Cassava as Livestock Feed in Africa

Proceedings of the IITA/ILCA/University of Ibadan Workshop on the Potential Utilization of Cassava as Livestock Feed in Africa

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International Institute of Tropical Agriculture
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About IITA

The goal of the International Institute of Tropical Agriculture (IITA) is to increase the productivity of key food crops and to develop sustainable agricultural systems that can replace bush fallow, or slash-and-burn, cultivation in the humid and subhumid tropics. Crop improvement programs focus on cassava, maize, plantain, cowpea, soybean, and yam. Research findings are shared through international cooperation programs, which include training, information, and germplasm exchange activities.

IITA was founded in 1967. The Federal Government of Nigeria provided a land grant of 1,000 hectares at Ibadan, for a headquarters and experimental farm site, and the Rockefeller and Ford foundations provided financial support. IITA is governed by an international Board of Trustees. The staff includes around 180 scientists and professionals from about 40 countries, who work at the Ibadan campus and at selected locations in many countries of sub-Saharan Africa.

IITA is one of the nonprofit, international agricultural research centers currently supported by the Consultative Group on International Agricultural Research (CGIAR). Established in 1971, CGIAR is an association of about 50 countries, international and regional organizations, and private foundations. The World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP) are cosponsors of this effort.

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Preface

The workshop on "Processing and utilization of cassava by smallscale farmers in Africa" was organized jointly by the International Institute of Tropical Agriculture (IITA), the International Livestock Centre for Africa (ILCA), and the University of Ibadan, Nigeria, at IITA from 8 to 11 March 1988. The workshop was funded by the International Development Research Centre (IDRC). Its main objective was to explore avenues for utilizing cassava and its by-products as livestock feed in Africa.

The workshop was well-attended by animal scientists, agronomists, and feedmill managers who all exchanged views on the subject and shared their experiences, particularly on the use of cassava for feeding animals in Africa.

At the meetings, workshop participants centered their technical contributions and discussions on the following themes:

- Roles of cassava in African farming and food systems
- Processing cassava for human food and livestock feed
- Utilization of cassava as food and livestock feed
- Potentials and impacts of cassava improvement
- Development and implementation of future strategies for improved cassava processing and utilization, particularly as livestock feeds in Africa.

Following the presentation of the technical papers, three special working groups were set up to find out the limitations and potentials of cassava use in livestock feeds, to examine existing technologies for processing and utilization of cassava for livestock feeds in Africa and identify research gaps, and to formulate future research strategies and action plans.

It is hoped that the publication of the contributions of the workshop participants will increase awareness of the public and private sectors about the limitations and potentials of cassava as livestock feed in Africa, and also encourage wide interest and further research efforts in the development of improved processing technologies for utilization of cassava in livestock feeds on the continent.

S. K. Hahn
Director Emeritus

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Acknowledgments

In acknowledging the various forms of support which contributed to the success of this workshop, a special debt of gratitude is owed to the International Development Research Centre (IDRC), Canada, for sponsoring the workshop, and to both ILCA and the University of Ibadan, Nigeria, for joining forces with IITA to organize and hold the workshop. The excellent leadership provided by Professor G.N. Egbunike in the organization of the workshop is particularly appreciated.

In producing this volume of proceedings, editorial processing and graphic design work was carried out by staff of the Publications Unit of IITA, while printing was paid for and executed at ILCA. The technical support of both institutes, IITA and ILCA, is gratefully acknowledged in making available this volume and thereby fulfilling the workshop's larger goals of increasing awareness of the subject.

I

Introduction

Introduction

S.K. Hahn

Animal scientists, agronomists and feedmill managers have exchanged views and two international centers, ILCA and IITA, have shared their knowledge and experiences at this workshop on production and utilization of cassava as livestock feed, which was held in the interest of national agricultural research systems and industrialists engaged in the production of animal feeds in Africa.

Cassava is one of the most important staple food crops grown in tropical Africa. Because of its efficient production of cheap food energy, year-round availability, tolerance to extreme ecological stress conditions, and suitability to present farming and food systems in Africa, it plays a major role in efforts to alleviate the African food crisis.

Traditionally, cassava tuberous roots are a major source of carbohydrates in human diets and are processed by various methods into numerous products utilized in diverse ways according to local customs and preferences. In some cultures, the leaves are also consumed as a favorite green vegetable. Many traditional foods processed from the roots and leaves of cassava thus constitute the major part of a family's daily food. However, cassava is frequently denigrated because its roots have a low protein content. But unlike the roots that are essentially carbohydrate, cassava leaves are a good source of protein and vitamins which can provide a valuable supplement to the predominantly starchy diets and feed. Cassava leaves are rich in protein, calcium, iron, and vitamins, comparing favorably with other green vegetables generally regarded as good protein sources. However, while the vitamin content of the leaves is high, the processing techniques used can lead to huge losses. Boiling of the leaves especially may reduce vitamin C substantially.

Cassava contains the cyanogenic glucosides, linamarin and lotaustralin. After tissue damage, these are hydrolyzed by the endogenous enzyme linamarase to the corresponding cyanohydrins. Further hydrolysis to hydrogen cyanide is responsible for the chronic toxicity associated with inadequately processed cassava products. Therefore, processing procedures must seek to reduce the cyanide in cassava before use. Various processing methods have been used to reduce cyanide quite effectively. For example, grating, sun-drying, boiling and fermenting can reduce cyanide considerably. Aerobic fermenting methods which are commonly used in many parts of Africa also increase the protein content of the final product by introducing molds to cassava tuberous roots.

In collaboration with national programs, IITA has developed high yielding, stable cassava lines, and many national cassava improvement programs in

Africa have released improved cassava varieties resulting from IITA's work. Higher productivity is therefore expected from these improved varieties and production technologies. As a result, a surplus is anticipated that could lower the farm prices of cassava products. This has led to a growing interest among government authorities and researchers in Africa on the improvement of processing and utilization of cassava and development of new or alternative uses and products.

Research strategies in national and international research institutes have focused mostly on preharvest activities. However, the future of cassava depends largely upon the development of improved processing technologies and of improved products that can meet the changing needs of urban people and on its suitability for alternative uses such as animal feeds and as industrial raw materials.

The limited supply of raw materials for the livestock feed industry has resulted in a continuous increase in the cost of production, causing a phenomenal rise in the unit cost of livestock products. Thus, these products have become too expensive for the majority of the population.

The principal future market for cassava is as livestock feed. Cassava has long been recognized by researchers in Africa as an appropriate animal feed and it has been used as an important and cheap feed in many European countries. Both roots and leaves are usable as livestock feed. Cassava offers tremendous potentials as a cheap source of feed energy for livestock, provided it is well-balanced with other nutrients. There is a great deal of current interest in the supplemental feeding of livestock with cassava in Africa.

Traditionally, cassava is fed to sheep and goats in the tropics and it can constitute 20–40 percent of compound livestock feeds, especially in poultry and pigs, with considerable reduction in production costs. However, there is a need to increase available knowledge of technology of utilization of cassava as livestock feed.

I believe that one limiting factor in using cassava as livestock feed is the lack of awareness about its potential and relevant technologies.

The objectives of this workshop are, therefore, to:

1. Collate information on traditional African processing technologies with emphasis on cassava as a livestock feed,
2. Review the marketing and economics of cassava by-products,
3. Recommend strategies for future research and development on the processing and utilization of cassava as a livestock feed, and
4. Disseminate up-to-date information on cassava.

On behalf of the organizing committee, I would like to express sincere appreciation to the International Development Research Centre (IDRC) of Canada, particularly Dr Kategile, for sponsoring this important joint workshop.

II

Utilization of Cassava

Cassava in African Farming and Food Systems: Implications for Use in Livestock Feeds

F.I. Nweke and H.C. Ezumah

Farming systems can be broadly defined to include the food system as a subset in the overall context of production of food and shelter materials. The food system may also be defined to include crop and livestock production systems as a subset when it is considered as a continuum of activities starting from production through processing and distribution to utilization of crop and livestock products for food. The importance of the latter definition is underscored by the decision, in 1987, to award the first General Foods World Food Prize, as follows:

> The concept of the total food chain lies at the heart of the General Foods World Food Prize, for each link in that chain plays a vital role. Every aspect of the production, processing and distribution of food needs to be considered, including farming, the agricultural sciences, food sciences and technology, nutrition, economics, technology transfer, governmental policies, transportation and distribution and education [General Foods 1987].

The General Foods' definition is adopted in this paper and livestock production systems as subsets of food systems. This paper will describe the role of cassava in the food crop production systems of tropical Africa. We will also explore the degree to which tropical African countries can meet their cassava needs for human consumption and generate a surplus for use in livestock feeds.

In collaboration with International Center for Tropical Agriculture (CIAT), Colombia, the Overseas Development Natural Resources Institute (ODNRI), and national agricultural research systems (NARS) in Africa, IITA has embarked on a continent-wide survey of cassava in Africa. The survey is called the Collaborative Study of Cassava in Africa (COSCA) and it is initially concentrated in six countries namely, Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire, selected partly on the basis of the importance of cassava in the farming and food systems of the countries. The survey data were analyzed on the basis of production projections using time series data provided by USDA as well as other secondary data.

Cassava in food crop and livestock production systems

The interrelationships between crop-based production systems and livestock-based systems are illustrated in figure 1, which shows a complex eastern Nigeria system, in which the family household is the major source of labor used for food crop and livestock production.

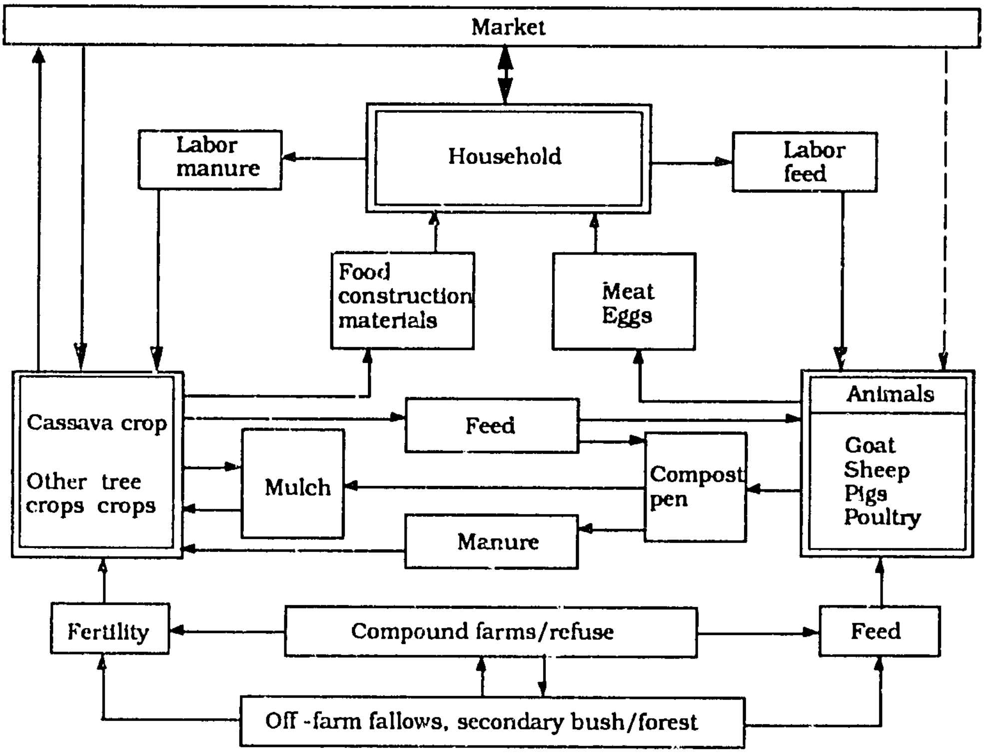

Figure 1: Interaction of crop and animal farming in a cassava-based system (adapted from Lagemann 1977)

In this food crop system, cassava is commonly intercropped with early maturing annuals such as maize, and vegetables like okro, egusi and bitter leaf. The crops intercropped with cassava in different parts of Africa vary with regions of growth and food preferences. In Zaire, the intercrop may be dominated by grain legumes such as groundnuts and phaseolus beans, while in Sierra Leone, The Gambia, Liberia, and Guinea, rice is the dominant intercrop. Protected trees like *Parkia*, and nonwoody perennials such as plantains and bananas, are also frequently grown in patches or as individual stands in cassava fields. While cassava and associated crops are the main food crops, trees provide fuelwood and construction materials.

Dry cassava peels are fed to goats and sheep, and pigs eat the tubers. In some countries, cassava leaves are consumed by humans and also fed to animals, or used as poultry rations. These animals provide the household with eggs and meat for consumption and the market. Animal wastes are incorporated with household refuse as mulch and used for soil enrichment or are carted directly into fields, especially those close to homes.

Some existing cassava cropping patterns modified to incorporate only two crops are illustrated in figure 2. Pattern 2 is common in Zaire and some countries in West Africa while pattern 4 is dominant in West Africa. Sub-

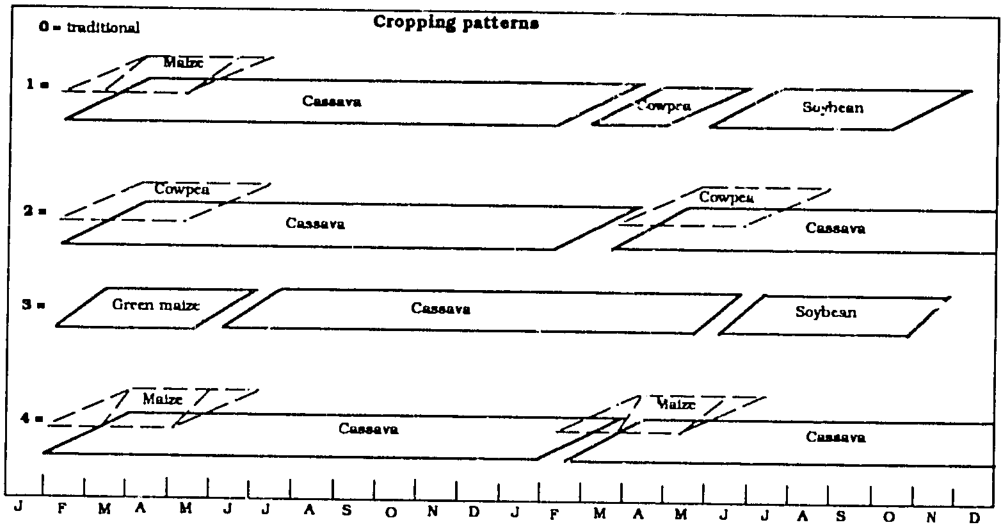

Figure 2: Cassava cropping patterns and alternative patterns for humid southern Nigeria

sidiary crops associated with these patterns may be fruits and leafy vegetables. Patterns 1 and 3 are further modifications of the traditional, complex crop mixture systems to nearly monocrop pattern (1) and a completely monocrop pattern (3). Soybean may be intercropped with cassava as in patterns 1, 2 or 4. Cassava is highly compatible as an intercrop with these annuals because of its slow initial growth, especially between planting and six to eight weeks of growth. The annuals which grow faster during the initial growth phases rarely compete adversely with cassava and have been shown to smother weeds. The advantage of soybeans, a relatively new crop in cassava growing areas of Africa, is that it will supply the deficient protein component to a predominantly cassava diet in both human food and animal feeds.

Cassava in food systems during crisis

The role of cassava in food systems will depend on what happens to real income. Cassava is a crisis crop. In times of war, drought or low national incomes, cassava consumption increases relative to alternative food staples such as yam, maize, rice, and wheat.

Cassava in certain forms is a low income consumers' staple. Although an individual may not increase the quantity of cassava consumed in a year, as national income declines, annual average cassava consumption per person increases because more people begin to substitute cassava for more expensive alternative food staples.

Between 1973 and 1985, the annual compound population growth rates varied from 2.7% in Ghana to 4.3% in Côte d'Ivoire while the per capita GNP was -3.1% for Ghana and -1.1% for Côte d'Ivoire (table 1).

Available consumption figures show that per capita consumption of cassava was increasing in the COSCA countries during the same period (figure 2, table 2). The weighted annual average per capita consumption of cassava increased by 5.66kg from 49.01kg during 1976-80 to 54.67kg during 1981-85, representing an increase of 12 percent.

In Nigeria, the annual average per capita consumption of cassava appears to have declined by 6% from 103.24kg during 1976-80 to 96.55kg during 1981-85. National incomes did not decline at a rapid rate before 1980. In addition, during 1979-83 the rate of food grains import was high. The Nigerian naira was overvalued so that the consumer price for the imported food grains was therefore highly subsidized. During 1980-83, there was a high incidence of cassava mealybug, and during 1985-88 there was a serious outbreak of cassava mosaic and bacterial blight, which caused considerable scarcity of cassava in Nigeria.

In 1985, the importation of food grains was banned and by 1986 the Nigerian currency was devalued so that although the ban on importation may not have been entirely effective, the consumer price subsidy resulting from the

Table 1. Population totals (1985) and growth rates (1973-1985), and GNP per capita (1985) and growth rates (1973-85) for COSCA countries

Country	Population		GNP per capita	
	Total 1985 (000s)	Growth rate 1973-85 (%)	1985 (US$)	Growth rate 1973-85 (%)
Côte d'Ivoire	10 072	4.3	620	-1.1
Ghana	12 710	2.7	390	-3.1
Nigeria	99 669	2.8	760	-2.5
Tanzania	22 242	3.4	270	-1.6
Uganda	15 474	3.1	-	-
Zaire	30 557	3.0	400	-2.6

Source: World Bank Atlas

Table 2. Average annual per capita consumption of cassava (kg) during 1976-80 and 1981-85 in COSCA countries

Country	1976-80	1981-85	Change	% change
Côte d'Ivoire	7.39	9.19	+ 1.80	+24
Ghana	18.72	24.62	+5.90	+32
Nigeria	103.24	96.55	-6.69	-6
Tanzania	50.08	56.10	+6.02	+12
Uganda	16.14	20.46	+4.32	+27
Zaire	107.48	125.52	+17.04	+16
Mean (weighted)	49.01	54.67	+5.66	+12

over-valued exchange rate was removed. Annual per capita consumption of cassava therefore increased in 1984 and 1985 beyond the 1976-80 average (table 2).

Importance of cassava in future food systems

The foreign debt burden and terms of trade, which are, at present, not in favor of primary products, suggest that the downward trend in real income in tropical Africa will continue for sometime. Cassava is therefore, likely to assume greater importance in the food system of the region in the future.

To determine the future importance of cassava in the food system of tropical Africa, we projected total production and consumption in COSCA countries to the year 2000, assuming that the 1975-85 cassava crop production trend would be maintained, and that the 1975-85 annual compound population growth rates would also remain. We also assumed an income elasticity of demand of 0.5%.

Income elasticity of demand for cassava has not been estimated in a systematic way. The Food and Agriculture Organization (FAO) assumes -1% for most tropical African countries while the International Food Policy Research Institute (IFPRI) assumes 0% for all tropical African countries. Available estimates for southeastern Nigeria is 0.5%. Iterated projections show that there are no significant differences in projections on the bases of the three elasticities. In the current situation when incomes are declining, population growth rate is the predominant determinant of cassava consumption in COSCA countries.

On the basis of these assumptions, the production of cassava in a country N in year 1 was estimated as:

$$P_N[t] = P_N[1985][1+G_N]^T$$

where:

$P_N[1985]$ = 1985 production trend estimate [MT] in country N,
G_N = annual compound rate of growth (%) of production during 1975-85 in country N, and
T = time interval between 1985 and t [years].

P_N [1985] is estimated as:

$$\log P_N [1985] = a + bT$$

where:

T = time interval [10 years] between 1975 and 1985.

The consumption of cassava in country N in year T was estimated as:

$$C_N[t] = C_N[1985][1+(L_N+I_N-E_N)]^T$$

where:

C_N [1985] = 1985 consumption trend estimate [MT] for country N,
L_N = annual compound rate of growth [%] of population during 1975-85 in country N,
I_N = annual compound rate of growth [%] of GNP per person during 1975-85 in country N,
E_N = income elasticity of demand [%] for cassava in country N, and
T = time interval between 1985 and t [years].

C_N [1985] is estimated as:

$$\log C_N [1985] = a + bT$$

where:

T = time interval [10 years] between 1975 and 1985.

Without population projections, it is not possible to estimate future consumption on a per person basis. Yet the negative rates of growth in real income and income elasticity of demand of less than unity suggest that per capita consumption of cassava will be higher in the year 2000 than in 1985 (figures 3 and 4).

By the year 2000, COSCA countries as a whole would generate a deficit of consumption needs over production of about 19 million metric tons or about 30 percent of the consumption needs. The level of the deficit varies from 10 percent in Uganda to 35 percent in Côte d'Ivoire and Ghana. The largest producing countries, Nigeria and Zaire, have average and above average levels of deficits respectively (table 3).

Table 3. Estimates of deficits of consumption needs over production of cassava (000 MT) by year 2000 in COSCA countries

Country	Production	Consumption	Deficit	Deficit as % of consumption needs
Côte d'Ivoire	1 613	2 479	866	35
Ghana	3 250	3 786	536	14
Nigeria	13 235	18 556	5 321	29
Tanzania	7 646	11 785	4 139	35
Uganda	3 729	4 161	432	10
Zaire	15 904	23 689	7 785	33
Total	45 377	64 456	19 079	30

Source: Based on USDA data

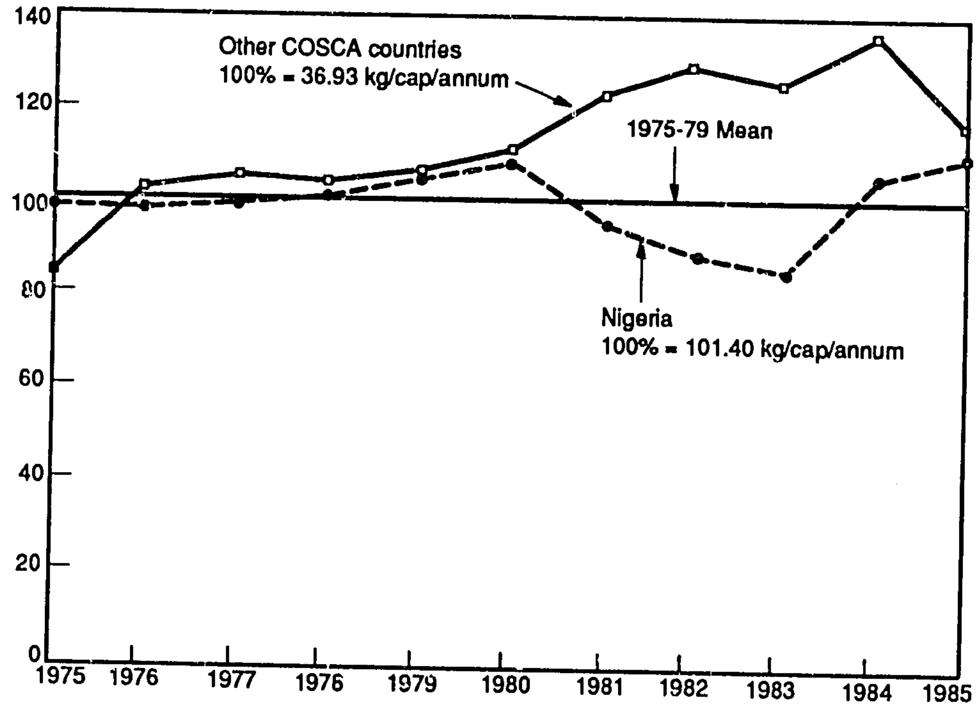

Figure 3: Indices (mean: 1976-80=100%) of per capita daily consumption of cassava in COSCA countries, 1975-1985 (based on USDA data)

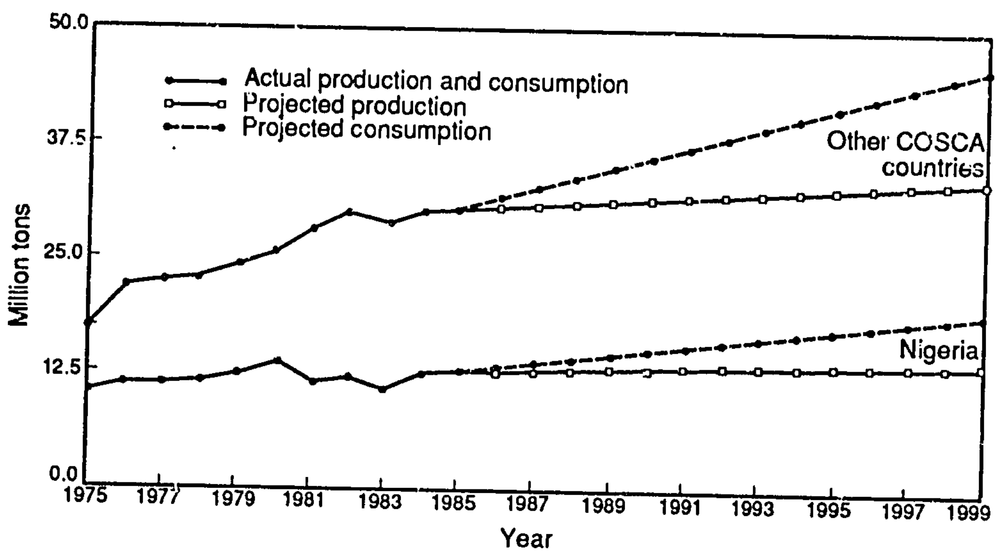

Figure 4: Actual production and consumption (1975-85) and projected production and consumption (1986-2000) levels of cassava in COSCA countries

Implications for cassava use in livestock feed

The assumption that the 1975-85 rate of production will continue to the year 2000 is perhaps the most subjective of all the assumptions behind the projections. It implies that substitutions in resource allocation will not take place. However, increased demand for cassava will raise its market value relative to alternative food staples. It is likely that resources will be reallocated away from relatively high cost alternative food staples to cassava and the deficits will be reduced.

Production costs are lower for cassava than for alternative food staples. Available farm management data indicate that labor constitutes 80 percent or more of production costs in smallholder cropping systems in Nigeria. Cost of production per metric ton (MT) is lower for cassava when compared with alternative food staples (table 4).

However, cassava also has a low market value. On per unit calorie basis, the market value of cassava is very low compared with alternative food staples (table 5). Market value determines the level of cassava production. Cassava receives an inferior allocation of land and labor where it competes for these resources with alternative food staples except in times of crises.

Table 4. Labor requirements for production of various food crops in Nigeria

Crop	Man-days/ha	Man-days/MT	Man-days/ Mcal
Cassava	183	21	21
Yam	325	45	69
Maize	90	121	36
Rice	215	145	60

Table 5. Purchase prices per thousand calories and grams protein from cassava, yam and cocoyam in southeastern Nigeria, 1984-85

Crop	₦/1000 calories	₦/1000 gm protein
Cassava	0.10	10
Yam	0.77	45
Cocoyam	0.89	50

In the Zaki-Biam area of Benue State of Nigeria where the cassava yield is almost four times the national average of about 8.0 MT per ha, land area allocation to cassava was less than 2.0 percent of yam land (table 6).

In contrast, in the Ezza area of Anambra State also in Nigeria where the cassava yield is less than national average, land area allocation to cassava is 60 percent of yam land. The market value for yam is 80 percent higher in Zaki-Biam and only 1 percent higher than cassava in the Ezza area (table 6).

Table 6. Yield (t/ha) and area (ha) per household for cassava and yam and net revenue (yam/cassava) ratio in predominantly yam producing areas of southeastern Nigeria, 1984-85 crop season

Parameter	Crop	Zaki-Biam	Ezza
Yield/ha	Cassava	31.00	7.56
	Yam	42.84	10.40
Area/household	Cassava	0.37	1.52
	Yam	2.10	2.52
Net revenue ratio	Yam/cassava	1.80	1.01

The extent of the allocation of resources from alternative food staples to cassava to generate surplus production over consumption needs for use in livestock feed will depend on the market value of cassava. A high demand for livestock products will raise the market value of cassava in livestock feed. However, a high demand for livestock products will be realized only if real incomes improve. Unfortunately, when this happens, consumers will also reallocate consumer resources away from cassava to alternative food staples unless cassava is transformed into products such as gari which are attractive to high income consumers.

It appears that the crisis value of cassava is not only its boon but also its bane. When national crises occur, such as rapidly expanding population and declining national incomes, cassava production expands. As soon as the crisis situation is resolved, cassava production declines, giving way to alternative food staples.

Conclusion

When real incomes rise to the extent that consumers will begin to afford it, they will also start to substitute more livestock products for food grains in the diets. Then the potential for generating surplus cassava for livestock feed will shift to technical factors.

An Overview of Traditional Processing and Utilization of Cassava in Africa

S.K. Hahn

Cassava is one of the most important staple food crops grown in tropical Africa. It plays a major role in efforts to alleviate the African food crisis because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions, and suitability to present farming and food systems in Africa (Hahn and Keyser 1985, Hahn et al. 1987).

Traditionally, cassava roots are processed by various methods into numerous products and utilized in various ways according to local customs and preferences. In some countries, the leaves are consumed as vegetables, and many traditional foods are processed from cassava roots and leaves.

Improvement of cassava processing and utilization techniques would greatly increase labor efficiency, incomes, and living standards of cassava farmers and the urban poor, as well as enhance the shelf life of products, facilitate their transportation, increase marketing opportunities, and help improve human and livestock nutrition. This paper presents a general overview of traditional cassava processing and utilization methods now used by small-scale farmers and processors in Africa, and examines the opportunities for improving postharvest technologies.

Why cassava needs processing

Fresh cassava roots cannot be stored for long because they rot within 3-4 days of harvest. They are bulky with about 70% moisture content, and therefore transportation of the tubers to urban markets is difficult and expensive. The roots and leaves contain varying amounts of cyanide which is toxic to humans and animals, while the raw cassava roots and uncooked leaves are not palatable. Therefore, cassava must be processed into various forms in order to increase the shelf life of the products, facilitate transportation and marketing, reduce cyanide content and improve palatability. The nutritional status of cassava can also be improved through fortification with other protein-rich crops. Processing reduces food losses and stabilizes seasonal fluctuations in the supply of the crop.

Constraints in the traditional processing of cassava

Environmental factors

During the rainy season, sunshine and ambient temperatures are relatively low for processing cassava, particularly in lowland humid areas where cassava is mainly grown and utilized. In other localities, particularly in savanna zones, water which is essential for processing cassava, is not easily available. During the early rainy season, the dry matter content of roots is usually lower than in the dry season, which can result in a lower yield of products. In the dry season when the soil is hard, harvesting and peeling tubers for processing are difficult and result in more losses.

Varietal factors

Cassava root shape varies among cultivars. Roots with irregular shapes are difficult to harvest and peel by hand, resulting in great losses of usable root materials. Root size also varies with cultivars although it depends more on environmental factors such as soil. Smaller roots require more labor for peeling. Varietal differences in dry matter content, and in starch content and quality influence the output and quality of the processed products. Cyanide content varies with varieties, but is also affected by the crop growth environment.

Agronomic factors

Time of planting and harvesting, and age of plant, from planting to harvesting, all affect starch content, yield and quality of products. Other agronomic practices such as intercropping, fertilizer application and spacing can also affect yield and crop quality.

Socioeconomic factors

Harvesting and transporting of roots from farm to homestead and subsequent processing are mainly done by women. Most of the steps in processing are carried out manually using simple and inexpensive tools and equipment that are available to small farmers. Cassava processing is labor intensive and productivity is usually very low. Transport of products to markets is made difficult by the poor condition of rural roads. The drudgery associated with traditional processing is enormous and the products from traditional processing methods are often contaminated with undesirable extraneous matter. Some of the products are therefore not hygienic and so are of poor market value. Better processing methods can improve the life-styles and health of rural people through higher processing efficiency, labor saving and reduced drudgery, all of which improve the quality of products.

Subsistence farmers harvest cassava when needed. Thus they leave the cassava in the ground for long periods, believing that the cassava is safer and would undergo less damage than when harvested. Although this system has certain merits, a delay in harvest can result in root losses due to root rots, damage by animals, and a decrease in the starch content in roots. Furthermore, keeping cassava in the ground prevents the use of that land for other purposes.

Traditional methods for processing cassava

Traditional cassava processing methods in use in Africa probably originated from tropical America, particularly northeastern Brazil and may have been adapted from indigenous techniques for processing yams (Jones 1959). The processing methods include peeling, boiling, steaming, slicing, grating, soaking or seeping, fermenting, pounding, roasting, pressing, drying, and milling. These traditional methods give low product yields which are also of low quality.

Rapid urbanization in tropical Africa increased mobility in both rural and urban areas and the changing roles and status of women have resulted in an unprecedented demand for convenience foods. Added to these factors is the high cost of fuel for cooking in urban areas at a time when fuel wood is not only inconvenient to use but is becoming increasingly scarce. Therefore, cassava processing and utilization technologies for the future should improve traditional methods and develop low cost equipment with low energy demands. Improved processing and utilization technologies should address issues related to farmers' (producers') and consumers' needs (particularly urban needs in future), and also to economic factors and nutritional values. Knowledge of the current traditional processing and utilization methods and of present urban patterns of consumption and changing urban needs will guide future strategies for cassava processing and utilization.

Improvement of nutritional values of processed products also requires special attention from policymakers and researchers. Cassava is frequently denigrated because its roots are low in protein. However, protein may be supplemented from other sources, particularly legumes; for example, fortification of cassava flour or gari with protein-rich soyflour can be achieved. Such fortified products will be nutritionally advantageous, and thus economical and acceptable to consumers.

Although cassava is regarded as subsistence crop of low-income families or as a "famine-reserve crop", about 60 percent of the cassava output of households in the Oyo area of Nigeria is sold for processing (mostly into gari) while the remaining 40 percent is consumed at home (Ikpi et al. 1986). A high proportion (50 percent) of cassava was also sold to food processors in the western region of Cameroon (Okezie et al. 1988), suggesting a changing status for cassava.

Processing techniques and reduction of cyanide in cassava

Cassava contains the cyanogenic glucosides, linamarin and lotaustralin which are hydrolyzed after tissue damage, by the endogenous enzyme, linamarase to the corresponding cyanohydrins and further to hydrogen cyanide [HCN](Conn 1969). The hydrogen cyanide is responsible for chronic toxicity when inadequately processed cassava products are consumed by humans and animals for prolonged periods. Therefore, traditional processing procedures must aim at reducing cyanide and improving storability, convenience and palatability.

