Economics of cassava product use in animal feeding
by G. Henry and C. Correa

INTRODUCTION

During the last 10 years, grain substitutes in animal feed rations have gained more importance for intensive animal production in the developing countries. In the EC and US corn, sorghum and soybean meal have traditionally been used to fatten poultry, pigs and cattle. However, government policy interventions have raised domestic prices of these crops, resulting in a search for cheaper feedstuff ingredients. Carbohydrate sources were found in (industrial) byproducts of other crops, i.e. cotton seed meal, citrus pulp, rice husks, etc. In addition, feed manufacturers started to experiment with imported "exotic" materials, like cassava. To supplement the relative low protein levels of these energyrich products, feeds were supplemented with soybean meal, fish meal, etc.

Besides developed countries, cassava can play a major role in animal rations grain substitution in developing countries. This potential is heavily constrained by existing direct and indirect government policies targeted to the principal grains. The indirect effects which generate severe adverse conditions for cassava demand and supply development.

This paper aims to assess the current situation, existing constraints and future potential for cassava as an animal feed ingredient. Most issues will be treated with a focus on Latin America. When possible, references are made to the Asian situation.The basic concepts are in general applicable to both continents.

The paper is organized as follows: The first section explains the changing trends in Latin American meat production and consumption, leading in the next section to a discussion on derived demands for animal feed stuffs. This is followed by a short technical note on least cost feed rations, and what role cassava can play for the animal feed industry. The CIAT experience is discussed, and the benefits from the Integrated Cassava Drying Projects. Finally the major constraints that cassava faces as a feed ingredient are summarized. The paper ends with conclusions and recommendations.

CURRENT SITUATION AND FUTURE GROWTH OF LATIN-AMERICAN MEATS

Resulting from population growth, improved standards of living and increasing urbanisation, the demand for animal proteins has increased during the last decades. In LDC, vegetable proteins are increasingly being substituted for animal proteins by the lower income classes. Additionally, this period has seen a dramatic increase in the consumption of poultry especially in Latin America.

Traditionally this continent has produced beef to take advantage of its natural native grasslands. Abundant low priced beef therefore have boosted average per capita beef consumption. Since the late 1960's beef production slowed down putting upward pressure on prices. During that time poultry production increased dramatically. The more efficient feed/meat conversion rate, coupled with a widespread and rapid adoption of cost reducing technology resulted in an annual production growth of 26% from 1960–1983 (Lynam, 1989). While real beef prices increased during the last two decades, poultry prices decreased. Consequently, the poultry share of the meat consumption basket has increased to over half of the beef share, while absolute meat consumption has increased significantly (Rivas, et al, 1989).

Rivas et al (1989) estimated the demand for beef, poultry and pork in Latin America, and found that although the income elasticity for poultry is higher than beef, total annual demand growth for 1970–1985 for beef is still higher. The estimates are 3.7%, 3.2% and 3.6% for beef, pork and poultry, respectively. Assuming that economic conditions do not worsen in Latin America, and that population and urbanisation growth continue in a similar fashion, these demand growth estimates may well be feasible until the year 2000 (*Ceteris paribus*). When assuming that production trends continue in a similar fashion, meat balances for 2000 can be calculated. Rivas et al (1989) show significant pork and poultry deficiencies under a conservative scenario, for Colombia, Venezuela, Brazil, and Mexico. Beef balances, on the other hand remain positive.

Thailand developed over the last decade into a major poultry producer and exporter and became a serious competitor for the US in the Asian market. A significant expansion of hog production is also foreseen. Projections by Schwartz and Brooks (1990), show that Thai per capita meat consumption will grow at an annual average rate of 4% until the year 2000, with more than half coming from pork production. When comparing developing and developed countries, it can be noted that during the last decade, poultry exports have decreased in the latter, while poultry imports have decreased in the former. This last phenomenon can be explained to a large extent by increased domestic poultry production and utilization.

THE WORLD ANIMAL FEED MARKET

Production and trade of traditional feed grains like sorghum and maize have experienced rather different developments during the last two decades. World production of maize has increased from 296 million MT in 1970, to 441 million MT in 1989. Production growth has been much stronger during the last decade in the developing countries than in the developed countries (FAO, 1990). World production of sorghum has seen only a slight (9%) increase over the last two decades and decreased during the eighties. It should be noted that the production decrease in developed countries has been almost fourfold compared to developing countries.

World cassava production has increased significantly over the last 20 years. In Latin America, however, production slowed down, especially during the seventies. During the eighties production has basically remained constant. It is hypothesized that increased product and market differentiation of cassava, have slowed down further production decreases during the eighties. While fresh cassava consumption has decreased, processed cassava utilization has gained a larger share.

Looking at feed-grain trade statistics in Table 1, it becomes obvious that developed countries changed from net importers to net exporters in the case of sorghum and maize. The reverse trend can be noted for developing countries. Traded volumes of sorghum and soybeans have hardly increased while the volumes of traded maize has increased fourfold. In the case of cassava it can be observed that the traded share of world production increased slightly (from 5.6 to 6.9%) over the last decade.

TABLE 1.**World Net-Imports of Major Animal Feed Stuffs (million tonnes)**

	1970/72	**1980/82**	**1987/89**
SORGHUM:			
Developed countries	-1.4	-0.1	1.6
Developing countries	1.3	0.2	-1.5
Latin America	1.4	0.9	-1.8
MAIZE:			
Developed countries	-4.5	11.6	16.9
Developing countries	4.7	-11.5	-16.2
Latin America	5.2	-0.3	-2.7
SOYBEAN:			
Developed countries	-0.1	0.7	-1.9
Developing countries	0.1	-0.7	1.5
Latin America	0.3	1.9	4.4

Source:FAO

The major conclusion that can be drawn from this is that developing countries have spent increasing amounts of foreign currency on imports of grains like sorghum and maize. Given their serious problems of foreign debt, limited currency and the increasing demand for animal proteins, the current situation suggests a large potential for increased substitution of feed grains by for example cassava.

THE ROLE OF CASSAVA AS ANIMAL FEED

Cassava can be utilized for animal feed in two principal ways. Of most importance is dried cassava root (chips or pellets) used as partial raw material for commercial animal feed rations. Although the usage of cassava products for animal feed purposes has been established for more than a decade in Asia, this is only just starting to develop in Latin America. Thailand, Indonesia, Vietnam and China are the main cassava exporters in Asia, of which Thailand has 86% of the export. Only since the mid 1980's (when cassava export prices plummeted), did Thailand start to substitute feed grains (maize) for cassava in the domestic animal feed industry. Cassava chips or pellets in these countries have to serve a first priority as export commodity in order to generate hard currency. However, under current conditions of changing domestic government policies, non-increasing EC-export quotas, and growing domestic animal feed demand, a significant increase in domestic cassava usage for animal feeds is visualized for Asia.

Secondly, and of much lesser importance, is on-farm utilization of cassava root and/or leaves for cattle and hog feeding. In many Latin American countries cassava have traditionally been fed to farm animals. Either on a large scale i.e. hog and dairy operations in Southern Brazil, or small scale i.e. subsistence farms in Paraguay and Colombia. (Lynam, 1989). In Asia a similar tradition can be observed i.e. in the Vietnamese highlands, Southern China and the Philippines. In Mexico the cassava has been used as silage with added proteins and minerals for hog

fattening.

Commercial animal feed rations either produced by small or large sophisticated feed companies are composed by using mathematical models for example linear programming. The principal objective of these models is to minimize costs of a variety of feed ingredients i.e. carbohydrates, proteins, vitamins, minerals, etc. each of which are constrained by maximum and/or minimum quantities and prices. The model will seek an optimum solution (the least expensive ration) subject to nutritional and price constraints. This is done through an iterative process based on simplex algorithms. Although this can be done by hand, nowadays the variety of ingredients and complexity of constraints require the use of computers.

Table 2 shows an example of a linear program solution of a broiler feed ration in Colombia, listing the different possible sources of energy, protein, fat etc. Additionally, it demonstrates how a slight price change effects the composition of the ration. In these two cases the price of cassava relative to sorghum is changed from 0.80 to 0.85. At the low cassava price, cassava enters the feed ration at 46.6%, while sorghum does not participate. When the cassava price increases to a level so that the cassava/sorghum price ratio becomes 0.85, cassava is excluded and sorghum enters the ration at 53.5%. The change of the cassava price will also effect the relative quantities of other ingredients i.e. sesame meal, vegetable fat, lysine, etc. These examples serves to demonstrate how a relatively small price change directly effects inclusion and relative participation of feed ingredients. This explains why feed ingredients like cassava may play an important role providing the price relative to major competing rawmaterials is low (See also Buitrago, 1990).

The potential for inclusion of dried cassava in animal feed rations has been recognized in several countries of Latin America. During the early 1980's in collaboration with several national institutions, the Cassava Program at CIAT instigated the first Cassava Drying Project

at the north coast of Colombia (Ospina and Wheatly, 1991). The project has been based on an Integrated System Approach combining cassava production, processing and marketing research aspects in order to develop the proper technologies. Small-scale farmers and cooperatives produce, process and market sun-dried cassava chips for the commercial animal feed industry. Rapid adoption of this methodology has resulted that currently in Colombia, approximately 16,000 MT of dried cassava chips are being produced every year. The differentiation of the traditionally fresh cassava market has increased overall cassava demand, reduced price variability, increased yields and has created incentives for adoption of improved production technologies. Not only have the incomes of poor farmers improved, also the small-scale rural agro-industries producing dried cassava have generated employment opportunities for many landless labour with low opportunity costs.

TABLE 2.**Sensitivity analysis for cassava price change in poultry feed ration**

	A	B
	(%)	(%)
Maize	0	0
Sorghum	0	53.5
Rice flour	0	0
Cassava flour	46.6	0
Rice bran	5	5
Wheat germ meal	10	10
Molasses	5	5
Soybean meal	0	0
Sesame meal	22.9	16.7
Cotton seed meal	0	0

Fish meal	0	0
Blood meal, animal	3	3
Bone meal	0	0
Salt	0.4	0.4
Calcium carbonate	0.1	0.8
Calcium phosphate	1.6	1.3
Vegetable fat	4.6	3.6
Lysine	0.6	0.5
Methionine	0.1	0.1

Scenario A: Ratio of Pcassava/Psorghum:.85
Scenario B: Ratio of Pcassava/Psorghum:.80

Besides Colombia, small-scale cassava-drying plants have been established in Ecuador, Paraguay, Panama, Mexico and Brazil. Figure 1 shows the rate of adoption and the estimated number of drying plants in Latin America. Once institution related cassava drying plants have initiated a dried cassava market in a country, it offers opportunities for individual farmers and non-affiliated commercial plants to produce dried cassava. As such, the technology of drying cassava is utilized by different user groups which accelerates its adoption.

LIMITATIONS TO DRY CASSAVA DEVELOPMENT

Although adoption of the dried cassava technology has been significant, several aspects have been limiting this process. The principal constraint is the complexity of government import, and pricing and marketing interventions. In general, one of the major objectives of government agricultural policies is to provide incentives for increased primary staple (food grains)

production and subsequently improve farmer incomes. In addition, many policies are aimed to provide urban consumers with inexpensive basic staples. As such, different policies within a country may have contradicting effects, resulting in a highly ineffective allocation of scarce resources.

Three types of policies are relative to the current discussion. They are direct policies, indirect policies and exchange rate strategies. Direct policies include a wide variety of policy instruments as input/credit (production) subsidies, trade quotas, levies, tariffs, qualitative restrictions, etc. The well known policies of this kind are the ones applicable to EC cassava product imports under the Common Agriculture Policy (CAP). Annual quotas at administrated prices are set for cassava pellets and chips imported from Thailand, Indonesia, Vietnam, China, etc. These policies attempt to protect the interests of the EC's feed grain farmers. (For further discussion, see Bottema and Henry, 1990).

Indirect policies, most probably have the largest adverse effect on the potential for cassava as an animal feed ingredient. Indirect policies are targeted at a specific crop, but can have additional effect on non-targeted crops. For example, Colombian and Venezuelan sorghum farmers are protected from low-priced import competition through a system of regulations and high domestic support prices (Table 3). At the same time animal feed manufacturers can purchase a quota at the world market price. As cassava is not being subsidided it cannot complete against these “artificial”prices.

Fig. 1: Total expansion of cassava drying plants in selected countries in Latin America (1981-90)

Source: CIAT, Cassave Economics, 1990

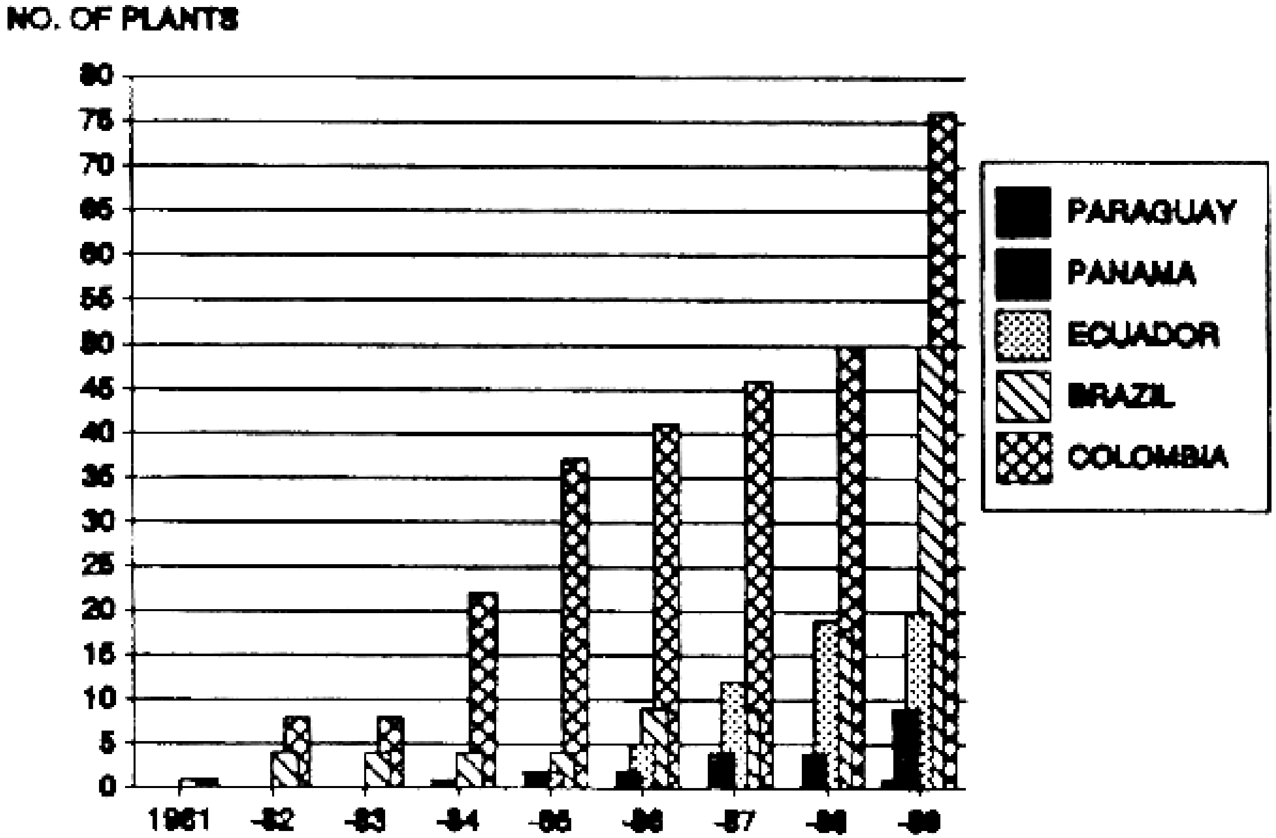

TABLE 3. **Composition of Import Prices, Colombian support prices and price ratio for sorghum, 1980–89**

Year	P	B	B/A
	import[a]	support[b]	ratio[c]
	US$ MT		
1900	145.94	22.25	1.54
1981	126.43	258.76	2.04
1982	98.36	269.93	2.74
1983	111.70	253.77	2.27

1984	105.82	231.79	2.19
1985	87.51	207.29	2.37
1986	71.39	168.59	2.36
1987	70.61	168.38	2.38
1988	89.99	174.15	1.94
1989	99.32	198.92	2.00

a *FOB. Rosario, Argentina*
b *Average semestral support price IDEMA*
c *Ratio of support price divided by import price*

Source: IDEMA, Bogotá, Colombia, 1990

Brazil exercises a direct subsidy on feed and food grain transportation. Maize produced in the South and Central West can be moved at low cost to deficient areas in the North and North East. Hence, this subsidy can shift the comparative advantage away from locally produced feed stuffs like cassava. Cassava will thus face heavy competition with cheap “imported” maize from the South. Table 4 shows that in spite of subsidies on maize, cassava can still be cost competitive. However, with the absence of these subsidies cassava could play a much larger role in the animal feed industry of North East Brazil.

The third relevant type of government intervention are exchange rate manipulations. This does not only effect feed grains and its substitutes, but the whole range of industrial and agricultural trade. In the case of Mexico, Peru and Venezuela (and many others), overvalued exchange rates have pushed domestic feed grain prices above world market prices. Hence, allowing cheap feed grain imports to capture a significant market share of the feed grain

industry.

There exist many more examples of adverse effects of government interventions on the development of cassava for the animal feed industry. For Latin America, Lynam (1989) and Peterson et al (1988). For Asia, Bottema and Henry (1990). It can be concluded that government policies severely constrain the potential role that cassava can play as an cost efficient substitute for commercial animal feed rations in LDC's.

Besides government intervention, the nature of price formation of existing (fresh) cassava markets has a negative effect on expansion into dried cassava markets (Lynam, 1989). Three inter-related aspects form the basis for this phenomenon. First, markets for fresh cassava are numerous and widely distributed. The bulkiness and perishability of the product and general high transport costs prevent a large spatial market. Secondly, the product characteristics translate into a high risk factor for the market agents and quality variability factors wll result in a high marketing margin. Thirdly, spatially fragmented markets with small volumes of product, often result in large annual price fluctuations, since there is no unified price structure.

Although suboptimal price formation can seriously impede the rapid development of an expanded market, the experiences of dried cassava in several Latin American countries have demonstrated that this constraint can be overcome.

TABLE 4. **Private and social costs of supplying maize and dried cassava to the northeast, Brazil, 1986**

Item	**Private Costs**		**Social Costs**	
	Absolute	**Cassava/Maize**	**Absolute**	**Cassava/Maize**
	(Cr$/metric ton)	(percent)	(Cr$/metric ton)	(percent)
Locally produced maize	1,517	86	1,405	88

Maize from south	1,616	81	1,468	84
Maize from central west	2,494	52	2,130	58
Imported maize	1,705	77	1,675	73
Locally produced cassava	1,306		1,231	
Maize price	1,690	77	1,690	73

Source: Lynam, 1989

CONCLUSIONS AND RECOMMENDATIONS

In this paper it was demonstrated that a relatively strong demand for animal protein will continue until the end of the century in the developing world. Likewise, domestic intensive meat production will increase. It was also noted, that LDC's have significantly increased feed grain imports during the last decade. In addition to the serious foreign debt problem, large grain imports pose an additional burden on LDC's foreign exchange resources. Given this reasoning, one can conclude that there exists a large potential for domestic produced cassava to substitute socially “expensive” feed grains in animal feed rations. However, a large and complex variety of government policies seriously constrain this potential. The nature of price formation of the traditional (fresh) cassava has an adverse effect on the expansion into dried cassava markets.

Notwithstanding, dried cassava production for the animal feed industry has increased significantly in several Latin American countries during the last decade. A methodology developed by CIAT, has instigated smallscale rural agro-industries producing cost effective dried cassava. This method has already shown to have generated considerable benefits, which to a large extent are captured by poor cassava farmers and the land-less rural population with

low opportunity costs.

The following recommendations are made in order to take full advantage of the existing potential for cassava as animal feed:

1. **A better understanding of needs to be acquired about the full extent of the effects of government policies on feed stuffs production, processing, marketing and trade aspects.**

2. ***Ex-ante* analysis needs to be conducted on the future impact of the "apertura" philosophy that will attempt to bring LDC's (and developed countries) in line with world agricultural markets. Government intervention measures will continue to be the key constraints to the development of cassava for the animal feed market.**

3. **The methodology developed, tested and diffused by CIAT, based on the Integrated Cassava Drying Technology, has been significantly adopted and shown great impact in Latin America (Figure 1). Asian and African countries with similar limiting conditions could take advantage of this methodology to expand cassava into a animal feed resource. However, CIAT is not the appropriate organization nor has the resources to diffuse this technology across the globe. NGO's must be identified to take over this task.**

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Sweet potatoes as animal feed in developing countries: present patterns and future

prospects
by G.J. Scott

INTRODUCTION

Many developing countries are under increasing pressure to make more effective use of available resources in the agricultural sector both to satisfy the growing demand for livestock products and to raise rural incomes by generating additional value added through processing. The cost of balancing domestic demand for livestock products with feed or livestock imports has become prohibitively expensive. The prospects for increases in the output of cereals of the magnitude required to meet livestock and human requirements remain problematic. Consequently, alternative sources of livestock feed both to spur domestic livestock production and to free cereal supplies for human consumption are receiving closer attention. Interest in the potential for a expanded use of sweet potatoes as animal feed in developing countries has arisen in this context.

