roots and then sun drying the slices until their moisture content is only 14 per cent: dry chips can be stored longer and are cheaper to transport. The recovery rate of chips from roots is about 20-40 percent. When the roots are not sorted, peeled and washed, the chips are usually brown in colour and have a high content of fibre sand and foreign objects as well as hydrocyanic acid. Trimming, peeling and washing the roots in a similar manner as for the processing of cassava flour are recommended in order to produce white chips of superior quality. The roots are shredded in a special machine, which is usually made locally. The machine consists of a rotating notched cutting disk or knife blades mounted on a wooden frame equipped with a hopper. The cassava roots are cut into thin slices and pieces as they pass through the machine. A
chipping-machine can do in one hour the work that used to take three days by hand.

Drying. Sun drying is used mostly where the sliced roots are spread out on drying areas, or concrete floors of various dimensions. The concentration of chips during drying should not exceed 10-15 kg/m², the required drying area space being about 250 m² for each ton per day of dried roots produced. To produce good quality chips the roots must be sliced and dried as quickly as possible after harvest. The chips should be turned periodically in the drying period, usually two or three sunny days, until the moisture content reaches 13 - 15 percent. The chips are considered dry when they are easily broken but too hard to be crumbled by hand. The thickness of the slices also has an effect on the quality of chips. Thick slices may appear dry on the surface when their internal moisture content is still high. When rain threatens during the drying process, the chips are collected by hand or by a tractor into piles under a small roof. Interrupted sun drying affects the quality of the finished chips and pellets. When the semidried chips are wet again by rain, they become soggy and upon completion of drying lose their firm texture. In rainy regions, where continuous sun drying is difficult, some form of artificial heat drying is required.

**Broken Roots.** Similar to chips in appearance, but generally thicker and longer, they are often 12-15 cm long and can jam the mechanism of handling equipment.

**Pellets.** The pellets are obtained from dried and broken roots by grinding and hardening into a cylindrical shape. The cylinders are about 2-3 cm long and about 0.4-0.8 cm in diameter and are uniform in appearance and texture. The production of pelleted chips has recently been increasing as they meet a ready demand on the European markets. They have the following advantages over chips: quality is more uniform; they occupy 25-30 percent less space than chips, thus reducing the cost of transport and storage; handling charges for loading and unloading are also cheaper; they usually reach their destination sound and undamaged, while a great part of a cargo of sliced chips is damaged in long-distance shipment because of sweating and heating. Pellets are produced by feeding dried chips into the pelleting machine, after which they are screened and bagged for export. The powdered chips which fall down during pelleting are re-pressed into pellets and the process is repeated. There is usually about 2-3 percent loss of weight during the process.

**Meal.** This product is the powdered residue of the chips and roots after processing to extract edible starch. It is generally inferior in quality to chips, pellets and broken roots, has a lower starch content and usually contains more sand. Meal perform badly in the transport system of a modern feed mill.

**Pulp.** During the processing of cassava starch, the residual pulp which is separated from the starch in the screening process is used as an animal feed. It is usually utilized wet drip-dry with 12-15% dry matter in the neighbourhood of the processing factory but is sometimes sun dried before it is sold. With efficient extraction the starch content is quite low and this pulp is be utilised by ruminant only.

**Composition of Roots**

<table>
<thead>
<tr>
<th>Moisture</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
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<tr>
<td>Sugars</td>
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<td>Protein</td>
<td>1.1</td>
</tr>
<tr>
<td>Fats</td>
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</table>
Nature of cassava

The plant
The cassava plant is a perennial that grows under cultivation to a height of about 2-4 meters. The large, palmate leaves ordinarily have five to seven lobes borne on a long slender petiole, and grow only toward the end of the branches. As the plant grows, the main stem forks, usually into three branches which then divide similarly. The roots or tubers radiate from the stem just below the surface of the ground. Feeder roots grow vertically from the stem, and storage roots penetrate the soil to a depth of 50-100cm. The capacity of the cassava plant to obtain nourishment from some distance below the surface may help to explain its growth in inferior soils.

Male and female flowers arranged in loose plumes are produced on the same plant. The triangular-shaped fruit each contain three seeds. The number of tuberous roots and their dimensions vary greatly among the different varieties. The roots may reach a size of 30-120 cm long and 4-15 cm in diameter, and a weight of 1-8 kg or more.