Cassava processing procedures vary, depending on products, from simple processing (peel, boil and eat) to complicated procedures for processing into gari, for example, which involve many more steps, namely peeling, grating, pressing, fermenting, sifting, and roasting. Some of these steps reduce cyanide more effectively than others. Processing techniques and procedures differ with countries and localities within a country according to food cultures, environmental factors such as availability of water and fuelwood, the cassava varieties used, and the types of processing equipment and technologies available. The most important traditional culinary preparations of cassava in Africa are "boiled or roasted roots", "fufu" (cassava flour stirred with boiled water over a low-heat fire to give a stiff dough), "eba" (gari soaked in hot water to produce a thick paste) and "chickwangue" (steamed fermented pulp wrapped in leaves).

Fermentation

Fermentation consists of two distinct methods: aerobic and anaerobic fermentation. For aerobic fermentation, the peeled and sliced cassava roots are first surface-dried for 1-2 hours and then heaped together, covered with straw or leaves and left to ferment in air for 3-4 days until the pieces become moldy. The fermented moldy pieces are sun-dried after the mold has been scraped off. The processed and dried pieces (called "Mokopa" in Uganda) are then milled into flour, which is prepared into a "fufu" called "kowan" in Uganda. The growth of mold on the root pieces, increases the protein content of the final products three to eight times (Amey 1987, Sauti et al. 1987). This fermentation method is also very popular in other parts of East Africa such as Tanzania, Rwanda, and Zaire.

In anaerobic fermentation, grated cassava for processing into "gari" is placed in sacks and pressed with stones or a jack between wooden platforms. Whole roots or pieces of peeled roots for processing into "fufu" are placed in water for 3-5 days. During the first stage of gari production, the bacterium *Corynebacteria manihot* attacks the starch of the roots, leading to the production of various organic acids (such as lactic and formic acids) and the lowering of substrate pH. In the second stage, the acidic condition stimulates the growth of a mold, *Geotrichum candida*, which proliferates rapidly, causing further acidification and production of a series of aldehydes and esters that are responsible for the taste and aroma of gari (Odunfa 1985). The optimum temperature for the fermentation for gari processing is 35°C, increasing up to 45°C.

For "lafun" production in Nigeria, peeled or unpeeled cassava tubers are immersed in a stream, in stationary water (near a stream) or in an earthenware vessel, and fermented until the roots become soft. The peel and central fibres of the fermented roots are manually removed and the recovered pulp is hand mashed or pounded. The microorganisms involved in "lafun" production include four yeasts: *Pichia onychis*, *Candida tropicalis*, *Geotrichum candida*, and *Rhodotorula* sp.; two molds: *Aspergillus niger* and *Penicillium* sp.; and two bacteria: *Leuconostoc* sp. and *Corynebacterium* sp. (Nwachukwu and Edwards 1987). Moisture, pH and temperature conditions are critical for the growth of these microorganisms in roots and thus for fermentation.

Dewatering the fermented cassava

During or after fermentation of roots for gari production, the grated pulp is put in sacks (jute or polypropylene) on which stones are placed or jacked-wood platforms are set to drain or press off the excess liquid from the pulp. In Zaire, the cassava pulp is taken out and heaped up on the racks in the sun for further fermentation and draining of the excess moisture. In this way, much of the cyanide is effectively lost with the liquid.

Tissue disintegration

Tissue disintegration in the presence of excess moisture during grating or fermenting in water permits the rapid hydrolysis of glucosides, effectively reducing both free and residual cyanide in the products. Fermentation in water appears a more efficient method for reducing the cyanide of roots. For example, this process reduced cyanide by 70-95 percent of the original level after the roots were soaked in water for 3 days (Hahn et al. 1987). Gari obtained through the processing procedures involving grating and/or fermentation showed 80-90 percent reduction in total cyanide content relative to freshly peeled roots (Mahungu et al. 1987). Oke (1968) reported HCN content of 1.9 mg/100g for gari, 2.5 mg/100g for fufu (Nigeria) and 1.0 mg/100g for fufu (Zaire) or lafun (Nigeria). HCN concentration in 202 gari samples collected across the cassava growing areas of Nigeria had 0-3.2 mg/100g with a mean of 0.6 mg/100g. Akinrele et al. (1962) stated that 0.3 mg HCN/100g was an acceptable level in gari. Therefore, adequately processed gari in Nigeria would contain acceptable levels of HCN. When gari is prepared into "eba", HCN is further reduced to even safer levels. By processing roots into "chickwangue" cyanide reduction of at least 90 percent was achieved (Mahungu et al. 1987).

Drying

Drying is the simplest method of processing cassava. Drying reduces moisture, volume and cyanide content of roots, thereby prolonging product shelf life. This processing is practised primarily in areas with less water supply.

Total cyanide content of cassava chips could be decreased by only 10-30 percent through fast air drying. Slow sun-drying, however, produces greater loss of cyanide. Sun-drying the peeled cut pieces of roots gave a HCN concentration lower than 10 mg/100g and loss was more effective than oven drying (Mahungu et al. 1987). Drying may be in the sun or over a fire. The former is more common because it is simple and does not require fuelwood.

Boiling

Boiling the peeled roots did not effectively remove HCN. Pounding the boiled roots into "pounded fufu" decreased the HCN concentration by only 10 percent. Therefore, only cultivars containing low cyanide are recommended for this method of preparation (Mahungu et al. 1987).

Processed leaves

Cyanide in pounded cassava leaves ("pondu" or "sakasaka") remained high at 8.6 mg/100g although 95.8 percent of total cyanide in leaves was removed through further processing into soup (Mahungu et al. 1987).

Milling
The dried root pieces and fermented/dried pulp are milled into flour by pounding in mortar or using hammer mills. Milling with hammer mills, done at village level, may also reduce cyanide. The dried cassava roots (both fermented and unfermented) are often mixed in a ratio of 2-3 parts cassava with one part of sorghum, millet and/or maize and milled into a composite flour. Mixing cassava with cereals increases food protein, and enhances palatability by improving consistency.

Processed products

Gari
Fresh roots are peeled and grated. The grated pulp is put in sacks (jute or polypropylene) and the sacks are placed under heavy stones or pressed with a hydraulic jack between wooden platforms for 3-4 days to express excess liquid from the pulp while it is fermenting. Fermentation imparts an acidic taste to the final product. The dewatered and fermented lumps of pulp are crumbled by hand and most of the fibrous matter is removed. The remaining mass is sieved with traditional sieves (made of woven splinters of cane) or iron or polyethylene mesh. After being sieved, the fine pulp is then roasted in an iron pan or earthen pot over a fire. If the sieved pulp is too wet, it takes longer to roast resulting in a finished lumpy product with dull colour. Palm oil may be added to prevent the pulp from burning during roasting and to give a light yellow colour to the gari. When palm oil is not added, a white gari is produced. Palm oil contains substantial quantities of vitamin A, therefore, yellow gari is 10-30 percent more nutritious and expensive than white gari. The garification or conversion rate of fresh roots into gari is 15-20 %. This value varies with cassava varieties, time of harvesting, age of plant and other environmental factors. Gari is very popular in Nigeria and less so in Cameroon, Benin, Togo, Ghana, Liberia, and Sierra Leone. In Brazil, this method is used for the production of "farinha de madioca".

Peeling is done mainly by women and children. The peeled roots are grated by women, using a simple traditional grater, but it is done by men if a power driven grater is used. Pressing is done by women in the traditional way but done by men when a hydraulic presser is used. The sieved fermented pulp is roasted almost exclusively by women in a pan or pot on the fire with fuelwood as the energy source.

Fermented and dried cassava pulp
"Lafun" in Nigeria, "cossettes" in Zaire and Rwanda, "kanyanga" and "mapanga" in Malawi, and "makopa" in Tanzania are various names for fermented and dried cassava products. The processing method to ferment and dry cassava pulp is very simple and does not require much labor. It is thus widely used for processing high cyanide cassava varieties in many parts of Africa where water for soaking is available. Whole or peeled roots are immersed in water for 3-4 days for fermentation and softening the tissues. The fermenting roots are then removed and broken into small crumbs, sun-dried on mats, racks, flat rocks,

cement floors or roofs of houses. Drying the fermented roots takes 1-3 days, depending on the prevailing weather. The dried crumbs are then milled into flour.

Wet pulp

The processing procedures for "wet pulp" and of fermented and dried pulp production are similar except for the drying. The wet pulp may be molded into balls, 3-5 cm diameter, put in boiling water and stirred thoroughly to obtain a stiff paste. Wet pulp of about 0.5-1.0 kg is packed in a plastic or polypropylene bag and marketed in cities in Nigeria, Ghana and Cameroon. Urban dwellers therefore do not need to buy fresh roots for processing into wet pulp to prepare wet fufu.

Smoked cassava balls ("kumkum")

Cassava is processed into smoked cassava balls in the same way as fermented and dried pulp is produced except that the fermented wet pulp is pounded and molded into round balls of about 4-7 cm diameter. These balls are then smoked and dried on a platform above the fire place in a special structure hung above the hearth. The dark coating caused by smoke is cleaned off and the cleaned balls are milled into flour before reconstitution into fufu (Numfor and Ay 1987).

Chickwangue

"Chickwangue" is the most popular processed food from cassava in Zaire. "Myondo" and "Bobolo" in Cameroon belong to this "Chickwangue" group. Similar products are produced in Congo, Central African Republic, Sudan, Gabon, and Angola.

Cassava roots are peeled, steeped in water for 3-5 days to ferment and become soft. The fermented pulp is taken out and the fibres are removed from it. The pulp is then heaped on racks for further fermentation or the heap is covered with leaves and pressed with heavy objects to drain off excess liquid. The pulp is then ground on a stone or pounded in a mortar to obtain a finer pulp. The fine pulp is wrapped in leaves of plantain or any plant of the Zingiberaceae family and tied firmly with fibres from banana. These are steamed in pots. Chickwangue is about 10 cm wide and 20 cm long. Myondo has a diameter of 1.5-2.0 cm and a length of 15 cm to 20 cm. Bobolo has a diameter of 2-4 cm and a length of 30-40 cm. The Gabon "Chickwangue" is smaller in size than that of Zaire.

Starch

Cassava roots are peeled, washed and grated. The grated pulp is steeped for 2-3 days in a large quantity of water, stirred and filtered through a piece of cloth. The filtrate stands overnight and the supernatant is then decanted. The starch sediments are air-dried under shade.

Dried cassava

The roots are peeled, sliced into small pieces and sun-dried on racks or roofs for 4-5 days or sometimes up to 3 weeks, depending on the weather and the size of pieces. Later, sun-dried pieces are milled into flour. This processing system is very simple but the processed products contain considerable amounts of cyanide. This method is widely used in many areas in Africa, particularly where water supply for fermentation is seriously limited.

Processing equipment

Traditional cassava processing does not require sophisticated equipment. Processing cassava into gari requires equipment such as grater, presser and fryer. The traditional cassava grater is made of a flattened kerosine tin or iron sheet perforated with nails and fastened onto a wooden board with handles. Grating is done by rubbing the peeled roots against the rough perforated surface of the iron sheet which tears off the peeled cassava root flesh into mash. In recent years, various attempts have been made to improve graters. Graters which are belt-driven from a static 5 HP Lister type engine have been developed and are being extensively used in Nigeria. Its capacity to grate cassava is about one ton of fresh peeled roots per hour.

For draining excess liquid from the grated pulp the sacks containing the grated pulpy mass are slowly pressed down using a 30-ton hydraulic jack press with wooden platforms, before sieving and roasting into gari. Stones are used in traditional processing to press out the excess moisture from the grated pulp. Tied wooden frames are used for this purpose in places where stones are not available. Pans made from iron or earthen pots are used for roasting the fermented pulp. Fuelwood is the major source of energy for boiling, roasting, steaming and frying. Fuelwood may not be easily and cheaply obtained in the future because of rapid deforestation.

Slight changes in the equipment used in processing can help to save fuel and lessen the discomfort, health hazard, and drudgery for the operating women. The economic success of any future commercial development of cassava processing would depend upon the adaptability of each processing stage to mechanization. However, the first step to take for improvement of cassava technologies should be to improve or modify the simple processing equipment or systems presently used, rather than to change entirely to new, sophisticated, and expensive equipment.

Storage of processed products

Processing, particularly drying and roasting, increases shelf life of cassava products. Good storage depends on the moisture content of the products and temperature and relative humidity of the storage environment. The moisture content of gari for safe storage is below 12.7%. When temperature and relative humidity are above 27°C and 70% respectively, gari goes bad (Igbeka 1987). The type of bag used for packing also affects shelf life depending on the ability of the material to maintain safe product moisture levels.

Jute and hessian bags are recommended in dry cool environments because they allow good ventilation (Igbeka 1987). When gari, dried pulp and flour are well dried and properly packed, they can be stored without loss of quality for over one year. Dried cassava balls ("kumkum") can be stored for up to 2 years (Numfor and Ay 1987). "Chickwangue", "Myondo" and "Bobolo" can be preserved for up to 1 week but they can be kept for several more days when recooked.

Cassava leaves as vegetable

Cassava shoots of 30cm length (measured from the apex) are harvested from the plants. The hard petioles are removed and the blades and young petioles are pounded with a pestle in a mortar. A variation of this process involves blanching the leaves before pounding. The resulting pulp is then boiled for about 30-60 minutes. In some countries, the first boiled water is decanted and replaced. Pepper, palm-oil and other aromatic ingredients are added. The mixture is then boiled for 30 minutes (Numfor and Ay 1987). Unlike the roots that are essentially carbohydrate, cassava leaves are a good source of protein and vitamins which can provide a valuable supplement to predominantly starchy diets. Cassava leaves are rich in protein, calcium, iron and vitamins, comparing favorably with other green vegetables generally regarded as good protein sources. The amino acid composition of cassava leaves shows that, except for methionine, the essential amino acid values in cassava exceed those of the FAO reference protein (Lancaster and Brooks 1983).

The total essential amino acid content for cassava leaf protein is similar to that found in hen's egg and is greater than that in oat and rice grain, soybean seed, and spinach leaf (Yeoh and Chew 1976) While the vitamin content of the leaves is high, the processing techniques for preparing the leaves for consumption can lead to huge losses. For example, the prolonged boiling involved in making African soups or stews, results in considerable loss of vitamin C.

Cassava leaves form a significant part of the diets in many countries in Africa. They are used as one of the preferred vegetables in most cassava growing countries, particularly in Zaire, Congo, Gabon, Central African Republic, Angola, Sierra Leone, and Liberia. The cassava leaves prepared as vegetable are called "sakasaka" or "pondu" in Zaire, Congo, Central African Republic and Sudan, "Kizaka" in Angola, "Mathapa" in Mozambique, "Chigwada" in Malawi, "Chombo" or "Ngwada" in Zambia, "Gweri" in Cameroon, "Kisanby" in Tanzania, "Cassada leaves" in Sierra Leone, "Banankou boulou nan" in Mali, "Mafe haako bantare" in Guinea, and "Isombe" in Rwanda. They are mostly served as a sauce which is eaten with chickwangue, fufu, and boiled cassava.

Utilization of processed products

Utilization in this paper includes cooking or preparation, and consumption. Cooking cassava consists of boiling, steaming, roasting and pounding. The peeled fresh cassava roots are eaten raw or eaten boiled and roasted. The fresh roots are boiled and pounded to obtain "pounded fufu". This is most popular in Ghana, and to some extent, in Nigeria and Cameroon. The processed cassava, either in the form of flour, wet pulp or gari is cooked and eaten in three main food forms: "fufu", "eba" and "chickwangue". The "fufu" group includes "amala" in Nigeria, "fufu" in Zaire, Congo, Cameroon and Gabon, "ugali" and "kowon" in Uganda and Tanzania, "nchima" in Mozambique, "nsima" in Malawi, "ubugali" in Rwanda, and "funge" in Angola.

Gari can be eaten dry or it may be soaked in cold water to which sugar is added. "Eba" is a very popular food in Nigeria and is gaining popularity in Cameroon, Benin, Ghana, Liberia and Sierra Leone because of its fast and easy reconstitution into a convenient food.

"Chickwangue" is a very stiff paste or porridge and is much stiffer than "fufu" and "eba". The size, shape and texture of the "chickwangue" food group vary among countries. "Myondo" and "bobolo" in Cameroon are essentially the same as "chickwangue" in preparation although shapes and sizes are different. "Chickwangue" and its analogues are produced from more hygienic procedures and contain less cyanide but they require much more labor for processing and preparation.

People in Zaire call manioc "all sufficient" because "we get bread from the root and meat from the leaves".

Modes of consumption

Cassava root based foods are all consumed with soups or stews. The soup is essential in the food system in Africa without which most foods cannot be eaten. Soup made of cassava leaves is often eaten with cassava root based foods. Therefore, the cassava root based foods which are essentially carbohydrate are supplemented for protein when consumed with protein rich soups or stews.

Potentials of cassava as animal feed

The major future market for increased cassava production is as livestock feed. Cassava has long been recognized by researchers in Africa as an appropriate animal feed and it has been used as an important and cheap feed in many European countries. Both roots and leaves are usable as food to livestock. Cassava is one of the most drought tolerant crops and can be successfully grown on marginal soils, giving reasonable yields where many other crops cannot do well. It is estimated that approximately 4 million tonnes of cassava peeling—useful as livestock feed—are annually produced as a by-product in Nigeria alone during processing of cassava roots. Therefore, cassava offers tremendous potentials as a cheap source of food energy for animals, provided it is well balanced with other nutrients. There is a great deal of current interest in supplementing feeding of animals with cassava in Africa.

The future of cassava

The future of cassava depends very much upon development of improved processing technologies and of improved products that can meet the changing needs of urban people, and, on its suitability for alternative uses such as animal feeds. Also important is the overall ratings of different products to meet the expectations of producers, transporters and consumers (table 1). Whereas the future is bright, more quantitative information on postharvest aspects of cassava culture in tropical Africa will help scientists orient their efforts to satisfy the many needs of both rural and urban dwellers.

Table 1: Subjective ratings of traditionally processed cassava products in Africa based on selected features

Feature (parameter)	Boiled cassava	Fufu fermented	Fufu unfermented	Gari	Chickwangue
Shelf life	1	5	5	4	3
Transportability	1	5	5	5	4
HCN content	2	5	3	4	5
Ease of:					
Processing	5	5	5	2	1
Preparation	4	4	4	5	2
Utilization	4	4	4	5	5
Processing hygiene	5	1	3	5	5
Total (ratings)	22	29	29	30	25

Note: Subjective ratings for desirability based on scale 1-5, 1 = lowest and 5 = highest.

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Utilization of Cassava in Nonruminant Livestock Feeds

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The cassava tuberous root is primarily a source of carbohydrate and can completely replace maize as an energy source in feeds for pigs and poultry. Its use for this purpose is presently limited to research centres and small-scale pig producers. For adoption by large scale commercial producers, appropriate technology needs to be developed to reduce the high moisture and hydrocyanic acid (HCN) contents of the tubers. Properly dried whole cassava tuberous roots can replace maize in nonruminant rations if the HCN does not exceed 100 ppm in finished feeds. Since cassava is low in protein, it is necessary to supplement cassava-based diets with animal proteins for the supply of methionine and lysine. Supplementation with a zinc salt prevents parakeratosis. Addition of oil and/or pelletizing is desirable. The co of cassava-based rations can be reduced by incorporating cassava leaves to enhance its protein contribution. Cassava peelings can also be satisfactorily used up to 40 percent for pigs, 15 percent for broilers and 27 percent for layers. The envisaged reduction in cost per ton of finished cassava-based feeds will result in the production of cheaper animal products in Africa.

Africa is currently plagued with a food crisis, due partly to the unprecedented rise in human population and the alarming drop in per capita food production particularly in the last decade (FAO 1986). The food deficit situation is indeed more serious with protein deficiency when compared to the availability of calories and the micro elements. Shortage of proteins, particularly those of animal origin, is prevalent in all parts of Africa where it is estimated that on the average, 10g of animal protein is consumed per day, compared to a recommended daily intake of 35g (ILCA 1980, FAO 1986). Poultry and pig production represent the fastest means of correcting the shortage of animal proteins in Africa. This is because, apart from their high rate of reproduction, poultry and pigs are characterized by the best efficiency of nutrient transformation into high quality animal protein, although the cost of this transformation is very high. Therefore, nutrient supply has to be judiciously manipulated to ensure the production of meat at economical rates.

Energy source constitutes between 45 and 60 percent of finished feeds for monogastric animals, and at present, corn constitutes the bulk of the energy source used in compounding concentrate rations. Other grains which are used to a lesser extent include sorghum, millet, wheat, barley, oats, cassava chips, and molasses. The difficulty of obtaining foreign exchange in many African countries has considerably reduced the imports of corn and other cereals. At the same time, local production of cereal grains remains grossly inadequate for direct human consumption, livestock feed, and for other industries. These shortages have therefore resulted in astronomical increases in the price of grains in recent times. In Nigeria, for example, prices of maize increased from ₦800 per ton to about ₦1 500 per ton between 1987 and 1988. This has adversely affected the cost of production of pigs and poultry which depend almost entirely on concentrate feeds. It is therefore necessary to investigate locally available alternative sources of energy for commercial pig and poultry enterprise in Africa.

Agronomic and nutritional potentials of cassava

Cassava is a major staple food widely cultivated in the lowland humid tropics. Cassava is capable of providing very high yields of energy/ha, for example, about 13 times more than maize or guinea corn (Oke 1978). Out of the estimated 125 million tons of cassava produced yearly (Phillips 1983), about 90 percent is used as human food while the remainder is used largely as animal feed and for other industrial products. The average yield of cassava in traditionally cultivated varieties is 6.4 tons/ha which is too low to sustain demands for human consumption and for industrial use. However, through the efforts of the IITA in Ibadan, varieties have been developed that could yield 15-20 tons/ha which is several times the average local yield under local agricultural systems. It will therefore appear that the high agronomic potential of cassava can be fully exploited to drastically increase production and thus provide enough cassava for use in feeding livestock without adversely affecting the needs for human consumption.

While the use of cassava for livestock feeding has been advocated by many researchers, its nutritional characteristics require a careful balancing for nutrients in which it is deficient, in order to ensure the satisfactory performance of livestock and cost-effectiveness.

The cassava tuberous root is essentially a carbohydrate source. It contains very little protein which is of poor quality. Cassava also contains the cyanogenic glucosides, linamarin and lotaustralin, which on hydrolysis yield hydrocyanic acid that is toxic to animals. In small doses cyanide is detoxified to thiocyanate, a goitrogen, by means of the enzyme rhodanase, making use of methionine as the sulfur donor. This amino acid therefore becomes a limiting factor in cassava feeds.

Nevertheless, cassava and its by-products can be profitably used in the feeding of monogastric animals if its nutrient composition is considered in the formulation of balanced rations that will guarantee the satisfactory productivity of stock.

Utilization of cassava in poultry feeding

Poultry feed constitutes more than 90 percent of all commercial rations produced by feed millers in Nigeria. The use of cassava as a substitute for maize will therefore make its greatest impact if it can be incorporated into commercial poultry feeds.

Studies conducted with cassava flour on poultry give conflicting results, particularly with young chickens. Satisfactory growth response has been obtained for growing chicks on inclusion of about 10 percent cassava flour in chick ration in most of the reported trials (table 1). Higher levels of inclusion of up to 50 percent have also given favorable responses in a few instances. A 40 percent inclusion of cassava flour in layers' rations has been found to be satisfactory for egg production.

Table 1. Summary of performance of poultry on cassava flour based rations

Class of chicken	% cassava replacement of maize in diet	Performance	Reference
Chicks	0.6	Satisfactory growth	Tabayoyong (1935)
Chicks	0-5	Satisfactory growth at all levels of inclusion	Tejada and Brambila (1969)
Chicks	10	Satisfactory growth	Klein and Barlowen (1954)
Chicks	0-50	Satisfactory growth at 10% inclusion	Job et al. (1980)
Growers	0-25	Satisfactory growth at 5% inclusion	Job et al. (1980)
Layers	0-40	Satisfactory egg production	Temperton and Dudley (1941)
Layers	50-60	Satisfactory egg production	Pillai et al. (1968); Enriquez and Ross (1972); Hamid and Jalaludin(1972)

Note: Chicks are 0-12 weeks

In the European Economic Community (EEC), a maximum of 20 percent inclusion of cassava in poultry rations has been fixed for satisfactory poultry production. The reasons given for limiting the use of cassava flour or chips in poultry rations include the dustiness of the feedstuff which causes irritation of the respiratory tract of the chickens unless the feed is pelletized or some oil is added. Pelletizing is also recommended as powdered starch has been reported to produce ulcerogenic effects in the gastric mucosa (Oke 1978). Dustiness of cassava feedstuff can reduce intake in poultry which adversely affects productivity.

The level of hydrocyanic acid (HCN) in cassava limits the use of cassava and its products for livestock feeding. Drying considerably reduces the HCN level and sun-drying has been demonstrated to be more effective than oven-drying (Tewe et al. 1980). Where the HCN is below 100 ppm, as in cassava flour or chips, cassava can be safely incorporated into rations as is allowed in the EEC (Delange and Ahluwalia 1983). It is however important to note that when cassava chips are sun-dried on the floor, they could be infected by microorganisms such as *Aspergillus niger*. This can predispose young chicks in particular to diseases such as aflatoxicosis and even increase mortality. The presence of microorganisms demands the use of antibiotics in dried cassava rations. In this regard, the drying of cassava chips particularly during the rainy season can pose serious problems of microbial infestation and these could be more serious than the hydrocyanic acid in dried cassava samples.

The presence of hydrocyanic acid calls for additional supplementation of cassava-based diets with methionine either in its pure form or as animal protein supplements, particularly fish meal. Lysine supplementation is also suggested for maximum efficiency (Oke 1978).

Cassava wastes constitute the major by-products of tubers used for preparing human foods and industrial starch. The mechanization of gari production in Nigeria has resulted in large quantities of peel and wasted small-sized tubers which are difficult to process, and are therefore discarded. Cassava peel accounts for between 10 and 13 percent of the tuber weight (Tewe et al. 1976). Results of studies on broilers and layers at the University of Ibadan presented in table 2 show that cassava peel increased feed intake, reduced body weight gain, and reduced nutrient utilization when fed to starter and finisher broilers at levels of between 0 and 30 percent replacement of maize (Tewe 1983). Even when the finisher broiler rations were supplemented with palm oil and groundnut cake to ensure that rations were isocaloric and

Table 2. Performance, nutrient utilization and economy of production in broilers fed various dietary cassava peel levels

Parameter	Cassava peel level (%)				
	0.0	7.5	11.5	22.5	30.0
Starter phase					
Weekly feed intake/ bird (g)	292.3	290.1	291.8	310.1	311.6
Weekly weight gain/bird (g)	132.8a	130.1a	129.6ab	126.3ab	120.1b
Feed intake/ weight gain	2.2	2.2	2.3	3.5	2.6
Mortality (%)	2.5	5.0	10.0	15.0	15.0
Nitrogen retention (%)	73.1	71.2	58.3	68.2	66.7
Protein efficiency ratio	1.80	1.80	1.89	1.75	1.66
Feed cost/live weight gain (₦/kg)[a]	0.98	0.97	1.00	1.01	1.11
Metabolizable energy (kcal/g)	2.81	2.76	2.71	2.68	2.62
Finisher phase					
Weekly feed intake/bird (g)	766.5b	791.1b	773.6b	813.2a	850.7a
Weekly weight gain/bird (g)	218.4a	219.3a	206.1ab	184.3b	180.1c
Feed intake/weight gain	3.6c	3.6c	3.8b	4.4a	4.7a
Mortality (%)	0.0	5.2	8.3	8.8	8.8
Nitrogen retention (%)	66.4	66.2	64.4	65.1	64.1
Protein efficiency ratio	1.34a	1.42a	1.35a	1.22b	1.14b
Feed cost/live weight gain (₦/kg)[a]	1.38	1.44	1.56	1.81	1.85
Metabolizable energy (kcal/g)	2.99	2.93	2.88	2.88	2.77

Notes: Values in the same row followed by the same letter(s) are not significantly different ($P < 0.05$)

[a] US$1.0 = Nigerian ₦2.6 (February 1987)

isonitrogenous, the performance of the broilers did not appreciably improve (table 3). In the third trial with layers (table 4), the inclusion of up to 27 percent of cassava peels at the expense of maize gave satisfactory feed intake, egg production and feed per unit egg produced. It should be noted that in trials 2 and 3 (tables 3 and 4) the economy of feed conversion was consistently more efficient with the rations based on cassava peel compared with the maize control.

Perhaps feeding cassava peel to cockerels holds the greatest potential. Preliminary studies have so far shown satisfactory performance in finisher cockerels with up to 45 percent inclusion of cassava peel as a replacement for maize in their rations.

Cassava leaves are rich in protein. According to Rogers and Milner (1983) the amount of protein (dry basis) ranges from 17.8 to 34.8 percent in eight Brazilian varieties. Studies in Nigeria by Tewe et al. (1976) also revealed a range of 29.8 to 33.7 percent protein (dry basis) in the leaves of different cassava cultivars. It is important to note that when cassava leaves are sun-cured or dehydrated, all the HCN is liberated and no toxic effects are therefore found when the leaves are consumed by animals. Ross and Enriquez (1969) used up to 20 percent cassava leaf meal in poultry diets and found a decrease in weight gain and feed efficiency when the diet had more than 5 percent cassava leaf meal. When cassava leaf meal was used up to 10 percent, no differences were observed in egg production, feed efficiency and egg weight. However, when 0.15 to 0.30 percent methionine and 3 percent corn oil were added, the results were similar to those from the control diet. Cassava leaf meal has some yellow pigment that gives a good egg yolk pigmentation, and it can be a substitute for all the alfalfa in the diet of laying hens.

Utilization of cassava in swine feeding

Since the pioneering work of Oyenuga and Opeke (1957) and Modebe (1963) in Nigeria, several researchers have confirmed the suitability of cassava for pig feeding and the potential of cassava meal as a good substitute for maize meal for all classes of pigs (Maner 1972; Tewe 1975, 1982; Job 1975; Adegbola 1977; Gomez et al. 1976; and Nghi 1986).

As in the case of poultry, certain precautions need to be taken to guarantee satisfactory performance of stock on cassava meal diets. These include the removal of cyanide through boiling, drying, grating, soaking, fermentation, or a combination of these processes to produce final products containing not more than 100 ppm HCN, and the prevention of microbial activity during sun-drying, particularly in a humid environment. High cyanide levels and the presence of microorganisms have been demonstrated to reduce performance and prevent hematological changes of growing pigs fed on sun-dried cassava-based rations (Tewe 1982, 1984).

The protein deficiency of cassava also demands higher protein supplementation in such rations. Maust et al. (1972) have also demonstrated that cassava can affect mineral balance, resulting in parakeratosis in pigs which can be prevented by including zinc salts in the diet. Dustiness of cassava-based rations can be removed by adding molasses, suitable oils or by

Table 3. Performance, nutrient utilization, and economy of production of finisher broilers fed varying cassava peel levels

Parameter	Cassava peel level (%)								
	0.0	7.5	7.5	7.5	15.0	15.0	15.0	22.5	22.5
Weekly feed intake/bird (g)	780.0ab	790.0ab	810.0a	800.0ab	810.0ab	810.0	77.0ab	740.0ab	780.0ab
Weekly weight gain/bird (g)	220.0a	296.3a	296.8a	243.3a	216.6a	226.6a	223.3a	160.0b	220.0a
Feed intake/weight gain	3.5a	3.2a	3.4ab	2.3b	3.7a	3.6ab	3.4b	3.6a	3.6ab
Mortality (%)	5.0	5.0	0.0	5.0	2.5	0.0	2.5	10.0	5.0
Nitrogen retention (%)	65.0	66.3	64.9	66.9	65.3	64.4	67.3	66.2	65.5
Protein efficiency ratio	1.40ab	1.51a	1.47a	1.49a	1.35ab	1.44ab	1.43ab	1.08c	1.40ab
Feed cost/live weight gain (₦/kg)[a]	1.45	1.33	1.26	1.32	1.42	1.22	1.23	1.81	1.19
Metabolizable energy (kcal/g)	2.91	2.93	2.80	2.85	2.93	2.70	2.76	2.91	2.64
Crude protein (%)	20.21	20.36	19.84	20.40	20.16	19.47	20.26	20.05	20.10

Notes: Values in the same row followed by the same letter(s) are not significantly different ($P < 0.05$)

[a] US$1.0 = ₦2.6 (February 1987)

Table 4. Performance, nutrient utilization, and economy of production in layers fed varying dietary cassava peel levels

Parameter	Cassava peel level (%)				
	0	6.82	13.64	20.46	27.28
Cost of feed[a]					
₦/t	359.3	337.4	314.3	291.8	269.3
₦/100 eggs	5.6	5.4	6.4	4.7	4.8
₦/kg eggs	1.0	2.0	1.2	0.9	0.9
Weekly feed consumption/bird (kg)	0.80b	0.70c	0.74d	0.78b	0.84a
Weekly crude protein intake/bird (kg)	0.14a	0.13b	0.13b	0.13b	0.14a
Weekly cyanide intake/bird (mg)	0.00c	14.74d	28.32c	44.78b	63.92a
Average initial body weight (kg)	1.83	1.78	1.78	1.72	1.71
Weekly no. of eggs produced/bird	5.24a	4.92c	5.20a	5.05	4.70c
Average weight of egg produced (g)	54.89c	55.69b	52.94d	53.67d	56.79a
Feed consumption (g/g egg produced)	2.81c	2.90b	2.81c	2.93b	3.21a
Metabolizable energy (kcal/g)	3.09a	3.07a	3.05a	3.09a	2.75b
Nitrogen retention (%)	58.48a	47.71a	47.53ab	45.48ab	39.19b
Weekly body weight gain (g)	0.012	0.009	0.010	0.004	0.005

Notes: Values in the same row followed by the same letter(s) are not significantly different ($P < 0.05$)

[a] US$1.0 = Nigerian ₦2.6 (February 1987)

pelletizing to make the feed acceptable to pigs.

The cost of these feed supplementations need to be compared with those for maize in practical swine feeding. It is noteworthy that the EEC imports cassava chips from Thailand for incorporation at up to 40 percent into swine rations. Growing pigs fed on a diet containing 40 percent cassava peel and discarded small tubers have been observed to perform satisfactorily (Tewe and Oke 1983, Tewe at al. 1987). Indeed, pigs fed on such rations produced leaner carcasses and showed an economy of feed conversion as shown in table 5.