This paper focuses on the following key questions:

1. What are current production and utilization patterns for sweet potatoes in developing countries?
2. Where, how and to what extent are sweet potatoes used for animal feed?
3. What is the potential for expanded use of sweet potatoes as animal feed?

As will be indicated below, the last two decades have witnessed some dramatic increases in the use of sweet potatoes for animal feed. Furthermore, the potential for greater utilization of sweet potatoes in this form would also appear to be bright.

PRODUCTION

Sweet potato is among the five most important food crops in developing countries in terms of total production (Horton 1988). Although the sweet potato *Ipomoea batatas* (L.) Lam is of New World origin, over 90% of developing country production is produced in Asia; 85% in China alone (Table 1). While sweet potato production and area planted in Africa practically doubled over the last three decades, they remain less than 5% and 15% respectively of developing country totals. Latin America accounts for about 2% of output and 3% of area planted.

TABLE 1. **Sweet potato production, area and yield in developing countries by regions, 1961–88**

	1961/63			1986/88		
Region	**Product[a] (000t)**	**Area[a] (000 ha)**	**Yield[a] (t/ha)**	**Product[a] (000t)**	**Area[a] (000 ha)**	**Yield[a] (t/ha)**
AFRICA[b]	3,464	646	5.4	6,264	1,202	5.2
(sub-saharan)	3,381	642	5.3	6,193	1,199	5.2
	3.6%	5.1%	70.9%	4.9%	13.3%	37.0%
ASIA[d]	86,853	11,595	7.5	116,261	7,481	15.5
	92.9%	92.2	100.8%	92.7%	83.3%	111.3%
(China)	78,694	10,333	7.6	108,063	6,306	17.1
	81.2%	80.3%	101,1%	86.2%	70.2%	122.8%
LATIN AMERICA[c]	2,787	342	8.2	2,284	298	7.7
	3.0%	2.7%	109.8%	1.8%	3.3%	54.8%
TOTAL	93,105	12,583	21.1	124,809	8,981	28.4

a percent of total production/area planted/average yield for all developing countries

b *Africa not including South Africa*

c *Africa-(Morocco, Algeria, Tunisia, Egypt, Libya)-(South Africa)*

d *Asia_ (Israel Japan)+Oceania-(Australia,New Zealand)*

e *North and Central America + South America*-(Canada,USA).

Source: FAO Basic Data Unit, unpublished statistics

Sweet potatoes are grown in some 98 developing countries (Table 2). However, the 15 countries with the largest production account for nearly 97% of this total (Table 3). These countries also account for 98% of the change in output since 1961.

TABLE 2. **Distribution of developing countries by volume of production, 1986–88**[a]

Sweet Potato Production	Number of countries			
	Africa	Latin America	Asia	Total
0 or no information	17	15	34	68
< 10,000t	10	21	13	43
<50,000t	12	3	6	21
<250,000t	7	4	3	13
>250,000t	8	4	9	21
Total	54	47	65	166

a *FAO includes various sites (e.g. Hong Kong) in the "developing countries" category. These figuresreflectthat categorization.*

Source: FAO Basic Data Unit, unpublished statistics

Recent trends in sweet potato area planted and production have been highly uneven. In a number of countries, output and area have fallen (e.g. China, Indonesia, Philippines, Brazil) since the mid-1970's (Table 3). Reasons cited for this include: (i) expansion of production infrastructure (i.e. irrigation) for other crops, (ii) switching to higher value vegetable crops in response to, (iii) growth in urbanization, incomes and the associated demand for more diversified diets (see, e.g. Calkins 1979; Chin 1989). Trends in sweet potato production have been just the opposite in several other countries.

TABLE 3. **Evolution of sweet potato production in developing countries, 1961–88**

	1986–88			**Change (%)[a]**								
	Production	**Area**	**Yield**	**Production**			**Area**			**Yield**		
	(000 t)	**(000 ha)**	**(t/h)**									
				1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
China	108,063	6,306	17.1	58	-13.3	36.9	-10.2	-30.7	-37.8	75.9	25.1	120
Indonesia	2,087	243	38.6	-21								
Vietnam	1,913	325	5.9	-4.6	74.0	65.9	-5	48.7	41.2	0.4	17.0	17.5
Uganda	1,698	388	4.4	201	2.5	209	209	-20.1	147	-2.6	28.3	25.0
India	1,385	172	8.1	78.2	-21.4	40.0	54.1	-22.9	18.8	15.6	1.9	17.9
Rwanda	940	131	7.2	11.9	64.7	84.3	8.5	61.6	75.4	3.1	1.9	5.1

Brazil	734	74	9.9	15.5	-56.1	-50	5.9	-51.6	-48.7	9.1	-9.5	-1.3
Philippines	711	150	4.8	11.8	-12.6	-2.2	17.7	-13.8	1.4	-5.0	1.5	-3.6
Burundi	619	85	7.3	-11.3	48.4	31.6	-0.5	27.1	26.5	-10.9	16.8	4.1
Korea Rep.	596	27	21.7	45.2	-64.7	-49	18.8	-69.6	-64.0	22.2	16.2	42.0
Bangladesh	573	53	10.8	94.9	-16.1	63.6	63.1	-17.0	35.4	19.5	1.1	20.8
Kenya	523	40	13.1	80.0	93.9	249	24.2	26.3	56.9	44.9	53.5	122.5
Korea DPR	492	34	14.6	38.4	55.0	114.5	42.9	44.3	106.1	-3.1	7.5	4.1
Papua New Guinea	471	104	4.5	36.2	17.1	59.4	21.8	15.7	40.9	11.8	1.2	13.1
Madagascar	467	92	5.1	-14.1	76.6	51.8	0.2	59.1	59.4	-14.3	11.0	-4.8
All Developing Countries	121,272	8,224	14.0	52.3	-12.0	34.1	-4.0	-25.6	-28.6	58.7	18.4	87.9

a *1=(1973–75 vs* 1961–63); 2=(*1986–88 vs 1973–75*); 3=(*1986–88 vs 1961–63*).

Source: FAO Basic Data Unit, unpublished statistics

Sweet potato output expanded rapidly during the last decade in various locations including Vietnam, Kenya, Rwanda, Burundi, the Democratic Republic of Korea and Madagascar (Table 3). Rapid population growth resulting in increased pressure on farm land was a prime factor explaining this trend in some countries e.g. Rwanda (see von Braun *et al*. 1988) while economic

and political disruptions of other agricultural activities probably contributed to this growth in other countries e.g. Vietnam (Mackay 1989).

UTILIZATION

Information about the utilization of sweet potato in developing countries is generally harder to come by and less reliable than is the case with other roots and tubers e.g. cassava, potato (see Horton *et al*. 1984). International statistics indicate that approximately one third of sweet potato production in developing countries currently goes to animal feed, although the overall average is highly inflated due to the importance of China and Brazil that use huge amounts of sweet potatoes for feed. This percentage appears to have steadily increased from about 10% in the early 1960s (Table 4).

TABLE 4. **Changes in utilization (%) of sweet potato in developing countries, 1986–88**[a]

	1961–63	1973–75	1986–88
Food	77.6	70.2	52.4
Feed	11.7	19.0	36.1
Processing	4.5	4.8	5.4
Seed	0.3	0.2	0.2
Waste	5.9	5.8	5.8

[a]***Data are for the 15 countries with the largest sweet potato production***

Source: FAO Food Balance Sheets, unpublished statistics

Growth in production and availability of cereals and the rising demand for meat products have

induced sweet potato producers to look for alternative outlets for the crop, especially in Asia where this trend has been particularly pronounced. Sweet potato use for animal feed is, with a few notable exceptions, less than 10% of output in sub-Saharan Africa and Latin America.

Amongst the 15 largest producers, FAO statistics indicate sweet potato use for animal feed is 40% of total output in China, 35% in Brazil, 30% in Madagascar, 17% in the Republic of Korea and 5% or less in the remaining 11 countries (Table 4). The estimated percentages have remained stable during the last three decades in all the countries except China (12% in 1961–63) and Korea (2% in 1961–63).

Recent Chinese estimates indicate as much as 65% of sweet potato output now goes to animal feed. Explanations for this sharp increase include growth in cereal production, meaning less sweet potato is needed to supplement cereal consumption; rising demand for meat products (principally pork) for which sweet potatoes serve as a feed component, and changes in government policy e.g. the introduction of the "responsibility system" which permits the sale of agricultural surpluses for profit. Furthermore, an EEC bilateral agreement allowed China to export up to 600,000t of dried sweet potato chips to member countries duty free during the 1980s (see Calpe, 1991).

It also should be noted that estimates of "processing" or "waste" as a percentage of sweet potato production are difficult to interpret. In many countries, waste in the form of damaged roots and vines are processed or fed to livestock. On the other hand, some production is lost due to physical or autolytic processes, microbiological attack, pest damage, and so on (see NAS 1978). Furthermore, postharvest losses for sweet potatoes like other root and tuber crops would appear to be higher than for the cereal crops, given their higher water content and bulkiness, (see Coursey 1982). But little quantitative information is available other than those based on inferences of an a priori type (i.e. sweet potatoes are perishable, therefore a certain

percentage of the harvest is lost) or desktop "guesstimates". Consequently, available statistics are unreliable when it comes to calculating the volume of unutilized supplies that might be converted into animal feed.

FEED PRODUCTION AND USE

Sweet potato is almost always used, in some form and amount, as an animal feed wherever it is produced in developing countries. Unfortunately, information about the exact nature, extent and evolution of these practices is handicapped by a lack of knowledge about the crop generally and the use for animal feed specifically. With that observation as a caveat, the meager evidence available about present practices suggests that sweet potato is most commonly used as animal feed on the farm itself. Roots, vines, and foliage are fed principally to pigs and cattle in unprocessed form. With certain notable exceptions, animal feed currently constitutes a minor share of the total utilization of sweet potato production.

Asia

Roots for pigs and vines for cattle are the most commonly cited forms of sweet potato utilization as animal feed in Asia (Table 5). Both are employed in a variety ways. Visually all feed production from sweet potato takes place at the farmer or village-level. Only limited quantities of composite feeds are produced industrially.

Uncooked roots are fed to pigs in China, parts of Indonesia (Irian Jaya), Korea, Papua New Guinea, Thailand, and Vietnam (see CIP 1989). These roots may be used fresh or after storage. Some farmers in China slice up the fresh roots to make them more digestible or feed them mixed with vines, other household feed sources (e.g. rice hulls, corn husks) or even purchased protein supplements. In Korea, these fresh roots include culls left from sales to the market

(Chin 1989). In Papua New Guinea, pigs will forage for roots or culls left in the field (Kanua and Rangat 1989).

Some farmers in China and the Philippines prefer to boil the roots first and then use them as pig feed. This practice reportedly improves digestibility. Cooked root-leftovers from human consumption serve as one form of pig feed in Papua New Guinea.

TABLE 5. **Sweet potato use as animal feed in Asia**

Country	Part Plant	Form	Animal(s) Fed
Bangladesh	Vines	Green	Cattle
China	Roots	Sliced, dried, ground,cooked	Principally pigs but also for cattle,poultry
	Vines	Green, from ensilage	Ibid
	Waste from Processing starch, noodles	Waste water	Pigs
India	Roots	Sun-dried chips	Pigs
	Vines	Green or after ensilage	Cattle
Indonesia (Java)	Roots,culs,vines	Fresh	Cattle
(Irian Jaya)	Roots	Fresh	Pigs
Korea,Rep.of	Roots,culls,stored roos	Fresh,stored limited quantity for high carbohydrate feed	Pigs, composite feeds for pigs, poultry and other domestic animals

	Vines,foliage	Silage	Livestock
Papua New Guinea	Roots	Fresh,stored	Pigs
	Leaves,vines	**Green**	**Pigs**
Philippines	Roots	**Cooked,dried chips, composite feed**	Pigs mainly, also poultry
	Vines	n.a.	**Pigs,carabao**
Taiwan	**Roots**	**Sliced,dried**	**Pigs**
Vietnam	**Roots**	**Fresh,sliced and dried**	**Pigs**
	Vines	n.a.	**Pigs**

n.a.= not available

Source: CIP 1989; Mackay et al, 1989

Many sweet potato farmers in northern China slice and then dry sweet potato roots before using them as pig feed (Lu *et al.*1989). This type of simple processing often takes place in the field itself. Slicing, then sundrying of the roots is a well-known procedure for production of pig feed from sweet potatoes in Taiwan (Calkins 1979; Tsou *et al.*1989). It has also been done on a more limited basis in the Philippines, (Palomar *et al.* 1989) and Vietnam (Hoang *et al.* 1989).

In China, sweet potato roots are also ground by various types of smallscale machines and used to make starch for noodles (see Tang *et al.* 1990). After draining off the starch, the remaining pulp is then used as is, fermented, dried, or stored to make pig feed. Waste water from village-level starch and noodle production also is fed to pigs.

Sweet potato vines and/or foliage are also used as animal feed throughout Asia (Table 5).

These parts of the plant are fed as is or after ensilage to cattle in Bangladesh, China, India, Indonesia (Java), and the Philippines (see CIP 1989; Mackay *et al*. 1989). They also serve as a form of pig feed in Papua New Guinea, Vietnam and are fed to poultry in China. In Bangladesh, India, and Indonesia, vines and/or foliage serve as a principal source of animal feed from sweet potato production. Nevertheless, available estimates indicate only a tiny fraction of sweet potato output used for this purpose.

Africa

Information about the use of sweet potato for animal feed in Africa is particularly sparse. The limited reports suggest that nearly all roots are for human consumption with only damaged ones being fed for livestock e.g. Rwanda (see Ndamaga 1988). Vines and foliage from the sweet potato plant are fed principally to cattle in a number of countries however (see CIP 1988).

In Egypt, Kenya, Mozambique, Rwanda, and Uganda vines and/or foliage are utilized as green fodder for cattle principally, but also for pigs and other small animals (Table 6). Two reasons why this practice is not more widespread are : i) farm households eat the vines in boiled form as a source to put on the basic staple (e.g. in rice in Sierra Leone); ii) farmers willl leave vines in the field to improve soil fertility.

TABLE 6.**Sweet Potato use as animal feed in Africa and Latin America**

Country	**Part of Plant**	**Form**	**Animal(s) Fed**
AFRICA			
Egypt	Vines	Green fodder	Cattle
Kenya	Vines	Green fodder	Cattle, pigs

Mozambique	Vines	Green fodder	Small animals
Rwanda	Damaged roots, vines	Fresh	Livestock
Uganda	Surplus roots and vines	Fresh	Livestock, pigs Fish
	Leaves	Fresh	
LATIN AMERICA			
Argentina	Roots,vines	Fresh	Pigs,cattle
Brazil	Roots, vines	Fresh	Dairy and beef cattle, pigs
Ecuador	Roots	Fresh	Pigs, goats, beef cattle
	Vines	Green fodder	Beef cattle, goats
Dominican Republic	Roots	Fresh	Pigs
	Vines	Green, ground	Cattle
Haiti	Culls, roots left in the field after harves	Fresh	Pigs
Jamaica	Roots	Fresh	Pigs
	Vines	Fresh	Pigs, cattle and other farm animals
Peru	Roots	Fresh	Cattle, pigs rabbits
	Vines	Fresh	Fodder for dairy cattle and small ruminants
Venezuela	Roots, vines	Fresh	Livestock

Source: Boy et al, 1988; CIP 1988,1988a.

Latin America

Sweet potatoes roots, vines and foliage are used for animal feed in a number of Latin America countries (Table 6). As the crop is typicallky grown on small farms, often for household consumption, Argentina,]Brazil and Peru are notable exceptions, statistics on utilization patterns for animal feed are clearly guesses. An estimated 35% of sweet potato production is used for animal feed in Brazil (Table 6), about 15% in the Dominican Republic (Baez 1988). This percentage is negligible for other countries in the region except in those cases where total sweet potato production in absolute terms is itself insignificant.

Roots are fed generally to pigs. Except in Brazil (Franca 1988) and Peru (Burga 1988) where the roots are used for cattle. In Argentina, the roots are thge culls left after grading for market (see Boy *et al*. 1988). In Haiti, pigs will dig up the roots that remain in the field after the final harvest (Polynice 1988). In every instance, these roots appear to be utilized in fresh form i.e. without cooking or drying. Sweet potato vines and foilage are also used as animal feed. In Argentina, Brazil, Ecuador, the Dominican Republic, and Peru, the vines and foliage are fed prinicpally to cattle, but also to pigs and rabbits (Peru) and to goats (Ecuador). In Argentina, Brazil, and the Dominican Republic in particular, fodder from sweet potatoes has served as an emergency supply of cattle feed for farmers in periods of drought or during the dry seasons (see Boy *et al*. 1988; Franca 1988; Baez 1988). The vines and foliage are used in unprocessed form in every instance except in the Dominican Republic where they are first ground and then mixed with sugar cane by-products before being to fed to livestock.

POTENTIAL FOR SWEET POTATOES AS ANIMAL FEEDD

Expanded use of sweet potato as animal feed appears to be promising for both agro-biological and socio-economic reasons. On the agro-biological side, sweet potato has a relatively short vegetative cycle (4-5 months).

Hence, it fits nicely into tight cropping systems. It therefore also products much more dry matter per hectare and per day than cassava (see Horton 1988). Sweet potato is widely adapted to diverse altitudes (up to 2000m) and temperature conditions. It requires pratically no cash inputs and minimal horticultural practices. Sweet potato also competes better with weeds than other root and tuber crops. It also has more potential for greater mechanized harvesting than cassava.

Improvements in yield, dry matter content, and digestiblity of the crop should make sweet potato incresingly more trractive as a source of animal feed. Average yields for sweet potatos in developing countries doubled over the last twenty-five years primarily because of developments in China (Table 1). Yet the yield increases in the People's Republic appear to have been largely the result of changes in cultural practices (i.e. increased plant density) rather than the utilization of improved varieties or of chemicl fertilizers and pesticides (Mackay 1989).; Moreover, average yeilds in China (17t/ha) are fifty percent or less of what is commonly achieved on experiment stations in developing countries. Up until recently, sweet potatoes have received relatively few resources for research and development in these countries. As pressure mounts on farmers to raise productivity, the potential gains to be made from improved sweet potato varieties and modern inputs should be more widely realized.

Most sweet potatoes currently cultivated in developing countries have a dry-matter content of around 30%. Results of research at the Asian Vegetable Research and Development Center show that "the mean dry matter content of breeding lined imporoved from, 25.9 percent to 35.1 percent in five years. Theoretically this program increased ship yield for animal feed by 40

percent." (Tsou *et al*. 1989). Moreover, the international germsplasm collection for this crop includes vareities whose drymatter content is as high as 45%. Clearly the potential is there to raise the sweet potato's utility for porocessing by incorporating varieties with higher dry-matter content into the material available to growers in developing countries.

Digestibility appears to be a problem in some countries for some varieties that are grown under certain types of conditions and for some types of animal feed (see, e.g. Tsou and Hong 1989). Improved digestibility of sweet potato varieties through bio-technology, or as Tsou *et al* (1989) point out "through selection of varieties with low trypsin inhibitor activities", should also help expand the plant's potential for wider use as an animal feed in developing countries.

SOCIO-ECONOMIC FACTORS

Sweet potato's potential for animal feed will also depend on socioeconomic factors including: i) growth in population and incomes, ii) growth in demand for cereals for human consumption and for animal products, and iii) the capacity of a given country to cover food deficits through imports.

Growth in population can affect the prospects for sweet potato utilization as animal feed in various ways. If population growth outstrips growth in cereal production, then those cereals currently sed for livestock feed will be required for sustaining levels of cereal consumption so as to minimize the need for expanded food or feed imports. Population growtgh in the countryside may induce farmers away from expanded cereal production to more high valued crops so as to maintain incomelevels. Growth in incomes may further aggravate this situation to the extent that consumers utilize these higher incomes in an effort to raise their consumption of both cereals and livestock products.