Clusters of root of the Bogor variety, ripe for harvesting, are shown in Figure 3. A cross section of the root is given in Figure 4. The peel consists of an outer and an inner part, the former comprising a layer of cork cells and the phellogen. The cork layer, generally dark-colored, can be removed by brushing in water, as is done in the washers of large factories. The inner part of the peel contains the phelloderm and the phloem, which separates the peel from the body of the root. The texture of the transition layer makes possible an easy loosening of the whole peel from the central part, thus facilitating the peeling of the roots.

The cork layer represents 0.5-2 percent of the weight of the whole root, whereas the inner part of the peel accounts for about 8-15 percent. In ripe roots this is generally about 2-3mm thick. The starch content of the peel is only about half that of the core. The peel is much firmer, hindering a smooth rasping by primitive raspers; small factories prefer to peel the roots before working them up. The loss of starch incurred by rejecting the peel, however, is not acceptable to the larger factories, which remove only the cork layer.

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**Soil**
Cassava grows best on light, sandy loams, or on loamy sands which are moist, fertile and deep, but it also does well on soils ranging in texture from sands to clays and on soils of relatively low fertility. In practice, it is grown on a wide range of soils, provided the soil texture is friable enough to allow the development of the tubers. Cassava can produce an economic crop on soils so depleted by repeated cultivation that they have become unsuitable for other crops. On very rich soils the plant may produce stems and leaves at the expense of roots. In some parts of Africa, freshly cleared forest soils are regarded as highly suitable after they have borne a cereal crop.

**Fertilization**
No fertilization is required when the land is freshly cleared or when there is enough land to enable the cultivator to substitute new land for old when yields fall. Like all rapidly growing plants yielding carbohydrates, cassava has high nutrient requirements and exhausts the soil very rapidly. When cassava is grown on the land for a number of years in succession or rotation, the soil’s store of certain nutrients will be reduced and must therefore be returned to the soil by fertilization.

Various experiments in Brazil, India, Africa and the Far East have shown significant increases in yield of roots as well as starch content - obtained by the application of fertilizers. Potassium salts favor the formation of starch, and nitrogen and phosphorus are essential for growth. However, if the soil contains large quantities of assimilated nitrogen, the result will be heavy development of vegetative growth without a corresponding increase in root production.

Generally speaking, fertilization is practiced at present in most parts of Africa and South America only on commercial plantations. In Thailand, only a few farmers apply artificial fertilizers, as they are usually too costly for the small farmer. Most farmers use different kinds of organic manures, such as cattle or duck manure or garbage.

The kinds and quantities of fertilizers required by a cassava crop depend on the nature of the soil.

**Harvesting**
Harvesting of cassava can be done throughout the year, when the roots reach maturity. In regions with seasonal rains, such as Madagascar, harvesting is usually done in the dry season, during the dormant period of the plant. Where rain prevails all year round, as in Malaysia, cassava is harvested throughout the year.

Maturity differs from one variety to another, but for food the tubers can be harvested at almost any age below 12 months.

From the standpoint of starch production, cassava should be considered ripe when the yield of starch per hectare is highest. An optimum age of 18-20 months was found in experiments with certain strains of the variety ‘S?o Pedro Preto,’ in a tropical climate (Java). The graph in Figure 7 shows the influence of age at harvesting on the starch yield, as found in an experiment with a definite strain.

Both root and starch production increase rapidly to their maximum value, after which root production decreases slowly and starch production much more rapidly, on account of the declining starch content of the tubers.

If the roots are left in the ground, starch content increases with age until, at a certain point, lignifications takes place, causing the roots to become tough and woody, so that they are harder to prepare for consumption and other uses.

Once the roots are harvested, they begin to deteriorate within about 48 hours, initially owing to
enzymatic changes in the roots and then to rot and decay. The roots may be kept refrigerated for up to a week. They may be stored in the ground for longer periods if they are not detached from the plant.