Apart from dried cassava, pigs can also be fed with fresh cassava tuberous roots, as is commonly practiced in small- and medium-scale pig farming enterprises in Nigeria. Such pig farmers usually depend on the cassava grown on their farm or sometimes supplement their cassava supplies with those purchased from neighboring farmers. Chopped cassava tuberous roots, either fresh or parboiled, are fed to the pigs but the death of many young pigs has been reported, caused by cyanide toxicity in fresh cassava tuberous roots. To overcome this problem, some of the farmers now sun-dry the grated cassava tuberous roots, with or without fementation, before feeding them to pigs.

In yet another group of farmers, the cassava peel together with discarded unwholesome tubers are chopped, sun-dried and mixed with concentrates to feed pigs. Therefore, inspite of considerable research efforts in Nigeria to

Table 5. **Cassava peel in growing pig rations: effects on performance, carcass characteristics and economy of production**

Parameter	Experiment I: Cassava peel level (%)				Experiment II: Cassava peel level (%)	
	0	10	20	30	0	40
Daily weight gain (kg)	0.41	0.38	0.39	0.40	0.49	0.53
Daily feed intake (kg)	1.45	1.45	1.46	1.60	1.35	1.31
Feed/gain	3.79b	3.79ab	3.69ab	3.96a	2.81	2.48
Dressing percentage	74.1	69.8	73.1	70.3	81.9	81.7
Percentage lean cut	64.52	55.42	66.94	64.84	66.9	64.5
Percent trimmed fat	10.69a	10.44a	9.29b	9.63ab	16.0	16.6
Gross gain/feed cost (₦)[a]	132.5	129.2	149.2	145.7	162.0	191.0

Source: Experiment I: Tewe and Oke (1983); Experiment II: Tewe et al. (1986)

Notes: Means without common letter(s) on horizontal rows are significantly different ($P < 0.05$)

[a] US$1.0=₦2.6 (February 1987)

formulate appropriate diets for feeding pigs, there has not been a uniform method for utilizing cassava as feed to meet the specific nutrient requirements of pigs at different ages and phases of commercial pig production.

Future perspective

The use of cassava in commercial pig and poultry feeding in Nigeria has been limited by many factors. The conservative attitude of feed millers to the use of locally available alternatives is now changing gradually. However, there is a lack of proper technology to produce cassava products of guaranteed quality that will meet the nutritional needs of these fast growing monogastric livestock for satisfactory productivity in commercial farms. There is need to obtain products with well defined standards in the following:

- Nutrient levels: energy, protein, fibre and mineral levels;
- Levels of anti-nutritional factors: hydrocyanic acid, phytates and oxalates;
- Microbial counts: levels of *Aspergillus* and *Eschericia* species;
- Levels of other contaminants: those introduced during the drying process;
- Moisture contents.

High moisture levels predispose cassava products to spoilage during processing, therefore, the construction of drying facilities that can be utilized in rural areas should be considered so that the processing can be carried out near farm sites. During the dry season, cassava can also be sun-dried.

Another major constraint is the economics of feed production when cassava tuberous roots are incorporated into finished livestock feeds. At present, one ton of cassava tuberous roots costs about ₦500 in the open market, giving an estimate of one ton of dry cassava flour at about ₦1500 (US$1.0 = ₦2.6, 1987). Dried cassava contains about 7% crude protein compared to 10% in maize, therefore an additional 80kg of protein must be added from a protein concentrate such as groundnut cake or soybean meal to produce a suitable feed. This will cost an additional ₦240. The present cost of maize is about ₦1500 per ton, therefore, cassava does not appear to be an economically attractive substitute for maize. To reduce the cost of cassava products, cassava leaf meal can be incorporated instead of the more expensive oil seed cakes to increase the protein content of the feed. However, one sure way to encourage the use of cassava tuberous roots in livestock feeding is to exploit its agronomic potential which can ensure the production of cassava tuberous roots in excess of the needs for human food so that the extra tubers can be used along with cassava peel and leaves to reduce the cost of finished commercial poultry and pig rations.

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A Review of Ruminant Responses to Cassava-based Diets

O.B. Smith

Cassava is a primary, secondary, or supplementary staple food for over 200 million people in Africa. To a limited extent, it is used as a livestock feed, particularly in nonruminant diets. Ruminants can be fed on cassava tuberous root, foliage, peel and residue obtained after processing cassava for fufu, gari, lafun (flour), and starch. Data presented show: tubers and peel are good energy sources, which when well fortified with nitrogen, minerals, vitamins, and roughage, promoted positive and high performance levels in dairy and beef cattle, sheep, and goats; the foliage, which is rich in nitrogen, fiber and ash, is a source of nitrogen and roughage for ruminants; residue from cassava processing degrades very well in the rumen, and has a high potential as energy feed. Constraints to increased utilization of cassava products as ruminant feeds include the difficulty of obtaining sufficient amounts and the cyanide content.

World production of cassava over the last two decades has steadily increased, mainly because of increases in the areas under cultivation. According to FAO (1985), total world production in 1968 was 85.6 million tonnes grown on 9.8 million ha. By 1979, the cultivated area was 13.5 million ha, with a total production of 123.3 million tonnes. The area cultivated in 1985 increased to 14.2 million ha, with a total production of 136.5 million tonnes. The yields in tonnes/ha for the 3 periods were respectively, 8.7, 9.2 and 9.2 for 1968, 1979 and 1985.

These figures are probably lower than the actual production figures, because cassava is still grown largely by subsistence farmers who cultivate small scattered plots which are often missed out during compilation for agricultural statistics. Nevertheless, based on the available figures, the annual world production of cassava is only exceeded by six other crops, mainly wheat, rice, maize, barley, potatoes, and sugar beets.

The most important use of cassava is as human food, serving as a primary, secondary or supplementary staple for over 200 million people in Africa. Cassava is also used as livestock feed, and regularly fed to sheep and goats on small-scale subsistence farms in Africa. In a recent survey of smallholder sheep and goat farmers in southwest Nigeria, a majority of the farmers indicated that cassava products and by-products were regularly fed to their animals as supplementary feed to grass and hay (Anon. 1988). The potential of cassava as a grain substitute in livestock feed is yet to be fully exploited, as only a small proportion of total world production is currently being used, mainly in compounded nonruminant diets. Ruminants can be fed not only cassava tuberous roots, but also the stem, leaves, and peel, and the various by-products of tuber processing such as residues from starch, gari, and fufu manufacture.

This paper reviews available information on the response of ruminants to a diet of cassava and its by-products. Constraints to increased utilization of these materials for ruminant feeding are identified, and solutions suggested to stimulate their increased use in ruminant feeding.

Response of ruminants fed on cassava and its by-products

The principal products of the mature cassava plant (12 months), expressed as a percentage of the whole part, were estimated as: leaves 6%, stem 44%, and tubers 50%. By-products of tuber processing are: peel 8% and pomace 17% (Devendra 1977). Other by-products include residues from the manufacture of gari, fufu and cassava flour (lafun). The nutritive value of any feed, and the livestock response to such feed, depend on a number of factors, including nutrient contents and availability; animal age, physiological state, the species, and associative effects of other feeds.

Nutrient content of cassava

The proximate, mineral and vitamin contents of cassava products are shown in tables 1, 2, and 3. The variability in the values shown in the tables is due to strain and varietal differences, location, soil type, other environmental conditions, and the method of chemical analysis (Seerley 1972). Processing is perhaps the most important factor responsible for the variation. Tubers may be peeled or unpeeled, washed (ash content), sun-dried or oven-dried while leaves may be analyzed fresh, or after wilting, dehydration or fermentation. Many authors often ignore these details in reporting nutrient contents, which renders comparisons inaccurate and therefore appraisal of nutritive values difficult and unreliable.

Table 1. Proximate content of cassava

Constituents (%)	Leaves (foliage)		Peel		Tuber	
	Range	Mean	Range	Mean	Range	Mean
Dry matter	19.5-33.0	(25.3)	27.3-33.5	(29.6)	13.0-43.2	(30.8)
Crude protein	14.7-36.4	(25.1)	2.8-6.5	(4.9)	1.5-3.5	(2.3)
Crude fiber	4.8-15.4	(11.4)	10.0-22.0	(16.6)	1.3-7.7	(3.4)
Ether extract	4.0-15.2	(12.7)	0.5-2.2	(1.3)	0.8-3.2	(1.4)
NFE[a]	37.3-51.9	(46.1)	62.5-72.9	(68.5)	88.0-94.1	(88.9)
Ash	5.5-16.1	(9.0)	3.5-10.4	(5.9)	1.6-4.1	(2.5)

Sources: Rogers and Milneru 1963, Oyenuga 1968, Seerley 1972, Devendra 1977, Khajaren et al. 1977, Montaldo 1977, and Asaolu 1988

Note: [a] NFE = nitrogen free extracts

Table 2. Mineral content of cassava

Mineral (mg/kg)	Leaves	Peel	Tubers
Calcium	1.1-1.4	0.31	0.02-0.35
Phosphorus	0.25-0.30	0.13	0.07-0.46
Magnesium	nd	0.22	1.10
Copper	8.0	nd	nd
Iron	450	904	8-65
Manganese	46.0	nd	18.0
Zinc	28.0	nd	nd

Source: Chadha 1961, Barrios and Bressani 1967, Devendra 1977, and Hutagalung 1977
Note: nd = not determined

Table 3. Vitamin content of cassava

Vitamin	Leaf content	Tuber content
Vitamin A (I.U.)	100 000-300 000	550
Riboflavin (mg)	2.5-4.3	0.3-0.8
Thiamine (mg)	0.3-2.7	0.4-1.6
Niacin (mg)	8.5-35.3	0.6-1.6
Vitamin C (I.U.)	520-1800	5-360

Source: De Brochard et al. 1957, Jones 1959, Chadha 1961, Müller et al. 1975, Hutagalung 1977, and Montaldo 1977

The tables also show that cassava tuberous root is low in protein, fat, trace minerals, and vitamins, and therefore mainly a source of energy. The bulk of the tuber (90 percent) consists of carbohydrates (Seerley 1972), made up of 3-4.5% fiber, and 96% nitrogen free extracts (NFE) (Hutagalung et al. 1973, Müller et al. 1975). According to Vogt (1966), the NFE is made up of 80% starch, the main soluble carbohydrate, and 20% sugar. A peculiarity of cassava tuberous root starch is the high amylopectin content (70%) making it a particularly suitable energy source for ruminants, particularly when combined with nonprotein nitrogen in feeds (Müller 1977). Although the peel contains a higher level of crude protein than the tuber, the total protein weight in the peel is low. Like the tuber flesh, the peel is deficient in fat, minerals, and vitamins, and would be useful mainly as an energy source. The energy value varies with the amount of flesh retained during the peeling process. In contrast to the tuber, cassava leaf is rich in protein (25%), ash (9%), fat (12.7%), and fiber (11%). The protein is of good quality, and the amino acid profile apparently compares favorably with that of soybean meal (Khajaren et al. 1977). It is high in lysine but low in sulfur-containing amino acids. The high level of crude fiber of cassava leaf or foliage (leaves and stems) makes it a particularly useful source of roughage for ruminants.

Utilization of cassava products and by-products by ruminants

Cassava foliage (leaves and stems): Leng and Preston (1976) suggested that ruminant feeding systems based on poor quality tropical foliages, crop residues or agroindustrial by-products, in which protein is one of the first limiting factors, may require additional protein and roughage to maintain an efficient rumen ecosystem that will stimulate nutrient intake and improve animal performance.

Several authors subsequently showed that cassava foliage could efficiently serve as a protein and roughage supplement to such diets. Moore (1976) demonstrated the feed value of cassava foliage for ruminants in a trial in which steers weighing 250kg were fed *Pennisetum purpureum* with varying levels of cassava foliage (table 4). Feed intake, growth rate, and feed efficiency were improved in diets containing cassava foliage supplements. Another set of steers fed on a basal diet of chopped sugarcane supplemented with either cottonseed cake, cassava foliage or *Desmodium distortium* foliage showed respectively, similar growth rates of 0.66, 0.62 and 0.58 kg/day.

Table 4. The value of cassava foliage as supplement to elephant grass

Parameter	Diet		
	100% grass	75% grass + 25% cassava foliage	50% grass + 50% cassava foliage
Daily gain (kg)	0.31	0.46	0.45
Dry matter intake (kg/day)	5.4	6.3	6.1
Feed efficiency (kg day/kg gain)	17.6	13.7	13.7

Source: Moore 1976

The results of other studies designed to evaluate animal responses to cassava foliage feed as a supplementary source of protein and roughage are summarized in table 5. In general, animal responses to the utilization of cassava foliage as a protein roughage supplement to sugarcane-based diets was positive but low (Meyrelles et al. 1977b). Higher and better responses were obtained when cassava foliage was used as a supplement to molasses-urea based diets (Fernandez et al. 1977, Ffoulkes and Preston 1978). Meyrelles et al. (1977a) attributed the poor animal responses on sugarcane-based diets to:

1. Low sugar content of the sugarcane diet, a situation aggravated by fermenting the sugarcane for 24 hours before feeding,
2. High solubility of the cassava foliage, and
3. Hydrogen cyanide (HCN) toxicity.

Indeed, evidence in subsequent trials (Meyrelles et al. 1977b, 1977c) showed that the combination of low sugar content of the basal diet and highly soluble cassava foliage protein could have contributed to the poor animal performance. No evidence was provided to implicate HCN toxicity.

Table 5. The value of cassava foliage as nitrogen-roughage source for growing cattle

Basal diet[a]	Cassava foliage (%)	Response	Reference
Sugarcane + urea	0, 15, 30, 45	Low response and not related to level of supplementation	Meyrelles et al. 1977a
Molasses + urea	3 (fresh)	Live-daily gain of 0.58 to 0.66 kg	Fernandez et al. 1977
Sugarcane	0, 15, 30, 45	Low growth rate, better on cassava foliage	Meyrelles et al. 1977b
Sugarcane + urea	20, 40	Low growth rate (0.14-0.24 kg/day), better with cassava foliage +urea	Meyrelles et al. 1977b
Sugarcane + cassava + sulfur	20	No effect of sulfur, improved performance with cassava chips	Meyrelles et al. 1977c
Molasses + urea	2, 3, 4.5 (fresh)	Linear increase in growth rate, 0.37, 0.47, 0.91 kg/day	Fernandez and Preston 1978
Molasses + urea + soybean meal	4.5(fresh)	High intake (6.1 kg/day), high growth rate (0.9 kg/day) on cassava foliage	Ffloukes and Preston 1978

Note: [a] Sugarcane is chopped, cassava is in chips

An experiment with dairy cattle in Costa Rica by Murillo (1952) which compared the value of cassava leaf meal with that of alfalfa meal showed that cassava leaf meal was a valuable feed for dairy cattle. Production of cows fed on cassava leaf meal was 90-96 percent of those fed on alfalfa meal. It was therefore concluded that cassava leaf meal was an economic replacement of alfalfa leaf meal. According to Ffloukes et al. (1978), cattle fed on chopped cassava foliage only, consumed up to 2% of their body weight (dry matter) and digested the material fairly well (66.5% dry matter digestibility). More recently, Smith et al. (1988) compared the rumen degradability of some foliages in cattle and goats. In all these ruminants a similarly high 48-hour degradability of 84.3% (mean) for cassava leaves was obtained which was higher than the degradability for *Leucaena leucocephala, Gliricidia sepium,* bamboo and oil palm leaves. Cassava foliage is thus a valuable feed material for ruminants. The feed value apparently decreases with age, and Müller (1977) suggested the foliage should be harvested at 3-4 months to ensure high nutrient content and to avoid reduction in tuber yield.

Cassava peel: This is an important source of energy in ruminant feeding systems, serving either as the main basal diet or as a supplement. Cassava is rarely fed fresh because of the high level of cyanogenic glycoside in the material. Sun drying, ensiling and fermentation are used to reduce the concentration of the glycosides to tolerable levels. Recent studies at the Obafemi Awolowo University, Nigeria, showed that cassava peel is rapidly and well degraded in the rumen. Asaolu (1988) reported dry matter losses of 70% (dried peel) and 73% (ensiled peel) in 24 hours in the rumen of sheep. Odunlami (1988) obtained a $t_{1/2}$ value of 26 hours for dried peel in goats. This value was similar to that obtained from cassava tuberous root meal (26.7 hours), yam peel (28.9 hours), and plantain peel (27.8 hours). Cassava peel dry matter losses in this study were 78% and 88% in 24 and 48 hours, respectively.

In another study comparing the rumen degradability of several crop residues in cattle, sheep and goats, Smith et al. (1988) reported high dry matter losses for cassava peel in the three ruminant species, with a mean value of 83% in 48 hours. These high rumen degradability values suggest that cassava peel could serve as a useful energy feed in ruminant diets.

Larsen and Amaning-Kwarteng (1976) fed grazing cross-bred cattle a supplement made up of molasses and dried or ensiled cassava peel at 0.7 percent of body weight, for about 6 months. Weight gains recorded were 0.07 kg/day for control (cattle grazed with no supplement), 0.29 kg/day for test (cattle grazed and supplemented with dried peel), and 0.33 kg/day for cattle grazed and supplemented with ensiled peel. In another study, Fomunyan and Mefleja (1987) fed sheep on three levels of dried cassava peel (0, 35, 70 percents of diet) in combination with *Pennisetum purpureum* at 70, 35, and 0 percents of diet, respectively. Cottonseed cake was supplied as a protein supplement. Dry matter intake, digestibility and growth rate increased linearly with increasing dietary levels of cassava peel (table 6). It was concluded that cassava peel-based diets have great potential as dry season feedstuff for sheep.

Table 6. Feed value of sun-dried cassava peel for sheep

Parameter	Diet		
	70% grass	35% grass + 35% peel	70% peel
Dry matter intake (kg/day)	0.87	1.36	1.06
Weight gain (g/day)	45.2	106.7	227.1
Dry matter digestibility (%)	50.7	79.0	88.1

Source: Fomunyan and Mefleja 1987

Dried cassava peel fortified with urea was compared with rice-straw fortified with urea as a dry season supplement for grazing sheep in Ghana (Otchere et al. 1977). The results showed that while sheep supplemented with rice straw and cassava peel gained weight, sheep used as control lost about 15 percent of their body weight during the dry season. The sheep supplemented with cassava peel gained more weight and maintained this weight gain advantage during the following rainy season when the control animals exhibited a high degree of compensatory growth.

Cassava peel could also be fed dried or as silage. Optimum conditions for making good quality cassava peel silage have been worked out by Asaolu (1988), who indicated that good quality silage could be obtained when peel is chopped to equal lengths of about 2cm for easy compaction. Moisture contents should be reduced from 70-75 % to about 40% by wilting (air drying) for 2 days before ensiling. A reduction of moisture content will ensure good fermentation even if the peels are not chopped to uniform lengths (Asaolu 1988). Under these conditions, cassava peel silage after 21 days was light brown in colour, firm in texture and had a pleasant odor. The pH was 4.4, and no fungal growth was observed.

Such good quality cassava peel silage and dried peel were fed to West African Dwarf sheep by Asaolu (1988). Two groups of sheep were fed diets made up of 80 percent dried (group 1) or ensiled (group 2) peel, supplemented in each case with 20 percent *Gliricidia* leaves. The sheep were compared to a control group fed solely on *Gliricidia*. The performance of the sheep is summarized in table 7 which shows that sheep fed mainly on cassava peel with a small supplement of protein-rich *Gliricidia* efficiently put on weight during this period.

Table 7. Performance of sheep fed ensiled or dried cassava peel

Parameter	Control	Test	
	100% *Gliricidia*	20% *Gliricidia* + 80% ensiled cassava peel	20% *Gliricidia* + 80% dried cassava peel
Dry matter intake (kg/day)	1.0a	0.7b	0.6b
Daily gain (g)	106.0a	81.0b	59.0b
Feed efficiency	9.9	9.8	10.8
Dry matter digestibility (%)	81.6a	76.0b	72.0b

Source: Asaolu 1988
Note: Within a row, values with the same letter are not significantly different (P< 0.05)

The data confirms a previous suggestion by Larsen and Amaning-Kwarteng (1976) that sheep may utilize cassava ensiled peel better than sun-dried peel. Hydrogen cyanide (HCN) intakes on the three diets were 48.8 (control) 93.3 (ensiled peel) and 166.1 (dried peel), all values in mg/day/head (Asaolu 1988). The differences observed in the performance of the sheep were attributed in part, to the different levels of HCN in the diets. Differences in protein intake also probably had an effect.

Another dry season feed formulation based on grass-legume foliage, cassava peel and poultry excreta was evaluated by Okeke and Oji (1988). The three feed materials were ensiled in the ratio of 60:20:20 on wet basis, and fed to West African Dwarf goats. Control goats were fed a maize silage diet, both diets being isonitrogenous (14 percent cassava peel). On the basis of favorable consumption and digestibility of the cassava peel diet, as well as normal rumen and blood metabolites, Okeke and Oji (1988) recommended that in anticipation of dry-season feeding, cassava peel could be used as an energy supplement in an ensiled mixture of grass-legume foliage and poultry excreta.

Cassava peel has also been fed to ruminants after fermentation. Adebowale (1981) substituted fermented cassava peel for maize to feed West African Dwarf sheep at graded levels of 0, 20, 40, and 60 percents over a 6 month period. It was concluded that fermented cassava peel should not constitute more than 20 percent of a concentrate diet in order to avoid a reduction in performance.

From the foregoing, it is clear that cassava peel could be fed to ruminants either as the main energy source, or as an energy supplement to foliages or poor quality feed. Because of rapid rate of degradability of cassava peel in the rumen, maximum animal response under these two feeding strategies can only be achieved with the provision of protein feed whose rate of rumen degradability is comparable to that of cassava peel for proper synchronization of energy and protein utilization.

By-products of cassava tuberous root processing

Apart from proximate contents there is very limited published information on the feed value of the variety of by-products obtained when cassava is processed for human consumption. In Nigeria, as in many other West African countries, cassava is processed into gari, fufu, lafun (cassava flour) and starch. The residues or by-products obtained from cassava processing are rich in fiber and soluble carbohydrates and are potential energy sources for ruminants. An indication of their potential feed value is given by the rumen degradability values obtained by Smith et al. (1988) for fufu residue (78.5% in 48 hours) and gari residue (88.5% in 12 hours).

Utilization of tubers

There is sufficient experimental data to suggest that ruminants respond favourably when fed on cassava tuberous roots. For example, the results summarized in table 8 show that: (a) all ruminant species can benefit from cassava feeding, and (b) associative effects of other feeds on the nature of response are important.

Ahmed (1977) fed fresh cassava tuberous roots to Friesian steers as an energy supplement to artificially dried grass. No effects were observed of the supplementation on any of the parameters, including dry and organic matter, and metabolizable energy. Cassava supplementation did not improve nutrient digestibility, probably because of inadequate dietary protein causing poor utilization of the extra energy supplied by the cassava. Rumen microbes broke down the more easily degradable soluble carbohydrates supplied by the cassava, rather than the cellulose in the basal grass diet. This led to a significant reduction in crude fiber digestibility in the cassava supplemented diet.

Table 8. Ruminant response to cassava tuberous root feeding

Ruminant species	Basal diet	Role and level of cassava tuber in diet	Response	References
Dairy cattle				
Cow	Maize diet	Substitute for maize	Lower milk yield but cost of production reduced	Peixoto et al. 1955
Holstein	Grazing	Energy supplement	Milk yield increased by 19.5%	Assis 1962
Holstein and Zebu	Fresh and ensiled cane	Energy supplement	No response to supplement	Estima 1967
Holstein and Zebu	Maize diet	Substitute up to 41.5%	Decreased production but lower cost	Cardoso et al. 1968
White Fulani	Hay, maize and protein sources	Replaced maize	Increased milk and fat yield	Olaloku et al. 1971
Beef cattle				
Calf	Commercial concentrate	Energy supplement	Increased live weight gain	Johnson et al. 1968
Bull	Maize-based concentrate plus hay	Replaced maize, but enriched with 2% urea	Growth rate of 0.81 g/day, efficiency of 10.1; performance similar	Lhoste 1974
Steer	Artificially dried grass	Energy supplement at 21% and 42% of diet	Intake similar, fiber digestibility depressed	Ahmed 1977
Steer	Sorghum-based diets	Replacement at 68%, 78%; plus urea	Reduced organic matter intake and growth rate; digestibility and feed conversion similar	Tudor et al. 1985
Goat	Maize diet	Replacement at 0, 20, 40, 60%	Reduced performance at levels 40% and 60%	
Goat	*Gliricidia sepium*	Supplement at 30DM/kg	Improved digestibility and digestible dry matter intake, but reduced growth rate	Anon. 1986
Goat	75% *Gliricidia* + 25% *Leucaena*	Supplement at 15 and 30 g dry matter/kg	Improved digestibility and similar growth rate as control	Anon. 1986
Sheep	Pangola grass hay, corn cob and bran	Substitution of corn-cob with cassava (20%)	Improved digestibility, body weight gain, and rumen function	Chicco et al. 1971
Sheep	Rice-straw based diet	Supplementation at 20-80%	Increased digestibility	Devendra 1977
Sheep	Molasses-urea diet	Supplementation at 20-80%	Decreased digestibility	Devendra 1977

By contrast, Lhoste (1974) obtained a much better response when maize was replaced with cassava in cattle diet. The cassava was enriched with 2% urea, and cattle weight gains obtained were 0.81 kg/day for both maize-based and cassava-based diets. On both diets, cattle required 10kg feed dry matter per kg weight gain. It was therefore concluded that it was feasible to substitute cassava for maize, provided urea was added to offset a nitrogen shortage.

A series of experiments was carried out by the Goat Research Group of the Obafemi Awolowo University in Nigeria during 1986 to evaluate the response of goats fed cassava tuberous roots as an energy supplement to grass-legume foliage basal diets. A summary of the results is shown in table 9. In the first trial, goats were fed a basal diet of *Gliricidia* ad libitum, with or without cassava supplement at the the rate of 30g dry matter/kg metabolic weight. The cassava was fed to the goats three hours before the basal *Gliricidia* was offered. The results showed an improvement in dry matter digestibility, which was however not reflected in the growth rates.

This discrepancy was attributed to a poor energy-nitrogen synchronization in the rumen. Most of the energy supplied by the cassava supplement was already dissipated before the nitrogen from the basal diet was made available.

Table 9. Response of goats fed grass-legume forages to cassava supplement

Basal diet	Method and level of cassava feeding	Digestibility (%)		Growth rate(g/day)	
		basal	basal + cassava	basal	basal + cassava
Gliricidia	30g dry matter/kg weight, fed once a day 3hrs before basal diet	nd	nd	23.3	14.3
Leucaena (25%) + Gliricidia (75%)	30g dry matter/kg weight, fed once a day 2hrs before basal diet	59.3	70.8	37.4	43.4
Guinea-grass hay (50%) + brewers grain (50%)	30g dry matter/kg weight, split-fed three times a day	60.5	72.7	18.6	53.6

Sources: Obafemi Awolowo University Goat Research Group 1986; Odunlami 1988
Note: nd = not determined

This was confirmed by the $t_{1/2}$ values (in hours) of the feeds used: cassava 26.7, gliricidia 53.7, leucaena 88.9, guinea-grass hay 210.0, and brewers grain 46.2 hours. Taking these into consideration, the feeding pattern was changed in subsequent experiments. In experiment 2, cassava was fed 2 hrs after the basal diet. The results showed that the growth rates reflected the digestibility patterns. In the third experiment, cassava supplement fed once a day a few hours after the basal feed was compared with split-feeding three times a day, simulating a steady energy release that matched the slow N release from the basal diet. The results indicated that supplementation improved digestibility; growth rate figures suggested an improved energy-nitrogen utilization. It could be concluded that in order to obtain maximum response from ruminants fed on cassava tuberous roots, two peculiarities of the material need to be recognized—the low nitrogen content and the rapid degradability in the rumen. Appropriate measures such as fortification with nitrogen, preferably nonprotein nitrogen, and split-feeding several times a day will ensure efficient utilization of nitrogen-poor basal feed by ruminants.

Constraints to widespread utilization of cassava products

One major constraint to the use of cassava products and by-products for ruminant feeding is the problem of obtaining sufficient amounts especially for beef and dairy cattle. By-products such as fufu and gari residues are not produced in sufficiently large quantities at accessible spots for easy collection and feeding to ruminants on a large scale. At present, they can only be used by small-scale farmers to feed sheep and goats.

Although the prospects of cassava leaves in ruminant diets appear promising, little is known about the effect of frequent foliage harvest on root yields. In order to fully exploit the potential feed value of cassava foliage for ruminants, agronomic studies are required to provide information on appropriate varieties for high foliage yield, plant population, cutting intervals and fertilizer practices.

Perhaps the greatest constraint to feeding cassava to ruminants is the problem of cyanide toxicity. Cassava plants possess two cyanogenic glycosides, linamarin and lotaustralin, which are broken down by hydrolytic enzymes present in the plant to hydrocyanic acid (HCN), a toxic compound, and acetone and glucose. The HCN content of cassava varies with variety, growing conditions, age of plant, and the part of plant. Typical values reflecting this variability are 568-950 mg/kg in root bark and 2-200 mg/kg in fresh root pulp.

The level of HCN that causes toxicity in animals is not known precisely, although it has been suggested that levels below 50 mg/kg are harmless. Acute HCN toxicity in ruminants is not common. Devendra (1977) reported a 40 percent mortality in weaned kids fed fresh leaves of a bitter variety containing 180-240 mg/kg of cyanide. Poor performance of ruminants fed on cassava products has sometimes been attributed to chronic HCN toxicity, although other reasons such as low dietary nitrogen could also be responsible. There is evidence that ruminants can use a variety of sulfur donors including elemental sulfur to detoxify cyanide of dietary origin. Thus, Blakley and Coop (1949) have indicated that HCN was rapidly detoxified in the rumen and liver by reactions using sulfide ions or cystine, concluding that approximately 1.2g of sulfur was required to detoxify 1.0g of HCN. Observations by other workers (Wheeler et al. 1975) showed that the supply of sulfur licks to ruminants effectively protected them against chronic cyanide toxicity. Therefore, HCN toxicity should not constitute a constraint to the feeding of cassava products and by-products to ruminants, as simple processing techniques such as sun-drying, ensiling and fermentation combined with the provision of adequate dietary sulfur effectively protect the animals from HCN toxicity.

Future research needs

Some research needs that have been identified by this review are as follows:

- Evaluation of the feeding value of the by-products of cassava processing and the development of feeding systems or packages based on these products.
- Agronomic studies on the production of cassava foliage specifying suitable varieties, plant populations, fertilizer requirements and cutting intervals, among other things.
- Development of appropriate feeding systems for cassava products to ensure optimal response.
- Detailed studies on chronic cyanide toxicity as it affects performance and the role sulfur supplementation could play in alleviating the condition.

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Effect of Protein Deficiency on Utilization of Cassava Peel by Growing Pigs

E. A. Iyayi and O. O. Tewe

Cassava peel has been used to replace maize as an energy source in the diets of growing pigs. 154 weanling crossbred pigs (Landrace x Large White) were provided with either cassava-based or maize-based diets. A 40 percent level of cassava peel in place of maize was adequate for growing pigs. Performance in terms of feed intake and growth rate was enhanced when the diets were supplemented with plant and animal protein sources. A dietary protein level of at least 15 % was necessary for satisfactory animal performance.

The widespread occurrence of cyanide in the *Manihot* species has been largely documented. The role of cyanide in the etiology of diseases such as goitre, cretinism, tropical amblyopia, ataxic neuropathy, and pancreatic diabetes has been demonstrated from clinical and epidemiological studies. In the manifestation of some of these diseases, cyanide may act directly or through its product thiocyanate. Most often, the ingestion of cyanide—either from a dietary source of cassava or other roots or vegetables containing cyanogenic glycosides—requires its detoxification in the body, to thiocyanate. The use of sulfur amino acids for the detoxification process often results in a shortage of these amino acids. Therefore, the introduction of cyanide in situations of low or marginal protein levels in the diets of animals can further aggravate an already critical protein situation. Since cassava is now extensively used in animal production programs, as well as for human consumption, it is important to elucidate the effect of low protein intake on metabolic processes. The studies reported in this paper were conducted to answer the following questions.

- Is a 40% level of cassava peel in diets of pigs suitable for their rearing under tropical conditions?
- What minimum level of protein is permissible in the diets of growing pigs when cassava peel is substituted for maize?

Materials and methods

The cassava peels used were obtained from the Texaco gari factory at Opeji near Abeokuta, Ogun State, Nigeria. They were sun-dried and milled for incorporation into the diets. In the first study, 64 pigs (Landrace x Large White) were weaned for 3 weeks before they were put on eight experimental diets, as shown in table 1. All the diets were isocaloric but diets 1, 3, 5, and

7 were maize-based and had respectively 20, 15, 10 and 5 % dietary protein levels. Diets 2, 4, 6 and 8 were cassava peel-based (at 40% replacement) and also had, respectively 20, 15, 10, and 5 % dietary protein levels. The animals were randomly allocated to treatments on the basis of body weight and sex, with two replicates per treatment.

In the second study, 96 pigs (Landrace x Large White) were weaned and randomly allocated to six experimental diets (table 2), according to body weight and sex. Diets 2, 4, 5, and 6 had respectively 20, 10, 20 and 10 % dietary protein levels. The four diets also contained cassava peel (40%) in place of maize. Diets 1 and 3, based on maize and without cassava peel, were formulated to contain respectively 20 and 10 % dietary protein. Diets 5 and 6 contained added cyanide as potassium cyanide.