Growth in the demand for cereals for human consumption and livestock products will also influence the prospects for sweet potato use as animal feed. The 1980s witnessed a slowdown in the rate of increase of production of cereal crops in a number of developing countries partly because the rate of increase in yields became more difficult to sustain. Should population growth rates fail to decline, the prospects for meeting domestic food requirements with local supplies become more problematic. Furthermore, if consumers, particularly in Africa and Asia, try to improve their diets by increasing consumption of livestock products at the same time, the pressure on the agricultural sector to meet the demand for livestock products through development of alternative production schemes could well increase utilization of sweet potatoes for animal feed.

Many countries have witnessed dramatic reversals of governemnt policy as regards food and feed imports over the last few years partly as a result of chages in world markets, the burden of accumulated debt, or in an effort to create more oppurtunities for domestic agricultural production. These policy changes and similar changes in the years ahead will strongly influence the potential for sweet potato use as animal feed.

It will take time to feel the full impact odf several of the agro-biological and socio-economic factors outlined above. In the meantime, the prospects for the expanded use of sweet potatoes as animal feed would appear to be greatest in those regions and coutries where a substantial supply of the commodity already exists, where feed shortages have already materialized and where continued or expanded imports of feed do not appear sustinable for economic or political reasons. A number of countries in Asia (e.g.China, phillippines) and to lesser extent in Latin America (e.g. Brazil, Peru, Dominican Republic) would appear to meet these criteria. Unfortunately, a detailed assessment of the marketing for sweet potatoes as animal feed in these countries is currently not availble. That task is what merits immediate attention.

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Appendix 1. Sweet potato production ('000 t) in developing countries, 1986–88.

	Africa Country	Latin America Country	Asia/Pacific/Middle East Country
O or no information	St.Helena	Nicaragua	Lebanon
	Cent. Afr. Republic	Colombia	Johnston Island
	Morocco	Greenland	Jordan
	Libya	Falk. Is (Malvinas)	American Samoa
	Gambia	Neth. Antilles	S.Arabia Km
	Namibia	Turks & Caicos Is.	Yemen Democratic
	Seychelles	Belize	Samoa
	Ghana	Panama	Allis & Furtuna Is.
	Tunisia	French Guiana	Kiribati
	Algeria	Us Virgin Islands	Yemen Arab Republic
	Guinea Bissau	Guyana	Wake Island
	Botswana	Costa Rica	Tuvalu
	Djibouti	Brit. Vgn Islands	Vanuatu
	Malawi	Guatemala	Mongolia
	Lesotho	St.Pierre & Miquelon	Qatar
	Sao Tome & Principe	Brit. Ind.Ocean Terr	Syria
			Oman
			Cocos (Keeling) Is.
			Kuwait
			Iraq

			Norfolk Island Midway Islands
			Afghanistan
			United Arab Emirates
			East Timor
			Tokelau
			Iran
			Nepal
			Gaza Strip (Palestine)
			Nauru
			Bhutan
			Turkey
			Xmas Island (Aust.)
			Cyprus

Appendix 1. (Continued)

REGION	Africa		Latin America		Asia/Pacific/Middle East	
	Country	Prod.	Prod.	Country	Country	Prod.
	<10,000 t	Mauritius	*	Cayman Islands[o]	*Guam[o]	*
	Zimbabwe	1	Montserrat[o]	*	Bahrain[o]	*
	Reunion	2	Bermuda[o]	*	Maldives[o]	*
	Gabon	2	Trinidad &	*	Singapore[o]	*

	Swaziland o	2	Tobago Suriname	*	Brunei Darussalam o	*
	Mauritania	2	St. Kitts & Nevis o	*	Niue o	*
	Togo	3	Antigua & Barbuda o	*	Hong Kong o	*
	Somalia	4	Grenada o	*	French Polynesia o	1
	Sudan	7	El Salvador	*	Macau o	1
	Senegal	7	Bahamas o	*	Cook Islands o	2
	Honduras	2	Saint Lucia o	1	Fiji	2
			Pac.Is.(Tru.Tr.) o	3	New Caledonia o	4
			Dominica o	2		
			Barbados o	3		
			Martinique o	3		
			Ecuador	5		
			Venezuela	7		
			Chile	7		
			Guadeloupe o	8		
			St. Vincent	8		
			Grenadns o			
				8		

<50,000 t	Congo[o]	10	Puerto Rico[o] Bolivia	10	Pakistan	16
	Cape Verde[o]	11	Jamaica[o]	24	Tonga[o]	18
	Cote d'Ivoire	12	Dominican Republic	39	Burma	26
	Sierra Leone	14	Comoros[o]	13	Malaysia[o]	37
	Liberia[o]	18			Kampuchea Democ.[o]	40
	Zambia	23			Solomon Islands	50
	Burkina Faso	27				
	Benin	36				
	Equatorial Guinea[o]	36				
	Niger	37				
	Chad	43				
	<250,000 t	Mozambique	54 Mexico	51	Sri Lanka	87
	Mali	57	Uruguay	60	Thailand	108
	Egypt	71	Paraguay	105	Laos	124
	Guinea	90 Peru	129			
	Ethiopia	138				
	Cameroon	151				
	Angola	180				
	> 250,000 t	Nigeria	260 Cuba	270	Papua New Guinea	471

		Tanzania	332 haiti	373	Korea DPR	492
		Zaire	373 Argentina	434	Bangladesh	573
		Madagascar	467 Brazil	734	Korea Rep	596
		Kenya	523		Philippines	711
		Burundi	619		India	1,385
		Rwanda	940		Viet Nam	1,913
		Uganda	169		Indonesia	2,087
			8			
					China	108,063

o Among 5 most important crops in terms of annual production (fresh weight)

** Less than 500 t*

Source: FAO unpublished statistics

Cultivation harvesting and storage of sweet potato products
by G.Paneque Ramirez

INTRODUCTION

The sweet potato (*Ipomoea batata* L.) is one of the twelve principal plant species utilized as a human feed throughout the world.

It can be cultivated in many different climatic conditions, and as a result large areas of sweet potato are cultivated in Asia, Africa, Europe, America and Oceania (Table 2). The various ways in which it can be used are shown in Table 1.

TABLE 1. **Use of tubers of sweet potato**

	Japan	USA
Starch, Alcohol, Wine	54%	0%
Cattle Feed	25%	10%
Human Food	15%	84%
Seed	6%	6%

TABLE 2. **World production of sweet potato (FAO 1987)**

Regions	Production (in 1000 ton)	% of world production
Africa	6.766	5.0
Asia	124.775	92.3
South America	1.546	1.1
North and Central	1.476	1.0
Oceania	0.570	0.4
Europe	0.103	0.0
Total	135.237	99.8

ECOLOGY

Sweet potato is a tropical and subtropical plant which can adapt to more temperate climates providing the average temperature does not drop below 20°C and minimum temperatures stay above 15°C. In other words it can be cultivated between the 30 and 40° latitudes in both hemispheres.

Temperature

For the cultivation of sweet potatoes a range of temperature between 15 to 33°C is required during the vegetative cycle, with the optimum temperature being between 20 to 25°C. The highest yields are obtained when temperatures are high during the day (25 to 30°C) and low by night (15 to 20°C); low temperatures during the night favour the formation of tubers, and high temperatures by day favour vegetative development. (Note: tubers development only occurs within a temperature range of 20 to 30°C, optimum 25°C and generally stops below 10°C).

Light

Sweet potato is a short day plant, that needs light for maximum development. However, the growth of the tubers appears not to be influenced by photoperiod alone. It is probable that temperature and fluctuations in temperature, together with short days favour the growth of tubers and limit the growth of foliage (Youg, 1962).

Altitude

In tropical regions it is possible to cultivate sweet potato from sea level to 2500 m; for example

in Bolivia, Peru and Colombia it is cultivated from sea level to 2300 m. (Del Carpio, 1969).

Moisture

Moisture has a decisive influence on sweet potato growth and production. In this context it is relevant to note the water content of the leaf is (86%), stem (88.4%) and tuber (70.6%).

At planting it is important to have moist soils in order to achieve good germination. The soil must also be kept moist during the growth period (60–120 days), though at harvesting the humidity must be low in order to prevent the tubers rotting (Carballo, 1979).

Conditions that favour the development of the vegetative part of the plant include an 80% relative humidity and moist soils.

Soils

Sweet potato can be cultivated in a wide range of soils, with the best results obtained in ferralitic, brown humic and calcimorphologic soils. Ideally the soil should be friable, have a depth of more than 25 cm. and have good superficial and internal drainage.

The chemical properties of the soil are less limiting than structural properties in obtaining good yields. For example, in sandy soils poor in nutrients good yields can be obtained whereas in rich soils the vegetation often becomes luxuriant and the roots large and irregular (in the sandy soils of Manacas Villa Clara, Cuba, yields of 28 t/ha. have been obtained).

Other problems include the difficulty of using machinery on hilly land and drainage on flat land.

The sweet potato also prefers lightly acid or neutral soils, with the optimum PH being between

5.5 and 6.5. Soils which are excessively acid or alkaline often encourage bacterial infections and negatively influence yields (Cairo, 1980).

PHYSIOLOGY

Generally the growth cycle of the sweet potato is from 3.5 to 7 months and takes place in three phases; these are:

a. **From planting to formation of tubers (40 to 60 days)**

b. **From formation of tubers to the time of maximum leaf development (60–120 days)**

c. **From maximum leaf development to the total development of tubers (45 to 90 days)**

Normally the cycle is completed within 100 to 150 days at which time the plant can be harvested.

MULTIPLICATION

Sweet potatoes are multiplied by both sexual and asexual means, though the former is only of interest to geneticists and plant breeders.

Asexual reproduction using tubers and stems is the form of production most commonly used.

Propagation by stem

Of the two systems of multiplication of sweet potato, this form is the quickest and most economic and therefore the most commonly used. The material to be used must be selected to avoid the transportation of eggs or larvae of *Cylas formicarius elegantus* S. to the new

plantation and to avoid the use of unwanted crossbred varieties. In order to avoid this it is necessary to establish "seed banks".

To maintain standards in Cuba it is necessary to obtain a certificate of quality from the CEMSA (Experimental Centre for Improvement of Agamic Seeds), before seed material can be used.

Requirements for the production of "seed material" are:

1. **The seed bank must not be planted in a field that has been used for sweet potato during the previous two years.**

2. **The irrigation system must be reliable.**

3. **The seed (stem) must be *Cylas formicarius elegantus* Summers and virus free and less than 0.5% must be infested with the nematode *Rotylenchulus remiformis* Linfod y Olivera.**

Other aspects to be considered are:

- **The cut stems must be planted within four days of cutting:**

- **The fertilisation applied to the soil at planting and after each cut will be as follows:**

Formula:

9.0–5–16.5	0.17 t/ha/cut
7.5–6–18	0.18 t/ha/cut
5.4–7–21	1.11 t/ha/cut

45 days after planting and after every cut, a 2% foliar urea spray (20 g/l with a final solution of 500 l/ha) must be applied (Lopez and Alvarez, 1971).

The first seed cutting to take place between 60 and 80 days after planting.

After each seed cutting, the following actions should be carried out:

- **Weeding**
- **Fertilization**
- **Hilling**
- **Irrigation**

Further cuts should be carried out every 60 days.

VARIETIES

Table 3 demonstrates the yields of 6 of the best varieties, grown in three different soil types and harvested at different times. Two of these varieties have only recently been produced. Note: the recently developed variety, CENSA, 85–48 which is a short cycle variety (90 to 100 days) has given excellent results in experimental conditions in terms of both tops and tuber yield (40 ton/ha).

TABLE 3. **Yields of tubers in 3 provinces of Cuba (ton/ha)**

Varieties	Pianar del Rio	Habana	Cienfuegos
Days to harvest	135	120	100

CMSA 78326	37.4	45.05	23.6
CMSA 78354	46.4	49.5	18.5
CMSA 78425	43.7	41.93	19.1
CMSA 78228	30.5	39.98	16.5
CMSA 85–48	=	=	25.4
Yabu 8	40.0	=	=

TIME OF PLANTING

In Cuba sweet potato can be planted all the year round if you have irrigation and appropriate varieties.

Where the soils are sandy or clay and irrigation is not available it is advisable to plant at the beginning of the spring, (April to May) though good yields can usually be obtained from July to January.

As indicated, time of planting depends upon the variety used; for example, the variety Cuba 3 gives better yields when planted during the dry season, with irrigation, than when it is planted during the rainy season with the same soil moisture content. Other varieties, like Haiti, give the same yields either when planted during the dry season with irrigation or during the rainy season with or without irrigation. The yield of this variety depends upon the soil moisture content which is the principal factor limiting the growth and development of tubers, and is independent of the time of planting.

DENSITY OF PLANTING

The distance between plants in any crop is a factor which can affect yields, however, in the

case of sweet potato no significant responses have been obtained with the different distances studied.

At CENSA the effect of planting distance between plants (22.5 to 30 cm.) and between rows (70 to 90 m.) under irrigation were studied; the best results (i.e. 30 ton/ha) were obtained planting at 90 × 22 cm and 70 × 30 cm.

In experimental work carried out at the Central University of Las Villas with different distances between plants and location of stems, i.e. perpendicular or across the hill, no significant yield differences were obtained. The distances studied were 90 × 30 cm and 90 × 15 cm.

On the basis of these studies, the planting density recommended by CENSA is 37000 plants/ha with the following distances of planting: Sept.-Feb. 0.90 × 0.23 m and March-August 0.90 × 0.30 m (Ministry of Agriculture, 1990).

FORMS OF PLANTING

1. In the furrow
2. In the upper part of the hill
3. On one side or on both sides of the hill.

METHODS OF PLANTING

Manual

In Cuba planting is generally done by hand, putting the stem on the hill or in the furrow and

covering it with earth using a spade.

Mechanical

In Cuba planting is done with a TR4 planter made in Bulgaria or another similar Trakia planter made in the USSR.

In order to obtain the best results the following planting procedure should be taken into account:

1. **- stems should be 25 to 30 cm in length**
2. **- the depth of planting should be between 7 to 10 cm**
3. **- planting should be on the hill**
4. **- 2/3 of the stems should be buried**

Cultivation

Cultivation activities depend on a series of factors including: variety, time of planting, type of soil, planting distance, etc. The objective should be to carry out as many operations as necessary to optimise vegetative development of the plants (Rodriguez Nodal and Morales Tejon, 1990).

CONTROL OF WEEDS

In this crop, weeds can be controlled by manual, mechanical-manual or chemical means.

Manual control alone is used only for small areas. Mechanical—manual control consists of a combination of between row and between plant cultivations, as follows:

1. **Mechanical cultivation using an inter row harrow and a manual cultivation between plants within 10 to 15 days of planting.**

2. **Hilling up around plants, 25 to 30 days after planting with the aim of reconstructing the hill to eliminate weeds and the incorporate fertilizers. If necessary, hand hoeing between plants should be done at this stage.**

In Cuba a second mechanical cultivation might be necessary for dry season planting.

Use of chemical products

There are many products on the market which can be used and their use will depend upon the chemical to be used.

FERTILIZATION

Due to the sweet potato's great yield potential (foliage and tubers) it requires a considerable amount of fertilization; this varies according to variety and soil type. The percentages of N.P. and K in the organic matter of sweet potatoes are as follows:

	N	P	K
Leaves	0.81	0.15	1.05
Roots	1.80	1.14	3.00

When 15 ton/ha of sweet potato are harvested approximately: 70 Kg of N; 20 Kg of P_2O_5 and

110 Kg of K_2O are extracted from the soil (Jacob and Uexkull, 1968).

Method and timing of fertilizer application

There are several different ways of applying fertilizer, including:

1. **In the furrow.**
   a. **Placing the fertilizer in the furrow and covering with soil from the hill.**
   b. **Planting the stem in a new hill after opening the furrow at a higher level than the fertilizer.**
2. **In the hill. The fertilizer is placed at points 30 cm apart within the furrow.**
3. **At 30 days after planting. The fertilizer is continuously spread along the the length of one side of the hill, following which it is covered using a double mould—board plough passed down the centre of the furrow.**
4. **At 20 or 30 days before planting (in sandy soils). After spreading the fertilizer it is incorporated using a harrow.**

The ratio and amount of fertilizer to be used in sweet potato production has been established in different countries. Examples are shown in Table 4.

TABLE 4. **Ratio and amount of nutrient applied to sweet potato crops in different countries (Kg/ka)**

Country	N	P_2O_2	K_2O	Nutrient Ratio

Korea	200	100	350	2:1:35
Taiwan	60	50	120	1:1:2
Thailand	20	30	=	1:1:0
Madeira Island	25	90	125	1:3:6:5
Egypt	25	100	75	1:4:3
USA	50	150	200	1:3:4
Puerto Rico	56	46	100	1:1:2
Cuba (ferralitics red soils)	71.6	71.6	205.8	1:1:3
Cuba (black soils)	62.6	62.6	142	1:1:2

IRRIGATION

Overall the sweet potato plant requires soils with a high moisture content. For vegetative growth its needs are moderate, though during the first month of growth when the tubers are developing the moisture requirement increases. During the final days of the cycle the moisture requirement reduces.

Furrow and sprinkler irrigation techniques can be used. It is best to carry out one irrigation before planting if the soil is not moist. The net application of irrigation should be between 200 to 250 m^3/ha every 7 to 10 days. This should be stopped about 15 days before harvest (INRA, 1972).

DISEASE AND PESTS

The sweet potato plant is not seriously affected by fungus diseases or virus attacks. Though it can suffer from insect attack.

Tetuan (*Cylas formicarius elegantulus* S.) is the most important pest that affects the sweet potato. The female lays its eggs in stems and roots and the larvae make galleries in the tubers which affects flavour (Dias Sanchez, 1980). In order to control this pest it is best to use "seed" from areas free of the pest, though various insecticides can be used to combat the pest; these are applied to the soil and stems.

Biological control

In Cuba the insect "Hormiga Leona" *(Pheidole megacephala frabricio)* has been used successfully to control the pest. This is achieved by distributing its colonies or nests around the fields at a rate of 13 per ha., 30 to 45 days after planting. Distribution of the fungus (*Blauberia bassiana* Bal.) over the plants 15 days after planting has also been successful.

Nematodes in general do not constitute a serious problem. The principal species are *Rotylenchulus remiformis* Lenford and Oliveira.

Overall, biological control, complimented by agronomic practices such as crop rotation is the best way to achieve success in sweet potato cultivation.

HARVESTING

The time of harvest largely depends upon the variety and soil moisture content during the first month of plant development. However the actual commercial varieties used take different times to harvest, for example:

- **early varieties take 3 to 4 months**
- **medium varieties take 4 to 6 months**

- **late varieties take more than 6 months**

The growth cycle of any variety can be altered by an excess of moisture in the first 3 months after planting. This produces an intense foliar development and a late formation of tubers. Often in these cases the number of tubers are reduced.

Methods of harvesting

Harvesting can be carried out in 3 ways: manual, semi-manual and mechanical.

The *manual* method is the simplest. It is usually used by the small scale producers and involves the use of a digging stick to lever the tubers out of the ground.

***Semi-manual*: This is the most frequently used method in Cuba and involves the removal of the foliage with the help of a harrow which clears the foliage from the area to facilitate the final harvesting. The elimination of foliage must be carried out 24 hours before harvesting. After the foliage is removed a double mould board plough is passed down the centre of the hill leaving a ridge in between the original two and ensuring that the soil does not cover part of the adjacent ridges. The tubers exposed after the first pass are picked up by hand and removed prior to making a second pass. Tubers are then again collected by hand.**

***Mechanical*: This system is not ideally suited to the conditions of Cuba. Where this system can be applied satisfactory results can be achieved with a potato harvester. With this equipment the tubers can be collected in bulk in the field or on a trailer running along side the harvester. The presence of foliage or inadequate soil preparation can make this type of harvesting more difficult.**

Conservation and storage

The tubers of sweet potato can be conserved in good condition for some time if they are stored in good conditions; for example:

1. **All tubers damaged by insects or fungus disease should be removed.**

2. **All tubers with mechanical damage should be removed.**

3. **Storage should be carried out in 45 Kg bags in store rooms with good ventilation and low humidity. The bags should be raised off the ground on wooden pallets. Stacks should be no more than 10 bags high with space around each for the circulation of air.**

4. **Once the tubers are bagged they should be transported within 24 hours.**

In countries such as USA, USSR and Japan some producers of sweet potato store their products in refrigerators at a temperature of 13–15 degrees C and with 80% relative humidity. In this way the tubers can be stored for 4 to 6 months.