Harvesting is still generally a manual operation, although equipment to facilitate this operation is being considered. The day before harvest, the plants are ‘topped’ - the stalks are cut off 40-60 cm above ground by hand, machete or machine and piled at the side of the field. This length of stalk is left as a handle for pulling. Material required for the next planting is selected and the rest is burned. In light soils the roots are slowly drawn from the soil simply by pulling the stems or with the help of a kind of crowbar, and the tubers are cut off the stock. In heavier soils a hoe may be required to dig up the roots before the plant is pulled out. It must be noted that once the plants have been topped, lifting of the roots must not be delayed, as sprouting and a drastic fall in the starch content of the tubers will result.

Post harvesting technology
Some institutes are researching cassava root processing in order to increase its value and use. Research has been done in many areas, including the following:

2. Processing for food industry: native starch, modified starch, flour as a substitute for wheat flour, monosodium glutamate, sorbitol, high fructose syrup, L-Lysine and citric acid.
3. Processing for the animal feed industry: cassava chips and pellets.
4. Processing for other industries: ethanol, biodegradable plastics, high water absorbing polymers and cyclodextrin.

Stem Cutting Technology
Cassava may be planted either from stem cuttings or from true seeds: true seed is used only for breeding programs, while cutting are used for commercial planting. Germination of stem cuttings changes with variety, maturity of the plants, storing ability and environmental conditions. Research related to stem cutting technology can be summarized as follows:

1. Stem cuttings should be taken from the middle part of 8-12 month old plants.
2. Stem cuttings should be used within 30 days after harvesting. However, for some cultivars, such as Rayong 3 and Rayong 90, stem cuttings should be used within 15 days after harvest.
3. Stems should be stored vertically under partial shading, in order to prolong the storage time.
4. The optimum length of stem cutting for commercial planting is 20–25 cm, and they should have at least 10 buds.
5. Stem cuttings may be treated with insecticides and fungicides if necessary.

Yield
Cassava is not usually grown on the soils where it would be most productive, i.e. light sandy loams, fertile and deep, which are reserved for other crops less tolerant of poor soils. When cassava is grown by traditional tropical methods, yields lie between 5 and 20 tons per hectare, varying with the region, the variety, the soil and other factors. However, when the crop is given more attention, yields of 30-40 tons per hectare are obtained. It has been reported that it is normal for some varieties, under appropriate cultivation methods, to yield over 60 tons per hectare.

The high yields frequently achieved at agricultural experiment stations and occasionally by some active farmers show what might be accomplished with improved varieties and better cultural practices.

Diseases and Pests
In many regions, diseases or pests do not normally affect the cassava plant. However, in others it may be attacked by the following:

1. Viral disease. Mosaic, the tobacco virus, may attack leaves, stems and branches. Many parts of Africa harbor these diseases, and attempts are being made to select cassava varieties resistant to it.
2. Bacterial disease. Bacteria such as Phytoponas manihotis (in Brazil), Bacterium cassava (in Africa) and Bacterium solanacearum (in Indonesia) may attack roots, stems or leaves of cassava plants.
3. Mycoses. Some kinds attack roots, stems, or leaves of cassava plants and cause various diseases.
4. Insects. Some insects affect the plant directly (locusts, beetles and ants); others affect the plant indirectly by the transfer of a virus (aphids).

5. Animals. Rats, goats and wild pigs are probably the most troublesome; they feed on the roots, especially in areas adjacent to forests.

Toxicity
The roots, branches and leaves of cassava contain a cyanogenetic glucoside called phaseolunatin, which breaks down upon harvest into the toxic hydrocyanic acid (prussic acid), acetone and glucose by the action of the enzyme linase. The presence of hydrocyanic acid is easily recognized by a bitter taste. At the harvest of cassava roots, the amount of acid in the plant varies from harmless to lethal - from a few mg to 250mg or more per kg of fresh root. Investigations show that the glucoside content in the cassava plant is markedly increased by drought and potassium deficiency.

Hydrolysis of glucoside by the enzyme can be accelerated by soaking the roots in water, crushing or cutting them, or by heating. Hydrocyanic acid content varies little in different tubers of one plant, but varies considerably in tubers obtained from different locations or different varieties. In sweet varieties, most of the acid is located in the skin and the exterior cortical layer, while in bitter varieties the acid is uniformly distributed in all parts of the roots.

In choosing a strain, the hydrocyanic acid content should be taken into account. Highly poisonous strains are preferred for the purpose of starch manufacture, thereby minimizing thefts by both animals and men.