Table 1. Composition of diets for animals (Experiment I)

Ingredient (%)	Diet							
	1	2	3	4	5	6	7	8
Yellow maize	51.5	29.0	54.5	42.5	41.0	55.5	23.0	25.5
Cassava peel	nd	40.0	nd	40.0	nd	40.0	nd	40.0
Cassava flour	nd	nd	nd	nd	26.0	nd	64.5	27.0
Groundnut cake	9.0	15.0	9.0	nd	nd	nd	nd	nd
Fish meal	3.0	4.5	3.0	9.0	nd	nd	nd	nd
Blood meal	3.0	4.5	3.0	3.0	nd	nd	nd	nd
Palm oil	nd	4.5	nd	3.0	nd	12.0	10.0	4.0
Wheat bran	31.0	nd	31.0	nd	30.5	nd	nd	nd
Bone meal	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Salt	0.5	0.5	nd	0.5	0.5	0.5	0.5	0.5
Min. /Vit. mix[a]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Protein (%)	20.00	20.00	15.03	15.20	10.01	10.10	5.20	5.15
Metabolizable energy (kcal/kg)[b]	3321.00	3217.00	3220.20	3204.00	3211.30	3222.00	3230.00	3204.60

Notes: [a] Min./Vit. Mix: Zoodry YM501 Vitamin and trace mineral Premix [Content /kg– Vit. A 12000001U, Vit. D 3200000001U, Vit. E 70001U, Vit. B_2 4000mg, Nicotinic acid 15000mg, d-pentothenate 8000mg, Vit. H (Biotin) 40mg, Vit. B_{12} 10mg, and Mn 20000mg, Fe 50000mg, Zn 100000mg, Cu 10000mg, Iodine 750mg, Co 300mg]
nd = not included

Results

Effect of 40% cassava peel level and dietary protein on performance

The mean values of performance parameters are presented in table 3. The levels of cassava peel and dietary protein significantly affected daily feed and dry matter intake ($P<0.01$) and growth rate ($P<0.05$). Pigs on higher levels of cassava peel-based diets had significantly lower ($P<0.01$) feed efficiency. Dietary protein level also had a significant ($P<0.01$) effect on feed efficiency.

Table 2. Gross composition of diets for animals (Experiment II)

Ingredient (%)	Diet					
	1	2	3	4	5	6
Yellow maize	51.5	29.0	41.2	55.5	29.0	55.5
Cassava peel	nd	40.0	nd	40.0	40.0	40.0
Cassava flour	nd	nd	26.0	nd	nd	nd
Groundnut cake	9.0	15.0	nd	nd	15.0	nd
Fish meal	3.0	4.5	nd	nd	4.5	nd
Blood meal	3.0	4.5	nd	nd	4.5	nd
Palm oil	nd	4.5	nd	2.0	4.5	2.0
Wheat bran	31.0	nd	30.2	nd	nd	nd
Bone meal	1.5	1.5	1.5	1.5	1.5	1.5
Salt 0.5	0.5	0.5	0.5	0.5	0.5	
Min./vit. mix [a]	0.5	0.5	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0

Notes: [a] Min/vit. mix: Zoodry YM501 Vitamin and trace mineral Premix [Content/kg—Vit. A 1200000IU, Vit. D 32 000 000IU, Vit. E 7000IU, Vit. B_2 4000mg, Nicotinic acid 15000mg, d-pentothenate 8000 mg,.Vit. H (Biotin) 40mg, Vit. B_{12} 10mg, and Mn 20000mg, Fe 50000mg, Zn 100000mg, Cu 10000mg, Iodine 750mg, Co 300mg]
nd = not included

The protein efficiency ratio of animals on the cassava peel-based diets was poorer ($P<0.05$) than that of animals on the corn-based diets. Table 3 shows that for almost all the performance parameters, a significant ($P<0.05$) difference was recorded between animals on the 15% and 10% dietary protein levels. Animals on the 5% dietary protein level were runty and malnourished.

Table 3. Performance of pigs on experimental diets

Parameter	Cassava peel (%)		Crude protein (%)			
	0	40	20	15	10	5
Initial weight (kg)	11.50	11.80	12.60	11.40	11.50	11.20
Final weight (kg)	30.10	33.52	55.50	30.20	19.30	13.25
Daily weight gain (kg)	0.22b	0.26a	0.51a	0.33b	0.09c	0.03d
Daily feed intake (kg)	0.72b	0.84a	1.33a	0.99b	0.49c	0.32c
Efficiency of feed utilization	5.09b	6.72a	2.64c	3.03c	5.52b	12.44a
Protein efficiency ratio	2.21a	1.90b	2.13a	2.43a	1.99ab	1.68b

Note: Values without common letter on the same horizontal row are significantly different

Discussion

The significantly higher feed consumption of the cassava peel-based diets can be attributed to the supplementation of the diets with rich protein sources and palm oil. Earlier work by Oke (1978) and Tewe (1987) showed that because of its low energy, dustiness, and low protein content, cassava root meal or cassava peel-based diets must be supplemented with rich protein sources and oil in order to improve their palatability and digestibility. Furthermore, such supplementation usually resulted in better profiles of amino acids and essential fatty acids. With respect to the effect of dietary protein, palatability could have played a major role. Since the higher protein diets were supplemented with protein ingredients such as fish meal, blood meal, and groundnut cake, the palatability of such diets could have been enhanced. Shield and Mohan (1980) reported higher feed intake and efficiency for animals on high protein diets.

The growth rate pattern closely follows that of feed consumption. It was clear that higher feed intake enhanced growth. Thus, in this study, apart from the levels of protein in the high protein diets (20 and 15 %) as compared with the low protein diets (10 and 5 %), the better quality of such diets resulted in better growth rates of the animals. More so, the feed efficiency and protein efficiency ratios suggested that the growth rates of animals on the 10 and 5 % protein diets were adversely affected.

The ratios of feed efficiency and protein efficiency for animals on the 20 and 15 % dietary protein levels were not significantly different, but were significantly different at the 10% level for almost all the performance parameters. This showed the 10% protein diet to be largely inferior to the 15% protein diets. Results of the study therefore show that the 10% level of dietary protein is largely unsuitable for rearing pigs, whereas, the 15 and 20 % levels are favorable in terms of performance of the animals. Our present study supports the earlier reports of Job (1975) and Tewe (1975) that dietary protein and not cyanide of the cassava peel was the major factor of concern in feed intake and growth. When pigs were fed sweet and bitter cassava roots, the toxic factor of bitter cassava did not have any inhibitory effect on growth (Job 1975, Tewe 1975). However, because of the interplay between cyanide and protein or more specifically the sulfur amino acids, high levels of cyanide present in some bitter strains of cassava could be a significant factor in the growth of the animals. Thus, the massive introduction of cassava in the presence of marginal levels of protein may result in the manifestation of poor pig growth.

Diets containing 40% cassava peel in place of maize are adequate for growing pigs, especially if such diets are supplemented with protein sources. A dietary protein level of 15% and above results in favorable performance.

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The Use of Cassava for Feeding Rabbits

T.A. Omole

Rabbits could be fed on 30% cassava root meal in their diets without adverse effects on body growth and organ measurements. Higher levels of dietary cassava should be carefully used to avoid the effects of harmful substances in the diet. Supplementation with 0.2% methionine or 2% palm oil is desirable in diets containing up to 4% cassava root meal. The reproductive ability of the rabbit is not impaired by the use of cassava root meal as long as other essential nutrients are supplied in the diet. The cassava peel will require a conscious supplementation of both methionine and dietary fat. About 5% palm oil will be useful for dietary cassava peel beyond the 30% level in the ration. Levels higher than 45% for both cassava root meal and cassava peel should be investigated under varying dietary conditions. Also, there is the need to explore the potential of cassava leaf meal and the various processing conditions that may affect the utilization of cassava root and by-products by rabbits.

The rabbit industry is growing in many countries in Africa today, hence feeding problems associated with poultry and pig farming are now being encountered by rabbit breeders who depend solely on pellets and concentrates for their animals. For backyard rabbit raising, which is widely practiced in most parts of Africa, feeding of green herbage is advantageous, since greens are available all year round in the coastal regions and low plains of the continent. If palatable greens are fed free choice, the amount of pelleted feed needed can be reduced by about 50 percent, with no adverse effects on performance (Cheek et al. 1987). Since most greens have a very high water content, large amounts have to be consumed to meet the nutritional requirements of the rabbit. Because they are noiseless, rabbits can be raised in garages and servants' quarters in urban centres without infringing on the peace of the neighbors. Very little space is usually needed. Cheek et al. (1987) described rabbit meat as a wholesome tasty product. Compared with most other meats, such as beef, chicken, lamb and pork, it is high in protein and low in fat, cholesterol, and sodium. The meat is white, fine-grained, delicately flavored, nutritious, and appetizing (USDA 1963).

The new impetus for rabbit production in Africa amongst a wide range of people creates the need for alternative cheap sources of rabbit feed to replace or supplement cereals in rabbit pellets in order to make rabbit production profitable.

Results by Eshiet et al. (1979) indicate that energy supply in the rabbit diet is critical for maximum utilization of nutrients. Cassava is one of the most productive tropical crops in terms of its energy yield-- 13 times more per hectare than for maize or guinea corn (Oyenuga 1961). The cassava root has an estimated average composition of 60-65 % moisture, 30-35 % carbohydrate, 0.2-0.6 % ether extract, 1-2 % crude protein. It has relatively low content of minerals and vitamins, although it is fairly rich in calcium and ascorbic acid and contains nutritionally significant amounts of thiamine, riboflavin and niacin. However, cassava contains undesirable compounds such as hydrocyanic acid (HCN) released through acid or enzyme hydrolysis of the cyanogenic glucosides, linamarin and lotaustralin, which could make its value as animal feed doubtful. This paper describes experiments in utilization of cassava for feeding rabbits.

Cassava root meal

Growth: Eshiet et al. (1979) fed 0, 15, 30 and 45 % cassava root meal, in isocaloric and isonitrogenous diets, to fryer rabbits. They observed that rabbits could tolerate up to 30% cassava root meal diet without adverse effects on feed intake and rate of growth. The 45 % cassava root level, however, gave poor growth and utilization efficiency. None of the cassava root meal levels influenced the carcass parameters and thiocyanate levels of urine and serum in the rabbits (tables 1 and 2).

Table 1. The effect of feeding graded levels of cassava root meal on the live performance of fryer rabbits

Parameter	Level of CRM[a] (%)			
	0	15	30	45
Rate of gain (g/rabbit/day)	18.25	18.53	18.52	16.72
Feed intake (g/rabbit/day)	24.02c	56.43a	60.54ab	79.92b
Feed/gain	2.63a	3.05b	3.26b	4.78c
Mortality (%)	25.00	12.50	12.50	25.00

Source: Eshiet et al. (1979)
Notes: [a] CRM = cassava root meal
Row means bearing different letters are significantly different ($P<0.05$)

In an attempt to make diets isocaloric the level of palm oil supplementation of the diets was decreased as the cassava root meal was increased to the extent that, while the control diet contained 2.5% palm oil, the 45% cassava root meal diet contained no added fat. This situation made it difficult to establish that 45% cassava root meal may not support a good growth rate for fryer rabbits, since the addition of fat to rabbit diet improves feed utilization (Raimondi et al. 1973). Cassava root meal is also deficient in essential fatty acids. Hudson and Ogunsua (1974) reported that fat in cassava tuberous roots contains 1.46% linoleic acid, which is low compared to the 60.8% in maize (Hilditch and Williams 1974). Omole (1977) indicated that under practical conditions, linoleic acid may be submarginal in cassava root meal diets containing low levels of yellow maize and no added fat. When diets were slightly modified by the addition of 20% palm oil to each diet, and 200g each of green herbage (*Aspilia africana*) was offered every other day, the performance of rabbits fed on 45% cassava root meal was as good as those on the control diet.

Table 2. Effect of cassava root meal on carcass characteristics and serum and urine thiocyanate concentrations of fryer rabbits

Parameter	Level of CRM[a] (%)			
	0	15	30	45
Carcass yield (g/100g live weight)	47.35	50.30	48.14	47.63
Skin (g/100g live weight)	10.03	11.18	9.75	9.00
Kidney (g/100g live weight)	0.56	0.64	0.55	0.53
Liver (g/100g live weight)	3.27	3.13	2.90	2.64
Intestine (g/cm)	0.15	0.17	0.15	0.18
Caecum (g/cm)	0.30	0.29	0.26	0.23
Serum thiocyanate (mg/100ml)	1.59	1.72	1.66	1.76
Urine thiocyanate (mg/100ml)	2.94	3.15	3.15	3.21

Source: Eshiet et al. (1979)
Note: [a] CRM = cassava root meal

Reproduction: Studies at the Obafemi Awolowo University in Nigeria showed that pregnant and lactating does could be fed with up to 45% dietary cassava root meal without any significant effect on litter size, birth weight of pups, and weaning weight of offspring (tables 3, 4, 5, 6 and 7).

Table 3. The effect of cassava root meal on the reproductive performance of rabbits at first breeding

Parameter	Level of CRM[a] (%)			
	0	15	30	45
Initial live weight of does (kg)	1.89	2.01	1.98	2.02
Prebreeding feed intake (g/rabbit/day)	92.93	92.10	93.31	98.05
Feed intake during gestation (g/rabbit/day)	107.74	113.66	111.28	124.17
Gestation length (days)	31.00	30.67	31.25	31.06
Number of pups per litter at:				
Birth	5.00	6.26	6.00	6.00
Weaning	3.00	5.00	4.20	5.67
Weaning weight (kg)	0.52	0.38	0.48	0.36

Source: Eshiet et al. (1980)
Note: [a] CRM = cassava root meal

The lactating dams grew normally on cassava root meal diets. The study covered three breeding periods which recorded striking similarities in reproductive performance between treatments suggesting that cassava root meal diets fed before breeding and during gestation had no adverse effects on the reproductive capacity of the does.

There has been some speculations about the possibility of intraplacental transfer of cyanide or its metabolic product, thiocyanate, from the maternal blood to the embryo. It has, however, been reported that in spite of the constant communication with the dam, the rat embryo appears to be protected from the toxic influences of cyanide or its biotransformation product, thiocyanate (Tewe 1975). Cassava root meal at 4% does not seem to adversely alter the urine and serum thiocyanate levels.

Table 4. Effect of graded levels of cassava root meal on the reproductive performance of rabbits at second breeding

Parameter	Level of CRM[a] (%)			
	0	15	30	45
Number of pups per litter at:				
Birth	6.67	5.67	6.67	5.67
14 days *post partum*	6.67	5.33	4.67	4.00
28 days *post partum*	5.00	4.67	4.00	4.00
Weaning	5.00	4.67	4.00	4.00
Live weight of pups at:				
14 days of age (kg)	0.14	0.15	0.15	0.15
28 days of age (kg)	0.35	0.37	0.34	0.40
Weaning (kg)	0.51	0.53	0.50	0.55

Source: Eshiet, Ademosun and Omole (1980)
Note: [a] CRM = cassava root meal

Table 5. Effect of graded levels of cassava root meal on the reproductive performance of rabbits at third breeding

Parameter	Level of CRM[a] (%)			
	0	15	30	45
Number of pups per litter at:				
Birth	6.00	6.00	6.00	6.00
14 days *post partum*	4.50	5.50	4.50	4.75
28 days *post partum*	4.00	4.00	4.00	4.00
Weaning	3.50	4.00	4.00	4.00
Live weight of pups at:				
14 days of age (kg)	0.19	0.17	0.18	0.19
28 days of age (kg)	0.37	0.35	0.37	0.36
Weaning (kg)	0.49	0.46	0.50	0.46
Serum thiocyanate (mg/100 ml)	1.20	1.26	1.36	1.14
Urine thiocyanate (mg/100 ml)	2.44	2.55	2.35	2.96

Source: Eshiet et al. (1980)
Note: [a] CRM = cassava root meal

Table 6. Effect of cassava root meal on fryer rabbits whose dams have also been on same diets

Parameter	Level of CRM[a] (%)			
	0	15	30	45
Initial live weight at 5 weeks (kg)	0.48	0.47	0.53	0.46
Final live weight at 13 weeks (kg)	1.46	1.38	1.49	1.37
Rate of weight gain (g/rabbit/day)	17.05	16.23	17.01	16.35
Feed intake (g/rabbit/day)	49.28	47.41	49.51	47.96
Feed/gain	2.89	2.93	2.91	2.94
Mortality (%)	0.00	0.00	0.00	0.00

Source: Eshiet et al. (1980)
Note: [a] CRM = Cassava root meal

Table 7. Effect of graded levels of cassava root meal on carcass characteristics, serum and urine thiocyanate of fryer rabbits whose dams have also been on same diets

	Level of CRM[a] (%)			
Parameter	0	15	30	45
Carcass yield (g/100g live weight)	46.86	48.07	49.02	51.55
Skin (g/100g live weight)	9.75	8.80	10.43	9.55
Kidney (g/100g live weight)	0.93	1.01	0.87	0.87
Liver (g/100g live weight)	2.88	2.95	2.98	3.03
Heart (g/100g live weight)	0.42	0.39	0.36	0.37
Pancreas (g/100g live weight)	0.21	0.24	0.20	0.21
Visceral fat (g/100g live weight)	0.60	0.53	0.86	0.67
Length of intestine (m)	2.80	2.20	2.47	2.58
Length of caecum (cm)	33.25	28.50	33.25	31.25
Serum thiocyanate (mg/100ml)	1.31	1.25	1.44	1.39
Urine thiocyanate (mg/100ml)	2.83	3.08	3.21	3.15

Source: Eshiet et al. (1980)
Note: [a] CRM = Cassava root meal

Cassava peel meal

Cassava peel contains 27.9% dry matter, 5.3% crude protein and 1.2% ether extract. It is relatively high in crude fiber (20.97%), and ash (5.93%). It contains 66.6% nitrogen free extract. However, it has a higher HCN content than the pulp.

Omole and Sonaiya (1981) evaluated the utilization of cassava peel meal by rabbits in two separate studies. Rabbits were fed graded levels of up to 40% cassava peel meal with either fishmeal or groundnut cake as the sole supplementation, or these same diets combined with 0.2% methionine supplementation. Cassava peel meal could make up to 40% of the ration of fryer rabbits without any deleterious effects on live performance, especially when fishmeal was used. Significant differences in feed values were associated with protein source rather than with the incorporation of cassava peel meal in the diet, at least to the 40% level, since the fishmeal diets were consistently superior to groundnut cake diets at all levels of cassava peel meal (tables 8 and 9). It appeared that the utilization of cassava peel meal by rabbits was limited by the balance of essential nutrients, especially sulfur amino acids in the diets. Job (1975) reported that methionine or elemental sulfur supplementation significantly improved the efficiency of protein utilization in pigs fed with cassava diets.

The crude fiber content of cassava peel could have significant effects when up to 40% of cassava peel meal is incorporated in the diet. For example, Omole and Onwudike (1981) reported growth depression in rabbits fed diets containing more than 10% crude fiber.

Although the HCN content of cassava peel is higher than that of the root, feeding relatively high levels of cassava peel does not seem to cause any problems of hydrocyanic toxicity, especially when the diet is supplemented with methionine. Serum and urine thiocyanate level of rabbits were not influenced when cassava peel meals were supplemented by methionine, as suggested by the results of Job (1975) on pigs. Maner and Gomez (1973) had noted an increase in urinary thiocyanate level of rats fed on methionine supplemented, cassava-based diets. It seems that supply of sulfur for HCN detoxification of cassava-based diets could take place only after the sulfur-amino acid deficiency in the diet had been taken care of.

Omole and Onwudike (1982) investigated the effects of palm oil in cassava peel diets for rabbits. In one experiment, they fed 0, 10, 20, 30, 40, and 50 % dietary cassava peel meal without dietary palm oil while in another, they included 5% palm oil with the same level of cassava peel meal. It was observed that dietary palm oil improved live performance in all the treatments, including the control that did not contain any cassava peel meal. In both studies, inclusion of up to 30% cassava peel meal seemed to cause no significant depression in growth or feed utilization (tables 10 and 11).

With palm oil supplementation however, judging from the serum thiocyanate level, the inclusion of cassava peel meal could be as high as 50%. Hutagalung (1977) attributed improved performance with feeding palm oil in cassava-based diets to increased energy intake by the animals. Recent reports, however, indicate that palm oil may play some additional role beyond increasing energy intake. Fomunyan et al. (1981) showed that the rate of hydrolysis of the cyanogenic glucosides in cassava to produce the poisonous hydrogen cyanide was greatly reduced with palm oil. They therefore suggested that in animals fed cassava-based diets, supplemented with palm oil, delay in HCN decomposition may prevent absorption of the cyanogenic glucosides.

Cassava leaf meal

There is very litte information on the feeding values of cassava leaf for the rabbit. However, cassava leaf has been used for feeding calves in France (Guin and Andovard 1910), and cattle in Cuba (Osvaldo 1976) and in Madagascar (Seeres 1969). It is considered to be a valuable forage in Brazil, especially during the dry season when most other crops are scarce (Gramacho 1973). Omole (1977) observed that cassava leaf is a good source of protein, fiber, minerals and vitamins. It contains approximately 25 8 to 27.3 % crude

Table 8. Effect of unsupplemented cassava peel meal and protein sources in live performance, carcass measurements, serum and urine thiocyanate levels of growing rabbits

Cassava peel meal (%)	0%		20%		40%		
Protein source[a]	FM	GNC	FM	GNC	FM	GNC	±SEM
Average initial weight (g)	575.6	578.2	580.2	584.7	579.4	582.1	nd
Average final weight (g)	1994.2	1659.7	1936.5	1635.5	1840.5	1453.5	nd
Daily feed intake (g)	76.27b	70.68b	77.26b	71.66b	77.47b	63.02a	3.72
Daily gain (g)	25.34c	19.31ab	24.22c	18.76ab	22.52bc	15.56a	1.97
Feed (g)/gain (g)	3.01a	4.66abc	3.19ab	3.82abc	3.44abc	4.05c	0.34
Liver (% body weight)	2.82	2.63	2.76	2.47	2.54	2.29	0.29
Kidney (% body weight)	0.64	0.55	0.64	0.53	0.59	0.49	0.08
Kidney fat (% body weight)	0.50	0.48	0.59	0.60	0.64	0.66	0.09
Carcass yield (%)	55.45	57.71	56.26	59.63	57.23	59.84	2.74
Serum thiocyanate (mg/100ml)	1.60a	1.59a	1.76ab	1.78ab	1.79ab	1.82b	0.10
Urine thiocyanate (mg/100 ml)	2.95a	2.97a	3.41b	3.33b	3.82b	3.64b	0.21

Source: Omole and Sonaiya (1981)

Notes: [a] Protein source FM = fishmeal, GNC = groundnut cake

Values in each row with different letters are significantly different ($P<0.05$)

nd = not determined

Table 9. Effect of methionine supplementation on live performance, carcass measurements, and serum and urine thiocyanate levels of rabbits fed cassava peel meal with proteins

Cassava peel meal (%)	0%		20%		40%		
Protein source[a]	FM	GNC	FM	GNC	FM	GNC	±SEM
DL Methionine (%)	0.2	0.2	0.2	0.2	0.2	0.2	
Average initial weight (g)	737.8	741.2	742.4	739.5	738.3	745.2	nd
Average final weight (g)	2188.8	1982.2	2155.8	1948.0	2033.6	1717.9	nd
Daily feed intake (g)	77.99b	75.79b	79.51b	81.9b	77.95b	68.79a	3.98
Daily gain (g)	25.91c	22.16bc	25.24bc	21.58b	23.13bc	17.37a	2.07
Feed(g)/gain (g)	3.01a	3.42ab	3.15a	3.79bc	3.7ab	3.96c	0.26
Liver (% body weight)	3.01	2.85	2.97	2.76	2.88	2.69	0.20
Kidney (% body weight)	0.64	0.61	0.64	0.58	0.61	0.53	0.06
Kidney fat (% body weight)	0.42a	0.45a	0.68b	0.62b	0.71b	0.68b	0.07
Carcass yield (%)	54.73	55.18	55.74	56.51	56.37	57.14	2.01
Serum thiocyanate (mg/100 ml)	1.58	1.58	1.67	1.71	1.75	1.77	0.11
Urine thiocyanate (mg/100 ml)	2.94a	2.93a	3.23ab	3.18ab	3.45b	3.39ab	0.24

Source: Omole and Sonaiya (1981)

Notes: [a] Protein source FM = fishmeal, GNC = groundnut cake

Values in each row with different letters are significantly different (P<0.05)

nd=not determined

Table 10. Effect of different levels of cassava meal and supplementary palm oil on live and carcass measurements of growing rabbits

Performance characteristic	Level of cassava peel meal (%) 0	10	20	30	40	50	SE (mean), Level of significance[a]
Average initial weight (g)	617.5	615.8	620.1	622.4	624.5	621.7	nd
Average final weight (g)	1942.5	1969.3	1955.7	1933.9	1663.9	1470.7	nd
Daily feed intake (g)	73.11a	75.17a	72.50a	75.18a	71.84a	69.63a	3.04NS
Daily gain (g)	23.66c	24.17c	23.85c	23.42c	18.56b	15.16a	1.03
Feed(g)/gain (g)	3.09a	3.11a	3.04a	3.21a	3.87b	4.59c	0.31
Liver (% body weight)	3.27a	2.83a	3.01a	2.95a	3.05a	3.07a	0.19NS
Kidney (% body weight)	0.52a	0.53a	0.57a	0.55a	0.49a	0.51a	0.05NS
Carcass yield (%)	56.53a	57.77a	57.86a	58.45a	59.17a	55.64a	1.98NS
Serum thiocyanate (mg/100ml)	1.56a	1.58a	1.57a	1.54a	1.57a	1.53a	0.05NS
Urine thiocyanate (mg/100 ml)	2.87a	2.98a	3.15ab	3.19ab	3.57ab	3.46ab	0.22

Source: Omole and Onwudike (1982)
Notes: Means within a row not followed by the same letter differ significantly
[a] NS = no significant difference at (P<0.05)
nd=not determined

Table 11. Effect of different levels of cassava peel meal on live carcass and organ measurements of growing rabbits

Performance characteristic	Level of cassava peel meal (%)						SE (mean), Level of significance[a]
	0	10	20	30	40	50	
Average initial weight (g)	963.7	958.4	956.5	965.5	959.0	968.0	nd
Average final weight (g)	2179.5	2238.0	2208.7	2079.9	1880.2	1611.2	nd
Daily feed intake (g)	70.56ab	72.89b	70.21ab	70.84ab	68.60ab	65.71a	3.53
Daily gain (g)	21.71c	22.85c	22.36c	19.90c	16.45b	11.65a	1.71
Feed(g)/gain (g)	3.25a	3.19a	3.14a	3.56a	4.17b	5.64c	0.30
Liver (% body weight)	2.95a	2.88a	3.01a	2.93a	2.98a	2.75a	0.18NS
Kidney (% body weight)	0.55a	0.56a	0.61a	0.59a	0.60a	0.60a	0.04NS
Kidney fat (% body weight)	0.39a	0.47ab	0.51ab	0.54ab	0.54ab	0.62b	0.09
Carcass yield (%)	57.34a	55.72a	55.49a	56.38a	57.28a	58.66a	1.57NS
Serum thiocyanate (mg/100ml)	1.59a	1.60a	1.69bc	1.71abc	1.76bc	1.83c	0.07
Urine thiocyanate (mg/100ml)	2.92a	2.98a	3.08a	3.14a	3.16a	3.27a	0.19NS

Source: Omole and Onwudike (1982)

Notes: Means within a row not followed by the same letter differ significantly

[a] NS = no significant difference at (P<0.05)

nd=not determined

protein, 7.6 to 10.5% fat, 5.7 to 8.8% ash, 4.8 to 7.9 % crude fiber and 50.1 to 51.9 % nitrogen free extract, on dry matter basis. The lysine content is considerably high (6.33 to 7.20% of crude protein), but methionine, and probably tryptophan, are deficient (Rogers and Milner 1963). Devendra (1977) observed that the sulfur containing amino acids, cystine and methionine, are low in relation to the others (table 12).

Cassava leaf may be very useful for rabbit nutrition as it compares favorably with alfalfa meal which has proved to be a very desirable feed for rabbits and is the largest single component of commercial rabbit feeds in the USA (Cheek 1987). It also compares favorably with *Aspilia africana* which is often used as the forage feed of rabbits in Africa.

Table 12. Amino acid profile in cassava leaves

Amino acid	Content (g/16g N)
Arginine	5.1
Cystine	1.0
Glycine	4.6
Histidine	2.7
Isoleucine	4.3
Leucine	4.7
Lysine	7.1
Methionine	1.1
Phenylalanine	3.6
Threonine	4.7
Tryptophan	1.0
Tyrosine	3.2
Valine	m6.4

Source: Devendra (1977)

Effect of processing on feeding value of cassava

There is no direct relationship between serum or urinary thiocyanate and growth performance and carcass characteristics in rabbits (Omole and Sonaiya 1981, Omole and Onwudike 1982). However, none of the studies reported for rabbits used a variety of cassava that is high in hydrocyanic acid. It is also possible that rabbits may be less sensitive to HCN intake than some other livestock species. It will be safe, however, to process the cassava products before they are incorporated in the diet.

There are various cassava processing techniques such as cooking, sun-drying, oven-drying, roasting, soaking, ensiling or fermentation and pulping of the tuber. No single processing technique will completely eliminate the HCN content of cassava products. While sun-drying may substantially reduce the

HCN content of cassava tuberous roots, Omole (1977) suggested that the heating process during rapid drying may degrade the hydrolytic enzymes of glucosides and thereby prevent the release of free HCN. These views have been confirmed by Gomez et al. (1984) who indicated that more than 86% of the HCN present in cassava was lost during sun-drying, and also Devendra (1977) who indicated a reduction of HCN by about 50% in oven-drying at 36°C for 24 hours (table 13).

Table 13. The effect of sun-drying on the hydrocyanic acid (HCN) content of cassava leaves

No. hours in sun	HCN content (mg/100kg)
0 hour (fresh)	235
2 hours	470
4 hours	475
6 hours	470
8 hours	445
10 hours	324
24 hours (oven, 36°C)	120

Source: Devendra (1977)

Tewe et al. (1980) suggested that cassava peel, either sun-dried or oven-dried, contained apparently high amounts of cyanide. More studies are needed to determine the form of processed cassava products that will be safe to feed rabbits. The level of reduction of HCN that will be manifested by the processing techniques must be considered along with labor costs and the effects of such processing on other nutrients in the cassava products.

It can be concluded that up to 40 percent of cassava root meal may be incorporated in the diet of fryer rabbits and breeding does, without adverse effects on growth and reproductive ability. Also, when offspring of such dams are fed on cassava root meals, their life performance, carcass characteristics, urine and serum thiocyanate contents are not adversely affected.

It is desirable to feed methionine or fat supplements along with cassava peel meal to enhance the utilization of the feed. If no supplement is fed, the peel should not constitute more than 33% of the diet. Levels higher than 40 percent for both the cassava root meal and the peel should be investigated further, especially under varying dietary and processing conditions. Feeding trials with cassava leaves should be conducted to establish the most economic ways to use cassava leaves in rabbit diets.

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The Potential of Cassava Peel for Feeding Goats in Nigeria

O. J. Ifut

Six rations numbered T_1 to T_6 [T_1: 100% *Gliricidia sepium*, T_2: 100% *Panicum maximum*, T_3: 100% cassava peel, T_4: 35% *G. sepium* + 35% *P. maximum* + 30% cassava peel, T_5: 70% *G. sepium* + 30% cassava peel, and T_6: 70% *P. maximum* + 30% cassava peel] were fed to 24 intact bucks of the West African Dwarf (WAD) breed. Four bucks were randomly assigned to each dietary treatment. The experiment lasted 90 days. Treatment effect on dry matter intake (DMI) was significant ($P<0.05$). Goats on diet T_4 consumed the highest dry matter (DM) and organic matter (OM); those on T_2 consumed the highest acid detergent fiber (ADF) and neutral detergent fiber (NDF), while those on T_1 consumed the highest amount of nitrogen (N). The least N consumption was by goats on diet T_3. Goats on T_3 digested the most DM and OM ($P<0.05$); those on T_2 digested ADF most ($P<0.05$); N and NDF were most digested ($P<0.05$) by goats on T_5; goats on T_3 had negative N digestibility ($P<0.05$). The highest levels of digestible dry matter intake (DDMI) and digestible organic matter intake (DOMI) were by goats on T_4 while those on T_1 had the least DDMI; those on T_2 had the highest digestible ADF intake (DADFI) while those on T_6 received the highest digestible NDF intake (DNDFI); the highest digestible N intake (DNI) was by goats on T_1 while those on T_3 had the least DNI. The diet numbered T_4 significantly ($P<0.05$) promoted positive body weight change while goats on T_3 lost weight daily.

Goats are one of the few trypanotolerant livestock species in the humid zone of Nigeria, where most households keep an average of 9 goats while larger numbers are kept in the savanna parts of the country. FAO (1980) estimated the goat population in Nigeria at 35.7 million.

The major constraint to goat production in Nigeria is the availability of suitable feeds (Adegbola 1982, Olubajo and Oyenuga 1974).

Gliricidia sepium is a perennial fast-growing, highly prolific, leguminous browse plant. The other desirable characteristics of *Gliricidia sepium* have been documented by Thomas (1961), Chadhokar (1982), Falvey and Lindsay (1982), and Sumberg (1984). Its utilization as livestock feed in Nigeria only recently received attention from the International Livestock Centre for Africa (ILCA 1983), Ademosun et al. (1985), Mba, Manigui and Awah (1982), and Onwuka (1983). It has 7.4-34.5 % DM on "as fed" or fresh basis; other contents, on DM basis, are OM (81.9-92.3 %), crude protein (CP, 19.4-26.1 %, i.e. N, 3.1-4.2 %), NDF (30.8 %), crude fiber (CF, 12.7-32.5 %), and 18.5-44.4 % ADF (King 1986, Ngone 1985, Mani 1984, Onwuka 1983, Chadhokar and Sivasupiramaniam 1983, Carew 1983 and Oakes and Skov 1962).

Panicum maximum, a widely distributed grass in Nigeria, is highly relished by ruminant animals. It has 23.5-29.9 % DM at harvest (Gbankoto 1982, Aken'ova and Mohamed-Saleem 1982, Olubajo 1977) and on DM basis, CP content of 4.9-12.8 % (i.e. N, 0.8-2.0 %), and 29.5-49.2 % CF as reported by Gbankoto (1982) and Aken'ova and Mohamed-Saleem (1982).

Cassava peel is a major by-product of the cassava tuberous root processing industry. In parts of Nigeria where cassava is grown and the tubers processed, the peel is largely underutilized as a livestock feed. In Nigeria, the average annual yield of cassava tuberous roots is 21.1t/ha (Hahn and Chukwuma 1986). Since the peel constitutes 20.1 percent of the tuber (Hahn, Chukwuma and Almazan 1986), it follows that about 4.2t of cassava peel per ha are available annually for feeding ruminants, especially goats. The following composition has been reported for cassava peel: residual DM 86.5-94.5 %, OM 89.0-93.9 %, CF 10.0-31.8 %, CP 4.2-6.5 % (i.e. N 0.7-1.0 %) by Onwuka (1983), Carew (1982), Adegbola (1980) and Oyenuga (1968).