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Feeding of sweet potato to monogastrics

by P.L. Dominguez

INTRODUCTION

The starchy roots and tubers produced in many tropical areas constitute an important energy source for human and animal feeding. Traditionally sweet potatoes have been cultivated in the tropical countries of Latin America and the Caribbean almost exclusively for tuber production to be used for human consumption, while its foliage has always been considered as a residue. The productive potential of certain varieties of sweet potato can reach from 24 to 36 t/ha/ crop of roots (Morales, 1980) and the foliage production can vary from 4.3 to 6.0 t dry matter/ha/crop (Ruiz *et al*., 1980).

CHEMICAL COMPOSITION

Sweet potato is one of the world's most important food crops. Its main nutritional importance has been its starch content. However, sweet potatocan also be asource of other nutritionally important dietary factors, such as vitamin A, ascorbic acid, thiamin, riboflavin and niacin.

The chemical composition of sweet potato roots and vines are shown in Table 1. Low protein, fat and fibre levels were found in the roots, but the high nitrogen-free-extract fraction in this tuber is indicative of their main potential value as an energy source. Vines have a lower carbohydrate content but are higher in fibre and protein and so their principal nutritive value is as a source of vitamins and protein.

Carbohydrates generally make up between 80 to 90 % of the dry weight of sweet potato roots, however the uncooked starch of the sweet potatoes is very resistant to the hydrolysis by amylase. When cooked, their susceptibility to the enzyme increases. Thus after cooking the easily hydrolysable starch fraction of sweet potato increases from 4% to 55% (Cerning-Beroard

and Le Dividich, 1976).

TABLE 1.**Chemical composition of sweet potato roots and vines (% dry matter)**

	Roots		**Vines**	
	Noblet *et al.*, 1990	**Dominguez, 1990**	**Godoy and Elliot, 1981**	**Dominguez, 1990**
Dry matter	=	29.2	15.0	14.2
N � 6.25	4.4	6.4	18.2	18.5
Ash	3.1	5.3	17.7	12.5
ADF	4.2	5.5	22.3	23.5
NDF	6.9	=	26.2	=
Lignine	0.7	=	5.7	=
Ether extract	0.6	=	=	=
Gross energy MJ/kg	17.1	16.5	=	14.4
DM				

Because the structure of sweet potato starch does not differ from that of cereals and mandioca (Szylit *et al.*, 1978) the difficulty with its digestion could very well relate to the larger size of the starch molecule (25 μ) compared to the latter's (12 μm). The protein content and quality of sweet potato roots and vines are two of the most important factors that deserve attention when sweet potato is used as a feed. Several environmental factors have been shown to influence protein content in sweet potatoes.

The effects of genotype on crude protein content are well described (Purcell *et al.*, 1972,

Edmond and Ammerman, 1971) as are those of cultural management and growth duration (Purcell *et al*., 1976).

Amino acid analysis of sweet potato roots and vines (Table 2) shows them to be of good nutritional quality but deficient in total sulfur aminoacids and lysine in terms of the ideals protein (Fuller and Chamberlain, 1982).

TABLE 2. **Amino acid content of sweet potato roots and vines [1]**

	Roots		**Vines**	
	Ideal Protein[2]	**Purcell *et al*., 1972**	**Li, 1982**	**Walter *et al*., 1978**
Isoleucine	3.8	4.2–10.1	3.9–5.1	4.9
Leucine	7.0	7.8–9.2	6.2–7.9	9.6
Total sulphur	3.5	2.8–3.8	3.0–3.9	2.8
Phenylalanine[3]	6.7	11.9–13.6	7.2–10.1	10.6
Threonine	4.2	5.5–6.3	5.1–6.1	5.3
Trytophan	1.0	0.8–1.2	=	=
Valine	4.9	6.8–8.3	4.9–8.2	6.3
Lysine	7.0	4.2–7.2	4.3–4.9	6.2
Chemical score	100	80–109	85–110	80
Total sulphur				
Lysine	100	60–103	61–70	88

1 ***g/100g protein***

[2] *Fuller and Chamberlain, 1982*

[3] *Phenylalanine + Tyrosine*

TABLE 3. **Inhibition of trypsine, %**

Raw soybean	89.5
Soybean meal	33.7
Raw sweet potato	78.8
Cooked sweet potato	16.7
Fresh vines	26.1
Vine meal	16.7

Source: Diana Martinez and P.L. Dominguez 1990 unpublished

The presence of trypsin inhibitors in the raw sweet potato roots could decrease the protein digestibility in mixed feed. The vines do not produce this effect because they do not contain great quantities of inhibitors. This trypsin inhibitor can be destroyed or reduced by preheating the raw sweet potato roots (Table 3). Cooking sweet potato is therefore necessary on account of two factors, i.e. starch digestibility and the presence of trypsin inhibitors.

THE USE OF SWEET POTATO IN POULTRY FEEDING

Sweet potato tuber and foliage products have been evaluated as a feed for poultry. Turner *et al.* (1976) examined various diets consisting of cooked sweet potato and a protein supplement for poultry feeding. Chicks fed on a starter feed reached slaughter weight sooner than when fed on sweet potato diets, however, with the latter the broilers had a higher dressing out percentage. The results of the organoleptic evaluation of birds slaughtered at 13 weeks of age

showed that meat from chickens fed a diet, where 75% of the corn was replaced by sweet potato, had the best flavour (Mohamed *et al.*, 1974).

Yoshida and Morimoto (1958) reported that the carbohydrate fraction in sweet potato to be about 90% digestible in chicks, while Fetuga and Oluyemi (1976) obtained a coefficient of metabolizable energy of 90,9 or 87,2 in diets where the tuber replaced 25 or 40% of the glucose in a basal diet; at both levels, rate and efficiency of gain were best for the sweet potato diets. These results suggest that, as an energy source, and at these levels of substitution the tuber is as efficiently used as maize by chicks.

The performance of two-week old birds fed rations containing sweet potato root meal replacing 0, 50, 75 and 100% of corn in the rations up to 6 weeks of age was studied (Table 4) (Gerpacio *et al.*, 1978). The comparison was carried out on the basis feed intake, weight gain, feed efficiency, dressing percentage and digestibility or availability of the major nutrients (dry matter, fibre, protein, energy). Performance of birds fed the sweet potato and especially at the higher levels, was less satisfactory compared with corn, suggesting that for the tuber, only 50 % or, at the most, 75 % replacement of the corn is advisable.

TABLE 4.**Evaluation of sweet potato roots as energy sources for broilers**

	Level of replacement of corn			
	Control	**50**	**75**	**100**
Initial weight 2 weeks, g	200	235	219	220
Feed consumption 2–6 weeks, g	2070	2141	2017	1937
Weight gain 2–6 weeks, g	775	764	719	676
Feed/gain	2.50	2.51	2.81	2.99
Dry matter digestibility, %	72.0	64.3	69.2	70.1

Crude fibre digestibility, %	59.5	40.4	34.0	50.2
Metabolizable nitrogen, %	72.6	61.8	70.8	65.6
Metabolizable energy, %	82.6	64.3	73.0	73.7

Source: Gerpacio et al, 1978

The presence of non-identified factors which inhibit the digestive and metabolic processes are suggested in sweet potato - based rations. These factors caused low dry matter digestibility and low metabolizable protein and energy values, even when the rations contained adequate and highquality proteins (Gerpacio *et al.*, 1978).

Studies with dehydrated sweet potato vine meal (Garlich *et al.*, 1974) have shown that this material can be used in poultry rations both as a source of protein and of xanthophyll pigment. The xantophyll of sweet potato vines is a good pigmentation agent for egg yolks and broiler skins.

DIGESTIBLE NUTRIENTS OF SWEET POTATOES FOR PIGS

Raw or cooked, peeled or unpeeled, sweet potato tubers have been evaluated in digestibility trials (Oyenuga and Fetuga, 1975). Peeling significantly increased digestibility of crude protein, ether extract and crude fibre but had no effect on digestible and metabolizable energy nor on total digestible nutrients. Cooking did not significantly affect the utilization of energy, but increased the digestibility of the nutrients.

Table 5 summarizes several of the main digestibility evaluation trials carried out on sweet potato.

Canope *et al.* (1977) found that cooking improved digestibility of all nutrients, but especially of nitrogen.

In a metabolism trial using village pigs (Rose and White, 1980) the animals received raw sweet potato tubers the digestible energy values 15.8 MJ/kg DM) were very high. This could have been be due to the low intakes in this experiment. For this reason a depression in apparent digestibility might be expected as the level of intake increased. However, there seems to be some indication of a difference between breeds in their ability to digest raw sweet potato.

Tomita *et al.* (1985) evaluated ensiled sweet potato. The high digestible energy value obtained was related to the high gross energy value of the silage and the poor nitrogen digestibility was probably due to antitryptic factors, which though low, are not totally eliminated by means of this method of conservation (Lin *et al.*, 1988).

The digestible energy, metabolizable energy and net energy of sweet potato for pigs have been estimated by Wu (1980) and Noblet *et al.* (1990). The different results obtained varied considerably; while Wu (1980) found that the NE of sweet potato (8.5 MJ/kg DM) was only 79% of that of corn, Noblet *et al.* (1990) showed that NE of sweet potato and corn were equivalent (12.3 MJ/kg DM).

TABLE 5. **Digestibility of sweet potato tuber (%)**

	Canope *et al.*, 1977		**Rose and White, 1980**	**Tomita *et al.*,1985**	**Noblet *et al.*,1990**
	Raw	**Cooked**	**Raw**	**Silage**	**Chips**
Dry matter	90.4	93.5	95.3	91	=
Energy	89.3	93.0	94.2	89	89.3
Organic matter	92.1	94.5	96.1	91	91.8

Nitrogen	27.6	52.8	49.8	32	52.3
DE, MJ/kg DM	14.1	14.5	15.8	16.3	15.3

TABLE 6.**Digestibility of sweet potato vine and root diets**

Digestibility %	**Sugar (65.1%)**	**CSP (72.8%)**	**CSP + SPV (65.8 + 10.0%)**
Dry matter	94.5	85.5	81.8
Nitrogen	89.6	76.0	73.3
Energy	93.5	89.2	85.6
Crude fibre	76.6	81.4	67.6
DE, MJ/kg DM	15.8	14.7	14.0

CSP - Cooked sweet potato soybean meal as source of protein
SPV - Sweet potato vines
DE - Digestible energy

Source: P.L. Dominguez, 1990 unpublished

Table 6 shows the digestibility of cooked sweet potato diets (18 % DM), in which 10 % of fresh foliage was, or was not, included (12–15 % DM), compared with a sugar based control, using soybean meal as a protein source (P.L. Dominguez *et al.*, 1991, unpublished data).

From the above results it is clear that the digestibilities of energy and fibre in sweet potato diets are high, though the nitrogen digestibility is somewhat low because of the poor

digestibility of sweet potato protein, even when cooked. The inclusion of foliage lowered the digestibility of all nutrients due to the increases in the fibre content of the diet. Nevertheless, the digestible energy values are acceptable and even higher than expected when compared with the values reported by Takahashi *et al.* (1968) for DE of foliage (4.1 MJ/kg DM). On the other hand, although the nitrogen retention is low in these diets, it is adequate, and it even increases when foliage is added (14.1 vs 16.4 g/day). All this confirms that foliage is an acceptable protein source for pigs when included at moderate levels in the diet.

SWEET POTATOES AS A DIET FOR PIGS

Experiments carried out using sweet potato for fattening pigs indicate that the best use of the nutrients is obtained when they are cooked (Corring and Rettagliati, 1969).

Watt (1973) summarized the results of feeding sweet potato to pigs. These conclude that cooking sweet potato increased live-weight gain when compared with raw sweet potato and that pigs grazing sweet potatoes require a protein supplement of 500 g concentrate per pig per day for optimal growth.

On the other hand, as raw sweet potato progressively replaces cereals in the diet (Table 7) daily weight gains tend to decrease, together with feed intake, without significant changes in feed conversion (Marrero, 1975).

TABLE 7. **Raw sweet potato as energy source for fattening pigs**

Corn (% DM)	88.2	46.8	22.4	8.5
RSP (% DM)	=	42.2	69.5	84.3
Intake kg GM/day	2.29	2.05	1.91	1.92
Liveweight gain, kg/day	0.74	0.65	0.58	0.57

Feed conversion kg DM/kg gain	3.16	3.23	3.31	3.37

Pigs 32–90 kg
RSP: Raw sweet potato

Source: Marrero, 1975

Due to its antitryptic factor content, raw sweet potato, used as a feed for growing-finishing pigs, needs more added soybean meal or some other protein supplement than cooked or dried sweet potato chips to acheive satisfactory performances. This fact indicates that the utilization of cooked or sun-dried chips is more economical than the use of raw sweet potatoes.

Several results (Lee and Lee 1979; Lee and Yang, 1979; Cornelio *et al*., 1988; Manfredini *et al*., 1990) have confirmed that the performance of pigs fed diets containing dried sweet potato chips is not comparable to that of pigs fed corn diets (Table 8), but daily gain and feed/gain ratio were acceptable when the pigs were fed diets where sweet potato chips replaced half of the corn in the diet.

TABLE 8.**Sweet potato chips as an energy source for fattening pigs**

Sweet potato chips % in diet	**Daily gain, kg**	**Feed/gain kg DM/kg**	**Source**
0	0.56	3.14	**Lee and Lee (1979)**
35–41	0.49	3.71	
69–81	0.48	3.80	
0	0.54	3.29	**Lee and Yang (1979)**
25	0.50	3.44	

50	0.48	3.52	
75	0.47	3.39	
100	0.50	3.23	
0	0.84	2.92	**Cornelio *et al*.(1988)**
15	0.74	3.23	
31	0.76	3.17	
46	0.72	3.38	
0	0.64	3.79	**Manfredini *et al*. (1990)**
20	0.62	3.94	
40	0.60	4.01	

TABLE 9. **Utilization of differents sources of protein for pigs fed cooked sweet potato**

	Protein contribution to the diet[2]				
Soybean meal	50.9[1]	62.9	=	=	=
Torula yeast	=	=	62.9	40.9	19.1
Meat and bone pastes	=	=	=	26.5	52.8
Intake kg DM/day	2.30	2.71	2.36	2.30	2.33
Liveweight gain, kg/day	0.77	0.77	0.78	0.78	0.70
Feed conversion kg DM/kg gain	3.01	3.51	3.03	2.95	3.33

1 ***Corn control diet; Pigs 29–90 kg***

[2] % of total protein

Source : Dominguez,1990

In Cuba, intensive and specialized pig production units use liquid feeds which are mechanically distributed through pipes to the troughs (Dominguez, 1990). The greatest part of the Cuban experiments carried out up to date using this equipment have utilised mashed cooked sweet potato tuber (18–20 % DM).

Table 9 shows the performance of pigs fed cooked sweet potato diets compared with a maize soybean-diet (Dominguez, 1990). The protein sources used were soybean meal and torula yeast and the latter was partially substituted by 35 and 70 % respectively of meat and bone pastes.

In all treatments, daily gains and feed conversions were similar or very close to those obtained with the maize-soybean diet. However, it is clear that the protein source used influences the performance of pigs consuming sweet potato. As a result even if the pigs fed the sweet potatosoybean showed the same weight gains as those on maize-soybean, the former needed a higher feed consumption and then had poorer feed conversions. On the other hand, both weight gain and conversion of pigs fed diets supplemented with torula yeast, as the only or major protein source, were equal to those fed the cereal diet; this may be due to its high content of lysine.

Considering, these results, it is evident that cooked and mashed sweet potato may totally replace maize for fattening pigs provided an adequate protein supplementation is used.

However, the total substitution of maize by sweet potato supplemented with torula yeast for

weaned piglets from 7 to 15 kg live weight decreased daily gains from 329 to 284 g/day and increased feed conversion from 1.95 to 2.48 kg/kg (Mora *et al*., 1990).

The supplementation of standard diets with sweet potato foliage did not improve the performance of pigs (Malynicz and Nad, 1973). Kohn *et al*., (1976) substituted part of a maize-soybean ration for 26 to 90 kg pigs with sweet potato foliage and obtained a decrease of daily gain and an increase of feed conversion.

TABLE 10. **Sweet potato foliage as a source of protein for pigs fed the tuber**

	Protein contribution[2]			
Soybean meal	62.9	47.7	32.3	50.9[1]
Fresh SPV	0	18.8	37.9	0
Intake (kg DM/day)	2.71	2.46	2.46	2.30
Liveweight gain, kg/day	0.77	0.69	0.64	0.77
Feed conversion, kg DM/kg gain	3.51	3.55	3.81	3.01
Fresh intake/gain, kg/kg Corn	=	=	=	2.80
Soybean meal	0.72	0.54	0.39	0.54
CSP	9.50	8.60	8.10	=
SPV	=	2.40	5.10	=

1 ***Corn control diet Pigs 29–90 kg***

2 ***% of total protein***

SPV - Sweet Potato Vines

CSP - Cooked Sweet Potato

Source: Dominguez, 1990

Table 10 shows the results of partially replacing 25 and 50 % of soybean meal as a protein source with fresh foliage in sweet potatosoybean diets (Dominguez, 1990). The use of fresh foliage at both levels decreased the intake of dry matter; probably due to the bulkiness of this feed (12–15 % DM). The high level use also resulted in poorer gains and feed conversion. However, with low level of substitution of soybean meal, feed conversions similar to those obtained with sweet potatosoybean diets were acheived.

When carrying out an economic analysis of the use of sweet potato forrage in pig feeding, it is important to note that the inclusion of the forrage in sweet potato-soybean diets results in a lower feed need per unit of gain so that when substituting 25% of soybean, the intake of this protein source is similar to that used in the maize-soybean diet.

Fresh foliage has been used for weaned piglets (6 to 12kg) to replace 10 % of the cereal concentrate. Animal performance was satisfactory both from the point of view of weight gain (186 vs 202 g/day), feed conversion (2.8 vs 2.5 kg/kg) and also with regard to mortality and herd culling (Mora *et al*., 1991).

On the other hand, the use of sweet potatoes does not affect carcass composition, lean meat content nor meat quality in the heavy pig (156 kg); however, the dressing out percentage was better for the control group (Manfredini *et al*., 1990).

SOME ECONOMIC ASPECTS

A simple economic analysis of the productivity of corn-soybean meal and sweet-potato-

soybean meal diets was carried out (Table 11) considering the world yield of these crops (FAO, 1989) and the pigs performance shown in Table 10.

The productivity of the tuber diet was similar to that of corn and soybean meal, whilst when vines are also used as a protein source the productivity increased 1.37 times with respectto the corn diet. Calculations were carried out considering only one annual harvest, though the sweet potato can actually be harvested two or more times in a year. Also the remaining vines can always be used in other species.

It is possible to assert that sweet potato crop, with the integration of vines as a protein source for pigs, can compete advantageously and surpass corn as a diet for swine in Cuban conditions.

TABLE 11. **Sweet potato crop as a source of feed for pig production**

	Corn SBM	CSP SBM	CSP SBM SPV[1]	CSP SBM SPV[2]
Productivity, ha/t liveweight	1.06	1.05	0.89	0.77
Liveweight yield t/ha	0.94	0.95	1.12	1.29

1 ***15% of DM SBM-Soybean Meal CSP- Cooked Sweet Potato***

2 ***30 % of DM SPV-Sweet Potato Vines Crops yeilds FAO (1989)***

CONCLUSIONS

The presence of antitryptic factors and low starch digestibility necesitate the prior treatment of sweet potato (dehydration or cooking) in order that it can be used efficiently in the diets of

monogastric animals. Dehydrated sweet potato can substitute up to 50 % of maize in diets for poultry and pigs with satisfactory results. When cooked sweet potato totally replaces maize in fattening pig diets an adequate protein supplement is always needed. Fresh foliage is very palatable for pigs and can economically be used in order to replace part of the protein of the diet. The inclusion of high levels of sweet potato in the diet does not affect carcass nor meat quality of pigs. It can be asserted that the sweet potato crop, with the integration of vines as a protein source, can compete advantageously and surpass corn as a diet for swine in Cuban conditions.

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Feeding systems for tropical rabbit production emphasizing roots, tubers and bananas by P.R. Cheeke

INTRODUCTION

Rabbits have potential as meat-producing animals in the tropics, particularly on subsistence-type small farms. Such characteristics as small body size (thus low daily feed requirements), short generation interval, high reproductive potential, rapid growth rate and the ability to utilize forages and fibrous agricultural by-products are attributes in favor of rabbit production (Cheeke, 1986). In spite of these apparent advantages, rabbit production has not yet achieved its potential in the tropics. Productivity is 50% or less of what is typical in temperate areas (a characteristic not unique to rabbits). While heat stress is a major factor accounting for the low productivity, inadequate nutrition is also very important. The limiting nutritional factor is probably digestible energy. Feeding programs that incorporate cull bananas, plantains, cassava, and various tropical fruits, sugar cane products, and agricultural by-products such as

rice bran and other grain-milling by-products, should be developed. These materials are excellent sources of digestible energy, and can be used to supplement legume forages (e.g. tree legumes) which are good sources of protein.