An average intake of 21.3g $kg^{-0.75}$ d^{-1} DM of *Gliricidia* has been reported for goats (Ademosun et al. 1985, Onwuka 1983, Carew 1983). Mba et al. (1982) reported values ranging from 31.4 to 50.2 % for kids on *Gliricidia* while Onwuka (1983) reported gains of 20 g/day for goats on sole *Gliricidia* diet.

Information is lacking on intake and utilization of *Gliricidia* + cassava peel, *Panicum* + cassava peel, and *Gliricidia* + *Panicum* + cassava peel when fed to goats. The present study was therefore conducted to assess the potential of cassava peel as a supplement to *Gliricidia*, *Panicum*, or both in goat feed.

Materials and methods

Twenty-four intact bucks, aged 6 to 9 months and weighing an average of 6.05kg (range = 5.0 to 10.0kg), from the University of Ibadan Teaching and Research Farm, were first purged of internal and external parasites with appropriate drugs. They were then housed in previously disinfected individual metabolism cages, and offered liberal but known quantities of experimental diets daily for a 21-day preliminary period to adapt the animals to the diets and the cage environment. Cool fresh water and salt lick were also offered in the cages. During the period, the daily voluntary feed intake was determined. Total faeces and urine from the experimental animal were collected during the following 7 days (days 22-28) and the last 7 days of the experiment (days 84-90). Confinement and feeding continued until day 90. The animals were weighed once a week (on the same day of every week at about the same time of day) in the morning before feeding and watering so as to minimize error due to "gut fill".

Fresh *G. sepium* branches (about 1.2m long and 1.5cm thick) with leaves and branchlets, and fresh *P. maximum*, chopped to about 2.0cm length, were obtained daily from ILCA in Ibadan, between April and July 1985. Cassava peel was obtained fresh from local cassava grating plants in and around the University of Ibadan campus. The peel was sun-dried for 3 to 4 days, depending on the intensity of the sun, packed in jute bags and stacked away in the store on raised wooden planks until required for feeding.

The diets fed to the goats (table 1) were 100% *G. sepium*, 100% *Panicum* *maximum* and 100% cassava peel, in treatments T_1, T_2, and T_3 respectively, and 35% *G. sepium* + 35% *P. maximum* + 30% cassava peel (T_4), 70% *G. sepium* + 30% cassava peel (T_5), and 70% *P. maximum* + 30% cassava peel (T_6). The amount of each diet offered to each experimental animal ensured a 5% leftover. Residues were collected after a 24-h feeding period, then weighed and used to determine the voluntary intake.

Table 1. Feed components in diets offered to West African Dwarf goats

Feed component (% w/w)	Diet					
	T_1	T_2	T_3	T_4	T_5	T_6
Gliricidia	100	0	0	35	70	0
Panicum	0	100	0	35	0	70
Cassava peel	0	0	100	30	30	30

Samples of *G. sepium*, *P. maximum* and cassava peel offered and rejected during the period were collected daily. A subsample of each was dried in a forced draft oven at 100-105°C for 48 h for DM determination. Another subsample was dried at 60°C for 48-72 h for chemical composition analysis. The samples for the whole collection period were bulked, milled in a laboratory hammer mill to pass a 0.6-mm sieve, thoroughly mixed, stored in bottles fitted with air-tight screw caps and kept in a dark cupboard until required for analysis.

Total faeces were collected in the mornings before feeding and watering during days 22-28 and the last 7 days of the experiment. The faeces were weighed fresh and 10% aliquot of each day's collection for each animal was taken, dried at 60°C for 48-72 h in a forced draft oven and bulked. A subsample of faeces from each animal was dried in a forced draft oven at 100-105°C for 48h for DM determination. The two 7-day faecal samples for each experimental animal were thoroughly mixed, milled in a laboratory hammer mill to pass a 0.6 mm sieve and put in sealed polythene bags. These were then stored in a cupboard at room temperature until required for analysis. 5g of the milled faeces were dried in an oven at 100°C-105°C for 48 h to determine its residual moisture content.

Total urine excreted by each experimental animal was collected daily in the morning before feeding and watering. The urine was trapped in a plastic bucket placed under each cage and to which 75ml of 25% H_2SO_4 had been added daily to curtail volatization of ammonia from the urine. The total volume of urine output per animal was measured and aliquots (10%) of daily output were saved in stoppered plastic bottles, numbered and stored in a deep freezer at -5°C. At the end of each 7-day collection period, the sample collections were bulked for each animal and subsamples were taken for analysis.

The milled samples of *G. sepium*, *P. maximum*, cassava peel and faeces were analyzed for DM, OM and N according to AOAC (1975) procedures, and

ADF and NDF according to the methods of Goering and Van Soest (1970) and Van Soest and Robertson (1980).

The data obtained were subjected to analysis of variance. Differences between treatment means were determined by Duncan's Multiple Range Test with computers at IITA, Ibadan, using Genstat V Release 4.04B program of 1984 by Lawes Agricultural Trust (Rothamsted Experimental Station).

Results and discussion

The chemical composition of the experimental diets is shown in table 2. The chemical components of *G. sepium*, *P. maximum* and cassava peel of this study compared favorably with values reported in the literature (Carew 1983, Chadhokar and Sivasupiramaniam 1983, Onwuka 1983, Aken'ova and Mohamed-Saleem 1982, Adegbola 1980, Olubajo 1977, Oyenuga 1968).

Table 2. Chemical composition of *Gliricidia sepium, Panicum maximum* and cassava peel fed to West African Dwarf goats

Chemical component (%)	Diet					
	T_1	T_2	T_3	T_4	T_5	T_6
Dry matter	31.0±0.6	24.7±0.4	86.4±0.2	45.4±0.4	47.7±0.5	43.2±0.3
Organic matter	91.3±1.3	87.7±0.6	89.3±1.8	89.4±1.6	90.7±1.5	88.1±0.9
Acid detergent fiber	28.3±3.7	40.2±1.4	23.9±3.5	31.1±2.8	27.0±3.0	35.3±2.1
Neutral detergent fiber	41.5±3.4	65.5±1.5	34.3±4.3	47.7±3.0	39.3±3.7	56.1±2.3
Nitrogen	3.8±0.1	1.7±0.2	1.0±0.4	2.2±0.2	2.9±0.2	1.5±0.3

Notes: The diets T_1 - T_6 are as composed in table 1

The DM and nutrient intakes by WAD goats are summarized in table 3. The highest DM and OM intakes were from T_4 diet, probably because the combination was palatable. Goats on T_3 had the least DM intake (DMI) despite the low ADF and NDF content of the peel. An inverse relationship has long been reported between the DMI and the fiber content of feed (Reid and

Table 3. Dry matter and nutrient intake (g kg$^{-0.75}$ d^{-1}) by West African Dwarf goats fed *Gliricidia sepium, Panicum maximum* and cassava peel

Nutrient	Diet					
	T_1	T_2	T_3	T_4	T_5	T_6
Dry matter	46.3±12.7c	63.5±8.8b	41.5±1.0c	86.4±7.4a	76.0±3.4ab	73.8±8.6ab
Organic matter	43.0±11.7d	55.1±7.6c	37.7±0.9d	77.3±6.6a	67.5±3.0ab	64.6±7.5bc
Acid detergent fiber	18.7±5.0c	27.5±4.7a	8.3±0.2d	20.8±3.2bc	20.5±1.8bc	26.9±3.7a
Neutral detergent fiber	27.7±7.1dc	44.4±7.0a	10.9±0.7f	36.2±4.8abc	36.9±2.8abc	41.1±5.3ab
Nitrogen	1.8±0.5ab	1.1±0.2d	0.4±0.0e	1.5±0.1bc	1.5±0.1bc	1.1±0.2d

Notes: [a] The diets T_1-T_6 are as composed in table 1
Means with the same letters in each row are not significantly different (P>0.05)

Klopfenstein 1983, Leaver 1974). The least DMI from T_3 was probably due to the lowest N content of the peel. This is supported by Rajpoot et al. (1981), Malachek and Provenza (1981) and Preston and Leng (1986) who had earlier reported that the low N content of feeds significantly (P<0.05) reduced the DMI from such feeds. The results of the present study, however, suggest that the relationship between dietary N content of feed and the feed DMI per metabolic size was rather weak (r=0.03, P<0.05). Nevertheless, the positive though weak relationship between N (or CP) and DMI from diet was similar to the stronger relationship (r=0.86, P<0.05) reported by Lippke (1980).

When dietary N content was correlated with the absolute DMI of the animals, the relationship was negatively significant (r=-0.43, P<0.01). This makes biological sense in terms of nutrient density of the diet because it suggests that an animal offered a low-N diet would tend to consume more of the diet in order to derive more of the needed N from the feed. However, this argument was not supported in the present study because the lowest DMI was recorded for goats on the lowest N containing diet (T_3).

The highest average daily OM intake (OMI) was by goats on T_4 diet. This tended to suggest that goats would benefit more from being fed *Gliricidia*, *Panicum* and cassava peel in approximately equal proportions. However, in the absence of *Panicum*, feeding of 70% *Gliricidia* + 30% cassava peel (T_5) to goats could be beneficial. This is probably because the high N content of *Gliricidia* complemented the high DM content of the cassava peel. The exclusion of *Gliricidia* from the diet would render diet T_6 (70% *Panicum* + 30% cassava peel) the best option for maximum OMI by goats. In general, however, the pattern of OMI followed that of DMI, since OM is an important component of DM.

The highest intake of NDF and ADF was by goats on T_2. The cassava peel (T_3) provided these in the lowest amounts to the experimental animals. The supplementation of 70% *Gliricidia* with 30% cassava peel (T_5) resulted in an ADFI which was 2.5 times, and an NDFI which was 3.4 times, that from T_2. This was probably because *Gliricidia* was more fibrous than the peel; indicating that the combination (T_5) was likely to result in gastrointestinal disorder which the peel alone is prone to induce. The ADFI from T_6 was significantly (P<0.05) the highest among the combined diets probably because *Panicum* contained the greatest amount of ADF. However, there was no significant difference (P>0.05) in NDFI between the treatment diets T_4-T_6.

Dry matter and nutrient digestibility coefficients and digestible DM and digestible nutrient intakes are presented in tables 4 and 5. The DM and OM of T_3 were the most digested by goats (table 3). Consequently, the digestible DM intake (DDMI) and digestible OM intake (DOMI) from T_3 were also the least. This very low DDMI and DOMI by goats on T_3 was reflected in the negative daily body weight change (-54.0g) as shown in table 6. It appears, therefore, that cassava peel alone is not suitable as goat feed. The DM of T_5 was digested most by goats, probably due to a better balance of nutrients resulting from the simultaneous feeding of N-rich *Gliricidia* (70%) and soluble carbohydrate-rich cassava peel (30%). Even the DM digestibility of T_6 was superior (P<0.05) to that of T_2, probably because the readily fermentable carbohydrates of the peel stimulated a large microbial population and acitivity within the gastrointestinal tract.

Diets significantly influenced ($P<0.05$) N digestibility. The N of T_5 was digested most though it was not significantly different ($P>0.05$) from T_1 or T_2.

Table 4. Dry matter and nutrient digestibility coefficients (%) by West African Dwarf goats fed *Gliricidia sepium*, *Panicum maximum* and cassava peel

Nutrient	Diet					
	T_1	T_2	T_3	T_4	T_5	T_6
Dry matter	54.2±5.7d	58.8±0.4d	75.0±1.8a	71.9±0.9ab	74.3±2.4a	65.2±6.7c
Organic matter	56.8±3.9c	61.1±4.4c	77.4±1.9a	73.1±0.9ab	76.6±2.3a	67.5±6.4b
Acid detergent fiber	42.9±5.5c	60.1±2.0a	33.4±0.8d	36.1±2.5d	46.2±3.8bc	58.4±3.3a
Neutral detergent fiber	48.2±6.9dc	54.5±1.7cd	38.6±1.0f	57.4±1.4bc	67.7±2.9a	62.6±7.2ab
Nitrogen	56.5±3.2a	27.1±14.3c	-6.4±0.2d	41.0±0.8b	57.3±3.8a	56.7±5.4a

Notes: The diets T_1-T_6 are as composed in table i
Means with the same letters in each row are not significantly different ($P>0.05$)

Table 5. Digestible dry matter and nutrient intake (g kg$^{-0.75}$ d^{-1}) by West African Dwarf goats fed *Gliricidia sepium*, *Panicum maximum* and cassava peel

Nutrient	Diet					
	T_1	T_2	T_3	T_4	T_5	T_6
Dry matter	25.4±8.8f	37.4±5.4de	31.1±1.5cf	62.1±5.3a	56.4±2.7ab	47.8±5.4bc
Organic matter	24.8±8.6f	33.7±4.9de	29.2±1.4cf	56.5±4.7a	51.7±2.4ab	43.4±4.6c
Acid detergent fiber	8.2±2.8c	16.6±3.3a	2.7±0.1d	7.5±1.2c	9.4±1.2c	15.7±1.7ab
Neutral detergent fiber	13.8±5.4b	24.3±4.5a	4.2±0.2c	20.8±3.2a	24.9±1.8a	25.6±3.3a
Nitrogen	1.0±0.3ab	0.3±0.2e	0.0±0.0f	0.6±0.1cd	0.9±0.1bc	0.6±0.1cd

Notes: [a] The diets T_1-T_6 are as composed in table 1
Means with the same letter in the same row are not significantly different ($P>0.05$)

Table 6. Body weight changes in West African dwarf goats fed *Gliricidia sepium*, *Panicum maximum* and cassava peel

Diet	Daily body weight change (g)
T_1	51.0d
T_2	25.7b
T_3	-54.8a
T_4	66.3f
T_5	54.2e
T_6	41.5c

Notes: The diets T_1-T_6 are as composed in table 1
Means with the same letter within a column are not significantly different ($P>0.05$)

The N digestibility of T_3 was negative due, probably, to the low N content of the peel. This is because the apparent digestibility coefficient of dietary N is dependent mainly upon the proportion of N in the feed. Consequently, T_3 actually reduced the digestible N supply of the goats. Hence, cassava peel is not suitable as the sole feed for goats.

The ADF and NDF of T_3 had the lowest digestibility of all the six diets, indicating that the fibers in the peel are probably resistant to degradation by rumen microbes. The feeding of *Gliricidia*, *Panicum* and cassava peel in almost equal proportions (T_4) did not significantly improve (P>0.05) the ADF digestibility of the cassava peel; the digestibility of ADF in *Gliricidia* and *Panicum* was, however, significantly (P<0.05) reduced. Supplementation of either *Gliricidia* and *Panicum* with 30% cassava peel (T_5 and T_6 respectively) did not seem to have any effect (P>0.05) on the ADF digestibility of either *Gliricidia* and *Panicum*. This suggests that the digestibility of ADF fraction of a feed is only partially affected by other nutrients.

The NDF fraction appears to be of more variable digestibility, depending on the composition of the diet. Diets T_4-T_6 contained NDF which was distinctly superior (P<0.05) in digestibility to that contained in either T_1 or T_3 but not T_2. The NDF digestibility is highest for T_5 and this might have been due to a better balance of nutrients, particularly N from *Gliricidia* and soluble carbohydrates from the cassava peel. It thus appears that the nutritional potential of cassava peel is best realized when fed to goats as a supplement to a leguminous browse feed.

The highest digestible DM intake (DDMI) was by goats on T_4, though this did differ significantly (P>0.05) from T_5.

Similarly, the highest digestible OM intake (DOMI) by goats on T_4 was similar to that by goats on T_5. Both DDMI and DOMI of T_4-T_6 differed significantly (P<0.05) from those of the sole diets T_1-T_3. These results indicated that supplementation of *Gliricidia* and *Panicum* with peel enhanced DDMI and DOMI by goats. Digestible N intake (DNI) from T_4-T_6 was superior (P<0.05) to that from T_2 and T_3. DNI from T_1, however, was similar (P>0.05) to that from T_5 probably due to the high proportion (70%) of *Gliricidia* in it.

Diets had a significant (P<0.05) effect on body weight changes of goats (table 6). Goats on T_3 lost an average of 54.8 g/day probably due to the very low DMI coupled with low N content. This suggests that cassava peel is a poor feed when taken as the sole feed. Trial with T_3 had to be suspended after the initial collection period (day 28) due to excessive body weight loss by the goats. It would, therefore, be undesirable to feed a sole cassava peel diet to goats. The highest daily body weight gain was by goats on T_4, probably because T_4 provided a better balance of nutrients for growth. Goats gained more weight when *Gliricidia* or *Panicum* were supplemented with cassava peel than when each was fed sole. This indicates that cassava peel is potentially beneficial to goats by improving the balance of nutrients.

Earlier workers have indicated inclusion of cassava peel in varying degrees in livestock feeds. Adegbola (1980) concluded that a 10% cassava peel meal inclusion in pig ration induced the fastest rate of weight gain and highest feed conversion efficiency. Onwuka (1983), concluded that 25% cassava peel+75%

browse was the best proportion for goats in terms of intake, digestibility and other performance parameters. In the present study, a 30% level of cassava peel has been shown to be beneficial to goats, but the actual amount of cassava peel suitable for inclusion in goat feeds needs further investigation.

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III

Varietal Improvement of Cassava

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Cassava Varietal Improvement for Processing and Utilization in Livestock Feeds

J.E. Okeke

Cassava improvement in Nigeria is reviewed to highlight research on the development of varieties with such desirable characteristics as: (a) resistance to pests and diseases, (b) high dry matter and starch content, and (c) high dry matter yields for food, animal feeds and industry. The initial approach was to develop varieties that were highly tolerant or resistant to primary biotic stresses, notably cassava bacterial blight (CBB) and cassava mosaic virus (CMV). Subsequently, screening for varieties with high photosynthetic efficiency and important morphological determinants of yield, and later crossing and selecting for high yield and high dry matter content resulted in over 80 recommended improved varieties currently available to Nigerian farmers. Varieties TMS 50395, TMS 91934, NR 8267 and NR 8212 were identified as suitable for animal feeds because of their high dry matter yield, high percent peel and high fibre content. However, high total dry matter yielders with low cyanide are preferred for animal feed.

Cassava improvement in Nigeria started about 1940 (Umanah 1977) with the collection and introduction of superior germplasm for improved yields and resistance against the cassava mosaic virus. The Gold Coast Hybrid (GCH 7) was the first recorded superior material with an average yield of 9 t/ha and a yield improvement of 28 percent over native varieties. Major improvements have since been made over the years, with the development of varieties which yield 2-3 times higher than native varieties.

Research in Nigeria has emphasized the development of high-yielding varieties with good food quality characteristics and resistance/tolerance to pests and diseases. Advances were made from the 1970s with the release of high-yielding varieties which were also resistant to the endemic diseases of native varieties, the cassava mosaic disease (CMD) and cassava bacteria blight (CBB). Selection parameters included starch and dry matter contents, HCN levels and yields of various food products. The heritability of harvest index which is the ratio of root weight to the weight of the entire biomass, was also emphasized during selection. Physiological and developmental processes that determine yield were also recognized in selection. Most of the recommended varieties are high yielders with high harvest indices (0.6-0.7) and less than profuse top growth. However, some of the varieties have partitioning mechanisms equilibrating top and root growths. Such varieties have been identified as good sources of carbohydrates and proteins for animal feeds.

Fresh cassava roots are fed directly to hogs, and for some decades, cassava has been the main carbohydrate base for swine nutrition in Nigeria. Modebe (1963) formulated cassava-based pig rations for exotic breeds in Nigeria, and whole life cycle swine feeding systems using cassava roots have been standardized (Gomez 1977). Until recently, poultry and other classes of livestock were raised exclusively on maize or grain carbohydrate-based feeds. The scarcity and high cost of maize have brought into sharp focus the value of utilizing cassava in the livestock production industry because of special inherent attributes such as high energy yields and continous availability. The demands for cassava roots for food, feed and industry have increased rapidly in recent times, resulting in a changing emphasis in the improvement of the crop. Cassava is a highly efficient plant. The entire top growth, stem, petiole and leaf blades, contain up to 17% crude protein (Mantaldo 1977). A Japanese factory in Thailand exploits this factor by pelletizing the top growth and exporting it to Japan as a protein source for use in animal feeds (Booth and Wholey 1978). Crude protein content of leaf blades ranges from 24-26 % in Nigerian cassava varieties (Okeke 1978). Müller et al. (1974) reported a crude protein content of 23.3% with a good amino acid profile which was low only in methionine and cystine.

The high levels of HCN in Nigerian cassava varieties (150-400 mg/kg) is a major constraint in using cassava meal in animal feed formulation. Oke (1969) reviewed the nutritional implications of HCN in animal feeds and highlighted the toxicity problems. High-yielding cassava varieties with low rates of detoxification during processing would be ideal for the livestock industry. Cassava roots are low in crude protein (2.0-3.2 %) most of which is in the peel. As unpeeled tubers are grated for cassava root meal (CRM), variability in peel content of tubers among varieties is exploitable for animal feeds.

The characteristics of currently recommended improved varieties favoring their use in animal feeds are presented in this paper.

Quantitative biology of cassava varieties suitable for livestock feeds

The entire cassava biomass is valuable to the livestock industry. The top growth is milled or pelleted as a protein source while the underground root tubers provide high energy carbohydrate. Wide variability in shoot morphology exists among cultivars. There are profusely branching types as well as nonbranching or sparsely branching types. There are also tall varieties (>1.5m) and short varieties (<1m) and the point of interception of radiation in a competitive environment is known to correlate with total dry matter production (Okeke 1979). These considerations formed the basis for the selections from recommended improved varieties presented in table 1. In this table, TMS 30572 is most widely adopted in Nigeria because of its good food quality characteristics, disease resistance, and yield superiority over native cultivars. It does not, however, compare favorably with the other four varieties in terms of total dry matter available for livestock and the low performance in this regard, appears to be associated with its low height and less than profuse branching habit.

Table 1. Quantitative characteristics of cassava varieties suitable for livestock feeds

Characteristics	Cassava variety				
	TMS 50395	TMS 91934	NR 8267	NR 8212	TMS 30572
Shoot morphology					
Branching order	5th	5th	4th	4th	3rd/4th
Dominant lobe no.	7	3	7	7	7
Canopy height (cm)	>1m	>1m	>1m	>1.5m	>1m
Dry matter yields (t/ha)					
Roots	8.9	7.9	8	9.8	6.1
Tops	10.8	9.6	9.4	8.2	5.2
Total biomass	19.7	16.5	17.4	18.0	11.3

Biochemical aspects of cassava utilization for livestock

Cassava substitutes for maize in livestock feeds, mainly for dairy and beef cattle, goats, pigs, and chicken up to 40 percent in the European Economic Community (Thanh and Lohani 1978). A 60 percent substitution with good balance in other nutrients was reported by Omole (1977) who also highlighted toxicity problems. Ngoka et al. (1984) substituted cassava root meal (CRM) for maize at levels 0-50-75-100 % in diets for layers, broilers and breeder stock, and recommended substitution up to 75 percent with appropriate processing to detoxify the CRM.

Thus, the toxicity caused by the presence of the cyanogenic glucosides, linamarin and lotaustralin, in cassava is well recognized. Oke (1969) postulated that the affinity of released HCN for metal ions such as copper and iron could pose problems with enzyme systems in chickens. The use of dried chips of high cyanide varieties for chicken, for example, has proved disastrous in feeding trials. A detoxification regime of grating to release bound cyanide, fermentation for 48 hours, dewatering and drying to 15% moisture was necessary to reduce total cyanide from 360 mg/kg to the safe level of 15-20 mg/kg (Okeke 1980).

Low cyanide cassava varieties

The use of low cyanide cassava varieties (<5mg HCN/100g) rather than the more dominant high cyanide (>15mg HCN/100g) varieties for feeds or food would eliminate fermentation in processing. Tubers of low cyanide cassava could be chipped or crushed and dried for use. Native low cyanide cassava varieties are inherently low-yielding and highly susceptible to disease attack. However, the consistently high performance of variety TMS 4(2)1425 over time and space has shown that it is possible to improve low cyanide cassava for high yields and tolerance/resistance to pests and diseases. Variety TMS

4(2)1425 has about 3.1 mgHCN/100g and yields over 20t/ha (IITA 1986). The top growth is however relatively sparse. The ideal cassava for livestock would be the highest aggregate yielder of total dry matter with minimum HCN content.

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The Adoption of Improved Cassava Varieties and their Potential as Livestock Feeds in Southwestern Nigeria

M.O. Akoroda and A.E. Ikpi

The beginning of cassava cultivation along the coastal parts of Nigeria has been recognized as early as 1667 and is traceable to Portuguese explorers and emancipated slaves from Brazil and the West Indies who had landed on the southern coast of Nigeria between the Bonny and Koko ports. Thus, cassava may actually have been introduced into Nigeria over 300 years ago although its systematic cultivation was never generally accepted and practiced until the late 1890s. Cassava became generally accepted and fully integrated into the farming systems of southern Nigeria a little over 130 years ago (Ekandem 1962, 1964; Agboola 1968, 1979).

Agboola (1979) states that cassava was moved from Fernando Po to the Warri area of Nigeria but its cultivation was not widespread until the turn of the nineteenth century. "As late as 1930, cassava had only made little in-road into Iboland". According to Agboola (1968), "emancipated slaves from Brazil, the West Indies, and Sierra Leone who returned to parts of Southern Nigeria after the 1850s, played an important role in stimulating the acceptance of cassava". These returnees; who knew how to process the crop into food, settled largely among the local people of Lagos, Badagry, Abeokuta and Ijebu, to whom they imparted their knowledge and also popularized the consumption of cassava in the local food economy. Eventually, demand for processed forms of cassava (gari, fufu, lafun, etc.) developed.

Cassava is not a principal carbohydrate crop in those parts of Nigeria approximately south of latitude 8°N which is described as southwestern Nigeria. In this zone, enclaves exist where yam, cocoyams and plantain dominate or are equal in importance to cassava.

The southwestern portion of Nigeria lies west of River Niger and south of latitude 8°N. Though diverse, 14 areas (figure 1) can be distinguished that are uniform as regards people, agroecology, farming and food patterns. A straight line from near Ibadan, through Ohosu and Agbor approximately bisects the region (figure 1).

The area has medium to high population densities and is well connected with roads for long hauls of agricultural produce. The dominant tribes are Yoruba, Edo, Ibo, Urhobo and Isoko, all of whom consume cassava as gari—the chief cassava product of commerce.

Research on the improvement of cassava has also been largely undertaken in this area, particularly at Ibadan by the Federal Department of Agricultural Research (FDAR) in Moor Plantation, IITA, and the University of Ibadan.

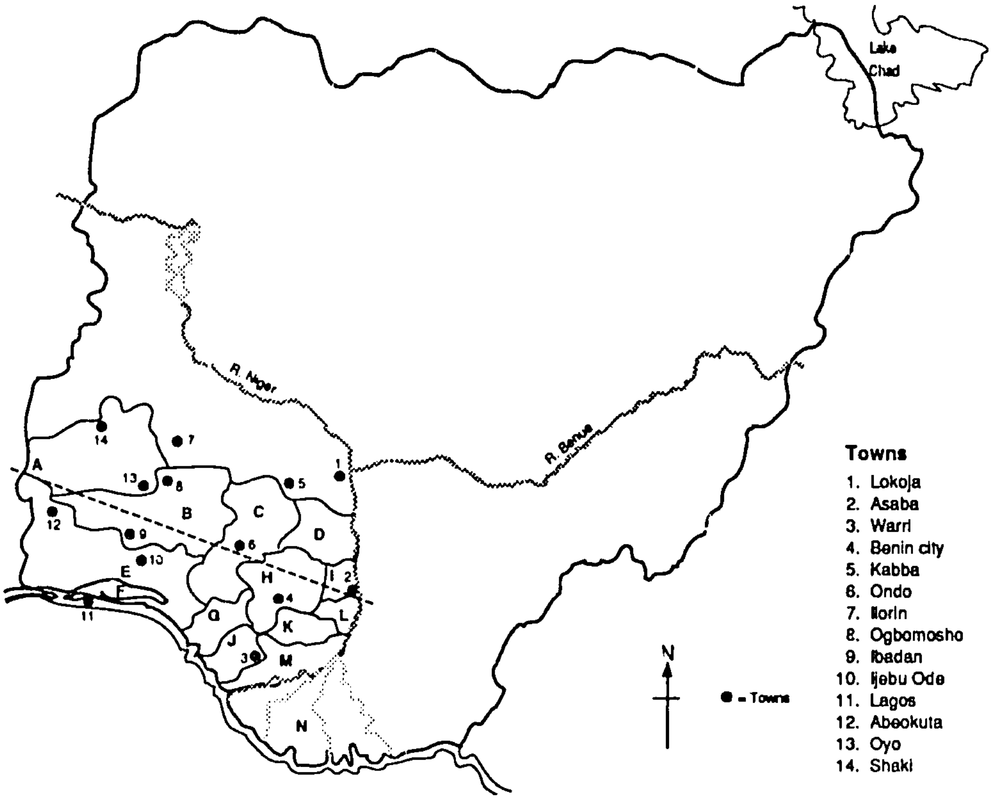

Figure 1: Map of Nigeria showing states in the southwest (Oyo—A, B; Ondo—C, G; Ogun—E; Lagos—F; Bendel—D, H, I, J, K, L, M; and western part of Rivers—N)

Though soil types vary, food crops grown bear little relation to changes in soil types. Sun hours vary widely from 22.5 hr in A to less than 15.0 hr in N (figure 1). Most of this area is within the high rainforest zone with an annual rainfall of 1250-4000 mm, but the average is about 1500 mm.

Cassava varieties in southwestern Nigeria

It had been suggested that before modern research on cassava started in Nigeria in 1954 at the FDAR, Ibadan, there were numerous local ecotypes of traditional clones. These varied in their tuber yields and general tolerance of prevailing pests and diseases. "Oloronto" (53101), a local cultivar from the Ibadan/Abeokuta area, was then recommended for southwestern Nigeria. It was later used in crosses in 1967 which led to the release of improved varieties such as 60444, 60447 and 60506 for the whole country.

In 1972 when cassava bacterial blight (CBB) became a scourge for cassava in the country, only 60506 and a few local types tolerated the disease. Breeding work at IITA later identified improved clones which were released after 1976. Releases of the first two IITA clones, namely TMS 30211 and TMS 30395, were rapidly followed by TMS 30572, TMS 30001, TMS 300017, TMS 30110, TMS 30337, TMS 30555, TMS 4(2)1425 and others (IITA 1984).

These improved varieties differed in their resistance to cassava diseases and pests such as CBB, cassava mosaic virus (CMV), cassava anthracnose disease (CAD), cassava mealybug (CMB) and cassava green spider mite (CGM). They also produced tubers with varying quality of roots at differing maturity duration and storage in the ground (table 1). These improved varieties always gave high yields (Okigbo 1978, Hahn 1983, Herren and Bennett 1984, IITA 1984, and Otoo and Hahn 1987). Farmers preferred improved varieties because of their higher yields, earlier maturity, high supression of weeds, and greater resistance to diverse diseases and pests (Akoroda et al. 1985, 1987; Ikpi et al. 1986).

A wide variety of cassava cultivars can now be observed in farmers' fields but one or two cultivars may occur more frequently in a given zone. Thus, the most commonly observed local cultivars in southwestern Nigeria are (a) "Odongbo" with its reddish petiole, cream-colored stem, moderate branching, and clear white flesh; (b) "Oyarugba dudu" with indeterminate growth habit, dark stem, and cream-colored petiole; (c) "Ege dudu" which is very similar to TMS 30572 and whose origin is suspected to be from IITA's stock dispersed by some extension staff in the early 1970s; and (d) "Isunikankiyan", a high-branching, erect cassava variety with reddish petiole, stem and periderm, usually early-maturing, mealy and sweet.

Normally, a field of cassava in southwestern Nigeria may contain different combinations of all four varieties including some other minor cultivars. However, the most commonly grown local variety in southwestern Nigeria is Odongbo—which bears different names in different parts of southwestern Nigeria, e.g. Jejeti in Warri, Bendel state.

Level of adoption of improved cassava varieties in southwestern Nigeria

The cultivation of improved cassava cultivars in different parts of southwestern Nigeria has been unequal principally because of their levels of yield performance and age of maturity (Otoo and Hahn 1987, Ikpi 1988). Table 1 summarizes the comparative performance of early and recent releases of improved IITA cassava varieties.

More recent releases such as TMS 4(2)1425, TMS 50395, and TMS 30572 are doing much better in farmers' fields than earlier releases such as clones 60506 and TMS 30001 (table 1).

Socioeconomic surveys of cassava adoption in southwestern Nigeria (Ay et al. 1983, Keyser 1984, and Ikpi et al. 1986) confirm that adoption levels depend on many factors, such as: (a) vegetation characteristics of area with regard to its suitability for growing other crops; (b) population density (which influences the number of cassava farmers that could adopt new improved varieties); (c) tribal preferences which restrict cultivation of cassava to poorer farmers who lack land and cash to expand cassava hectarage upon adoption of improved varieties; (d) relative competition with cassava in each locality by other carbohydrate crops, e.g. maize, yam, and plantain; (e) proximity of high density population that does not farm but consumes cassava as gari; (f) local presence and capacity of the propagule distribution agency as source of planting materials for small farmers; and (g) farmers' own perception of overall benefits from improved cassava varieties relative to local varieties. This farmers' perception of benefits is not only based on superior yields of fresh tuber, but also on harvest duration, quality of processed product for food, labor needs and general economics of the improved varieties within local situations.

Table 1: Comparative performance of early and recent improved cassava varieties of IITA in southwestern Nigeria

Variety	Root yield (t/ha)	% of check	Harvest duration (months)	Root HCN content (mg/100g)	Source of clone
TMS 4(2)1425	20.9	211.1	9-15	3.12	IITA
TMS 30001	13.2	133.3	9-15	3.95	IITA
TMS 30572	14.4	145.5	9-15	4.99	IITA
TMS 50395	14.4	145.5	9-15	4.99	IITA
60506 (check)[a]	9.9	100.0	15-18	4.51	FDAR

Source: Umanah (1976), Otoo and Hahn (1987)
Note: [a] Clone used as check in IITA breeding work, yielded 38.7 t/ha before advent of many new diseases and pests

An overview of the level of adoption of improved cassava varieties on a scale of 1 to 5 (where 1 is little or no adoption, and 5 is intense or almost total adoption with over 75 percent of the cassava hectarage being planted with improved varieties) is presented in table 2. An average adoption rate of 2.7 has been observed which is a statistically better-than-average rate of adoption for the zone.