Murgueito (1990) has suggested that tropical animal production should become more intensive, with animals managed in confinement. Tropical forest destruction is of global significance, and clearing of rain forests for pasture has contributed significantly to forest destruction. By skillful use of sugar cane products, agricultural by-products and tree forages in an intensive, integrated sustainable agricultural system, animal productivity can be increased and environmental impacts of livestock production reduced. Rabbits, being small, herbage-consuming animals kept in confinement, would seem to be ideal components of intensive livestock production programs in the tropics.

The major nutritional requirements of rabbits of concern in small-scale tropical rabbit production are protein and energy. The rabbit is a small herbivore that has evolved a digestive tract uniquely suited to the utilization of herbage. Some of the characteristics of its digestive tract, which have been described in more detail by Cheeke (1987), will be briefly discussed. The digestive strategy of rabbits is to focus digestive effort on high quality components of plant cells, and to rapidly excrete the less easily digested fibrous material. This is accomplished by muscular activity of the proximal colon. Selective separation of the low density fiber particles and their excretion in the feces occurs, while the high density particles and fluid are transported by reverse peristalsis from the proximal colon to the cecum. Microbial fermentation is accomplished by cecal microorganisms. At least once per 24 hours, the cecal contents are evacuated, covered with a layer of mucus secreted by goblet cells in the proximal colon, and excreted as cecotropes. The cecotropes (soft or night feces) are consumed directly from the anus. Cecotrophy provides the animal with the products of microbial fermentation, such as microbial protein, volatile fatty acids and the water-soluble vitamins. The ability of

rabbits to efficiently digest the protein in forages is associated with cecal fermentation and cecotrophy (Robinson *et al*., 1985).

PROTEIN SOURCES

Because of their efficient digestion of protein in forages and agricultural by-products, rabbits can derive most or all of their protein requirements from these materials. In the temperate countries, *Medicago sativa* (alfalfa, lucerne) is usually the major ingredient in rabbit diets. It provides protein, cecal-fermentable energy, minerals and vitamins, and is a good source of indigestible fiber. Even though the digestibility of fiber in rabbits is low, fiber is important in the diet because it is necessary for normal gut motility. With low fiber diets, hypomotility of the cecum and proximal colon occurs, leading to disturbances in cecal flora, and a high incidence of enteritis and diarrhea. The standard diets used at the OSU Rabbit Research center are based on alfalfa meal and wheat milling by-product (wheat mill run, middlings, bran or shorts). Excellent performance has been achieved with a diet containing alfalfa meal and wheat mill run as the sole sources of energy and protein (Raharjo *et al*., 1986a).

I propose that it should be feasible to develop similar types of diet programs for rabbits in tropical countries, using tropical forages in place of alfalfa, and rice bran, cassava, bananas and other fruit, roots, tubers, sugar cane and various by-products as sources of energy. Because of the cecal fermentation processes previously discussed, rabbits can derive more energy from fibrous non-lignified materials such as rice bran and other milling by-products, peels of banana, cassava and sweet potato and other similar products than can swine and poultry. Rabbit production can be successfully based on these products whereas poultry production cannot.

In order to most effectively develop feeding programs for rabbits utilizing tropical feeds, it is

necessary to have a data base on their specific feeding properties for rabbits, including digestibility, palatability, nutrient content and effects on gut function and enteric disease. Raharjo (1987) conducted extensive studies of tropical feedstuffs in Indonesia as his Ph.D. thesis; parts of this work have been published (Raharjo *et al.*, 1986a,b; 1988). This work revealed major differences in the digestibility of protein and energy in numerous tropical forages (Table 1). In general, many of the legumes, particularly tree legumes, had digestibilities comparable to those of alfalfa meal. Most tropical grasses, despite their deceptive lush, succulent appearance in some cases, are highly indigestible and should not be considered as suitable forages for rabbit production. In the case of legumes, one of the factors affecting digestibility and intake is their tannin content. Raharjo *et al*. (1990) found that black locust (*Robinia pseudoacacia*) leaf meal, a material with a high tannin content, had a very low nitrogen digestibility in rabbits and negative nitrogen retention (Table 2). Various tropical tree legumes such as *Leucaena leucocephala* and *Calliandra* spp. contain high levels of tannins, as do cassava and banana leaves. Processing methods such as ensiling and ammoniation should be evaluated for their effects on tannins.

TABLE 1.Digestibility in rabbits of some tropical forages fed in the fresh (wilted) state (adapted from Raharjo *et al*., 1986).

		% Digestibility		
Forage	**Dry Matter**	**Gross Energy**	**Crude Protein**	**Neutral Detergent Fibre**
Tree legumes				
Albizia falcata	74.7	70.3	73.4	63.0
Calliandra calothyrsus	49.5	51.4	49.8	25.6
Leucaena leucocephala	74.2	69.5	75.9	54.5
Sesbania formosa	69.5	65.8	64.2	46.5

Sesbania sesban	79.3	77.5	83.9	62.6
Non-woody legumes:				
Cassia rotundifolia	41.6	40.1	57.5	26.8
Centrosema pubescens	43.0	54.2	72.9	32.5
Desmodium heterophyllum	28.1	48.7	52.1	13.6
Nenotonia wightii	49.4	39.8	56.6	38.7
Pueraria phasoloides	46.4	44.3	65.6	27.4
Stylosanthes guianensis	43.4	55.1	58.9	18.5
Grasses:				
Brachiaria brisantha	16.7	24.5	17.8	11.3
Chloris gayana	38.9	36.3	32.4	41.9
Panicum maximum (Guinea)	12.3	10.7	13.0	7.3
Paspalum plicatulum	35.0	33.7	21.2	29.6
Pannisetum purpureum	46.3	45.2	64.7	42.8
Setaria spendida	15.0	9.4	6.2	9.0
Agr. By-product Cassava tops	49.9	47.0	42.0	33.0

TABLE 2. Nutrient digestibility (%) of a tannin-containing forage (black locust) compared to alfalfa (adapted from Raharjo et al, 1990)

Item	� Cecotrophy*	Alfalfa	Black Locust
Dry matter	+	60.5	37.9
	-	51.0	32.9
Nitrogen	+	68.7	14.1

	-	53.5	3.9
ADF	+	5.7	-66.1
	-	-3.8	-40.1
NDF	+	31.7	-11.4
	-	21.2	-7.8
N-ADF	+	50.7	-41.8
	-	40.6	-20.5
N-retention (%)	+	38.8	-5.4
	-	23.7	-7.1

*** *Cecotrophy was prevented by fitting the animals with a collar that prevented ingestion ofcecotropes*.**

Tannins are inactivated under alkaline conditions (Price *et al*., 1979). Other toxins in legume forages may also be of concern. Leucaena contains the toxic amino acid mimosine which causes poor growth, dermatitis and hair loss in rabbits (Ekpenyong, 1985). The relative importance of various toxins in leucaena to animal feeding is not clear (D'Mello and Acamovic, 1989). Dietary additives such as ferric sulfate and polyethylene glycol (PEG) are effective in overcoming growth inhibitory properties of leucaena (D'Mello and Acanovic, 1989) but the practicability of this approach in small scale rabbit production is questionable. The low digestibility of leucaena crude protein in rabbits (Harris *et al*., 1981; Tangendjaja *et al*., 1990) has been attributed to tannins by these authors. Tangendjaja *et al*. (1986) studied the changes in toxin content of leucaena leaves with leaf age. Mimosine was highest in young leaves (4.5%) and decreased to 2% by 10 weeks. There were no changes in fiber, tannin or phenolic concentrations with age, but protein decreased from 31% in young leaves to 14% in leaves 10 weeks of age.

While more complete information is needed on the feeding value of tropical legumes for rabbits, it seems apparent that various legumes could serve as the forage base for small-scale rabbit production. To reduce the likelihood of toxicity problems, use of a mixture of forages rather than a single species is recommended. Leucaena, for example, may be unsatisfactory as the sole forage, but a useful component of a forage mixture. The feasibility of small scale ensiling of forages in plastic bags or containers should be investigated. Ensiling with or without ammoniation may provide a means of detoxifying tannins, mimosine and other toxins, and storage of feed for the dry season. It would also be advantageous in eliminating the daily burden of forage collection. It is necessary to have more data of the type reported by Raharjo *et al*. (1986) so that only forages with high nutrient digestibility are used.

Besides tree legume forage, many other possibilities exist for the forage component, such as the leaves of sweet potato, ground nut, cassava and other crops, banana, papaya and other fruit crops, and grasses that have been tested to ensure adequate digestibility. Sweet potato foliage is very palatable to rabbits (Raharjo, 1987) and supports good performance (Mutetikka *et al*., 1990), while Rhodes grass *(Chloris gayana)* has a very low digestibility (Raharjo *et al*., 1986a) and does not support good rabbit performance (Mutetikka *et al*., 1990). Cassava forage contains condensed tannins and cyanogens (Reed *et al*., 1982) which may reduce palatability (Raharjo, 1987) and probably reduce animal performance. Again, by using a mixture of forages, effects of toxins can be minimized.

In addition to forages, other sources of protein may be needed. Usually, the most suitable protein sources will be those which are somewhat high in fiber, reducing their suitability for use with swine and poultry. Copra meal and palm kernel meal are examples. Groundnut meal, cottonseed meal and other common plant proteins may also be used if economics allow.

Tropical forages can supply a major part of the protein and fiber needs of rabbits. However,

feeding forage alone will not support adequate growth and lactational performance. Supplementation with sources of energy is needed. Potential energy sources include roots and tubers (cassava, sweet potatoes), fruit (bananas, plantains, mangos, etc.), rice bran and other grain processing by-products, sugar cane products (whole cane, derinded cane, molasses, juice) and fats such as palm oil. The main apparent disadvantage of roots, tubers and fruit is their high water content. However, this may actually be an advantage. Enteritis in rabbits is provoked by overloading of the cecum with readily fermentable carbohydrate (Cheeke, 1987). Highly concentrated starch sources such as cereal grains promote carbohydrate overload. Although cassava and bananas are high in soluble carbohydrate, their high water content limits rate of dry matter intake and may reduce enteritis by supplying frequent small intakes of starch rather than large intakes of pelleted feed at one time, which is likely to cause carbohydrate overload. By not providing any other source of water, frequent intake of the forage, fruit and roots is promoted.

Omole (1990) has reviewed the use of cassava in rabbit feeding. Both cassava meal and cassava peel meal have supported adequate performance (compared to controls in the same environment) when used at levels up to 30–40% of the diet. In an experiment in Scotland, performed with cassava meal imported from Thailand, Radwan *et al*. (1985) observed excellent growth rates (41 g/day) of rabbits fed diets with up to 50% cassava meal, substituted for barley. Omole and Sonaiya (1981) noted better growth of rabbits when fishmeal rather than groundnut meal was the protein supplement in diets containing cassava peel meal, reflecting the poor protein quality of cassava protein. Cassava peel meal may contain a moderately high level of cyanogenic glycosides, which can be hydrolyzed to yield free cyanide. Omole and Onwudike (1983) reported evidence that inclusion of 5% palm oil in rabbit diets containing cassava peel meal reduced toxic effects of cyanide and increased the urinary excretion of thiocyanate in the urine. The necessity of processing cassava to reduce cyanide levels before use in rabbit diets has not been established in published work. Because any form of

processing adds to feed costs and reduces the practicality of use of cassava on small farms, further research should be conducted with feeding raw cassava roots without processing, to determine the effects on performance and blood cyanide levels. Simple on-farm techniques such as chopping and partial sun-drying may also be adequate in reducing free cyanide in cassava.

Bananas should also have potential as a means of supplementing forages to increase energy intake, although little data has been published on banana feeding to rabbits. Gidenne (1986) fed whole green banana to rabbits fed ad libitum with commercial pelleted diet. Rabbits consumed up to 120 g per day of fresh banana, equal to about 32% of total dry matter consumption. Presumably, if the amount of pelleted diet had been restricted, banana intake would have been greater. Gidenne (1986) estimated the digestible energy value of green banana to be 3640 kcal/kg DM. More research is needed on feeding green and ripe bananas to rabbits as supplements to forage-based diets, using a feeding system that would be appropriate for small scale tropical rabbit production.

Sweet potato is another crop for which there is little data available relevant to rabbit feeding. Raharjo (1987) and Mutetikka *et al*. (1990) found that sweet potato forage was very palatable to rabbits. If this observation extends to the roots as well, they should be valuable as energy supplements. The use of mixtures of bananas, cassava and sweet potato should also be examined.

Other products with potential as energy supplements for rabbit production in developing countries are sugar cane, sugar cane juice and molasses. Sugar cane might be regarded as the tropical equivalent of grain (Preston and Leng, 1987). If the outer rind is removed, sugar cane is readily consumed by rabbits (Kentor, 1990). Sugar cane juice has also been fed with some success (Solarte, 1989). Molasses is highly palatable to rabbits, and can be mixed with dry

ingredients to form a palatable mash that is well accepted (Kentor, 1990). In Haiti, a large commercial rabbitry uses a concentrate supplement of wheat milling by-product mixed with 25% molasses (Kentor, 1990). Sucrose acts as a preservative (mold inhibitor), which is a further advantage of its use in a concentrate supplement.

Grain milling by-products such as rice bran and wheat bran are excellent feedstuffs for rabbits (Raharjo *et al*., 1986a, 1988). The fiber fraction is not lignified, and has a high digestibility in rabbits. Grain by-products provide useful amounts of protein, energy and fiber, without inducing enteritis problems from carbohydrate overload (Cheeke, 1987). Thus where these products are available, they can form the basis of the concentrate part of rabbit diets. In Indonesia, for example, rice bran is readily available and is used as a moist mash to supplement free choice forages (Cheeke, 1983). In those areas where rice bran and molasses are both readily available, a mixture of these two ingredients will provide a palatable, high energy supplement.

FEEDING SYSTEMS

Where rabbits are raised on a back-yard scale on subsistence-type farms in the tropics, feeding systems should be as simple as possible. In many instances, the feeding system can be based on free-choice forages with a concentrate supplement. Bananas, cassava, sweet potato roots, other starch crops and fruits and sugar cane are products which could be fed without much processing. Since they are succulent, high-moisture materials, they can be fed without the provision of drinking water. Rabbits full-fed on tropical forage may not consume enough to satisfy their water requirements (Jin *et al*., 1990). Supplementation with roots (cassava, sweet potato) and fruit (banana) may allow the animals to meet their water requirements as well as increasing energy intake.

Thus the simplest feeding system would be the free choice feeding of good-quality tropical forages supplemented with roots, tubers and fruit. The adequacy of this feeding system needs to be established by feeding trials conducted in tropical environments.

Another feeding system is the preparation of a concentrate mash. Mashed roots, tubers and fruit could be mixed with rice bran and molasses to produce a palatable mash or meal-type diet. By adjusting the proportions of bran, a mixture with optimal moisture content could be prepared. Sufficient molasses could be added to inhibit mold growth. Such a mixture could be stored in sealed plastic bags, and prepared at intervals of perhaps once a week.

In some situations, it might be desirable to preserve feed for feeding at a later date, such as conservation of feed for the dry season, or storage of excess cull fruit or tubers. This could be accomplished by the ensiling process. Bananas can be readily ensiled (Le Dividich *et al*., 1975), because of their high content of readily fermentable carbohydrate. Bananas, sweet potato, cassava, and other fruits could be ensiled with rice bran to produce a high energy concentrate supplement. Silage could be readily prepared on small farms by packing into inexpensive plastic bags. A quantity could be removed for feeding each day, with the bag resealed to prevent spoilage. As a refinement of this system, the forage component could be included in the silage. Tropical forages are often difficult to ensile, because of their structure and low content of fermentable carbohydrate. By combining them with bananas and other products rich in soluble carbohydrates, a complete feed could be prepared as silage. This would facilitate small scale rabbit production by eliminating the daily need for collecting greens. Enough silage could be readily prepared at one time to last several months. It would be stored anaerobically in plastic bags in the shade, and used as needed.

RECOMMENDATIONS

Rabbit production offers great potential as a means of converting tropical forages and agricultural by-products to human food (rabbit meat). However, this potential has not been realized to much extent. With a few exceptions, most rabbit projects in developing countries have failed to be sufficiently productive to have much impact. While there are a number of reasons for this, one of the major ones is nutrition. Feeding programs currently used result in extremely low growth rates, prolonged time for animals to reach slaughter weight, and a lack of reproduction.

I recommend that a pan-tropical series of feeding trials be conducted at a number of research stations, following standard protocols so that the individual trials can be evaluated, analyzed and reported as a single study. Researchers in Africa, Central America, South America and South-east Asia should be identified for participation. The objective is to evaluate the use of common feedstuffs under conditions simulating their use by small farmers. A series of experiments is suggested as a focus for discussion.

1. Evaluation of bananas, cassava and sweet potatoes as supplements to tropical forages.

***Objective:* To determine the productivity of rabbits fed forage free choice and either cassava, bananas or sweet potatoes free choice, with no processing. This would be the most simple feeding system possible.**

Treatments:

1. **Control: pelleted diet**
2. **Banana free choice + forage free choice**
3. **Cassava free choice + forage free choice**

4. Sweet potato free choice + forage free choice

Ten breeding does per treatment would be fed these diets for a period of one year, and production of meat rabbits measured. This would be a sufficient period to demonstrate conclusively if the treatments based on roots, fruit and forage can sustain rabbit production.

The pelleted diet would be a standard commercial diet from North America or Europe, distributed to each investigator. The use of this standard diet would provide a standard of comparison among experiments in different countries. Further, it would help answer a very important question: To what extent is nutrition responsible for poor performance of rabbits in the tropics? In temperate countries, average daily gain (ADG) of market rabbits is 35–45 g. Typical values from experiments reported from the tropics are ADG of nil to about 20 g per day, with 3–8 g being a common range. There has not been a comparison of rabbits in the tropics and in temperate countries fed exactly the same diet, to determine how the animals could perform in the tropics if fed an adequate diet. This experiment would demonstrate what levels of production are possible in tropical environments, so that the responses to diets of tropical ingredients can be adequately assessed.

2. Development of a concentrate supplement using agricultural by-products.

Objective: To prepare a mixed mash-type concentrate based on a dry ingredient (rice bran or other grain milling by-product) with bananas, cassava and sweet potato. The mash could be tested with and without molasses. In sugar cane-producing areas, molasses or cane juice would be beneficial in providng energy and palatability, and retarding mold growth.

Treatments:

1. Control: pelleted diet or other standard

2. **Tropical forage ad lib + banana mash*–**

3. **Tropical forage ad lib + cassava meal**

4. **Tropical forage ad lib + sweet potato mash**

5. **Tropical forage ad lib + BCS + mash**

* **Mash composition:**

	%		%
bananas	50	**mineral-vitamin premix**	**2**
rice bran	33	**mold inhibitor**	±
molasses	15		

+ BCS = equal proportions of banana, cassava and sweet potato in the above mash formula.

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Availability of banana and plantain products for animal feeding
by G.M. Babatunde

INTRODUCTION

Most of the developing countries have been battling against the problem of how to adequately feed their livestock and poultry because of inadequate production of conventional ingredients for livestock feeding. Many of these countries are also well blessed with considerable good fertile, arable land, good sunshine and abundant and well distributed rainfall. The inadequate quantities of concentrated feedstuffs they produce yearly are competed for by humans and their livestock. Usually humans have to have their needs satisfied first leaving the remainder for livestock.

Some countries have liberal import-export policies which allow the importation of those ingredients in scarce supply. Others make it a national policy not to import those ingredients which would have gone a long way to solving their livestock feed problems on the grounds that they want to stimulate internal production and self sufficiency. Failure to achieve these aims has led to animal scientists looking for other ways of solving the feed problem. One of these is the increased use of unconventional feed ingredients, notably the agro-industrial by-products and farm wastes, for which humans do not compete. Nigeria took a giant step in this direction recently when it set up Task Forces on Alternative Formulations of Livestock Feeds aimed at producing cheaper, costeffective livestock feeds largely from the unconventional agro-

industrial by-products. Two such crops, which are frequently produced in quantities that exceed either export or local demand and can be used in unconventional feeding systems, are bananas (*Musa sapientum* L.) and plantains (*Musa paradisiaca* L.).