In terms of actual hectarage cultivation of improved versus local/traditional varieties of cassava, Ikpi et al. (1986) showed that in Oyo state alone, there was a 25 percent level of adoption of improved cassava varieties within the cropping systems of the people. A more recent evaluation of 1987 plantings (Ikpi 1988) covering 360 farmer respondents in Oyo, Ondo, and Kwara states, showed that the level of adoption of some of these improved cassava varieties had increased appreciably to 36.0% in Oyo (Oyo State), 47.2% in Oyun (Kwara State) and 34.8% in Owo (Ondo State). This gave an estimated average of 39.3% level of adoption in southwestern Nigeria (table 3). In other words, approximately 34% of the farming population of these three states adopted and planted improved cassava varieties on their farms.

The levels of adoption of improved cassava varieties summarized in table 3 show an annual rate of increase of 11% for Ondo State and 22% for Oyo State, giving a generalized average annual rate of increase of adoption of 16.5% for southwestern Nigeria. At that estimated average annual rate of increase and assuming that all other adoption factors hold, it will take approximately six years from 1988 for all the farmers in the zone to adopt improved varieties of cassava. This should be seen as the challenge of the next decade (1990s) for the national agricultural research system (NARS) and agricultural extension systems.

Table 2. **Environmental variables in relation to the adoption of improved cassava varieties in sectors of southwestern Nigeria**

Sector code	Sector name sector[a]	Main agro-ecology of cultivation[b]	Farmland for food crop staples	Population density	Relative status of cassava to other local	Improved cassava adoption (1 = least 5 = intense)
A	Oyo North	G-D	+	Low	C/M.Y.S.	1-2
B	Oyo South	R	-	High	≥ Y.M.	3-4
C	Ondo Inland	R-D	-	Moderate	C/M.Y.	2-3
D	Bendel North	R-D	+	Low	C=Y.M	1-2
E	Ogun State	R	-	Moderate	<...	4-5
F	Lagos State	M-F	-	High	C≥ Y.M	3-4
G	Ondo Littoral	M-F	-	Low	C≥P	2-3
H	Bendel Edo	R	-	Moderate	C≥ Y.P	3-4
I	Bendel Ibo	R	-	Moderate	C/Y.P	1-2
J	Bendel Warri	M-F	-	Low	C>...	2-3
K	Bendel Ethiope	F	-	Moderate	C>...	4-5
L	Bendel Isoko	F	-	Moderate	C>...	3-4
M	Bendel Ijaw	M-F	-	Low	C=/P	1-2
N	Rivers Ijaw	M-F	-	Low	C/=P	1-2

Notes: *a* G = guinea savanna, D = derived savanna, R = rain forest, M = mangrove swamp forest, and F = freshwater forest
b + is sufficient, - is deficient.
c C = cassava, M = maize, Y = yam, P = plantain, S = sorghum; and the symbols: / is secondary to, = is co-equal with, > is dominant, ≥ is dominant over or co-equal with, ... is other starchy staples.

Table 3. Levels of adoption of improved cassava varieties in Kwara, Oyo and Ondo States of Nigeria

LGA/State[a]	No. of respondents	Average ha. cultivated to level of adoption (%)						Annual rate of increase
		Improved	Local	Total	1985	1987	% change	
Oyun, Kwara	108	0.89	0.66	1.55	na	47.2	nd	nd
Owo, Ondo	112	0.70	1.37	2.07	28.5	34.8	22	11%
Oyo, Oyo	140	0.70	2.13	2.83	25.0	36.0	44	22%
Average	120	0.76	1.39	2.15	na	39.3	nd	16.5%

Source: Ikpi 1988
Note: [a] LGA = Local Government Area
na=not available, nd=not determined

The sociology of cassava adoption and spread

Adoption of improved cassava cultivars begins from the decision of farmers to replace old inferior varieties or to supplement their stock of planting materials with new improved varieties or simply by extending cultivated land areas. Mathematical extrapolations of areas presumed to be plantable from the annual increase of distributed cuttings are insufficient to explain the pattern of adoption of improved varieties.

In southwestern Nigeria, the spread of suitable crop varieties does not usually follow commercial pathways. Family relations and neighborhood friends first receive gifts of cuttings from primary recipients. Occasional sale of propagules occurs only where buyers appreciate the benefit which they could derive from growing such new varieties. Perhaps the most important step in adoption is farmers' awareness of the qualities of improved varieties. Ordinarily, methods used to create awareness among farmers include (a) on-farm trials; (b) demonstration plots controlled by agricultural extension agents; (c) field days for farmers; (d) agricultural shows to which farmers are invited; and (e) personal experience through trial planting, since some farmers are always willing to test any new variety on a small part of their farm.

We believe that awareness promotes demand, and demand is a force for rapid adoption and spread. Where farmers receive some cuttings of a new variety without a proper knowledge of its novelty or superiority, they simply plant it. They do not inspect it or evaluate its performance relative to local varieties. Consequently, the new variety is mix-planted with other varieties and such adoption cannot be followed and assessed.

One social aspect in the distribution of cassava is that the rate of spread from one village to the other is very slow or nonexistent in some cases. Thus, spread is almost confined to within the village. The concept of community multiplication farms particularly in small villages has been tested and proved superior to individual ownership or engagement in propagule multiplication.

Spread from one village to the other also depends on the presence and frequency of contacts which may be familial, commercial, or sociocultural (agricultural shows, communal ceremonies etc.). With better communications by road and water information on the performance of new varieties is circulated more readily through personal contacts. Where the level of adoption in a village is high, that is, the number of growers who agree to continue the cultivation of the new varieties as a percentage of those who originally received it, spread is also likely to be high. This is because more people tend to inform others or move propagules to other localities.

The movement of a variety from one location where it was originally deposited to another location is regarded as spread, which may be of two kinds. First, materials may move from a farmer who has originally received it in location A to a farmer in location B where the material has never been distributed. In the second type of spread, a farmer in location X may send materials to a farmer in location Y where farmers already have the same variety. Both types of spread occur randomly and can be estimated by sample surveys and reconnaissance.

It is necessary to sketch the adoption and spread of new varieties five years after their initial release from a research agency. In this way, early action can be taken to derive more benefits from the potentials of improved cassava varieties.

Many factors govern the adoption of new cassava varieties. Under normal circumstances, the willingness of farmers to test and continue to grow new varieties increases with real yield differences between cassava varieties when they are planted in their own fields with their own level of crop management; the availability of local markets that can absorb all or most of farm output at fair prices; reduced or no increase in demand for family labor for production, processing, transportation, and marketing of produce; and little or no need for new inputs or difficult operations within prevailing cropping systems. One important point is that farmers in many localities differ in their principal motive for cultivating cassava. There are also several microenvironmental variables that combine to influence adoption of new varieties. These variables specifically include (a) road outlet for output from cassava farms; (b) transport system; (c) cost of product relative to that of transportation; (d) the absorptive capacity of local markets to which farmers sell their cassava tuberous roots; (e) quantity of plantable stems that reach a cassava farmer at planting time; and (f) quantities of planting stems from the field of a farmer that are replanted after each harvest of the season's crop.

Some changes are inevitable if new varieties must be used. The duration of crop growth implies new planting and harvesting dates. A 12-month cassava variety must not be harvested in 24 months or at other times. The yield potential of a new variety is usually not attained under peasant farming because of mixture of several varieties, poor crop handling, low soil fertility, crop mixtures, suboptimal stem quality, and stand population. Adoption of varieties does not, therefore, depend only on the presence of inputs which enable farmers to obtain maximum yields.

Cassava as a livestock feed resource

Since the early 1930s cassava has been known and used as a livestock feed substitute instead of grains for poultry and rations. The first large-scale commercial users and adopters of cassava as a livestock feed resource were livestock farmers of the European Economic Community (EEC). Cassava as a substitute resource in livestock feeds became fashionable first because of its relative cheapness compared with grains (especially corn) and later because of the increased demand of corn for human and other industrial uses such as in textiles, breweries and bakeries.

Several nutritional and feeding experiments on the potentials of cassava as a substitute for grain have been carried out since the time Tabayoyong (1935) first incorporated 30% and 60% levels of cassava starch extract into chicken diets (McMillan and Dudley 1941, Klein and Barlowen 1954, Vegt and Penner 1963, Vegt and Stute 1964, Vegt 1966, Barrios and Bressani 1967, Rendon et al. 1969, Montilla et al. 1969, Olson et al. 1969, Montilla 1970, Maust et al. 1972, Chou and Müller 1972, Armas and Chicco 1973, Müller et al. 1974, Hutagalung et al. 1974, Montilla et al. 1975, Adegbola 1976, Enriquez and Ross 1967, Gadelha et al. 1969, Obiora 1978, Olson et al. 1968, Phuah and Hutagalung 1974, Squibb and Wyld 1976, and Adesida 1979). The major findings of these studies may be summarized as follows:

1. Cassava can be substituted as a feed ingredient for corn and/or other grains without negatively affecting poultry feed consumption.
2. The nutritive content and value of cassava meal in livestock feed depends on the cassava variety used, the age of the cassava tuber, and the processing technology used in producing the cassava meal.
3. Low-HCN cassava varieties (sweet) are preferred by chickens to high-HCN cassava varieties (bitter).
4. Levels of substitution of cassava for grain higher than 20% produce deleterious effects on the health of chickens and cause reduction in weight gain and feed conversion efficiency, especially after the fourth week.
5. Excessively fine (powdery) nature of cassava flour influences the feed intake negatively and diminishes consumption of cassava meal.
6. Cassava pellets can be used up to 20% level without any adverse effect on the birds provided that the diets are balanced with other nutrients.
7. The level of cassava substitution in the chicken (especially broiler) ration can be increased beyond 20% by adding 5% animal fat in order to reduce the powdery nature of the cassava-based rations.
8. When added as a moderator in cassava-based poultry rations, methionine improves the quality and utilization of the dietary protein in the ration by detoxifying the prussic acid which is normally released during the hydrolysis of linamarin and lotaustralin in the cassava meal/flour, thereby increasing feed palatability. Without methionine supplementation, birds deteriorate in weight gain at three weeks of age, with significant differences in feed conversion efficiency when cassava levels exceed 20%.
9. Addition of molasses and soybean oil to cassava-based rations does not have any beneficial effects.

10. Addition of animal fat and soybean flour makes cassava-based rations isocaloric and isoproteinaceous and increases digestibility of the protein in the ration.

Three important studies conducted in Nigeria deserve special mention. Adegbola (1976) showed that the quality and utilization of the dietary protein in a properly balanced diet could be improved through the addition of methionine to cassava-based rations. He revealed that the methionine served as the detoxicant of any prussic acid released during the hydrolysis of linamarin and lotaustralin. He also drew attention to the need to relate responses to added methionine in rations to the levels of protein in the diet as well as to the nature and palatability of the feed. He stressed that methionine shares its role with other sulfur-donors such as cystine, thiosulfate and elemental sulfur, but is preferred to the others because it is a metabolizable essential amino acid that yields cystine.

Obiora's study (1978) showed that gari could replace maize in broiler finisher rations. He found that the feed conversion efficiency was best when the feed contained a gari-to-maize ratio of 29:24.5%. He concluded that gari could replace all the maize in a broiler finisher diet or constitute up to 49% of the whole ration without any decrease in growth rate or carcass quality; provided the ration was balanced for protein and amino acids. He gave the best substitution level of gari as 50% or 29% of the whole ration.

Adesida (1979) used a linear programming model to determine least-cost broiler rations that substituted cassava for maize and found that with cassava prices at ₦150.00 per tonne, the optimum mix required a maximum level of 30% cassava and that the cost of feed increased as the price of cassava increased. She also found that there was a gradual reduction in weight gain as cassava levels increased beyond 8% in starter diets.

The economics of cassava as a livestock feed resource

Although studies have been conducted on livestock feeds and feeding using cassava, the economics of substituting cassava for maize has not been systematically considered. Until 1985, cassava was relatively cheap (low priced) in southwestern Nigeria, costing N30.00 for 200 unharvested stands in the field or an estimated ₦120.00 per tonne. By 1988, three years later, cassava prices had increased to between ₦250.00 and N280.00 for 200 unharvested stands in the field, calculated to be equivalent to between ₦1400.00 and ₦1500.00 per tonne of tubers.

At a conversion rate of 25% at which fresh cassava tubers are converted into useable cassava meal or flour that can be incorporated into poultry rations, it is calculated that for every tonne of fresh cassava produced, only 250 kg of cassava flour will be available as livestock feed. Secondly, given that other carbohydrate sources, such as corn, usually constitute a minimum of 75 percent of the weight of finished rations, to prepare 1 tonne of poultry feed using only 20% substitution level of cassava for maize will require 62 kg of cassava meal per tonne of finished ration. This will cost approximately ₦375.00 for the cassava component needed. When included in the costing, the necessary protein, amino acid (methionine) and antibiotic supplementation will increase the price further. For example, incorporating methionine and soybean meal alone will double these costs. Thus, cassava may be substitutable for maize but cost considerations do not give it high recommendation.

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IV

Processing of Cassava

Processing Cassava for Animal Feeds

G.B. Oguntimein

Animal feed has always been a major limiting factor in the growth of the livestock industry in developing countries. Most of the feed ingredients are imported and a large proportion of foreign exchange is spent for this purpose. This paper discusses the unit operations in the production process for cassava chips, pellets, and feed grade single cell protein from cassava roots and by-products, together with current research efforts to improve these processes.

Availability of animal feed is one of the greatest constraints to the expansion of the livestock industry in developing countries. Apart from the high and fluctuating costs, some of the ingredients used in mixed feeds, notably cereal grains, are in high demand for human consumption. In view of the dwindling supply of the conventional feed resources and the shortage of foreign exchange for importation, alternative sources produced locally within these countries are being investigated.

This paper discusses the processing of cassava into animal feed in the form of chips, pellets and feed grade single cell protein. The cassava plant, made up of the roots, leaves and stem, is a good source of carbohydrate and protein as shown in table 1. The different parts of the plant can be used as animal feed. The leaves can be used as silage, dried for feed supplementation and as leaf meal for feed concentrates. The stem can be mixed with leaves and used as ruminant feed, or dried for feed concentrates. The roots can be

Table 1. Percentage composition of cassava plant

	Root		Leaf		Stem
	Fresh	Dry	Fresh	Dry	Dry
Moisture	66.7	12.6	nd	nd	nd
Crude protein	2.6	2.0	7.1	24.1	17.2
Crude fiber	4.9	4.0	1.4	26.0	23.5
Soluble carbohydrate	88.2	75.7	nd	nd	nd
Fat	1.0	0.7	nd	5.0	nd
Ash	3.3	5.0	nd	8.0	nd
Dry matter	nd	87.4	nd	16.1	nd
Nitrogen free extracts	nd	nd	nd	39.9	nd

Note: nd = not determined

chipped or pelletized and used as feed, while the root peel, broken roots, fiber and baggase from starch extraction and gari processing can be dried and used directly as animal feed or as substrate for single cell protein production. The use of cassava root as animal feed is increasing in importance in the developing countries of Latin America and Asia where an export market for this commodity has developed. The European Economic Community imports about 6 million tonnes of cassava annually in the form of pellets or granules. Thailand and Indonesia are the world's largest exporters of dried cassava products, largely in the form of pellets. In Thailand, cassava is almost entirely utilized as cassava pellets and starch for export.

Processing of cassava into chips and pellets

The flow chart for this process is shown in figure 1. The production of chips is an intermediate stage in the production of pellets. There is very little difference in the technologies used at different scales of chip and pellet production. The main difference is in sun-drying and mechanical drying. Chips can be produced by very simple techniques in the household or village as well as on a large mechanized scale.

About 2.5-3.0 tonnes of fresh roots are required for 1 tonne of pellets giving a conversion rate of 33-40 %. The first step can be washing and peeling, depending on the quality of the harvested roots. The amount of soil that

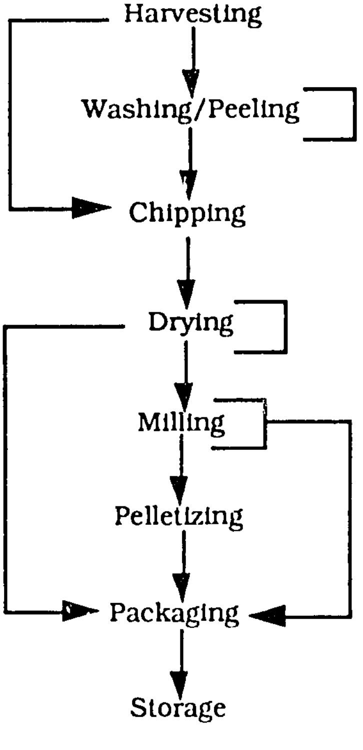

Figure 1: Flow chart for the production of cassava chips and pellets

passes into the final product is largely determined by soil type and weather conditions during harvesting; wet clay soils tend to adhere to the roots. This leads to an increase in the conversion rate but dirt and peel reduce the quality of the final product. After washing, the roots are dipped in a 3% lime solution to neutralize the acid juice and prevent deterioration. The roots are usually cleaned manually in concrete tanks or mechanically in troughs with agitating paddles on a horizontal shaft. The rotating paddles push the roots from one end to the other, while they are washed. Chain conveyors are used to move the roots from the washer outlet to the chipper or to a holding tank where the washed roots drain. This unit is not advisable for a processing plant handling less than 25 tonnes per day because of the huge capital investment needed to establish it.

The next unit operation is chipping. As is common in household processing this is done by hand or by a simple machine which consists of a driven disc with radial chipping slots fitted with cutting blades. There are two common types, the Malaysian and the Thailand models. The Malaysian type consists of a heavy rotating circular steel plate about 12mm thick and 1m in diameter to which six blades are attached. The blade consists of a 1-1.5 mm steel plate that is corrugated at the cutting edge. The chipping wheels are usually mounted in wooden frames incorporating feed hoppers and driven by petrol, diesel, kerosine or electric motors. The Thailand model consists of a thin circular plate made from the ends of a 200-litre oil drum into which cutting edges are chiseled. These crude cutting plates are usually mounted on a fairly standard machine, frequently equipped with small wheels for mobility and a short elevator that deposits the chipped roots into hand carts (Booth and Wholey 1978). In Nigeria, manually operated chippers have been designed and fabricated by the Rural Agro-industrial Development Services (RAIDS) and IITA's Postharvest Unit. The length of the chips depends on the angle of contact of the roots with the blade. The size of the chips varies but generally they are 3-6 mm thick, 6-10 mm wide, 100-250 mm long. The chips produced by the Malaysian-type chipper are more uniform with better geometry and they partially separate the thin brown root skin, which falls to the base of the machines from the chips (Booth and Wholey 1978). The cost of chipping increases as the size of chips gets smaller, since more energy is expended in breaking up the same amount of material (Manurung 1974). The choice of a chipper depends on the scale of operations in the processing plant.

The next unit operation is drying. Drying methods can be classified according to the technological level and cost. Natural drying, one of the methods, is done on cement floors which are sometimes painted black for better absorption of radiant energy or on trays for artificial drying. The factors that affect cassava drying time are the geometry (shape and size) of the cassava chips, the chip loading per unit drying area, air speed, temperature, humidity, radiation, as well as dry matter content of the fresh chips. In artificial heat dryers, all these parameters can be optimized to minimize the drying time and guarantee a high quality product. In natural drying methods, in which the heat source is solar radiation, air speed, temperature, and humidity depend on the environmental conditions, and very little control can be exerted over them. The optimum cassava chip size for natural drying on cement floor or trays is a rectangular shape with dimensions 8x8x50 mm according to Roa (1974). When three different geometrical shapes– rectangular bars 10x10x50 mm, slices 10mm thick, and cubes 10x10x10 mm–were compared in drying trials using static bed dryers with 100mm layers it was found that the cube-shaped cassava chips had the highest drying efficiency. The load of cassava chips per unit area measured in kilograms of fresh product per square meter is a function of the air flow through the chip layer. Chip load for natural drying on cement floor is restricted due to the reduced airflow at the soil level, and depending on the climatic condition, the optimum load is 5-10 kg/m^2. For horizontal trays it is 20-30 kg/m^2 and for vertically loaded trays it is 30-40 kg/m^2. As a result of the higher loading on trays, the capital cost per unit throughout for tray drying is 30 percent less compared to concrete floor drying (Best 1978). In addition, chips dried on trays are better in appearance and more uniformly dried than those dried on concrete floors.

The dry matter content of fresh cassava is affected by several factors such as the variety, harvesting age, and the agronomic conditions, but in general, it ranges between 30-40 %. The selection of varieties with high dry matter content is important because drying time, and labor requirements per tonne of dry cassava are reduced. In case of artificial drying, fuel cost is reduced.

Sun-drying is a very labor intensive operation, requiring about 35-40 laborers per hectare of drying floor.

Artificial dryers

Three types of artificial dryers are commonly used for cassava drying:

1. **Static bed dryer** which is a batch system with low throughput and low heat efficiency. In addition, the product has a nonuniform moisture content.

2. **Moving bed dryers** which allow continuous feeding of wet material from one end and continuous withdrawal of dried product from the other end. They have a higher throughput with uniform moisture content because of better temperature control and higher heating efficiency. The only disadvantage is high fuel consumption.

3. **Rotary dryers** in which the wet material rotates within a cylindrical chamber through which hot air circulates while the product is continuously mixed. The interior surface of the chamber is provided with agitating blades that mix the product as the chamber rotates, forcing the product to fall through the hot air flow. Both concurrent and countercurrent flow configurations are possible. This system has a high drying rate as high air temperatures can be used, though this sometimes results in case hardening and scorching.

The selection of any of these methods of drying depends mostly on the amount of cassava to be dried, the availability of capital and labor cost, as well as the availability of relatively cheap energy.

After drying, the cassava chips are packed in either jute or polyethylene bags, or processed further into pellets. The commercial purpose of pelletizing cassava root products is to decrease the volume by 25-40 percent to produce a uniform product, to facilitate bulk handling during transportation, loading and reloading and to eliminate the dustiness of the product. Pelletizing contributes significantly to the density, durability, and quality of the product. If the chips are big, the cassava chips are first harmmer-milled and then preconditioned. During the preconditioning the moisture content is increased to between 16 and 18 %. This is usually achieved either by spraying water or by adding steam. The addition of moisture and heat increases the effectiveness of the pellet-making machine in terms of output, die life, energy savings, volume reduction, and nutritive value of the product. According to Fetuga and Tewe (1985), the heat generated by steam treatment and the high pressure during pelletization can release the cellulose from the lignin-cellulose bonds, thereby increasing the digestibility of starch and fiber. Pelletization of cassava diets also increases the nutrient density and in this form, about 50 percent root and 20 percent leaves can be used to replace almost all of the cereals and about a third of the soybean meal in a broiler diet.

Pelletization is done in continuous die presses with capacities from 2 to 8 tonnes per hour. The chips are forced through small holes in the die causing a rise in temperature through friction. This gives the pellets cohesion, but also causes considerable wear on the die and makes pelletizing energy intensive, about 60-140 kwh per tonne. The best results are obtained with rather small chips with 13-14 % moisture content which are heated to 65°C and moistened to 15-17% just before pressing. After pressing, the pellets are cooled, during which the moisture content drops to 14%, and packed in jute or polyethylene bags.

Factors affecting the quality of pellets are the composition of the material, protein, starch, fiber, and fat content. Protein-rich materials plasticize when heated and act as a binder to produce strong pellets. Starches gelatinize when heated in the presence of water and also act as binder to produce strong pellets. Fibers are difficult to compress but when they are present in sufficiently fine strands in the pellet, they give toughness to the product. Fats act as lubricants, resulting in easy pressing and therefore high capacity and lower power consumption.

Processing of cassava leaves and stems

Dried cassava leaves and stems have been fed to pigs, poultry, and dairy cattle. The meal produced from them has a nutritive value similar to that of alfalfa though deficient in methionine, isoleucine and threonine (Peyrot 1969, Rojanaridphiced 1977, Normanha 1962). Cassava leaves are a good source of about 20% protein. The amount of protein depends on the stage of growth. The processing of the aerial part of the cassava plant made up of both the leaves and the stem is shown in figure 2. For the extraction of cassava leaf protein, the leaves and the stem are interacted in a chopper or grinder and the juice pressed out. The extracted juice is then coagulated with injection of steam. The pressed cake is sent to the dehydrator. The coagulated juice is

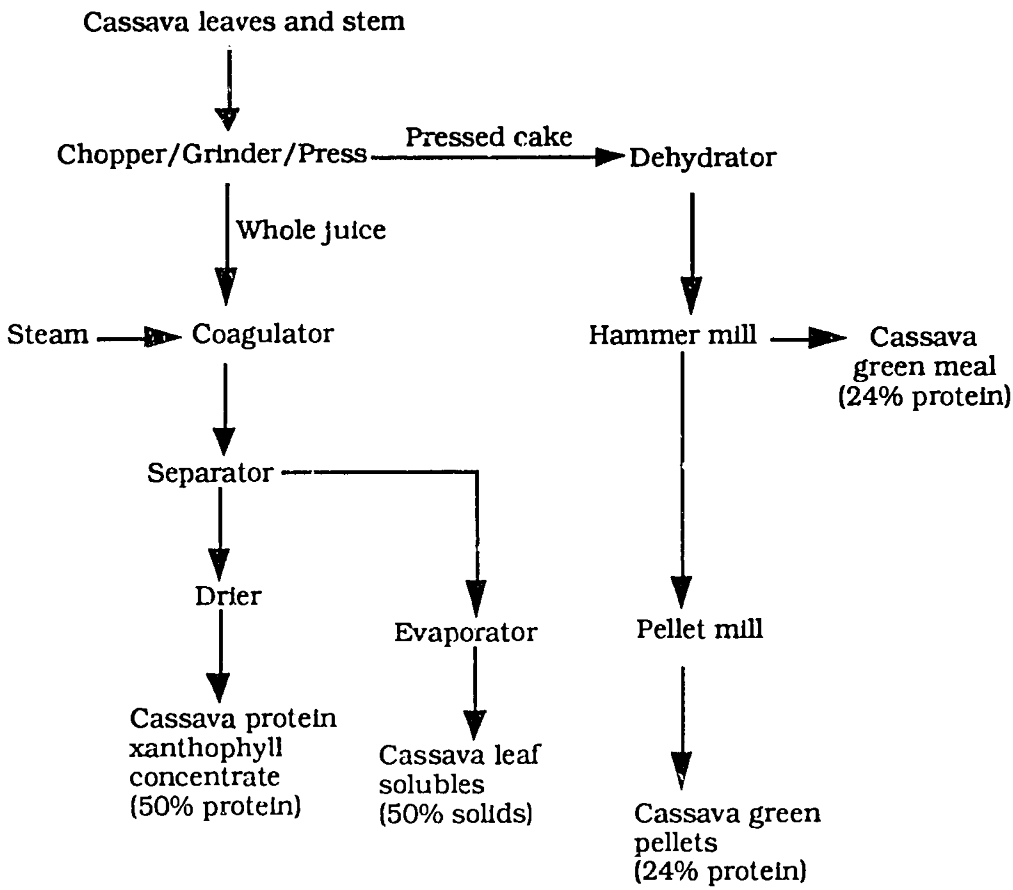

Figure 2: Flow chart for processing cassava leaves and stems

then sent to a separator where the soluble fraction is separated from the green curd and moved to the evaporator where it is concentrated to 50% by volume. The curd is sent to the drier to produce the cassava protein concentrate which is 50% protein (Müller 1977).

Pellets and cassava meal can be produced from either the pressed cake or whole leaves and stem by first passing them through a dehydrator to reduce the moisture content to about 15-20 %. The dried cake is then passed through a hammer mill to produce the cassava green meal which contains about 24% protein. The dried meal can be further processed into pellets by passing through a pellet mill to produce cassava green pellets. Antioxidant is sometimes added at the milling stage.

Production of single cell protein from cassava

The use of cassava as substrate for single cell protein has been investigated since the mid-1960s. Gray and Abou-El-Seoud (1966) grew some filamentous fungi on ground cassava roots, supplemented with ammonium chloride and corn steep liquor, to obtain biomass containing 13-24% crude protein.

Shrassen et al. (1970) described a process in which the yeast *Candida utilis* fermented enzymatically hydrolyzed cassava in a submerged culture to produce a product containing 35% crude protein on a dry weight basis. Gregory (1977) using *Aspergillus fumigatus* 1-21A fermented whole cassava in a nonaseptic continuous fermentation system to produce single cell protein containing 37% crude and 27% true proteins. The fungi was a nonrevertible sporogonous mutant of *A. fumigatus* 1-21. This product was fed to rats and produced good growth responses. *Rhodopseudomonas gelatinosa*, a photosynthetic bacterium, was cultivated on cassava starch medium under aerobic dark and anaerobic light conditions. The optimum temperature for growth was found to be 40°C with maximum growth rate and growth yield of $0.23h^{-1}$ and 0.40g cell/g starch and $0.13h^{-1}$ and 0.83g cell/g starch, respectively for the aerobic dark and anaerobic light conditions (Norparatharaporn et al. 1983). Ghoul and Engasser (1983) developed a process for protein enrichment of cassava by enzymatic hydrolysis and *Candida utilis* fermentation. In this process, cassava starch is first liquefied by thermostable α-amylase and then saccharified by glucoamylase before fed-batch fermentation of the hydrolyzed cassava by *Candida utilis*. A product with 70g/L yeast concentration was obtained after 20 hours of fermentation at a maximal 50% biomass conversion, with 40% crude protein.

Single cell protein can be produced by two types of fermentation processes, namely submerged fermentation and semisolid state fermentation (figure 3). In the submerged process, the substrate to be fermented is always in a liquid which contains the nutrient needed for growth. The substrate is

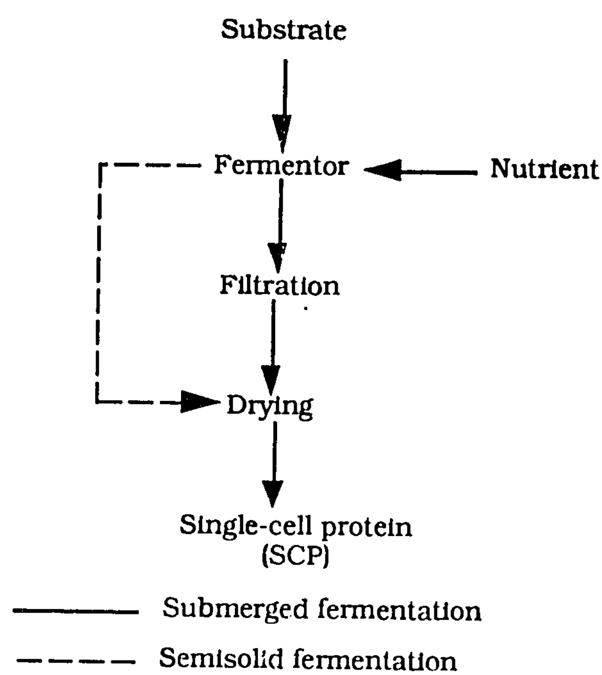

Figure 3: Flow chart for single-cell protein production

held in the fermentor which is operated continuously while the product biomass is continuously harvested. The product is filtered or centrifuged and then dried. For semisolid fermentation, the preparation of the substrate is not as elaborate; it is also more conducive to a solid substrate such as cassava waste. Submerged culture fermentations are more capital intensive and have a higher operating cost when compared with semisolid fermentations which, however, have a lower protein yield. The major proportion of the production cost in most fermentation processes is the cost of the raw materials which can be up to 25-70 percent (Moo-Young et al. 1979). In effect, the cost of cassava will determine the economic feasibility of any single cell protein processed from cassava. In view of the present cost of fresh cassava roots in Nigeria, its use as a substrate is not economic. Thus, the potential of single cell protein from cassava can be realized when fresh cassava roots are cheap.

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Constraints and Projections for Processing and Utilization of Cassava

S. O. Onabowale

The possibility of substituting cassava for maize in the diet of laying and growing chickens was investigated. The hydrogen cyanide contained in cassava was detoxified using three different methods namely: fermentation, acid hydrolysis, and a combination of both. Acid hydrolysis was most effective in removing 98% of the total cyanide content of the cassava tuberous roots while fermentation, combined with acid hydrolysis and fermentation alone, reduced cyanide content by 95% and 87.84% respectively. Detoxified cassava diet was then formulated and used in feeding tests on chickens. Egg production efficiency of chickens fed on the cassava-based formulation was higher (71.43%) than egg production (66.67%) from chickens fed on maize-based ones. In growing chickens, the detoxified cassava rations produced no adverse effect on performance and mortality. An added advantage was that the cassava-based feed was cheaper than the maize-based feed.

Cassava (*Manihot esculenta* Crantz), also known as manioc or yuca in some parts of the world, has been a major food crop in Nigeria for more than a century. Cassava is considered an important source of energy in Nigerian diets. Cassava is known to produce 250 000 calories/hectare/day compared to 200 000 for maize, 176 600 for rice, 114 000 for sorghum and 110 000 for wheat.

Poultry production is an important industry in Nigeria which has more poultry than all other African countries (FAO 1980). Consumption of poultry meat is also increasing faster than that of other kinds of meat in Nigeria. Feed represents a major proportion of the overall production cost in the poultry and livestock industry in Nigeria (Longe and Adetola 1983). A major constraint in the industry is the availability of feed ingredients all the year round at economic prices. This problem is further compounded by the fact that most of these ingredients are imported, at high foreign exchange costs. For example, the amount of maize imported in 1982 cost Nigeria the foreign exchange equivalent of over ₦14 million. Therefore, alternative sources of energy for animal feeds which are nutritionally adequate and cheap must be found locally to reduce the cost. One source of great potential which is increasingly being used for animal feeds is cassava which can completely replace maize in livestock and poultry feed formulation.

Raw cassava roots must be used immediately, processed, or preserved, in order to prevent decomposition. Moreover, the presence of toxic hydrogen cyanide in cassava is a limiting factor in its use as food for man and livestock. Thus, processing helps to remove or reduce the level of toxic cyanogenic glucosides present in the cassava root, as well as altering the availability of the energy of the cassava. Many traditional methods have been developed in various parts of the world for preparing cassava for human consumption and feed. These vary according to the form in which the cassava is to be consumed from simple sun-drying to complex methods involving fermentation (Wyllie et al. 1984). Modern methods of detoxification of cassava for poultry feeds which is highly mechanized has been developed at FIIRO (Federal Institute for Industrial Research, Oshodi, Nigeria) in addition to the traditional processes. These modern methods are used to detoxify cassava, which can then be used to compound poultry feeds.