BANANAS AND PLANTAINS, THEIR DISTRIBUTION AND PRODUCTS FOR LIVESTOCK FEEDING

Both bananas and plantains are crop plants found mostly in the humid tropics where they are used as staple foods for humans. There are more than 32 species and 100 sub-species of bananas in existence, each with minor morphological differences from the others. The banana plant produces bunches with varying number of small, fleshy fingers, sometimes up to 200 fingers, while the plantain produces bunches with fewer but bigger fingers. Bananas are the type normally exported around the world, while plantains are rarely exported but are used locally in various forms by humans. Plantains in fact are often regarded as the "cooking bananas".

According to the FAO statistics (1988 FAO Production Yearbook), the total production of bananas in 1988 was 41.9 million tonnes while that of plantains was 24.0 million metric tonnes. If it is also assumed that about 30–40% of the total production of bananas and plantains are potentially available for livestock feeding as a result of their being rejected for export, accidentally damaged in the field, domestic wastes, etc. In this way, approximately 12–15 million tonnes of bananas and 7–9 million tonnes of plantains could be available each year for use as livestock feed.

Tables 1 and 2 show the world distribution of bananas and plantains respectively. South America and Asian countries, notably Brazil, Colombia, Ecuador, India, the Philippines, China and Indonesia are the world leading producers of bananas, most of which are exported to the developed world. North and Central America and Africa are the other leading producers of

bananas. Africa leads all other regions in the production of plantains, with Cameroon, Nigeria, Rwanda, Tanzania, Uganda and Zaire being the main producing countries. South America (Colombia, Ecuador) and North and Central America are the other main producers, though their production figures far behind those of African countries.

TABLE 1. **Major banana producing countries of the world (x 1000 metric tonnes, Fresh Weight)**

Countries	**1979/81**	**1986**	**1987**	**1988**
World total	**36,704**	**41,123**	**42,173**	**41,913**
Africa: Total	**4,705**	**5,476**	**5,665**	**5,879**
Cameroon	1,096	1,436	1,440	1,480
Kenya	134	145	146	148
Cote d'Ivoire	163	137	136	130
Tanzania	992	1,100	1,200	1,300
Uganda	366	440	450	460
N & C America: Total	**7,037**	**6,714**	**6,560**	**6,353**
Costa Rica	1,134	1,000	1,050	1,050
Dominican Republic	298	422	373	391
Guatemala	476	496	470	470
Honduras	1,402	1,020	904	1,030
Mexico	1,435	1,473	1,058	1,080
Nicaragua	139	101	119	144
Panama	1,048	907	1,251	900
S. America: Total	**9,033**	**10,517**	**10,870**	**10,707**
Brazil	4,348	5,052	5,145	5,139

Colombia	1,060	1,300	1,300	1,300
Ecuador	2,104	2,316	2,387	2,238
Paraguay	304	325	423	420
Venezuela	892	1,007	1,038	1,050
Asia: Total	**14,350**	**16,730**	**17,406**	**17,303**
Bangladesh	651	758	689	690
China	1,296	1,402	2,233	2,350
India	4,403	4,608	4,500	4,600
Indonesia	1,886	2,079	2,100	1,860
Philippines	3,877	3,832	3,780	3,645
Malaysia	452	480	485	490
Thailand	1,550	1,596	1,604	1,606
Vietnam	855	1,400	1,425	1,450
Total developed countries	**798**	**953**	**923**	**922**
Total developing countries	**35,906**	**40,171**	**41,250**	**40,991**

Source: FAO Production Yearbook 42, 1988

TABLE 2. **Major plantain-producing countries of the world (x 1000 Metric Tonnes; Fresh Weight)**

Countries	**1979/81**	**1986**	**1987**	**1988**
World Total	**21,180**	**23,558**	**23,876**	**23,971**
Africa: Total	**15,660**	**16,836**	**17,132**	**17,397**
Cameroon	1,022	980	10,000	1,100

Gabon	165	170	175	180
Ghana	793	680	700	700
Guinea	350	350	350	350
Kenya	233	265	266	270
Malawi	106	112	113	114
Nigeria	1,328	1,700	1,700	1,800
Rwanda	2,136	2,100	1,130	2,140
Tanzania	992	1,100	1,200	1,300
Uganda	5,896	6,660	6,726	6,630
Zaire	1,435	1,500	1,510	1,520
N & C America: Total	**1,546**	**1,688**	**1,683**	**1,737**
Cuba	87	170	163	165
Dominican Rep.	592	650	610	670
Costa Rica	87	80	120	120
Haiti	288	275	281	275
Honduras	132	180	180	180
Puerto Rico	86	90	92	94
Nicaragua	84	85	85	85
South America: Total	**4,288**	**4,153**	**4,284**	**4,016**
Bolivia	117	106	100	110
Colombia	2,328	2,242	2,374	2,191
Ecuador	728	776	848	850
Peru	666	575	495	415
Venezuela	427	427	437	420

Asia: Total	**1,684**	**880**	**776**	**820**
Burma	206	218	216	220
Sri-Lanka	1,477	663	560	600

Source: FAO Production Yearbook, Vol. 42, 1988

Fresh Bananas and Plantains have a high water content (78–80%), with the dry matter consisting mainly of starch (72%) which turns into simple sugars during ripening. The remaining material has a low content of protein, vitamins, and inorganic nutrients; the protein is very deficient in lysine, methionine and tryptophane. The fruits also contain varying levels of active tannins, the factor that is responsible for the astringency of raw, green bananas. The tannins reduce as ripening progresses because they are in the polymerized form. The tannins inhibit enzyme action and in particular the proteases, which reflects in the reduced digestibility of the crude protein fraction when raw green bananas are fed.

BANANA AND PLANTAIN PRODUCTS AVAILABLE FOR LIVESTOCK FEEDING

Every part of the banana and plantain plant (except the roots and suckers) can be and have been used to feed livestock in various parts of the world. Most of the research work on this subject has been carried out in Latin America and certain Asian countries; including India and the Philippines. From the literature it is apparant that the following materials have been fed with varying degrees of success to various types of livestock:

i. **Fresh, green, chopped or unchopped green banana fruits with peels.**

ii. **Ripe, raw whole banana or plantain fruits.**

iii. Dehydrated, sliced, milled, whole, green bananas or plantains.

iv. Cooked, green, whole banana and plantain fruits.

v. Dehydrated, milled, green and ripe plantain or banana peels.

vi. Chopped, fresh, green plantain and banana fruits ensiled with molasses, grass, legume, rice bran or any other products that will increase their feeding value.

vii. Whole, fresh, green leaves, fed directly to animals or after being ensiled with an easily fermentable carbohydrate such as molasses.

viii. Banana and Plantain stalk or pseudostem, chopped and fed raw, or ensiled with easily fermentable carbohydrates, e.g. molasses.

The best way of feeding fresh green banana or plantain fruits is to chop them and sprinkle some salt on the slices since the fruits are very low in the in-organic nutrients. Cattle and pigs relish this material. For ensiling purposes, the chopped green bananas or plantains are preferred to the ripe fruits which lose some of their dry matter and, in particular sugars during ensiling. Similarly, green fruits are more easily dried than ripe fruits which are very difficult to completely dehydrate.

Table 3 shows the composition of the plantain products while Table 4 shows that of the vegetative parts. Table 5 shows the decrease in the tannin contents of the pulp and peels of bananas during ripening while Table 6 shows the composition of reject bananas at different stages of maturity and preservation.

The current importance of banana and plantain product use, in livestock feeding, varies

considerably from country to country. In Latin American countries and some Asian countries that produce bananas in very large quantities, they have considerable quantities of under or over-sized, reject or damaged bananas available for livestock feeding. In African countries, where little export takes place and most of the bananas and plantains are consumed, with relish, it is almost unthinkable to feed livestock on bananas and plantains. In these countries only the fruit that is completely unfit for human consumption and the peels are available for livestock feeding. In such places the feeding of the vegetative parts of the plant, the pseudostem and the leaves are likely to be of greatest significance, since these are not currently widely utilized for feeding to livestock. Instead, they are allowed to rot away in the fields. For the fruits to have any commercial use in livestock feeding, the industries would have to considerably expand and exceed internal demand. In this context, many African, Latin American and Asian countries have the means in terms of fertile land, climate and human resources to produce such an expansion.

TABLE 3. **Composition of Banana and Plantain Parts and Products**

Parts/Products	**Dry Matter**	**Ether Extract**	**NFE**	**Crude Fibre**	**Ash**	**Crude Protein**	**Digestible Energy Cattle**	**DE Swine**	**ME**	**TDN**
Banana Peelings,	18	1.5	6.0	4.8	4.0	1.7	0.5	190	NA	NA
fresh[1]	100	8.3	33.5	26.7	22.0	9.5	2.76	1058	NA	NA
Banana Peelings,	90	11.6	51.2	13.4	8.5	4.8	3.11	2837	2693	64
boiled, dehydrated[1]	100	13.0	57.2	15.0	9.5	5.3	3.48	3168	3007	72
Banana Peelings,	91	13.4	51.0	11.5	9.9	5.4	3.25	3140	2977	71
dehydrated[1]	100	14.7	56.0	12.7	10.8	5.9	3.56	3446	3267	78
Plantain Peelings,	16	0.8	12.5	1.3	0.1	1.3	0.56	593	560	13

fresh[1]	100	5.0	78.4	8.1	0.6	7.9	3.52	3705	3498	84
Banana fruit, fresh,	74	0.8	65.1	1.0	2.9	4.0	2.59	2838	2693	64
without peelings[1]	100	1.1	88.2	1.3	4.0	5.5	3.52	3846	3650	87
Banana fruit, boiled	91	3.3	76.0	4.7	4.1	3.2	3.21	3334	3177	76
dehydrated[1]	100	3.6	83.4	5.4	4.5	3.5	3.52	3659	3487	83
Banana fruit, de-	87	2.7	71.0	1.0	4.6	3.9	3.02	3171	3015	72
hydrated[1]	100	3.1	81.7	3.0	5.3	4.5	3.47	3648	3469	83
Banana fruit, w.o	91	0.9	82.6	1.6	2.9	3.6	3.23	3589	3417	81
peelings, dehydr-ated[1]	100	0.9	90.3	1.7	3.2	3.9	3.53	3924	3736	89
Whole ripe banana fruit peelings[2]	19.62	0.87	82.87	5.20	5.5	5.55	NA	NA	NA	NA
Fresh, matured banana peelings[2]	13.06	6.97	67.68	5.74	12.56	7.04	NA	NA	NA	NA

1 ***Central and South East Asia Tables of Feed Composition (1982)***

2 ***Fonseca (1976)***

TABLE 4. **Composition of Banana/Plantain Vegetative Parts and Products**

Banana/Plantain Parts	Dry Matter	Ether Extract	NFE	Crude Fibre	Ash	Crude Protein	Digestible energy Cattle

Banana stem, fresh Mature[1]	6	0.1	3.6	1.5	0.6	0.5	0.17
	100	1.9	57.1	23.7	9.7	7.6	2.72
Plantain stem, fresh[1]	**6**	**0.1**	**4.0**	**0.8**	**0.9**	**0.2**	**0.16**
	100	**1.2**	**66.6**	**13.8**	**15.6**	**2.8**	**2.60**
Banana leaves, fresh[1]	24	1.4	9.3	7.0	2.2	4.2	0.68
	100	6.0	38.6	28.8	9.3	17.3	2.82
Banana leaves, Suncured[1]	**84**	**1.4**	**52.2**	**22.8**	**8.4**	**9.2**	**2.30**
	100	**1.5**	**55.5**	**24.3**	**8.9**	**9.8**	**2.45**
Banana leaves, fresh immature[1]	18	0.8	7.6	4.6	1.5	3.7	0.54
	100	4.2	41.9	25.4	8.1	20.5	3.00
Plantain leaves, fresh[1]	**19**	**1.0**	**8.3**	**4.4**	**2.3**	**2.8**	**0.52**
	100	**5.3**	**43.8**	**23.6**	**12.4**	**14.8**	**2.73**
Banana, Aerial part, Silage[1]	20	0.7	9.8	5.2	3.1	1.1	0.47
	100	3.4	49.1	25.9	16.3	5.5	2.37
Fresh banana pseudo- stems, India[2]	**5.1**	**2.3**	**60.5**	**20.5**	**14.3**	**2.4**	-
Fresh banana, whole plant[2]	20.9	1.9	85.2	3.3	4.8	4.8	-
Banana silage, immature fruit 1.57 molasses[2]	**25.6**	**3.5**	**83.2**	**3.5**	**5.1**	**4.7**	-

[1] ***Central and South East Asia Tables of Feed Composition (1982)***

[2] ***Extracted from Bo Gohl (1981)***

TABLE 5. **Changes in amount of active tannin in the pulp and peel of bananas during ripening**

TABLE 5. **Changes in amount of active tannin in the pulp and peel of bananas during ripening process expressed as units per 100g of tissue**

Days	Fruit condition	Pulp	Peel
0	Green	7.36	40.5
1	Green	8.01	34.0
2	Green	7.57	28.3
3	Green	4.30	25.4
4	Green	5.02	25.9
5	Colouring	4.30	16.5
6	Colouring	3.87	18.1
7	Colouring	1.95	11.2
8	Eating ripe	2.84	4.6
9	Eating ripe	1.99	4.7
10	Over-ripe	2.00	4.5
11	Over-ripe	1.32	3.5

Source: Von Loesecke (1950) cited by Clavijo & Maner (1975)

TABLE 6. **Composition of banana export rejects at different stages of maturity and preservation**

Characteristics	Green 1–5 days after picking	Ensiled green	Ripe	Ensiled ripe
Banana	20		18	
Banana pulp (% DM)	80		82	
Dry matter content of fresh feed	21.2	29.0	21.7	23.5

Crude fibre (% DM)	3.7	5.3	3.8	6.1
Crude protein (% DM)	6.4	3.8	5.3	8.1
Alcohol-soluble sugars	1.8	0	73.6	17.3
Starch	72.3	70.9	3.4	6.8
Ash	4.6	3.8	5.2	5.7
pH	-	4.2	-	3.8
Losses as % of Ensi-	-	13.5	-	33.9
led DM				

Source: Le Dividich, Seve and Geoffroy (1976)

EXPERIENCE WITH THE FEEDING OF BANANAS AND PLANTAINS TO LIVESTOCK AND POULTRY

A study of the available literature on the use of bananas and plantains for feeding livestock shows that most of the research work in this area was carried out in the Latin American countries which collectively produce about 35–50% of the worlds total banana production. This research interest reflects the huge ammount of bananas rejected for export in these countries and that cannot be used for local human needs. In contrast little research has been carried out on the use of plantains in animal feeding since they are mostly grown for local consumption and practically all except very bad rejects are consumed by humans. The account below gives summaries of the major experimental findings on the use of bananas and plantains with the various types of farm animal.

The pig

Undoubtedly the species that has been used most extensively for banana feeding studies is the pig. One of the best publications on the feeding of bananas to pigs is that of Clavijo and Maner, (1975). In that review paper, it was clearly demonstrated that pigs can successfully utilize bananas in the fresh or dried meal forms and that the pig will consume large quantities of bananas and grow well if those bananas are sufficiently ripe (Hernandez and Maner, 1965). It was further shown that when the banana was fed green, combined with 30% protein supplement, they voluntarily consumed only about 50% as much as when fed ripe ones (Table 7). This resulted from the over consumption of the protein supplement at the expense of the energy rich green bananas which resulted in their reduced growth rate. Cooking slightly improved the performance and resulted in a greater amount of bananas being consumed though not enough to match that of ripe bananas.

The difference in the consumption patterns of pigs on ripe and unripe, green bananas is essentially due to the bitter, astringent taste of the unripe fresh green bananas and plantains caused by the high levels of free, active tannins, which also depress the digestibility of proteins in the diets.

TABLE 7. **Performance of growing finishing pigs (1) fed ripe, green or cooked green bananas (2)**

	Treatments			
		30% protein supplement3		
Parameters	**Control maize supplement**	**Plus ripe bananas**	**Plus green bananas**	**Plus cooked green bananas**
Avg. Daily Gain (kg)	0.68a	0.566	0.46c	0.50c
Avg. Daily Feed				

(kg):				
Banana (kg)	-	8.85a	4.25c	6.20b
Supplement (kg)	-	0.71a	1.04c	0.88b
Total Dry Feed (kg)	2.31a	2.48a	1.89b	2.11a
Feed/Grain Ratio	3.41a	4.44b	4.16b	4.26b

1 ***18 Pigs/treatment, replicated twice, avg. initial wt. 28.5 kg, average final weight 92.0 kg***

2 ***Source: Hernandez & Maner (1965) cited by Clavijo & Maner, 1975***

3 ***Supplement made up of fish meal, cottonseed meal, maize vitamin, minerals and antibiotics***

TABLE 8. **Performance of growing-finishing pigs (1) fed ripe bananas (2) and either a 30% or 40% protein supplement free-choice**

Parameters	**Treatments**		
	Control	**Banana plus 30% protein supplement**	**Banana plus 40% protein supplement**
Protein in concentrate (%)	16	30	40
Avg. daily gain (kg)	0.87a	0.77b	0.66c
Avg. daily fresh bananas (kg)	-	8.29	8.85
Avg. daily bananas (kg. DM)	-	1.84	1.97

Avg. daily supplement (kg)	-	0.82a	0.62b
Total daily air dry feed (kg)	2.64	2.66	2.59
Feed/gain	3.04a	3.47a	3.92b
Feed in mixture consumed (%)	16.0	12.4	13.0

1 ***Total of 72 pigs, 4 replications of 6 pigs/treatment; avg. init. wt. 23.2 kg; avg. final wt. 90.1 kg.***

2 ***10% DM basis used for bananas***

Source: Calles et al, 1970

Von Loesecke (1950, cited by Clavijo and Maner, 1975) postulated that the total tannins present inthe fruits remain constant during ripening but that while the "free tannins" are reduced as ripening progresses (Table 5) the content of bound "inactive" tannins increases. It has been suggested that the bound, "inactive" tannins or "tannates" are inert and do not impart any bitter taste. Clavijo and Maner (1975) have advised that when feeding banana or plantain pulps which are very high in water and low in protein, vitamins and minerals (Table 3), these must be fed together with appropriate supplements. Calles *et al*. (1970) fed 30% and 40% protein supplements to growing, finishing pigs ad lib together with ad lib fresh, ripe bananas also fed *ad lib*. Their results (Table 8) showed that the 30% protein supplement gave better growth than the 40% protein supplement because of the increased consumption of metabolisable energy from the 30% protein supplement which contained more energy than the 40% protein

supplement.

Although pigs relish fresh ripe bananas and plantains, they are unable to consume enough to satisfy their needs during lactation, though they can probably consume sufficient to meet their needs during gestation. Clavijo *et al*. (1971) confirmed this in a controlled feed intake study on gestating sows fed a controlled diet versus a banana diet plus 40% protein supplement. The gestating sows on the banana plus protein supplement diet performed better than those on the control diet, gaining significantly more weight during gestation and producing heavier piglets at birth.

On the other hand, the studies by Clavijo and Maner (1971) with lactating sows showed that sows fed a banana plus 40% supplement diet performed worse than those on a controlled diet (Table 9). The sows on the banana diet produced lighter piglets at birth, fewer pigs weaned, had higher piglet mortality, and lost more weight during the study period.

The use of dried, milled banana has also proved to be a useful pig feed. In particular using this material in this form enables it to be incorporated into diets at much higher levels than using fresh bananas. In a classical study on the comparative responses of growing-finishing pigs to diets containing graded levels of 0, 25, to and 75% green banana meal, Celleri *et al*. (1971) demonstrated gradual but significant decreases in the average daily gains of pigs as the level of banana meal increased. Similar decreases were reported by Oliva *et al*. (1971) in addition to a worsening of feed efficiency ratio (Table 10). While the use of fresh ripe bananas will not normally supply the full needs of the sow for lactation, studies with the dried, milled green bananas by Clavijo (1972) showed that bananas presented in this form could successfully be incorporated into sow lactation diets to satisfy their needs.

TABLE 9. **Performance of lactating sows fed either a complete concentrate or ripe bananas**

plus protein supplement

Parameters	Treatments	
	Control	Banana plus 40% protein supplement
Avg. pigs per litter, No.	8.5	8.7
Avg. weight of birth (kg)	1.31	1.24
Avg. pigs weaned, No.	6.3a	5.9b
Mortality (%)	26.4	30.3
Avg. daily concentrate (kg)	3.66	1.02
Avg. daily consumption bananas (kg)	-	11.22
Avg. daily protein consumed (kg)	0.586	0.520
Weight loss of sows, (kg)	9.5a	11.3b

Source: Clavijo & Maner, 1971

TABLE 10. **Performance of growing-finishing pigs fed diets containing varying levels of green banana meal**

Treatments	Diets				
	1	2	3	4	5
Celleri et al. (1971)[a]					
Level of green banana meal (%)	0	25	50	75	-
Average No. of days to slaughter	119	121	124	128	-
Average daily gain (kg)	0.67	0.65	0.63	0.61	-
Average daily feed (kg)	2.45	2.54	2.54	2.55	-
Feed/gain ratio	3.66	3.88	4.04	4.19	-

Oliva et al. (1971)[b]					
Level of banana meal (%)	0	12	24	36	48
No. of days on trials	126	126	128	131	143
Average daily gain (kg)	0.62	0.60	0.61	0.59	0.54
Average daily feed (kg)	2.62	2.59	2.78	2.82	-
Feed/gain ratio	4.24	4.35	4.36	4.48	5.23

a ***Celleri et al., 1971: Used dehydrated commercial banana meal pellets. Significant treatmentdifferences in all parameters except the average daily feed*.**

b ***Oliva et al., 1971: Utilized sun-dried green banana slices for meal preparation. Significanttreatment differences (P < 0.05) in all parameters except the average daily feed*.**

Clavijo and Maner (1971) and Le Dividich and Canope (1975) also demonstrated the differences in the ability of the pig to utilize green versus ripe bananas in the fresh or the dried, milled forms. The results of the formers studies are presented in Table 11. The negative protein digestibility value for the fresh green banana reflects the high level of free active tannins present while its residual presence in the ripe fresh banana might account for the slightly negative digestibility value.

TABLE 11. **Coefficients of digestibility and digestible and metabolisable energy values of fresh and dried ripe and green bananas**

	Fresh		Meal	
Digestibility	Ripe	Green	Ripe	Green
Dry matter (%)	84.25	76.93	-50.52	83.63

Protein (%)	-42.65	-102.00	-126.61	3.38
Crude fibre (%)	78.01	56.98	39.40	78.35
Ether extract (%)	32.40	-24.87	24.50	22.09
Nitrogen-free extract (%)	92.43	92.74	68.60	92.51
Total Digestible Nutrients (%)	81.51	83.13	57.39	80.94
Digestible energy Kcal/kg DM	3114	3119	1703	3207
Metabolisable energy Kcal/kg DM	2967	3141	1520	3173

Source: Clavijo and Maner, 1971

The table also shows that the green, dried, milled form gave comparable results to the ripe fresh form, but the dried ripe milled form produced the worst results. This was most probably due to difficulty of drying the ripe banana, which must be heated to a high temperature for a long time before it is completely dry. Under such extreme drying conditions, many of its nutrients are destroyed or denatured which shows in the reduced digestibility and lower digestible and metabolisable energy values of the dried, milled, ripe bananas.

It has been suggested by Le Dividich and Canope (1974) that dried, milled, green bananas can be used in the diets of piglets from as low as 5 Kg live weight, if properly supplemented with protein, vitamins and minerals. Young pigs also relish ripe fresh bananas, but care must be taken in feeding this material to piglets since they can suffer digestive problems when consuming ripe bananas in large quantities.

Only few studies exist on the use of plantains in pig feeding. One of the few, studied the use of plantains peels for feeding pigs was conducted by Fetuga et al, (1975). The study involving the determination of the nutrient digestion coefficients of yellow maize, maize cobs, yam peels and

dried, ripe, milled plantain peels using three weight groups of pigs (18 kg, 45 kg and 65 kg live weight) in straight digestion trials. The results (Table 12) showed that apart from the maize cobs, the plantain peels were more poorly utilized by the 18 kg weight group than the maize and yam peels. As the pigs became bigger (45 and 65 kg groups) the utilization of plantain peels was inferior only to yellow maize.

Finally, attempts have also been made to feed ensiled bananas to growing and fattening pigs with some success. Le Dividich and Canope (1975) showed that although green banana silage depressed the digestibility of protein in the diet, it had essentially the same nutritive value as ripe fruit. However silage made from ripe bananas did not perform as well as that made from green bananas. Le Dividich and Canope (1975) also showed that ensiled green bananas could successfully serve as a basic feed for gestating sows but not for lactating sows even if the silage was generously supplemented with molasses and protein.

TABLE 12. **Mean Nutrient digestibilities (%) for yellow maize, maize cobs, yam peels and plantain peels as determined at three weights (18,45 and 65 kg) of growing pigs**

Pig wt. (kg)	Feeds	Digestion coefficients (%)									
		Dry Matter	+SE	Crude Protein	+SE	Crude Fibre	+SE	Ether Extract	+SE	Nitrogen Free Extract	+SE
18	YM	91.7a	1.44	85.2a	1.68	56.7a	1.22	89.0a	2.42	95.6a	1.04
	MC	9.0c	0.68	-24.6c	0.74	31.7c	0.45	-44.8d	4.74	20.9b	0.36
	YP	85.4a	1.79	67.6b	1.48	51.9ab	1.38	42.8c	2.11	94.8a	0.98
	PP	78.4b	1.86	59.2b	1.92	48.9b	1.42	65.1b	2.04	89.9a	1.21
	Mean	66.1x	2.11	46.9y	1.97	47.3x	1.18	38.0y	2.86	76.3y	1.18
45	YM	91.5a	1.36	84.9a	1.57	86.4a	1.49	86.2a	1.88	94.3a	1.04
	MC	27.3c	1.06	-22.8d	1.22	58.6c	1.32	-4.1d	1.28	58.8b	1.24

	YP	83.4b	1.69	54.4c	1.62	77.5b	1.77	32.2c	1.38	90.2a	1.33
	PP	83.5b	1.82	66.4b	1.86	81.2ab	1.58	63.0b	1.78	86.2a	1.42
	Mean	71.4y	1.64	45.7y	1.79	75.9y	1.74	45.1y	1.87	82.4y	1.38
65	YM	92.8a	1.52	87.8a	1.48	87.2a	1.53	90.6a	1.86	95.4c	1.24
	MC	47.3c	1.14	-8.1d	a	64.8c	1.28	-2.3c	1.84	64.4c	1.26
	YP	81.4b	1.74	40.5c	1.03	85.8ab	1.48	37.2b	1.76	88.6b	1.18
	PP	76.7b	1.83	47.4b	1.44	80.4b	1.62	39.0b	1.68	81.7b	1.27
	Mean	74.6y	1.84	41.9y	1.58	79.6y	1.63	41.1y	1.92	82.5y	1.22
					1.73						

YM = Yellow maize;
ME = Maize cobs;
YP = Yam peels;
PP = Plantain peels;
SE = Standard error of means
a-c = Within weight groups values in the same column, with the same letter are not significantly different (P<0.05)

x,y = Weight group means in the same column followed by the same letters are not significantly different (P<0.05)

Source: Fetuga et al., 1975

Ruminant animal feeding

Although it would appear that the ruminants are well suited to use the vegetative parts and

peels of bananas and plantains, the amount of experimental work reported on the feeding of these products to ruminants is surprisingly less than that carried out with pigs. In 1981, Bo Göhl reported that banana leaves could be used as emergency feed for ruminants, but that the digestibility decreased as the level of banana leaves increased in the ration. He further stated that the pseudostems could be fed fresh, but that chopped ensiled pseudostems enriched with readily fermentable carbohydrates was the best way of feeding them to ruminants.

Foulkes and Preston (1978) reported that the dry matter of banana leaves and pseudostems was relatively digestible for ruminants, ie; 65% digestibility for leaves and 75% for the pseudostems. However, despite this apparently high DM digestibility, the leaves and pseudostems alone can barely meet the maintenance requirements of ruminants. They recommended that urea and a highly digestible forage or sweet potato foliage should be used as supplements to pseudostems or leaves being fed. In fact, it has been well established that the greatest limitation to using bananas as a feed for ruminants is the lack of fermentable nitrogen and hence banana diets must always be supplemented with a source of nitrogen such as urea. Perez and Roldan (1984) further clarified this situation when they compared banana diets fed with and without cotton seed cake to cattle in Colombia. Their results are shown in Table 13 and show that significant improvements in ADG were obtained as the level of cotton seed cake supplementation increased from 1 to 2 kg/day/cow.

Dehydrated, green, milled banana (banana pulp flour) has been successfully used as a source of starch in the preparation of calf feeds and specifically in the manufacture of milk replacers. In Ecuador, Spiro (1973) Rihs *et al*. (1975) tested various levels of banana flour in ruminant diets and found that banana flour could successfully replace up to 50% of the cereal in the feeds of young growing and finishing cattle.

Chenost *et al*. (1971) and Geoffroy and Chenost (1973) carried out digestibility trials on goats

in cages and reported that when bananas and forages were offered *ad lib*. separately, the kids consumed bananas at a level amounting to about 20–40% of their ingested dry matter. When the two were blended together, the dry matter and digestible organic matter rose sharply as the content of bananas increased in the ration from 0 to 20%. Also, the DM intake was greater when ensiled rather than fresh green bananas were fed.

TABLE 13. **Growth of cattle fattened under commercial feedlot conditions in Colombia on reject bananas (40% of Diet DM), chopped elephant grass (42%) and kudzu legume forage (18%) with different supplements**

Protein supplement	Initial Liveweight (kg)	Daily gain (kg/d)	Days on feed	Comparison
No supplement	330	0.83	90	Female adult
	325	0.64	90	Male adult
	334	0.80	90	Female old
	324	0.88	90	Female young
	240	0.91	100	Male young
	350	0.61	100	Male old
1 kg/d cottonseed cake	381	1.15	60	+ sulphur
	391	0.97	60	- sulphur
	332	0.98	60	urea/molasses
	322	0.97	60	Aqueous urea
2 kg/d cottonseed cake		1.60		Chianina x zebu
		1.14		Zebucrosses
		1.25		Zebu bulls
		1.10		Zebu steers

		1.66		Chianina bulls
		1.50		Chianina steers

Source: Perez & Roldan (1984) cited by Preston and Leng (1987)

In Guadeloupe, Geoffroy (unpublished, cited by Le Dividich *et al*. 1978) investigated the possibility of substituting the cereal component in the diet of lactating goats with either green, or ensiled bananas and found that complete replacement of the cereals with bananas resulted in increased dry matter intake, significantly higher milk yield and better weight gains.(Table 14). Similar results were obtained by Geoffroy and Chenost (1973), who used banana meal and banana silage to replace the cereal in a concentrate diet.

TABLE 14. **Influence of different kinds of energy and N-supplementation of feed intake and milk production in dairy goats**

Energy source	**Cereal**		**Green Bananas**		**Ensiled Bananas**	
N_2 source Level of Urea (N as % total N)	Soybean cake (0)	Soybean cake + Urea (32.2)	Soybean cake (0)	Soybean cake + Urea (28.9)	Soybean cake (0)	Soybean cake + urea (28.5)
Dry matter int- ake of *Pangola* (regrowth of 50 days) (g/day)	679	686	176	321	319	330
Bananas	-	-	1330	1278	1099	904
Concentrates	828	749	448	189	404	160
Total DM intake	1507a	1435b	1954c	1788d	1822d	1394b
DM intake/100 kg live wt. (kg)	3.14	3.34	4.17	3.26	3.67	3.24
Milk production (kg/day)	1,627	1481b	2028c	1599a	1878d	1447b

Buter fat content (g/kg)	25.8	26.3	25.4	30.0	27.0	27.5
Concentrate/ Milk (g/kg)	509	506	221	118	215	111

Source: Geoffroy (unpublished) cited by Le Dividich et al. (1978)

Finally, Viswanathan *et al*. (1989), in India, used sheep to investigate the nutritive value of banana stalk. In this study dried banana stalk replaced 0, 20, 40 and 50% Paragrass hay. The feeding trial lasted for 60 days and showed that feeding the banana stalk did not have any detrimental affect on the health of the animals and that although the daily liveweight gains were low the rate increased up to 40% level of inclusion after which it started to decline. The dry matter intake per Kg 0.75 was fairly similar in all treatments. Of all the nutrients, the digestion coefficient for crude protein was lowest and cellulose the highest. However, since these results were based on a limited number of samples it is difficult to base any valid judgement upon them.

Poultry

Experiments on the feeding of banana and plantain products and by-products are few. However, considering the nature of the gastro-intestinal tract of the domestic fowl and its limited capacity, it would appear that, when fresh, these materials, which have a high moisture and low energy and protein content, are unlikely to meet the energy and protein requirements of poultry. On the other hand dried banana or plantain fruit or pulp with higher energy densities could meet appetite limitations if well supplemented with protein, vitamins and minerals. Similarily, the low energy, low protein and high fibre content of dried banana or plantain peels suggest that, even in the dried form, these materials will not be good replacements for materials such as maize or guinea corn in conventional diets.

For example, Tewe (1983), investigated the replacement of 0, 7.5, 15, 22.5 and 30% maize with

equivalent quantities of dried plantain peelings in broiler diets over a 10 week feeding period. His results (Table 15) showed that as the level of dried plantain peel meal increased beyond the 7.5% level, there were significant reductions in the weekly weight gains of the broilers, with the broilers on the 30% plantain peel meal gaining least and having the poorest feed conversion efficiencies. Although the cost per kg. of feed reduced with increasing inclusion of plantain peel meal the feed cost per kg. gain steadily increased with the increased plantain peel meal inclusion. Tewe concluded that plantain peel meal can successfully be included in broiler rations up to 7.5% beyond which it is detrimental.

TABLE 15.**Performance characteristics of broilers raised on varying dietary plantain peel levels**

Parameters	**Diets**				
Starter Phase	1	2	3	4	5
Feed intake/bird/wk(g)	292.3b	299.2ab	288.8ab	322.8ab	323.4a
Wt. gain/bird/wk(g)	132.8ab	135.2a	121.9b	131.9ab	129.7b
Feed/gain	2.20b	2.21b	2.37ab	2.45ab	2.49a
Protein efficiency ratio	1.98a	2.05a	1.92b	1.95b	1.91b
% Mortality	1.5	7.5	15.0	5.0	2.5
N_2 Retention (%)	73.97	74.14	69.25	61.91	70.30
Finisher Phase					
Feed intake/bird/we (g)	786.5b	762.3b	760.1b	800.6b	905.1a
Wt. gain/bird/we (g)	218.4a	206.3ab	202.1ab	167.2b	163.0b
Feed/gain	3.60c	3.69c	3.76c	4.79b	5.55a
Protein efficiency ratio	1.32a	1.29a	1.33a	1.04b	0.90b
% Mortality	0	2.8	0	2.7	0

N_2 Retention (%)	66.40	65.65	65.02	64.05	64.18
Starter-Finisher Phase					
Feed intake/bird/we (g)	490.0[bc]	484.4[c]	477.4[c]	513.9[b]	556.1[a]
Wt. gain/bird/we (g)	166.9[a]	163.7[ab]	154.0[b]	146.0[c]	143.0[c]
Feed/gain	2.93[c]	2.96[c]	3.10[c]	3.52[b]	3.89[a]
% Mortality	2.5	10.0	15.0	7.5	2.5
N_2 Retention (%)	0.98	1.10	1.27	1.23	1.14

a, b, c: means without common superscripts in horizontal rows are significantly different (P < 0.05)

Source: Tewe (1983)

Since meal from whole fruit is richer in energy than the peel it would appear that a much higher level might be included. Bo Göhl (1981), however, stated that high levels of banana meal tended to depress growth rate and reduce feed efficiency and so recommended that not more than 10% of the grain portion of the poultry diets should be replaced by banana meal.

ECONOMICS OF FEEDING BANANA PRODUCTS TO LIVESTOCK

Consideration of the cultural practices for producing bananas and plantains and the growth pattern of the plant strongly suggest that the overall cost of production is low, relative to the costs of other crops. In terms of yield energy per hectare, bananas/plantains are considered second highest to cassava ie; 25,120 Joules versus 36,480 Joules per hectare for cassava. To put this in context it should be noted that energy yields for cereals per hectare are in the 10,000 Joule range.

In order to maintain cost advantage of bananas and plantains over cereals as animal feed only minimum processing of the fruits can be carried out. Assuming that this is the case and that the materials do not depress livestock performance, the feeding of whole; chopped; raw; ripe; banana and plantain fruits or their peels, leaves and pseudostems are likely to offer considerable cost-saving.

Systems of processing include ensiling, which is a low cost system producing nutritious products and drying and milling. The latter probably produces the most useful products, but their cost of processing is also the highest and so should only be used when the cost benefit ratio favours it. Cooking also enhances the value of the fruit, but again, increases production costs. From the nutritional point of view cooking, drying and milling do not have any advantage over whole; chopped; green or ripe fruit and so should be avoided wherever possible.

NEW TECHNOLOGIES FOR BANANA/PLANTAIN FEEDING

From the literature, there do not appear to be any new processing technologies currently being developed for plantains or bananas. It is also unlikely that any new processing technologies can be developed to make the plantain and banana fruit more nutritious and usable, than present technologies, without significantly increasing costs. Probably the area with greatest potential for improving technologies is in the use of pseudostem or stalk and the leaves. Since a great deal of the dry matter of these materials is fibrous, new technologies might aim at making the fibre more digestible, in the same way that grass and straw are processed using alkali or ammonia treatment. Treatment that could significantly increase the nutritional value of this fibrous material could be of tremendous economic importance because these constitute the main bulk of the banana plant, most of which are currently wasted.

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Economic aspects of banana and plantain use in animal feeding: the Cameroon experience

by R.T. Fomunyam

INTRODUCTION

Cameroon produces about 2.3 million tons (Table 1) of plantains and bananas annually (World Bank 1984, Ministry of Agriculture, 1982–83, 1984). Approximately half of this is consumed domestically while less than two fifths is exported. The remaining quantities are either discarded as waste products or are allowed to rot in the fields during harvest. While the plantain and banana fruit is a valuable foodstuff for human consumption, the waste part of it can be fed to livestock. Studies have shown that waste plantain and banana (fruits, stems and leaves) can be used as energy sources for livestock, and in particular during the dry season when there are feed shortages. Unfortunately, however, little is known about the economic benefits that can be obtained from feeding these materials to livestock. This paper examines the economic aspects of using plantains/bananas and their by-products to provide feed for livestock in Cameroon.

FEED COSTS

The main cost of livestock production is related to the provision of a sustainable energy source. Feed cost account for 60 to 80% of livestock production costs (Ademosun, 1976) and the energy component of feed accounts for 60 to 70% and protein component 14 to 20% of feed costs. Since animals eat primarily to satisfy their energy needs, the energy source must be available, adequate and cheap.