Mechanized processes of cassava detoxification

Detoxification of cassava whole tubers (unpeeled), cassava waste, and cassava peel for the removal of residual cyanide can be achieved by fermentation, acid hydrolysis, and fermentation followed by acid hydrolysis.

Fermentation process

Washing and grating: The first stage of this process consists of washing the unpeeled cassava tubers which have been previously cut into small sizes, or the cassava waste or cassava peel. The washed cassava samples are then fed through a conveyor to a grater where they are properly grated to specific size.

Fermentation: The grated cassava or the cassava mash is poured into a 400-litre tank which had been constructed from plastic, fiber glass, or such other materials as aluminium. A known quantity of water is added to the cassava mash, mixed thoroughly and left to stand for 24 hours. Because of the toxic hydrogen cyanide given off, it is essential that adequate ventilation is provided.

Dehydration or dewatering: The fermented liquid cassava mash is dewatered, using either a basket centrifuge and hydraulic press or a screw press to produce a thick fermented cassava cake of about 45-47% moisture content.

Drying: The fermented cassava cake is normally broken down into small pieces and fed directly into a fried rotary louvre dryer at temperatures of about 75°- 100°C where the moisture content is further reduced to a low level in order to give dried cassava cake a long shelf life.

Sieving: The dry cassava cake is sieved using a sieving machine with a mesh aperture of 450μm-2mm, 630μm-2mm and 1000μm-2mm for unpeeled cassava tubers, cassava waste, and cassava peel respectively.

Milling and packaging: The oversized particles of cassava cake or grit are milled to the particle size of the sieve, using the Bentall disc attrition milling machine. The final powdery detoxified cassava products are then collected and packaged in cellophane bags ready for use for ration formulation at rates varying from 40-45 % of the concentrate mixture for poultry.

Hydrogen cyanide determination: The hydrogen cyanide levels of the cassava mash before fermentation, after 24 hours fermentation, and of the final detoxified cassava products are determined using the modified method of the AOAC (1972) (table 1).

Acid hydrolysis process
In this process, the washing and grating stage adopted in the fermentation process is also used. In acid treatment process, a known concentration of mineral acid, such as concentrated hydrochloric acid previously diluted with water to give a known strength of the acid, is added to the cassava mash, mixed thoroughly and allowed to stand for 2 hours for acid hydrolysis to take place. This is followed by the neutralization of the acid with a known concentration of mineral alkali such as sodium hydroxide for 5 minutes. Dewatering, drying, sieving, milling, packaging, and hydrogen cyanide determination as in the process of fermentation, are also carried out.

Fermentation coupled with acid hydrolysis process
The cassava is fermented as described in the fermentation process, after which it is subjected to the acid hydrolysis process. Dewatering, drying, sieving, milling, packaging, and hydrogen cyanide determination are also carried out. The detoxification processes of cassava (whole tuber, waste, or peel) for the removal of toxic residual cyanide are shown in figure 1.

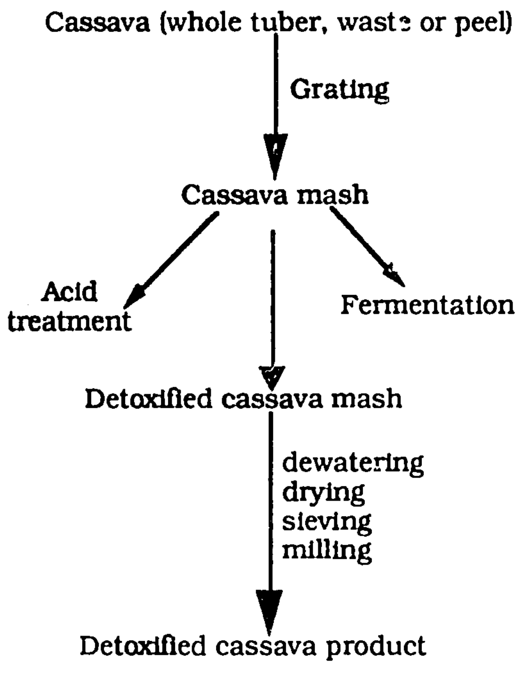

Figure 1: Flow chart for mechanized detoxification processes of cassava for feeds

Table 1. pH and hydrogen cyanide contents during detoxification of cassava

Cassava material	Untreated	After 24 hrs	Final product	% loss HCN	After 24 hrs	After acid hydrolysis	Final product	% loss HCN	Untreated	After acid hydrolysis	Final product	% loss HCN
Unpeeled tuber												
HCN (ppm)	156.00	83.20	18.98	87.84	83.30	15.60	7.80	95.00	156	6.50	3.00	98.00
pH	6.03	5.25	nd	nd	4.17	4.10	nd	nd	6.03	4.04	nd	nd
Cassava peel												
HCN (ppm)	180.00	52.50	18.46	89.75	52.58	14.30	9.10	95.00	180	7.00	4.00	97.73
pH	5.37	3.91	nd	nd	3.78	4.08	nd	nd	5.37	4.30	nd	nd
Cassava waste												
HCN (ppm)	130.00	75.00	20.80	84.00	76.50	12.20	10.40	92.00	143	7.30	4.68	96.73
pH	5.54	3.75	nd	nd	3.80	4.20	nd	nd	5.83	4.70	nd	nd

Note: nd=not determined

The dewatered cassava cake is granulated with a hammer mill to an appropriate particle size that will facilitate heat transfer during drying. The wet detoxified cassava granules are fed into a drier of the tray, the fluidized-bed, or the rotary type and dried to a low moisture content to make it shelf-stable. The close relationship in chemical composition between cassava and maize makes it possible to substitute cassava for maize in the production of livestock and poultry feeds as an energy and cabohydrate source. An example is the cassava peel (table 2). The leaves of cassava, especially in the dried forms, can be incorporated into the ration for pigs, poultry and dairy cattle.

Table 2. Proximate composition of maize and dried cassava peel (% dry matter)

Ingredient	Dry matter	Crude protein	Crude fiber	Ether extract	Ash	Nitrogen-free extract
Maize	86.2	8.8	2.5	3.6	1.4	83.6
Cassava peel	87.6	5.1	15.7	2.1	6.1	71.0

The mechanized process of fermentation is essentially similar to the traditional method, but machinery and equipment have been employed to replace manual labor for unit operations. Also, additional steps have been added to the traditional method in order to confer on the detoxified cassava, and thus the feed, a long shelf-life, good consumer appeal, and improved wholesome conditions.

Utilization of detoxified cassava in poultry feeds

The detoxified cassava products (whole tuber, waste, or peel) have been supplemented with other locally available ingredients and vitamins at FIIRO to provide a complete feed formulation for growing and laying chickens at rates varying from 40 to 50 % of the concentrate mixture. Findings from animal feeding studies show that the detoxified cassava-based feeds compared well with the control (a maize-based commercial product). Egg production efficiency of chickens fed on the cassava-based feed was higher (71.43%) than that (66.67%) in chickens fed on maize-based diet (table 3). In growing chickens, the detoxified cassava-based rations produced no adverse effect on bird performance and mortality; percentage survival was high in all cases.

The cassava-based grower feed also enhanced growth rate which was manifested by the rapid gain in weight of the chickens. The feed conversion efficiency of the cassava-based feed was the same as that of the maize-based commercial feed. The cassava-based feed did not have any adverse effect on the vital organs.

Projections

Investment requirements for a cassava feedmill and the profitability of setting up such a mill depend largely on the cheapness of available cassava. It is also

Table 3. Effects of cassava-based diets on chickens

Parameter	Group		
	Control	Experiment I	Experiment II
Initial body weight(g)	500-1045	585-950	660-870
Average weight gain/week(g)	117.50	209.00	111.28
Survival rate (%)	85	100	88
Average feed intake week(g)	704.78	760.46	689.81
Average water intake/week(ml)	1697.59	1743.94	1458.38
Total no. of eggs produced	96	105	99
Weight of whole egg produced (g)	40.5-60.5	38.4-63.9	40.0-57.8
Egg size (cm)	5.60-8.95	5.35-9.50	6.00
Egg production efficiency (%)	66.67	71.43	61.91
Feed concentrate efficiency (kg/dozen eggs)	2.08	1.99	2.10

Notes: The chickens used for control were on a diet of Mitchell growers and layers feed; chickens for experiment I were on a diet of cassava-based layers and growers feed; and chickens for experiment II were on a diet of cassava-based layers feed.

necessary to project the cost of the equipment/machinery, utilities, and chemicals necessary for the detoxification processes of cassava.

The following lists the required machinery and equipment, utilities and chemicals, along with some of their 1988 costs in Nigeria.

Machinery and equipment

- Cassava grater (4 tonnes/hr)
- Pulper/mixer
- Aluminium tank (400-litre)
- Hydraulic press
- Hammer mill
- Blower
- Packaging equipment
- Weighing scale

Utility requirements

• Clean water	1500 litres/hr
• Electric power	60 kw, 3 phase
• Diesel oil	153 litres
• Polythene bags	12 pieces – N0.53/piece

Current prices of utilities

Water	N18.00
Diesel oil (30 kobo/litre)	N45.90
Electricity for 8 hrs	N33.00
Polythene bags	N6.36
Subtotal	N103.86

Current prices of equipment and chemicals

Cassava grater		₦990.00
Dryer	)	
Mixer	)	
Hydraulic press	)	₦12500.00
Hammer mill	)	
Blower	)	
Aluminium tank		₦1000.00
Concentrated HCl (2.5-litre)		₦40/bottle
Caustic soda pellets		₦40/50kg
Insurance		₦1580.00
Subtotal		₦16 220.00

From these prices, at least ₦16,324 will be required for equipment purchase and installation, chemicals, and utilities. For a cassava plantation, about 1000 acres of land will be necessary. The price per acre varies according to the location and this will directly affect the price of cassava roots per ton.

Constraints

The bulk of cassava grown in Nigeria is produced by peasant smallholders under traditional agricultural practices. Consequently, the average yield is low, ranging from 7-10 tonnes per hectare, which is much lower than the world average of 30-40 tonnes per hectare.

Moreover, the cost of cassava has been unstable during the last five years. Increased labor wages for planting and harvesting and increased cost of transporting harvested tubers to processing plants as well as erratic climatic patterns seem to have affected the price of cassava.

Another constraint of utilizing cassava for feed is the competition for cassava by man for food and industry. Cassava is utilized in the production of gari, fufu, cassava flour for human consumption, and for industrial starch used in textile industry. Thus, the amount of cassava available for the production of animal feed is very much reduced.

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V

Cassava Utilization in Selected Countries

The Use of Cassava in Broiler Diets in Côte d'Ivoire: Effects on Growth Performance and Feed Costs

Y.O. Tiémoko

In recent years, poultry farming has increased throughout the world, especially in developing countries. According to the projections for the year 2000, overall world production of poultry will increase twofold, while the increase in developing countries alone will be threefold. Although poultry farming supplies the populations in large urban centres with animal proteins, it should be acknowledged that this form of farming is very expensive and depends mainly on imported inputs. This form of rearing essentially requires chicks from selected stocks and whole feeds made from raw materials which are mainly imported.

There is a pressing need to explore the use of local foodstuffs, hitherto underexploited by poultry farmers in order to reduce feed costs and the dependence of local production on imports. Among the many products which could be used to develop feed for poultry, cassava is of special importance.

Cassava has a high production potential and can adapt to different types of soils. It is an energy source which could take the place of maize or other cereals used for feeding poultry in tropical Africa. Cassava roots can be used to make flour with an energy value of more than 3000 kcal of metabolizable energy per kg (Müller and Chou 1974, Stevenson and Jackson 1983, Kirchgessner 1985). Cassava tuberous roots have not always been properly used because of their high linamarin content. Linamarin is a cyanogenic glucoside which releases highly toxic cyanide (HCN) during hydrolysis at the time of digestion (Scott et al. 1976, Stevenson and Jackson 1983, Preston 1987).

Cyanide is believed to be responsible for many of the poor results obtained when using cassava to feed livestock although only little accurate information on the effective incidence of the HCN rate on the performance of animals is available (Gomez 1985). Experiments conducted using cassava flour have given somewhat contradictory results. Müller and Chou (1974) and Stevenson and Jackson (1983) report that a rate of up to 50 percent of cassava in the diet by no means impaired the growth performance of poultry, whereas Longe and Oluyemi (1977) as well as Willie and Kinabo (1980) observed a linear decrease in the weight of poultry resulting from the increase in the quantity of cassava included in the ration. Gomez (1985) showed that diets including more than 10 to 20 percent of cassava varieties with low or high HCN contents gave similar results.

The aim of this paper is to briefly consider the effects of incorporating cassava flour as a substitute for maize in broiler diets by closely observing the growth performance of the animals. The socioeconomic constraints which hamper the use of cassava as food for livestock, i.e. the opportunity cost of cassava for human nutrition, will also be discussed.

Materials and methods

Five hundred one-day old chicks obtained from the industrial cross of broilers (improved stock) were reared in a henhouse on the ground until they were 7 weeks old. During the first 29 days, the birds were given a conventional diet of 2900 kcal/kg with 22% protein. During the experimental phase ranging from the 29th to the 49th day, four isoenergetic and isoproteinaceous diets including 0%, 10%, 20% and 30% cassava were given in replacement of maize (table 1). A fifth diet included a commercial product. The daily feed consumption, live weight and mortality rate of the birds were recorded for each treatment.

Table 1. Composition of the experimental rations

	Percentage of cassava in the ration			
Raw materials	0%	10%	20%	30%
Ingredients				
Maize	60	50	40	32
Cassava flour	0	10	20	30
Rice flour	12	14	13	10
Cottonseed cake	7	8	7	6
Soybean cake	6	7	7	7
Fish flour	9	9	11	13
Wheat middling	4	0	0	0
Premix[a]	2	2	2	2
Nutrients[b]				
Energy (kcal ME/kg)	2992	2995	2989	2989
Protein (%)	19.08	19.10	18.96	18.90
Lysine (%)	1.02	1.03	1.07	1.12
Methionine (%)	0.40	0.40	0.42	0.43
Methionine + cystine (%)	0.71	0.70	0.70	0.71
Calcium (%)	1.00	1.00	1.12	1.26
Available phosphorus (%)	0.56	0.57	0.61	0.66
Cellulose(%)	3.80	3.70	3.60	3.40

Notes: [a] One kg of Premix provides phosphorus 2.1g, calcium 3.4g, sodium 1.54g, magnesium 0.25g, manganese 120mg, zinc 80mg, iron 48mg, copper 0.4mg, cobalt 0.2mg, flavomycine 2mg, vit. A 10000 IU, vit. D 31000 IU, vit. E 10mg, vit. B_1 1.6mg, vit. B_2 3.2mg, vit. B_6 2.4mg, vit. B_{12} 8mg, folic acid 0.6mg, pantothenic acid 14mg, choline 80mg, vit. K_3 2mg

[b] Data based on INRA (1984)

A simulated study was carried out to determine the advantage of cassava over maize, assuming that the incorporation of cassava in the diet had no adverse effect on the growth performance of animals. The simulation determined the price limit for cassava to remain competitive with that of maize in a minimum cost diet for broilers.

Results and discussion

The incorporation of cassava flour in poultry diet at rates ranging from 10% to 30% did not affect the final weight or the gain in weight ($P > 0.05$) of the chickens (table 2). If the rate exceeded 10%, however, the feed consumption index increased, resulting in a decrease in the nutritional efficiency of the diet. The simulated economic study enabled us to calculate the "interest" price of cassava as a feed for broilers. Considering that the price of maize was 70 CFA/kg and taking into account the prices and nutritional values of other available raw materials, the minimum cost price for cassava-based diet was calculated at 52.73 CFA/kg. If cassava is sold below this price, the minimum cost diet including 51.5% cassava and maize (at 70 CFA/kg) was rejected. However, when cassava exceeded this top price, maize was a more economical energy source (table 3).

Table 2. Effect of cassava on the growth performance of broilers

	Percentage of cassava in ration				Commercial check
	0%	10%	20%	30%	
Live weight at 49 days old (g)	1657a	1617a	1610a	1623a	1656a
Weight gain (29-49 days)	977a	936a	930a	943a	976a
Food consumption (29-49 days)	2471	2361	2615	2789	2618
Consumption index (29-49 days)	2.53a	2.52a	2.81a	2.96a	2.68a

Note: The mean values on the same row followed by the same letter are not significantly different ($P > 0.05$)

The weight gain performance observed during this experiment corroborated the results obtained by Chou et al. (1974), and Stevenson and Jackson (1983), but contradicted those of Longe and Oluyemi (1977) as well as Wyllie and Kinabo (1980), who observed a negative correlation between the rate of cassava in the diet and the growth of broilers.

The rate of incorporation of cassava seemed to adversely affect the shelf life of the feed when served in the form of flour, whereas the use of pellets containing up to 50% (Stevenson and Jackson 1983) and 58% cassava (Müller and Chou 1974) did not affect the consumption index of broilers and resulted in a better storage capacity of the cassava-based diets. The use of flour was not satisfactory in terms of storage efficiency, especially when the incorporation rate of the product exceeded 10% (Müller and Chou 1974, Yeong et al. 1978, Wyllie and Kinabo 1980).

Table 3. Effect of cassava price fluctuations on the composition of a growth ration

Raw material	Ration cost 50 CFA/kg	52 CFA/kg	53 CFA/kg
	% ingredient		
Maize	0.0	0.0	43.5
Cassava	51.5	51.5	0.0
Cottonseed cake	10.0	10.0	10.0
Fish flour	12.0	12.0	12.0
Soybean cake	8.4	8.4	2.3
Wheat middling	11.5	11.5	24.0
Salt (NaCl)	0.2	0.2	0.2
Palm oil	4.2	4.2	4.0
DL Methionine	0.2	0.2	0.0
Premix	2.0	23.0	2.0
Cost (CFA/kg)	87.8	88.8	89.2

Note: The growth ration was a 3000 kcal metabolizable energy per kg, 19% protein diet

The apparent heterogeneity of the results obtained on cassava was due to the great variability of the energy value of the product. The quality of cassava is very heterogeneous and its energy value varies considerably with the proportion of cellulose and silica it contains (INRA 1984). Müller and Chou (1974) showed that the use of cassava in the form of pellets improved its nutritional efficiency since starch and cellulose were better absorbed. Moreover, these authors observed that by subjecting the pellets to heat treatment during preparation certain growth inhibitors contained in cassava were destroyed. Longe and Oluyemi (1977) have shown that the age of broilers affected their digestion of the starch present in cassava, and digestion seemed to improve with age.

There is considerable literature on the use of cassava for animal feeding (Gomez 1985). However, only little information is available on the economic advantage resulting from its use. This is surprising because economic considerations are of paramount importance, since cereals can be replaced by cassava only if the nutritionally equivalent mixture of cassava with proteinaceous foodstuffs is cheaper than feed prepared with cereals (Müller and Chou 1974). The previous study showed that under the economic conditions described above the price of cassava must not exceed 75 percent of that of maize used as a reference, if it is to compete successfully with maize. If market prices of cassava in Côte d'Ivoire are considered, this condition is rarely met. The price paid for cassava is generally high and often greater than the price of maize. Under present market conditions, it seems that the opportunity cost of cassava for human consumption exceeds its value for animal feeding. This illustrates the major role of cassava in the nutrition of the rural populations of Africa where this tuber crop provides over 200 million people with 50 percent of their calorific needs (Hahn 1985). In southeast Asia and Latin America where cassava is widely produced, consumption is rather low (24 and 35 kg/pers/year respectively), whereas in Africa it reaches 102kg and can even go up to 300kg or more in certain countries of Central Africa (Truman 1985).

There is no doubt that cassava can replace cereals as an energy source for animal feeding in Africa. However, cassava is still a subsistence crop in Africa rather than a competitive commercial commodity because of the limited size of farms, the poor productivity of the crop (an average of 6.5 tons/ha), and the lack of facilities for efficient processing and distribution.

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Evaluation of Cassava as Energy Source in Dairy Cow Concentrate Feeds in Kenya

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Results are presented of two experiments carried out to investigate the optimal inclusion level of cassava root meal (CRM) in dairy concentrates using, respectively 12 and 10 lactating cows in 3x3 and 2x2 latin square designs. The treatments included isonitrogenous diets A, B, C containing 0, 200 or 450 g/kg CRM respectively in experiment I, and diets A and B with 0 or 570 g/kg CRM respectively in experiment II. Total substitution of maize meal with cassava had no significant effect on the in vivo digestibility of either the dry matter or organic matter. Complete substitution of maize meal with cassava meal was economical and was associated with a reduction in the feed cost of Ksh. 328 (US $10) per tonne. Thus, cassava meal is an acceptable ingredient in concentrate feeds and it can totally replace maize meal in the concentrate diets for cows producing approximately 12kg of milk per day.

Cassava (*Manihot esculenta* Crantz) is widely grown in many tropical countries for its edible roots. In Kenya, the main producing areas are western and coastal regions, below 1500m (Acland 1973). The cassava plant is tolerant to drought, it can produce relatively high yields in soils of low fertility, and can withstand suboptimal agronomic conditions. These qualities make cassava an ideal crop for semiarid areas of Kenya which are being inhabited by people moving from high to low potential areas because of high human population pressures.

In 1988, the area estimated to be under cassava cultivation in Kenya was 53 500 ha and the projected production was 450 000 tonnes. This gives an average yield of 8 tonnes/ha. However, the yields can be as high as 25 tonnes/ha (Acland 1973).

Most of the roots produced are consumed in the households, and the surplus is sold in local markets. At the Kenya coast, some of the fresh roots are sold to the cassava starch manufacturing factory. Domestic demand for cassava food fluctuates according to the supply of cassava substitutes (mainly maize) and market prices vary according to the supply. In the producing areas, particularly in western Kenya, cassava is sold in the market in the form of dry chips. The fresh roots are peeled, cut into chips and fermented before sun-drying or just sun-dried after being cut into chips. Fermentation and sun-drying reduce the content of the cyanogenic glucosides (Ravindra et al. 1983). Cassava, a high calorie and low protein (about 2-2.5%) source, needs to be combined with complementary protein sources such as oil seed cakes and/or nonprotein nitrogen compounds such as urea in animal feeds.

Information on the use of cassava as livestock feed is scanty. Abate (1981) noted a decrease in the growth rate of beef calves offered a concentrate diet containing cassava as the main source of energy. Also, dairy cows receiving cassava root meal (CRM) as the sole concentrate ration showed no significant reduction in milk yield (Anon. 1984). Work from other countries indicate that cassava root meal can replace cereals such as oats (Mathur et al. 1969) and barley (Brigstocke et al. 1981) in dairy cow concentrate diet as the main source of energy. In these trials there was comparable performance in milk yield, butterfat and liveweight gains. Brigstocke et al. (1981) also noted that diets containing cassava were cheaper. Animals on CRM-based diets have been shown to require higher mineral supplementation, particularly sulfur, than those fed on cereal-based diets (Lisovets and Lipyenchik 1982).

In Kenya, the energy component of the concentrate rations in livestock feed is mainly supplied by cereals and the by-products of cereal milling industries, with maize being the most widely used. Maize is also a staple food of most people apart from its being used in the formulation of monogastric diets, hence, there is need to exploit alternative sources of energy in animal feed formulation to release more maize for human consumption.

The purpose of the experiments described here was to evaluate the potential of CRM as energy source in the dairy concentrate feed in order to identify the optimal inclusion level.

Materials and methods

Diets: In experiment I, ground cassava chips and maize meal were used as main energy sources in formulating three isonitrogenous concentrate rations. The levels of both ingredients were varied to determine the effect of partial replacement of maize with CRM on milk yield. The dry cassava chips were mainly the peeled and fermented type, procured from local markets in western Kenya. The concentrate diet without cassava had maize inclusion level of 546 g/kg whereas those with cassava had reduced maize levels of 346 and 96 g/kg respectively. These concentrate diets are denoted as rations A, B and C, as shown in table 1.

For experiment II the same feed ingredients as in experiment I were used, but molasses was included to formulate two isonitrogenous concentrate rations. Ration A had maize at a level of 570 g/kg while ration B had CRM replacing all the maize at the same level. Molasses was added at a level of 2% to reduce dustiness and to improve the palatability of the cassava diet which had urea. The detailed formulation of the diets is shown in table 1.

Animal and experimental design: In experiment I twelve cows, four each of Friesian, Ayrshire, and their F_1 cross—in 2nd-4th week lactation and 4th-20th week lactation—were divided into four groups with one cow of each genotype in each group. The animals varied in liveweight from 366kg to 470kg at the beginning of the experiment. They were allocated to the three treatments in a 3x3 latin square design which was replicated four times to consist of three periods each of 30 days, 7 days being allowed for adaptation to different diets and 23 days as the feeding period. Period 2 however had an adjustment period of 12 days because two animals had to be replaced in group III, one because of chronic eye problem and the other due to misrecording of her genotype. Similarly, one animal was replaced in group IV because of lameness.

Table 1. **The physical composition of the concentrate diets based on maize and cassava root meal (g/kg, air dry basis)**

Ingredient	Experiment I			Experiment II	
	A	B	C	A	B
Maize meal	546	346	96	570	0
Cassava root meal	0	200	450	0	570
Cotton seed cake	318	318	318	290	290
Wheat bran	136	136	136	110	110
Molasses	0	0	0	30	30
Urea (46% N)	0	4.8	10.8	0	19.6
Mineral premix[a]	30	35	35	30	35
Cost per kg[b]	3.79	3.71	3.53	3.81	3.48

Notes: [a] The mineral premix as Maclik from Wellcome Kenya Ltd.
[b] The costs per kg of diet are for 1988, in Ksh (Kenya shillings)

For experiment II, ten cows in 2nd-5th week lactation and 7th-28th week lactation were divided into five pairs according to their milk yield during the previous two weeks. They weighed an average of 460kg at the commencement of the experiment. The experimental design was a 2x2 latin square with five replications. Two periods, each of 42 days, with 14 days for adjustment to the diets were used in the trial.

Feeding and management of the animals: In both experiments, the cows grazed pastures predominantly composed of Rhodes grass (*Chloris gayana*) from 0800 to 1530 h and were offered the concentrate feed at each milking around 0700 and 1600 h everyday. Concentrates were fed according to the mean weekly milk yield, at the rate of 400 g/kg of milk produced, and were offered in two equal portions, one for each milking.

Milk yield was recorded at each milking and butterfat content was determined. The cows were weighed once a week and accorded other normal management practices.

Intake and digestibility: In a supplementary trial, the digestibility of the concentrate rations in each experiment was determined in conventional metabolism stalls using steers. The basal diet of chopped grass hay (mainly *Themeda* spp.) was fed, allowing feed residue of 20 percent. In experiment I, three steers per ration with mean weights ranging from 462-510 kg were used during a collection period of 7 days, following an adjustment period of 16 days. The concentrates were fed at a rate of 6 kg/steer/day, a figure obtained from an average amount of concentrate consumed by the cows when on the feeding trial. In experiment II, four steers per ration, with mean weights ranging from 272-278 kg, were used over collection and adjustment periods similar to those in experiment I. The steers received concentrates at an average daily rate of 5 kg/steer.

Analytical methods: The analytical methods followed in both experiments were similar. Two samples of milk were taken once each period from morning and evening milk for butterfat determination once every 2 weeks. Fresh feed and fecal samples were pooled at the end of the digestibility experiments and subsamples taken for analysis according to AOAC (1975).

Since three cows were introduced into experiment I, their missing values (milk yield, butterfat and body weight from period 1) were estimated using the missing data technique in a latin square (Kwanchai and Arturo 1984).

Digestibility coefficients of hay alone and the total ration (concentrate + hay) were determined directly while those for the concentrate portion were calculated by differences as described by Giger and Sauvant (1983). The digestibility coefficients thus obtained were used as reference to performance study on lactating cows.

The data obtained on intake, digestibility and performance were subjected to variance and covariance analyses and differences between treatment means tested using Student's t-test (Snedecor and Cochran 1980).

Results

Table 2 shows the chemical composition of the concentrate diets based on maize and cassava which were similar in crude protein, crude fibre and ash.

Milk yield, milk fat and liveweight: For experiment I the mean milk yield and butterfat content are shown in table 3. There was no significant difference in milk yield between treatments. The milk yield was 11.7 kg/day for the ration without cassava, and 11.1 and 11.6 kg/day for the rations with 200 and 450 g cassava per kg, respectively.

The differences in the pretrial period and the differences between the concentrate feeds were not significant. There were no significant differences in milk fat concentrations for the rations A, B and C.

Differences in liveweights of the cows were not significant; mean figures were 415 kg, 416 kg and 417 kg for the cows offered rations A, B and C, respectively.

Table 2. The percentage chemical composition of the diets based on maize and cassava root meal

Component (%)	Experiment I				Experiment II		
	Hay	A	B	C	Hay	A	B
Dry matter	91.39	91.45	91.79	91.73	83.56	89.84	89.86
Crude protein	3.44	17.99	17.85	17.71	3.74	16.67	18.79
Crude fibre	39.77	7.03	7.25	7.35	38.00	7.21	7.34
Ash	9.98	5.08	5.50	6.00	10.14	5.26	6.17

Note: The ingredients of diets for experiments I and II are as composed in table 1

For experiment II there was no significant difference in milk yields for the treatments without- and with-cassava (table 3). The % butterfat for each of the diets without- and with-cassava was 4.2% (table 3). The liveweight of the cows on rations A and B were 483 kg and 481 kg respectively, the difference not being significant.

Intake and digestibility: Results of dry matter and organic matter intake and digestibility of the different diets with- and without-cassava in each of the experiments are summarized in tables 4 and 5.

Table 3. **Mean milk yield and butterfat content of cows on maize and cassava root meal based concentrate diets**

Milk/butterfat	Experiment I			Experiment II	
	A	B	C	A	B
Milk yield (kg/day)	11.7	11.1	11.6	11.3	11.1
SEM		±0.27		±0.16	
F-test		NS		NS	
Butterfat %	3.7	4.0	3.7	4.2	4.2
SEM		±0.09		0.00	
F-test		NS		NS	

Notes: The ingredients of diets for experiments I and II are as composed in table 1
SEM = standard error of mean, NS = not significant

Table 4. **Mean intake and digestibility of concentrate diets by steers**

Factor	Experiment I				
	Hay	A	B	C	SED
Dry matter intake (kg/day)	7.4a	10.7b	11.3b	11.2b	±0.5
Organic matter intake (kg/day)	6.6a	9.9b	10.4b	10.3b	±0.4
Dry matter digestibility (%)[a]	48.7	nd	nd	nd	
Dry matter digestibility, hay + concentrate (%)	nd	52.3a	57.8a	57.7a	±2.6
Dry matter digestibility, concentrate alone (%)	nd	61.4a	67.1a	67.1a	±4.7
Organic matter digestibility (%)[a]	52.7	nd	nd	nd	
Organic matter digestibility, hay + concentrate (%)	nd	58.2a	60.7a	60.6a	±2.5
Organic matter digestibility, concentrate alone (%)	nd	63.2a	68.7a	68.7a	±4.6

Notes: The ingredients of diets for experiment I are as composed in table 1
Means with different letters within a row are significantly different (P < 0.50)
SED = standard error of difference, nd = not determined
Digestibility of hay alone was included in the ANOVA

Table 5. Mean intake and digestibility of concentrate diets without cassava by steers

Factor	Experiment II			
	Hay	A	B	SED
Dry matter intake (kg/day)	3.7a	8.2b	7.8b	0.3
Organic matter intake (kg/day)	3.3a	7.6b	7.2b	0.3
Dry matter digestibility (%)[a]	46.8	nd	nd	
Dry matter digestibility, hay + concentrate (%)	nd	57.3a	59.1a	2.3
Dry matter digestibility, concentrate alone (%)	nd	66.1a	68.0a	3.4
Organic matter digestibility (%)[a]	51.3	nd	nd	
Organic matter digestibility, hay + concentrate (%)	nd	59.6a	61.5a	2.1
Organic matter digestibility, concentrate alone (%)	nd	66.1a	68.3a	3.0

Notes: The ingredients of diets for experiment II are as composed in table 1
Means with different letters within a row are significantly different ($P < 0.50$)
SED = standard error of difference, nd = not determined
[a] Digestibility of hay alone was included in the ANOVA

Discussion

It is evident from the nonsignificant differences in milk yield and butterfat (table 3) that cassava could replace maize totally in concentrate rations for lactating dairy cows. This was not surprising considering the nonsignificant differences in total dry matter and organic matter digestibility coefficients of the diets compounded from cassava and maize sources. It is clear from tables 4 and 5 that higher levels of cassava (up to 570 g/kg of the concentrate diet) had no adverse effect on DM and OM intake and digestibility of the rations. Similarity in digestibility coefficients of DM and OM in diets containing 0, 21 and 42 % CRM had been reported by Ahmed (1977). Recently Abate (1983) noted that total substitution of maize with cassava in weaner beef calf concentrate feed had no significant effect on DM digestibility.

The nonsignificant differences in milk yield and butterfat content by cows offered diets without- and with-cassava is in line with reports of Mathur et al. (1969) who found that cassava could totally replace oats in the concentrate feed. Bristocke et al. (1981) studied the effect of replacing barley with cassava up to a level of 400 g/kg in the concentrate supplement for dairy cows and found that feeding them with cassava generally increased milk yield, but this was not apparent in the present experiments. Brigstocke et al. (1981) observed that feeding cassava to dairy cows produced no significant reduction on butterfat content. Similar results are obtained in the experiments reported here.

Since the cows were evaluated on the basis of milk yield, it could be expected that cows on diets with cassava received almost the same amount of concentrate feed as those on diets without cassava. The saving from inclusion of cassava in the concentrate ration varied according to the prevailing prices of the feed ingredients. Taking the price of dry chips at Ksh2.50/kg and maize at Ksh3.30/kg (1988 prices), total substitution of maize with cassava (diet A vs diet B in experiment II) was associated with a reduction in the cost of the feed ingredient of Ksh328 (US $18) per tonne. The same costing procedure revealed that the feeds with cassava were cheaper (Abate 1981, 1983) and that the weight gain of calves which received cassava over 8 months after supplementation was not significantly different from those which were offered maize. Similarly, Brigstocke et al. (1981) noted that it was cheaper to replace barley with cassava.

In both experiments, dry matter intake and digestibility were higher with the addition of only concentrate to the rations rather than the hay dust alone. No significant differences were observed between the groups receiving concentrate.

It is concluded that cassava root meal is an acceptable ingredient in the concentrate feeds and is a complete substitute for maize in diets for dairy cows producing approximately 12 kg of milk per day.

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Processing and Utilization of Cassava as Livestock Feed in Tanzania

F. P. Lekule and S. V. Sarwatt

Results of studies on feeding mainly cassava roots to nonruminants indicate that cassava is comparable to other energy sources but requires protein, mineral, and vitamin fortifications when fed to pigs and poultry. Research on the use of cassava for ruminants, especially dairy cattle, needs greater attention. It is however noted that the high market value of fresh cassava hinders its use for feeding livestock. It is concluded that the promising potential of cassava as a livestock feed must be examined in the context of other factors, e.g. market price of cassava, alternative feeds available, storage and transportation problems, availability and prices of protein supplements.

Cassava, a tropical crop and one of the twelve most important food crops grown in the world, provides subsistence to as many as 500 million people (Boccas 1987). Tanzania produces about 6.8 million tonnes of cassava annually (FAO 1983), which is 5.5 % of total world cassava production (or 14% of Africa's). In contrast, maize production is about 2 million tonnes per annum and production of other food crops is even much lower. The adverse climatic conditions in most parts of the country favor production of cassava which can tolerate drought, poor soils, many pests and diseases and not compete with other food crops for inputs and time during planting and harvesting.

The potential of cassava as a livestock feed has been well reviewed by Müller et al. (1975). In Tanzania, there is substantial information on cassava and its feed value for pigs (Wyllie and Lekule 1980, Babyegeya 1980, Kakala 1981, Sarwatt et al. 1988 and Lekule 1988), poultry (Kinabo 1977) and for ruminants (Massawe 1977 and Mngulwi 1983). In spite of this information on the utilization of cassava as a livestock feed, its adoption in the livestock feeding systems in Tanzania has been very low. This paper reviews various ways of processing cassava and examines some of the factors limiting the utilization of cassava in livestock diets.

Cassava production in Tanzania

Cassava production trends in Tanzania is shown in tables 1 and 2. The area under cassava cultivation has been increasing by 10 000 hectares every year since 1967 while yields have been increasing by 50 000 tonnes a year. Based on these figures, the 1988 cassava production can be estimated at about 7 million tonnes. "Kilimo Bora Mkoa wa Tanga" in 1980 reported that yields of fresh cassava in the region were between 5-10 tonnes/ha. These values are low when compared with high yielding varieties that can give 15-25 tonnes/

ha or selected varieties that have given 30-35 tonnes/ha (Hahn 1986). It is therefore possible to double or triple cassava yields with appropriate inputs.

Table 1. Cassava production trends in Tanzania

Year	Area harvested (1000 ha)	Yield (kg/ha)	Production (1000 tonnes)
1967-71	695	4854	3373
1979	930	4892	4550
1980	940	4894	4600
1981	950	4895	4650
1983	1300	5231	6800

Source: FAO 1983

Table 2. Cassava purchases from farmers in Tanzania

Year	Quantities purchased (metric tonnes)
1974/75	18 621
1975/76	17 635
1976/77	19 746
1977/78	36 937
1978/79	63 767
1979/80	44 015
1980/81	7 516
1981/82	9 223
1982/83	18 764
1983/84	30 687
1984/85	19 824

Source: FAO 1983

Cassava processing in Tanzania

Leaves: Cassava leaves are normally sun-dried in the open or may be dried in ashes but this takes a longer time (10-15 days). The resulting hay is then mixed in the diets in the proportions required. In the dried form, cassava leaves can be stored for a long time. Drying the leaves also reduces HCN content. Mngulwi (1983) reported HCN content of 1210 ppm of DM for fresh leaves and 30 ppm for dried leaves.

Roots: It is a common practice to sun-dry the roots when they have been chopped into small pieces. Peeled roots are normally fed to pigs and poultry while unpeeled roots are fed to cattle. The peel is rich in protein, fat and ash (table 3). Peeled fresh roots can be fed to pigs and poultry at low levels without any signs of toxicity.

Table 3. Proximate composition and mineral content (% of dry matter) of serveral cassava varieties with different treatments

Component	Variety and treatment								
	NMC peeled	Mzungu peeled	Kigoma		Ndunga		Nsenene peeled	Mixed peeled	Mixed root peels
			Peeled	Unpeeled	Peeled	Unpeeled			
Crude protein	2.15	2.62	1.89	1.73	2.40	2.14	3.25	2.13	5.38
Crude fiber	2.83	3.55	3.76	3.53	3.50	3.25	nd	nd	nd
Ether extract	0.97	0.50	0.62	1.81	0.46	0.60	0.92	0.86	1.34
Ash	1.76	2.49	1.84	3.42	1.64	3.12	2.84	2.85	5.81
Nitrogen-free extract	92.29	90.84	91.89	89.51	93.75	91.14	nd	nd	nd
Calcium	0.46	0.06	0.07	0.09	0.07	0.11	0.07	0.05	0.45
Phosphorus	0.06	0.25	0.28	0.45	0.24	0.11	0.05	0.12	0.08
Starch	nd	nd	nd	nd	nd	nd	87.89	80.88	15.86

Source: Lekule 1988
nd = not determined

Cassava-based diets for pigs

The first serious scientific work in Tanzania on substituting cereals (mainly maize) with cassava in pig diets was initiated at the Sokoine University of Agriculture in the seventies (Wyllie and Lekule 1980). Subsequent work was conducted by Babyegeya (1980), Kakala (1981) and Lekule (1988).

Wyllie and Lekule (1980) found no significant differences in average daily weight gain, feed conversion efficiency or carcass characteristics when cassava replaced 0 to 54 % of maize in diets of growing-finishing pigs. In another trial, the same authors found that replacement of cassava by cane molasses resulted in a linear decrease in liveweight gain and feed conversion efficiency. In both cases, energy sources intake were restricted to about 50% of recommended values by NRC (1979). Kakala (1981) used fresh cassava leaves and raw cassava tuberous roots as substitutes for a mixture of sorghum and wheat bran. Inclusion of cassava leaves at 30% in the ration was observed to depress the growth of young pigs. However, overall growth and feed efficiency from 18 kg to 80 kg were not influenced by the level of cassava products.

In a series of experiments using fresh cassava tuberous roots and cassava root meal as the only source of energy (Lekule 1988), average growth ranged from 533 to 566 g/day for restricted pigs and from 551 to 737 g/day for ad-lib fed pigs. There was no significant difference in daily weight gain and feed conversion efficiency between pigs fed the cassava-based dites and the commercial pig feed. Feed conversion efficiency was improved by feed restriction. Carcass characteristics were not significantly influenced. Similar results had been obtained by Kakala (1981) but Babyegeya (1980) reported improved dressing percentage with increase in cassava levels. Although most of the workers have not found any significant effect of cassava inclusion on growth and feed efficiency (Wyllie and Lekule 1980, Babyegeya 1980). Kakala (1981) found that cassava products depressed digestibility of dry matter and energy. It is possible that the depression was caused by the cassava leaves which are known to be high in crude fiber content. Results of recent experiments have shown that cassava root diets are highly digestible (over 80% dry matter digestibility) and are similar to cereal-based diets (tables 4 and 5).

Table 4. Composition of diets containing varying amounts of cassava root meal

Composition	Treatment			
	1	2	3	4
Ingredients				
Cassava root meal	0	20	40	60
Maize meal	45	30	15	0
Cottonseed cake	10	15	20	25
Rice polishings	20	25	15	0
Kapok cake	11	6	6	11
Fish meal	2.5	2.5	2.5	2.5
Limestone	1.0	1.0	1.0	1.0
Vitamin-mineral mixture	0.5	0.5	0.5	0.5
Dry matter composition	90.5	90.2	89.7	91.6
% dry matter				
Crude protein	17.7	16.2	16.2	16.8
Crude fiber	6.5	6.4	6.6	8.9
Ether extract	6.3	5.8	5.5	5.1
Nitrogen-free extract	64.6	66.4	66.2	64.2
Ash	5.3	5.2	5.2	5.1
Calcium	0.7	0.7	0.8	0.9
Phosphorus	0.7	0.9	0.8	0.9
Lysine	0.8	0.7	0.7	0.6
Methionine + cystine	0.7	0.6	0.5	0.4

Cassava-based diets for poultry

Substitution of maize by cassava root meal as a cheap source of energy in broiler rations have been carried out by Kinabo (1977), who reported that in 0-2 weeks, body weight gains increased as the cassava level in the rations rose from 17 to 34 %, but at 41 % and 51 % levels body weight gains decline. The differences between the body weight gains of chicks fed the high cassava diets (41 % and 51 %) and the control were however not significant. Feed conversion ratio of chicks fed diets containing 34 %, 41% and 51 % cassava was significantly poorer ($P < 0.01$) than either the control or the diet with 17% cassava.

Cassava as a feed source for ruminants

There is a very limited research on the use of cassava as ruminant feed in Tanzania, probably because ruminants are mainly raised on pasture. In one study, Massawe (1977) replaced maize bran with cassava and recorded lower milk yield when cassava was the only supplement, probably due to the low level of protein in cassava.

However, because home-grown cassava is relatively cheaper than purchased concentrates for dairy cattle, the potential of cassava as an alternative energy source in dairy feeding systems needs more research. More attention should be paid to those areas of the tropics with a tradition of cassava cultivation.

Table 5. Effect of level of cassava root meal on digestibility and nitrogen retention by pigs

Item	Level of cassava root meal (%)				
	0	20	40	60	±SE
Dry matter (%)	78.5	80.2	79.3	79.1	0.7
Organic matter (%)	80.5	82.3	81.9	81.1	0.7
Crude protein (%)	77.3	76.0	76.5	76.0	1.7
Crude fiber (%)	25.1a	34.3ab	24.1a	37.5b	3.3
Ether extract (%)	77.9a	78.8a	88.1b	85.9b	1.3
Nitrogen-free extract (%)	87.2	89.1	88.3	88.1	0.9
ME (MJ/kg DM)[a]	14.7	14.8	14.8	14.7	0.1
Nitrogen balance (g/day)	10.9	7.3	11.3	9.3	1.7
N-retention (% intake)	29.0	21.2	33.3	26.3	3.2
N-retention (% digested)	41.1	28.8	43.6	33.9	4.4
Average daily gain (g/day)	286.0	249.0	392.0	383.0	67.9

Notes: Values in the same row bearing different letters are significantly different ($P < 0.05$)
[a] ME = Metabolizable energy

Present and potential roles of cassava as a livestock feed

In areas where cassava is a staple food, there is always an excess of production which is sold to the National Milling Corporation. The quantities indicated as purchased (table 2) reflect cassava production over and above the demand for human consumption. Most of this excess is exported while the rest is utilized for industrial starch production. Hence, such quantities could be available for livestock feeding to replace some of the imported yellow maize commonly included in poultry and pig feeds. At present, it is only when grains are in very short supply that small amounts of cassava are included in feeds.

Why cassava is not widely used for livestock feeding

The main reasons for limited use of cassava for livestock feeding can be summarized as follows:

1. Cassava is produced in dry areas where intensive livestock production is not practiced and the main livestock species are ruminants.
2. The high price of cassava makes its use in livestock feeds uneconomical.

3. Cassava has low nutritive value hence diets from it require high protein fortification or amino acid supplementation due to the low content of amino acid (table 6). This would therefore make cassava diets too expensive.
4. Harvesting, processing and handling of cassava is difficult and incovenient, and this discourages large scale farmers from planting cassava for livestock feeding.

Table 6. Amino acid composition of common cassava varieties in Tanzania

Amino acid (g/kg dry matter)	CRM, peeled (Kigoma variety)	CRM, peeled (Mzungu variety)	CRM, peeled (sweet varieties)
Alanine	1.26	0.63	2.10
Arginine	1.98	0.50	1.55
Aspartic acid	1.63	0.89	3.56
Cystine	0.25	0.14	0.54
Glutamic acid	4.23	2.91	4.08
Glycine	0.71	0.51	1.79
Histidine	0.38	0.17	0.71
Isoleucine	0.58	0.43	1.90
Leucine	0.91	0.69	2.95
Lysine	0.88	0.27	1.29
Methionine	0.23	0.17	0.55
Phenylalanine	0.55	0.41	1.87
Proline	0.75	0.51	1.93
Serine	0.73	0.45	2.00
Threonine	0.61	0.29	1.71
Tryptophan	0.35	0.16	0.48
Tyrosine	0.25	0.14	1.28
Valine	0.73	0.54	2.33

Note: CRM = cassava root meal

Conclusion

In many parts of Tanzania, only one energy source is available as livestock feed and this could be cassava. As an energy source, cassava root is an excellent livestock feed, but it must be processed to reduce the HCN content to nontoxic levels. For nonruminants, the diets must be formulated with care, paying attention to the balance of limiting amino acids, minerals, vitamins and essential fatty acids. Despite being rich in amino acids, vitamins and minerals, cassava leaves do not at the present time, offer much promise as livestock feed.

The price structure of cassava roots has been one of the major limitations to its use in animal feeds since economic considerations are of prime importance and the use of cassava will only be feasible when cassava-based diets are cheaper than diets based on other energy sources. Where other energy sources are not available, the value of the livestock products must be weighed against the market price of cassava.

More research is required to stimulate the use of cassava for feeding dairy cattle, pigs and poultry especially in rural areas which are out of the reach of commercial feeds.

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Cassava Production and Utilization in Liberia

S. Ravindran and D. Kenkpen

Liberia is situated between latitudes 4-9°N and longitudes 7-12°W with a total land area of 111 400 km^2. The country has a humid tropical climate with a rainy season extending from April to November. The average annual rainfall varies from 1800 mm in the north to 5000 mm at the coast. The dry season extends from December to March and the highest air temperature recorded has not exceeded 34°C. The 1985 census recorded a national population of 2.1 million; 80-85 percent of the working population was engaged in agriculture and forestry with over 90 percent of these earning a living from traditional agriculture.

Agriculture in Liberia was previously dominated by export crops which included rubber, oil palm, coffee, cocoa and citrus. Although these export crops still account for a substantial portion of Liberia's foreign exchange earnings, an increase in food crop production is now very evident. Food crops grown include rice (both upland and swamp), cassava and other root crops, banana, pulses and vegetables. The most prevalent methods of cropping are "slash and burn" and shifting cultivation. At present, food crops are produced mainly by subsistence farmers.

Production and processing

Cassava is now the second most important food crop in Liberia. It is grown throughout the country, although the area covered may vary considerably for different counties. A survey conducted by the Liberian Ministry of Agriculture in 1978 indicated that the total area covered by the crop in 1977 was only 86 000 ha with an average yield of 1800 kg/ha, and that 39 400 or 26 percent of all agricultural households in the country were involved in the production of cassava. However, cassava cultivation in the country increased substantially early in the 1980s. Total production for 1985 was estimated at 283 million kg which represents a significant increase of 23 percent compared to the 1984 production figures of 218 million kg. The same increase was also noted for area harvested (113 100 ha) and yield per ha (2500 kg). The number of households growing the crop in 1986 amounted to 95 400 or 62 percent of all agricultural households (FAO 1980).

Almost all the cassava harvested in Liberia is processed into various forms for human consumption. Cassava is normally left in the ground until it is required for sale, consumption by the farmer, or processing into a more durable form. Besides the tubers, the leaves are consumed extensively as vegetable. Cassava is traditionally boiled soon after harvest or processed into farina (gari), starch, fufu, or dumboy.

Farina or gari is the dry finely granulated product prepared from partially fermented cassava. If prepared correctly, well dried farina may be stored for many months without deterioration. The basic procedure for farina production is simple; the cassava is peeled, grated, and allowed to ferment for about 1-2 days when water is extracted by compression of the mash, then roasted. Farina is produced throughout the country, especially in Bassa, Bomi and Nimba counties.

For preparing fufu, cassava is fermented under water in used oil-drums and then hand-pounded in a large wooden mortar prior to moisture extraction; the fufu thus produced is sold in the local market. Under rural preparation methods the fresh peeled roots are placed under water for about 3 days and allowed to absorb water and ferment until soft. After fermentation, the water is drained off, most of the fiber removed and the roots pounded in large wooden mortars until a soft mash is formed. Excess water is extracted from the mash by placing heavy objects such as rocks on top of sacks containing the fufu. The consumer who buys fufu in the market normally adds water to the mash and sieves the mixture to remove the remaining fiber.

Cassava chips are prepared by peeling, washing and slicing tubers into suitable sizes followed by drying. Sun drying is the simplest, most economical method but has the disadvantage of taking up a large area of ground. The partially dried chips are loaded onto fine mesh grids within the house and allowed to dry for 2-3 days.

Cassava flour is obtained from dried cassava chips by grinding in hammer mills, cylindrical mills or by hand-pounding in a mortar.

Dumboy is prepared by boiling fresh cassava so that the roots become soft and split. The boiled roots are placed in a wooden mortar and hand-pounded with or without plantains.

Research

The Central Agricultural Research Institute (CARI), Suakoko in Bong County of Liberia has a Root and Tuber Research Program which places particular emphasis on cassava. The program is partially financed by the International Development Research Centre (IDRC) of Canada. Cassava research at CARI is focussed on developing cassava varieties for high yields, disease resistance and root quality. Three high yielding varieties, CARICASS I, CARICASS II, and CARICASS III have already been released and are under multilocational and on-farm trials. The yields of these varieties have been proven to be superior to the local variety both at on-station and on-farm trials (table 1).

The Animal Nutrition Project at CARI has been conducting feeding trials on livestock and poultry using both cassava tuberous roots and leaves. The main objective of this research program is to formulate balanced feed rations for pigs and poultry using cassava as major energy source to reduce competition of animals for imported cereal grains.

Table 1. Comparative yields of CARI improved cassava varieties and the local type, without fertilizer application; Liberia, 1983-84

Cassava variety	On-station yields (CARI)	Off-station yields (Liberia)		
		Cape Mount County	Nimba County	Bassa County
	t/ha			
CARICASS I	32.8	31.8	20.5	26.6
CARICASS II	58.4	58.4	16.4	39.6
CARICASS III	29.0	29.0	9.8	31.5
Local	nd	7.8	4.3	nd

Source: IDRC Year 2 Annual Progress Report (1983-84): Root Crops Project, Liberia
Note: nd = not determined

Cassava leaves for animal feeding are processed by spreading and shade-drying. When dried the leaves are milled and preserved in polythene bags. Cassava tuberous roots for animal feeding are washed and sliced into thin slices (2-3 cm) without peeling. They are dried on a wire mesh over a low fire. The dried cassava chips with approximately 8-10% moisture are either stored in jute bags or milled and stored in polythene bags for future use. Shelf-life under room temperature for cassava flour is 4 to 5 months whereas the chips can be stored without deterioration for over 8 months.

When cassava flour was incorporated into the diets of Hampshire and Segher breeds of pigs to constitute 40% of their rations, their performance in terms of growth, productivity and carcass quality was not adversely affected. On the other hand, the final weight of Segher breeds in the treatment group was 5% more than the control group fed on corn-based rations (CARI 1985-86). However, such compounded pig feeds containing cassava as basal diet were always balanced for protein using ground soybean (15%) and blood meal (5%). Broiler rations containing 10% cassava flour and 12% cassava leaf meal are reported satisfactory for obtaining 1.5 kg live weight per bird at 42 days (CARI 1979-80). At CARI, prolonged use of cassava tuberous roots as pig feed has so far not caused diseases like goitre, sterility, or neurological disorders. This may probably be due to the addition of protein diets like vegetable oil meal, legume leaf meal, or blood meal into such mixtures. However, vomiting was observed in weaner piglets when fed with raw cassava.

Cassava as animal feed

Large scale utilization of cassava as animal feed is only practiced by CARI and a few commercial pig farmers in the country. However, feeding of cassava leaves, cassava peels and unwanted (thin) tubers to pigs and small ruminants is commonly practiced in the rural areas. The quantity used for feeding livestock in the country may not exceed 1 percent of the total production. This may be due to insufficient production and current high price ($5 to $8 for 45.4 kg bag of fresh tubers).

The acceptance and cultivation of high yielding cassava varieties like CARICASS I, CARICASS II and CARICASS III by farmers is naturally expected to increase national production levels of cassava. Higher production of cassava may lead to its increased utilization as animal feed. In this vein, CARI has already released into the market some animal feed formulations based on the cassava tuberous root as a major energy source. However, better cassava processing and storage techniques appropriate to the country will have to be developed if full benefits are to be obtained.

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VI

Reports of Working Groups and Workshop Recommendations

Reports of Working Groups

Report of Working Group A

Feeding cassava to ruminants

Scenario A—Cassava surplus

1. The circumstances
In the circumstances of surplus cassava production, both cassava and its by-products can be used for animal feeding. Research confirmed the biological feasibility of using cassava and its by-products for feeding ruminants. The economics of this depends upon prevailing market prices.
Small ruminants: Cassava and its by-products can be fed to small ruminants provided adequate roughage is available. The energy from cassava will improve digestibility of dry matter and nitrogen.
Beefcattle: The economics of using cassava tuberous roots in beef cattle rations requires further study. Cattle in sub-Saharan Africa are usually free ranging, and their major areas do not overlap with cassava producing areas. Cassava tuberous roots and/or peels could provide complementary energy to a low cost N source such as poultry manure for cattle concentrate. Research is needed to investigate this further. Short-term wilting (3-4 hours) of cassava leaves gives toxic levels of HCN, but 48-hour wilting is safe. Cassava leaves contain 20 percent protein and could be an important source of nitrogen.
Dairy cattle: In smallholder dairy units in Tanzania, cassava tuberous roots with dried *Leucaena* and a mineral supplement support levels of milk production of 10-12 liters per day in crossbred Freisian cows on natural grazing and twice-daily milking. Research is needed on other combinations of cassava and legume forages that can be produced on-farm and are suitable for smallholder and commercial dairy units.

Cassava varieties that produce high leaf yields and fewer tubers exist and are frequently used as vegetable for human consumption. These varieties could be investigated as a forage protein source. The effects of leaf harvesting on the tuber yields of high yielding cassava varieties, the timing of leaf harvesting, and its effect on HCN levels in the tubers should be studied. The economics of labor for leaf harvesting, and the possibility of direct grazing on mature plants before lifting the tubers should be studied. Little information is available on the feeding value of cassava stems, but the group believed that this would be a low priority research area.

When a surplus of cassava exists, the overriding consideration for its use in livestock feed will be the relative prices of animal products, cassava, protein supplements, and competing energy sources.

2. Target groups

For the use of cassava for ruminant feeding, three main target groups were identified. The groups are:

a. Farmers with access to limited resources (small-scale);
b. Farmers with better access to resources (medium/large-scale); and
c. Small-scale feed processors.

The other groups considered were traders with short-term livestock holdings, and large-scale feed processors.

Traders may purchase feed packages. Large-scale producers have not been responsive to changes in technologies that would permit the use of cassava for ruminants. Ruminant feed accounts for only about 5 percent of commercial feed production. Small-scale feed processors are likely to be more receptive to change.

The differentiation between small-, medium-, and large-scale producers was discussed, but an Africa-wide definition was difficult to formulate. The general descriptions of "subsistence" and "commercial" were taken as acceptable working terms.

3. Research strategy

The major research focus would be the development of feeding systems using cassava with home-grown N-rich forages for subsistence farmers, and other low cost N sources (poultry manure, urea) for commercial farmers. Small-scale feed processors would also rely on low-cost N sources (locally available) to mix with the cassava. Rapid fermentation of cassava in livestock rumen is best utilized in combination with an NPN source (urea) or forage legumes that can be consumed before cassava. This might be practicable if cattle grazed a legume pasture, and then received a cassava concentrate on return to the kraal. Adequate on-station and on-farm testing are needed before new packages are extended to farmers. With dairy cattle, the long-term effects on reproduction should also be tested. Research into small-scale processing of cassava should be encouraged.

4. Prioritization and formulation

Cattle, sheep and goats can utilize tubers, leaves, peels and other processing by-products. The priority given will depend upon the relative importance of the various animal species in a given environment. Kenya and Tanzania may prefer to use tubers for dairy cattle, while in southwestern Nigeria, where few cattle are found, cassava may be fed to small ruminants.

Energy feeds are important for draft animals, but cassava producing areas do not overlap with draft use. Therefore, if cassava is to be used as a feed source, it will be in the form of processed concentrate.

5. Economic and social implications
Use of cassava for animal feed will raise demand, and hence stabilize prices when surplus cassava is produced. The market structures and pricing policies should be in place to cope with increased production of animal products. Eventually, increased production of animal products will raise family income, but initially, more family labor will be required. This may come from the women and children in the farming families. With increased income, hiring of labor may be possible. Cooperative grouping of producers and processors may also emerge.

Scenario B—Cassava insufficiency

1. The circumstances
In the circumstances of insufficient cassava production, by-products (peel, leaves, other processing by-products) can be used for animal feed. However, because of infrastructural inadequacies there may be localized areas of cassava surplus, although there may be a deficit throughout the African continent.

2. Target group
The target group to use the cassava by-products will now be predominantly small farmers. Very little cassava or cassava by-products will reach the small farmer from processors for animal feed.

3. Research strategy
There is a need for industrial users of cassava to examine the uses of, and animal responses to cassava by-products. The economics of using fibrous by-products should be studied.

4. Prioritization and formulation
Cattle, sheep and goats will feed on leaves, peels and other processing by-products.

5. Economic and social implication
The use of cassava by-products will provide additional income to the farmer.

Report of Working Group B

Feeding cassava to nonruminants

1. Current knowledge and application
There is abundant literature to indicate that cassava and its by-products in the fresh and dried forms can be fed to different classes of livestock. For monogastrics, tubers can be fed at levels of 20-40 percent. The major constraints of cassava product utilization are its (a) low protein, (b) high cyanide content, (c) dustiness, and (d) microbial contamination due to high moisture content.

Supplementation of cassava diets with soybean meal is recommended. Where practicable, fishmeal supplementation should be adopted to meet the lysine and methionine requirements in such rations. Processing techniques have also been developed to reduce the cyanide contents of cassava to low levels. In this regard, a level of 100 ppm total HCN should not be exceeded in cassava products for animal feeding. Pelletizing is recommended to reduce the dustiness of feed in large scale feedmilling. Vegetable or animal fat or molasses can be used to reduce dustiness and boost energy content of the rations. Materials should be dried to as low as 12 percent moisture content to reduce the incidence of microbial growth. Introduction of other contaminants during drying should be avoided. The adoption of these recommendations should be guided by their economic implications.

2. Research gaps and future actions

While there are several methods for cyanide determination, there is the need to adopt a uniform analytical technique so that results from different areas can be compared. There is also need to develop a rapid, simple and cheap technique for cyanide determination on farm sites. In this regard, it was noted that the picrate test, though rapid, does not guarantee the estimation of total HCN in the cassava material.

There is the need to study the present forms in which cassava is processed and fed to livestock particularly on farm sites in different regions of Africa. Researchers should also intensify on-farm research and interaction with cassava/livestock farmers. This will form the basis for the development of cassava processing and utilization programs that will be evolved from existing on-farm practices.

Due to the scarcity of fishmeal in many African countries, it is necessary to explore the utilization of other animal by-products that can be used to supplement for lysine and methionine in cassava-based rations.

3. With cassava surpluses

In African countries where there is surplus in cassava production over that required for human consumption, the surplus can be used in industry or livestock feeding, or exported. In addition to feeding fresh or ensiled cassava and its by-products to pigs, the possibility of feeding wet material to poultry has been demonstrated in some countries. Adoption of such a feeding system can contribute significantly to the expansion of small-scale poultry units in different regions of Africa.

4. General comments

It is recognized that the adoption of any of the recommended processing and utilization techniques will be primarily dictated by economic implications. It is envisaged that even where there is a deficit in cassava supply, techniques can be developed and adopted for the utilization of cassava leaves, stems and peels with favorable economic returns to the farmers. It is necessary to encourage cassava farmers to integrate livestock production into their farming systems such that the by-products of cassava can be used for livestock feeding, while the manure from such stock can be utilized for production of vegetables and other crops. This practice will enhance the economic efficiency of such farming systems.

Finally, it should be recognized that it is socially and economically advantageous to encourage the utilization of cassava in animal feeding, because experiences have confirmed that increase in production of cassava leads to a glut in the cassava market. The price instability that prevails discourages the expansion of cassava cultivation and utilization. The diversion of such excess cassava for animal feeds will guarantee price stability of cassava, and encourage sustained cassava production.

Report of Working Group C

Processing technology of cassava to animal feed

1. Examination of technologies

The group examined different aspects of processing of cassava into animal feed. The objectives of processing are to:

a. Extend the shelf life of the crop for safe storage,
b. Make for easy handling and marketing,
c. Improve on the palatability of the cassava-based diet, and
d. Maximize the natural components and reduce the toxic ones.

In attempting to achieve these objectives, the differences and similarities were highlighted among the various cassava processing technologies of the countries represented (Nigeria, Liberia, Togo and Uganda). The links were established between cassava type (high or low cyanide content) and complexity of processing and type of animal to which the feed was directed. Generally speaking, pigs were found to be the least problematic in terms of cassava variety and processed form while poultry animals presented the most specific feed requirement category. Many different sequences and combinations of the cassava processing plant were explored. It was decided that the emphasis would be on small farmers as our primary target groups, commercial farmers and feed processors would later evolve. The unit operations in these processes included chipping, grating, shredding, fermenting, drying and packaging. The fermentation step is included to reduce the cyanide content to levels below 100 ppm. This step is optional depending on the cyanide content of the raw material used. In addition, the production of single-cell protein was also considered and though this is not economically sensible at the farm level, more work needs to be done on improving the economic feasibility on a large scale.

2. Research needs

The group observed that there were certain areas where research needs to be conducted in order to optimize the efficiencies of cassava processing methods.
Composition changes: There is the need to monitor the changes in nutritive

and toxic composition of the plant through the unit operations of the above processes and in particular the cyanide levels.

Cyanide determination: There is a need to develop simple, cheap and effective on-farm techniques.

The use of cassava leaves and stems is not very common in countries represented despite its abundance and high protein content. It was therefore suggested that research be done on the scientific and socioeconomic constraints which have hindered their utilization.

There is a pressing need to define and categorize the different varieties of cassava plant in terms of their cyanide content and their ecological and geographical locations, to facilitate the appropriate processing technologies.

There is also the need to design and fabricate equipment for use at the local level with the following characteristics: (a) simplicity, (b) affordability, (c) utility, and (d) adaptability to both existing food technology equipment and local environmental constraints.

This feature of adaptability should acknowledge the need to utilize other farm by-products with cassava for animal feed purposes. The importance of drying was emphasized in order to achieve the stated objectives. Work has been done by the Postharvest Unit of IITA in this area— in terms of optimum crop size (3x7mm), and loading capacity (5kg/m^2) on concrete form which can reduce moisture content from 60-70 percent to 13-14 percent in a day during the dry season. But there is a need for more research to test this technology under various environmental conditions.

The socioeconomic implications of the above were also considered. It was observed that there is a need to:

a. Describe and analyze existing socioeconomic patterns in cassava producing and consuming areas,
b. Focus on possible innovative individuals or groups who may readily accept and use new technologies,
c. Identify existing and possible marketing channels from producer to consumer in terms of economic viability in various national settings, and
d. Be aware of the dangers of disrupting existing regional farming systems and ensuring that processing and marketing innovations would rather improve and facilitate the utilization of available resources for the benefit of all socioeconomic groups.

In order to achieve all of these it would appear necessary to establish a cassava network for the African subregion. This network would hold annual meetings and regularly publish a newsletter to review the state of cassava production, utilization and processing in Africa.

Workshop Summary and Recommendations

Summary of workshop

Cassava is a staple food for over 200 million Africans and can thrive even on infertile soils, adverse climatic conditions and low input management. Cassava and its by-products—peel, leaves and stems—have the potential to satisfy the energy demands for both humans and livestock if the demonstrated agronomic potential is fulfilled. The objectives of this workshop were, therefore, to explore avenues for utilizing cassava and its by-products for livestock feed, firstly using materials surplus to human requirements, and secondly when tuber production is insufficient to meet human needs.

Cassava tuberous roots are basically used as human food in sub-Saharan Africa, hence their use as livestock feed has low priority and limited to times of local surplus production or when infrastructural inadequacies may restrict marketing and distribution.

Studies indicate that cassava and its by-products in fresh and dry forms can be fed to different classes of livestock. For nonruminants, tubers can be fed at levels between 20-50% of dry matter intake, and peel and leaves can also be used. Biological constraints to the amounts of cassava which can be incorporated in livestock feeds include low protein and high cyanide content. Other constraints include microbial contamination during prolonged drying using traditional methods, and the dustiness of cassava meal.

Traditionally, peel and leaves are fed to ruminants, but excellent supplementary feeds can be formulated from tubers in combination with low cost nitrogenous sources.

Recommendations

1. To compensate for the low protein content, and the deficiency in sulfur amino acids in cassava tuberous roots, the use of high protein plant and animal feed stuffs to balance diets for nonruminants is recommended. For ruminants offered cassava-based rations, the use of low cost nitrogen sources such as urea, *Leucaena* and poultry manure should be explored.
2. For livestock feed, the levels of cyanide in cassava products should not exceed 100 ppm (total HCN). There is need for a simple and reliable method for the determination of total HCN. In this regard, a simple but reliable method should be developed into a simple package for use by extension workers.

3. For storage of dried cassava, the moisture content should not exceed 14%. Low cost, rapid drying methods should be developed to reduce the level of microbial contamination in the dried product. Simple packaging techniques are also needed since dried cassava is hygroscopic. Simple drying facilities could be organized through cooperative farmers' groups at village level.

4. For feed compounders, the addition of vegetable oil, animal fat, or molasses reduce the dustiness of compounded feed and increases palatability. Where economically viable, pelletizing of the compounded ration is also recommended.

5. While insufficient cassava is available to meet human demands, the use of cassava by-products for animal feed is recommended. By-products are of low value, and their use at village level should be encouraged by smallholder farmers to supplement ruminant livestock. By-products from food processing units if not used immediately should be sun-dried to allow for storage. If sufficient quantities are available, feed compounders should explore the economics of the inclusion of cassava peel in livestock feed formulations.

6. Surplus cassava production leads to price instability. The additional market that would be created if tubers were thus used for animal feed would improve price stability for the commodity, to the benefit of producers and consumers, and would encourage the adoption of improved varieties and agronomic production practices.

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