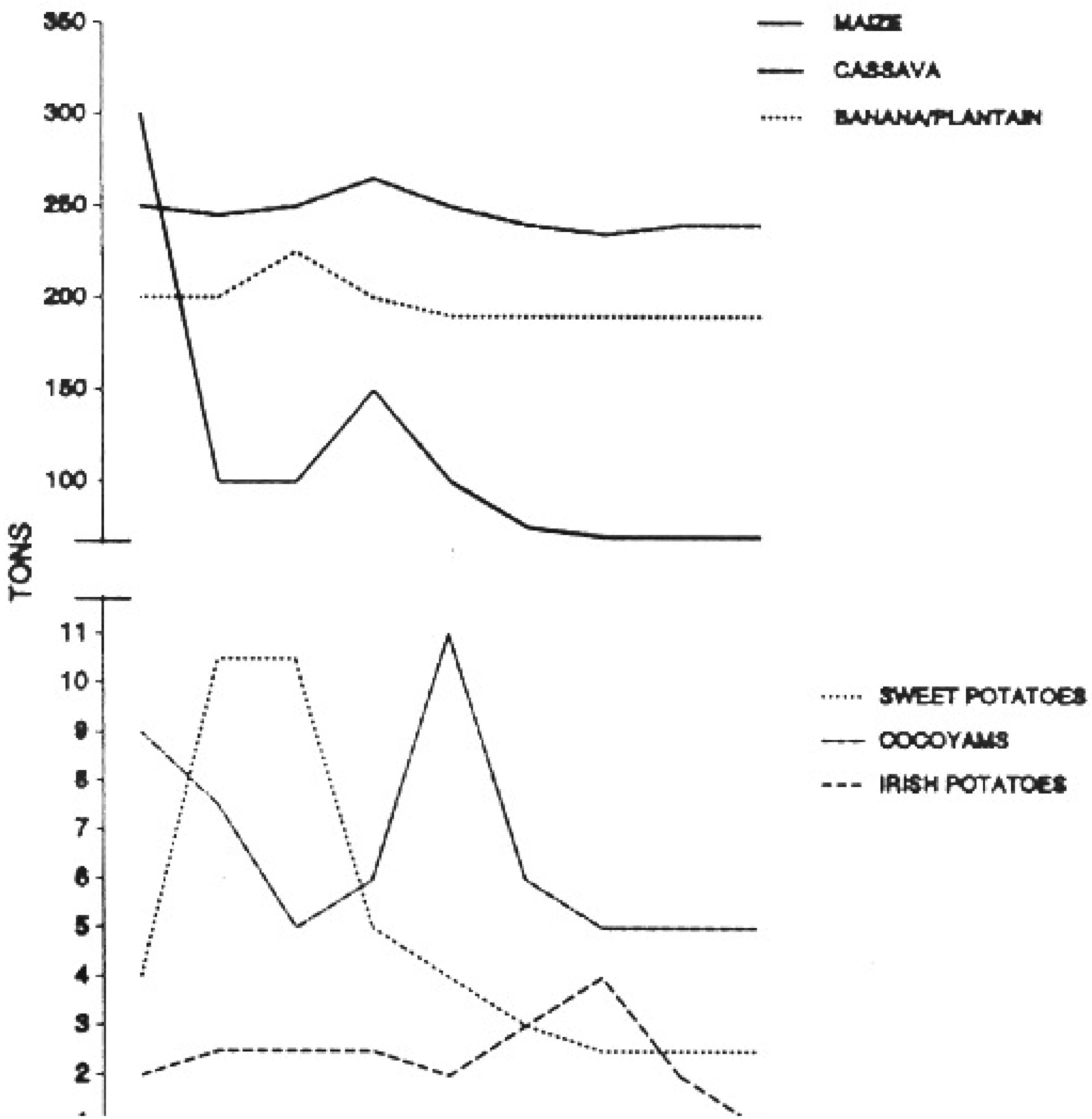
Feed prices can only be low if the prices of the feedstuffs which make up the feed are low. Feedstuffs should therefore be obtained when prices are low and stored for use when needed. Figures 1 and 2 (MIDENO, 1984; FAO-PFLRP, 1990) show that prices are low shortly after harvest in Cameroon. Other means of reducing the cost of feed include the use of unconventional crops produced in excess of human demand, possibly during seasonal gluts, as substitutes for more expensive or unavailable feed items. The development of such technologies could then be adopted in the field.

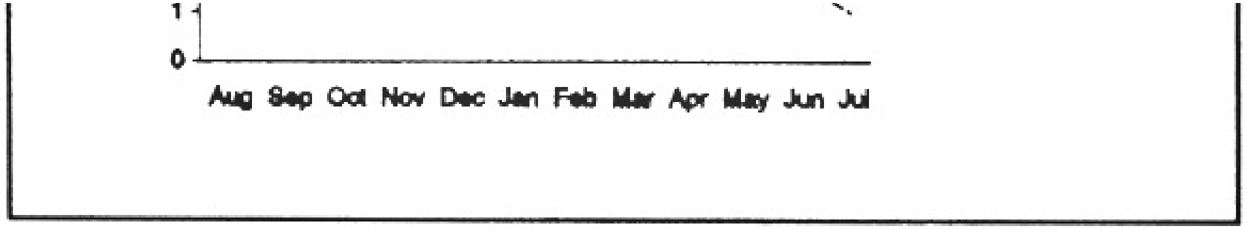
TABLE 1. **Rural production of a variety of energy sources in Cameroon (tonnes)**

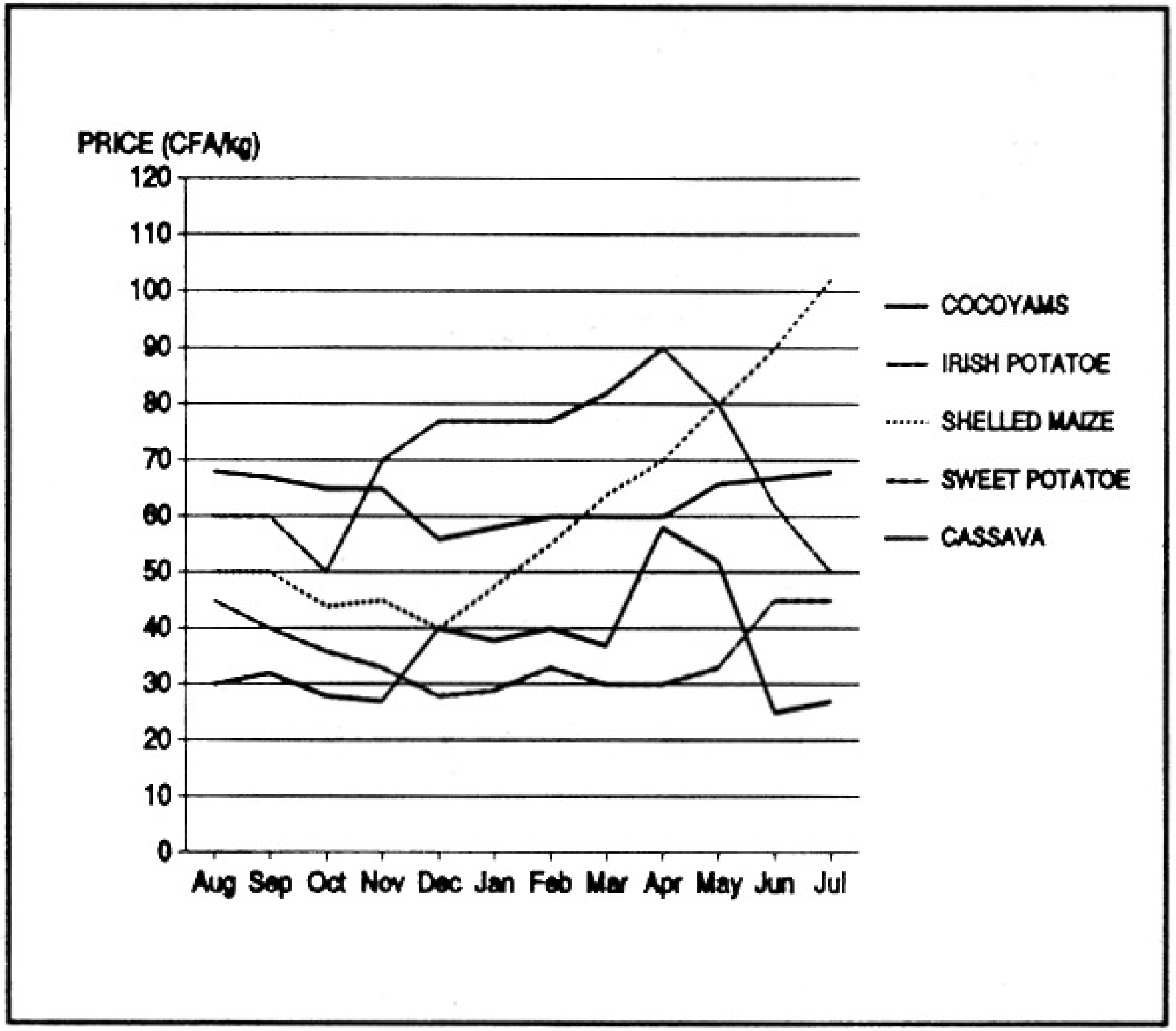
Crops	Provinces										
	Extreme North	North	Adamawa	East	Central	South	Littoral	South West	North	West	Total
Maize	43310	13110	43310	26420	15440	3810	6900	11210	168990	112760	374880
Cocoyams	2	2	2	9840	28260	8340	11540	49330	39860	40330	191800
Cassava	4	4	80	197	374	129	98	304	110	88	1385
Plantains	-	4	4	144400	190700	57100	63500	49500	258900	276900	1401600
Bananas	-	4	4	42500	116000	21700	46100	219000	198300	206800	850400
Yams	1	1	2	2	18550	2	7860	11200	19780	38140	109420

Irish Potatoes	-	-	-	-	-	-	-	-	5010	5050	10410

FIG. 1: CROP PRODUCTION TRENDS IN THE N. E. PROVINCE




1
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul


PRICE (CFA/kg)
120
110
100
90
80
70
60
50
40
30
20
10
0
Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul
COCOYAMS
IRISH POTATOE
SHELLED MAIZE
SWEET POTATOE
CASSAVA

Maize is the staple feed in Cameroon and the competition for maize between humans and livestock is unacceptable. Bananas and plantains are available in Cameroon all year round and can be used to replace maize in animal feeds in Cameroon. The major costs of the use of these materials are transportation, processing and storage since feed grade bananas and plantains can be obtained at almost no cost. Using this technology more meat could be produced from this source of energy in a free market situation. However, in practise meat price fixing usually kills any effort to increase meat production and lack of meat standards and grading does not encourage efficient animal feeding and the maintenance of feed quality.

WAYS OF REDUCING FEED COSTS BY ENSURING A CONSISTENT SUPPLY OF FEEDSTUFFS

Feed ingredient shortages cause feed shortages, losses in animal weight and mortalities, particularly in the dry season. This is costly in terms of loss of protein for family consumption and income from the sale of animals. Table 2 shows that with a little effort 276,000 tons of pseudostems worth 5.5 billion FCFA, 69,000 tons of leaf meal worth 22 billion FCFA, 60,650 tons of peels worth 2.4 billion FCFA and about 35.545 tons of waste fruit worth 755 million FCFA could be used each year as animal feed thus ensuring animal feed security in Cameroon.

Increasing the quantity of feedstuff available will ensure better livestock feeding and generate cash revenue from sales of excess feedstuffs. The greatest constraints to putting these feedstuffs on the market are the costs and availability of transportation, processing and storage. Referring to the first constraint, trucks and trains carry cotton and other goods from the Northern part of Cameroon to the south for export and rather than go back empty, could easily transport feedstuffs from the south to the north where the largest number of livestock are raised. The estimated cost of transportation is 20 FCFA/ton. With regard to processing, this cost could be kept low since Cameroon has plenty of free and cheap sunshine to dry livestock feed grade bananas and plantains and by-products during the dry season.

TABLE 2. **Quantities and costs of banana feedstuffs in Cameroon**

		Dry matter feedstuff quantities			
	Yield (000 tons)	Pseudostems	Leaves	Peels	Waste Fruit
Plantains	2,000	240,000	60,000	48,000	32,610
Bananas	300	36,000	9,000	7,000	2,935
TOTAL	2,300	276,000	69,000	55,500	35,545
Cost/kg (FCFA)		20	33	39	21
Number of persons employed		315	88	645	378

In the wet season wood is available and the technology of cocoa drying could readily be applied to banana/plantain processing. The process would provide employment for many unemployed Cameroonians. Table 2 shows that a total of 1,421 persons earning the minimum wage of 23,000 FCFA each per month could be employed yearly on processing, thus introducing about 392 million FCFA into the rural economy.

WAYS TO REDUCE FEED COSTS BY UTILIZATION OF BANANAS AND PLANTAINS IN LIVESTOCK FEED

In this experiment forty-eight pigs were used in an experimental trial in which sun-dried waste banana meal replaced maize at 10, 20 and 30% levels in test diets (Table 3) (adapted from Fombad, 1984).

Chemical composition of vitamin/mineral premix: "A vitamin/mineral premix manufactured by BEMIS CO. Inc. Mass. USA to contain: Calcium 27%, phosphorus 10%, Iron 0.60%, Zinc 0.35%, Manganese 0.24%, Copper 0.06%, Iodine 0.002%, Cobalt 0.0026%, Selenium 0.004%, and, per kilogramme: Vitamin A (USP units) 220,000, Vitamin D (USP units) 66,000, Vitamin E (IV units)

440, Vitamin K (mg) 88, Vitamin B12 (mg) U.79, Niacin (mg) 1122, Pantothanic acid (mg) 550, and Riboflavin (mg) 132".

Results in Table 4 show a dry matter feed intake of 2.27, 2.32, 2.34 and 2.33 kg corresponding to daily weight gains of 0.54, 0.55, 0.54 and 0.53 kg/pig/day. Although feed conversion increased as the level of bananas increased, no significant differences were seen between the diets. Analysis of costs and returns using prevailing market prices showed that daily feed costs declined with increasing levels of banana meal in test diets. This indicates that apart from adequately replacing maize the banana meal also reduced the feed cost of the grower pig feed at all the levels tested.

In terms of net returns over feed costs, incorporating banana in pig diets at the 10% level gave a slightly higher return of 38,258 FCFA compared to 37,601 and 37,235 FCFA for the 20% and 30% levels of banana inclusion.

TABLE 3. **Percent composition of grower pig diets containing sundried waste bananas**

Feed ingredient	Diet 1	Diet 2	Diet 3	Diet 4
Maize	60.00	50.00	40.00	30.00
Banana meal	=	10.00	20.00	30.00
Brewers dried grains	9.25	8.25	7.25	6.25
Palm kernel cake	6.00	6.00	6.00	6.00
Fish meal	3.50	3.50	3.50	3.50
Palm oil	2.00	2.00	2.00	2.00
Bone meal	1.00	1.00	1.00	1.00
Cotton seed cake	17.00	18.00	19.00	20.00
Dicalcium phosphate	0.50	0.50	0.50	0.50

Vitamin/mineral premix	0.25	0.25	0.25	0.25
Salt	0.50	0.50	0.50	0.50
	100.00	100.00	100.00	100.00
Cost FCFA/kg	71.5	68.8	66.8	64.4
Calculated analysis:				
Energy (kcal/kg DE)	3263.22	3304.36	3345.50	3386.72
Crude protein (%)	19.5	19.22	19.02	19.00

From the results shown in Table 3, it is clear that 30% banana meal can be safely consumed by pigs. At the current time it is estimated that 10,000 tons of waste banana dry matter could be produced in the country. If this were used at the 30% level in pig grower diets it would enable the production of an additional 2,000 tons of pork sold at the prevailing market price of 1,000 FCFA/kg pork to total 2 billion FCFA. However, if increased waste banana were available and with a national pig population of 439,000 in the country, eating about 2 Kg feed per day, in which 30% banana meal could replace part of the 60% maize component, for 150 days this would save 79,000 tons of maize worth 7.9 billion FCFA. This could be used by humans, used for other livestock production e.g. poultry or be exported to generate revenue.

TABLE 4.**Feed intake and weight gains of pigs fed sun-dried banana meal**

Characteristics	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**
Daily feed intake (kg/animal)	2.27	2.32	2.34	2.33
Daily weight gains (kg/animal)	0.54	0.55	0.54	0.53
Feed conversion ratio	4.20	4.21	4.33	4.39
Feed costs (FCFA/animal)	15.905	15.640	15.319	14.705
Returns from sales (FCFA)	52.920	53.900	52.920	51.940

Returns over feed costs (FCFA)	37.015	38.258	37.601	37.235

WAYS TO REDUCE FEED COSTS BY UTILIZATION OF BANANA/PLANTAIN BY-PRODUCTS

Use by Ruminants

Banana/plantain pseudostems, leaves and peels though low in energy and deficient in most nutrients can be converted into meat by ruminants with appropriate supplementation. In a trial, sun-dried banana forage (pseudostems and leaves) was fed ad libitum to four lots of bulls. The first lot of 3 bulls received no protein supplementation with while the other three lots ate banana forage supplemented with 750 g/day/bull cotton seed cake; 1500 g/day/bull of dried leucaena leaves and 500 g each of cotton seed cake and *Leucaena* leaves/day/bull respectively.

TABLE 5. **Costs and returns of fattening bulls with banana forage supplemented with leucaena leaf and cotton seed cake**

Characteristics	**Type of protein supplementation**			
	None	**Cotton seed cake**	**Leaucaena Leaves**	**Leucaena and cotton seed cake**
Daily gain (g)	8.9c	142.8bc	417.4a	357.1ab
Daily feed intake (g/bull/day)	3.08	3.30	3.39	3.55
Daily protein intake (g/bull)	240	573.8	615.9	590.53
Feed costs (FCFA/bull)	6,921	10,503	10,990	10,812
Returns over feed costs (FCFA)	-0.9	18.1	57.2	48.5

a,b,c Significant at P<0.05

Source: Beramgoto (1989)

The results of the trial are given in Table 5 and show that significantly more weight was gained by bulls fed the leucaena supplemented diet, followed by bulls fed the combination of leucaena leaves and cotton seed cake; the lowest gain was by bulls fed only the mineral supplemented forage diet. The costs of the non-protein supplemented diet were lower (6,921 FCFA) than the other diets which were similar in price (10,503, 10,998 and 10,812 FCFA respectively). Returns over feed costs were greatest for animals fed the diet supplemented with leucaena (57.2 FCFA/day) followed by those fed the leucaena/cotton seed cake supplement (48.5 FCFA) and least for bulls fed the cotton seed supplemented diet. (18.1 FCFA). Animals fed the non-protein supplemented forage registered a net negative return.

As mentioned earlier if this forage could be sent to the northern part of Cameroon, great savings in terms of animal losses, spread of disease and waste of human labour could be avoided and particularly at periods of transhumance. It is also estimated that an additional 1,300 tons of beef worth 13 billion FCFA could be produced if this were to take place.

Another very important benefit would be releasing the pressure on the already over-grazed pasture in the northern part of the country. Degraded pastures result in eroded soils, advancement of the desert and invasion of pastures by unwanted weeds; a very expensive price that Cameroon cannot and will never be able to afford to pay.

Use by Rabbits

The provision of adequate supplies of fibrous feeds for feeding rabbit is difficult to achieve all

year round. In a trial (Fomunyam, 1985) 42 rabbits were fed test diets (Table 6) which contained either 30% sun dried banana leaves, 30% fresh banana leaves or a 30% combination of the fresh and dry leaves.

Results (Table 7) showed that there was no significant difference in weight gains of rabbits fed the three diets. However, daily feed intake was significantly higher (67.4 g/rabbit) for animals fed fresh leaves compared to 53.8 g/rabbit for those fed the combination of leaves and 44.6 g/rabbit for those fed the diet with dry leaves. The results also show that although there was no difference in feed costs, the net returns over feed costs were highest (35.072 FCFA) for rabbits fed dry leaves, followed by 28,879 FCFA for rabbits fed fresh leaves and 20,730 FCFA for rabbits fed the mixture. One rabbit died in the group fed the combination of leaves thus accounting for lower net returns for this group.

In backyard production systems banana leaves can be harvested from plants around the home which involves no extra costs of transportation, processing or labour.

CONCLUSION

Greater animal feed security and increased and lower cost meat production are possible in Cameroon if waste bananasplantains and their by-products are used. The processing of these feedstuff would also provide employment and cash revenue to the rural economy. The environmental benefits from stall feeding this feedstuff also look very promising.

TABLE 6.**Composition of Rabbit Diets containing Banana/Plantain leaves**

Feed ingredients	Form of leaf			
	Dry	**Fresh**	**Fresh & Dry**	**Banana/Plantain leaves**
Dry banana/plantain leaves	30.0	=	15	

Fresh banana/plantain leaves	=	30.0	15.0	
Rice bran	4.0	4.0	4.0	
Brewers dried grains	9.0	9.0	9.0	
Corn	33.7	33.7	33.7	
Palm oil	2.0	2.0	2.0	
Blood meal	3.0	3.0	3.0	
Palm kernel cake	3.0	3.0	3.0	
Cotton seed cake	13.0	13.0	13.0	
Vitamin/mineral premix	0.3	0.3	0.3	
Bone meal	1.5	1.5	1.5	
Salt	0.5	0.5	0.5	
	100.0	100.0	100.0	
Calculated analysis:				
Energy (Kcal/kg)	2570	2570	2570	338.4
Dry matter (%)	98.0	04.9	95.3	20.0
Crude protein (%)	15.7	15.7	15.7	3.6
Crude fibre	8.2	8.2	8.2	12.0
Cost/kg feed (FCFA)	88.0	88.0	88.0	20.0

TABLE 7. **Performance and Economic data for rabbits fed diets containing banana/plantain leaf**

	Form of leaf	

Characteristics	Dry	Dry & Fresh	Fresh	SEM
Total feed cost (FCFA)	25,968	38,350	31,261	
Cost/kg weight gain (FCFA)	1,971[x]	3,012[y]	2,470[z]	0.08**
Total number of live rabbits	15	14	15	0.01
Final live weight of rabbits	2.01	2.13	2.00	0.03
Total revenue (FCFA)	61,040	59,080	60,140	0.02
Net returns over feed	35,072[z]	20,730[x]	28,879[y]	0,01**

[+] *1 Kg of rabbit live weight sells for 2,00 FCFA within rows*

[xyz] *means bearing the same superscript are not significant at P<0.001*

** *Significant at P<0.01*

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