

## Chapter 4

## Feed resources for non-ruminants

*There are many feed resources in the tropics that can be used as alternatives to cereal grains for feeding to monogastric animals. Most of these are rich in either carbohydrate (e.g., sugar cane and sugar palm products, fruits, roots and tubers) or oil (e.g., the African oil palm). Almost all are low in protein.*

*The total allowance of protein can be reduced by some 35% (compared with recommended standards for cereal grain diets) when the dietary protein is mainly derived from oilseed meals and animal and fish by-products, since the amino acid profile of these feeds is better balanced than that in cereal grains. There are also opportunities to provide part of the protein from water plants and leaves of trees and crop plants.*

*Research that leads to the identification and appropriate processing of new protein sources from plants with high productive potential will facilitate the adoption of non-cereal grain feeding systems for monogastric animals.*

### **SUSTAINABLE PRODUCTION SYSTEMS**

The first step must be to examine the role of non-ruminant livestock in the overall farming system, so that from the beginning the issues of sustainability in its broadest sense are addressed. The following guidelines are proposed:

- The feed should be grown and processed, the animals raised, and the excreta recycled, on the farm where the enterprise is situated.
- The feed should be derived from a crop that is part of an environmentally sustainable farming system which optimizes biomass productivity per unit of solar energy, minimizes inputs of agro-chemicals, and maintains (preferably enhances) soil fertility and biodiversity.
- The production system should be integrated with other farming

activities so as to optimize (i) use of family labour (especially the women) and; (ii) recycling of excreta as nutrients for ruminants and fish or as substrate for biogas production and as fertilizer for crops raised in both soil and water.

- Maximum advantage should be taken of the animal's innate ability to: (i) select what is good for it (or what it likes); and (ii) process (i.e., grind with the teeth or in the gizzard; or extract oil or juice by chewing) natural feeds.

It is assumed at the outset that future feed resources for monogastric animals in the tropics will not be cereals, but rather locally available feed resources that can be produced on the farm with comparative advantage in sustainable, non-subsidized production systems. This hypothesis gives rise to a series of consequences the outcome of which is that the husbandry of monogastric livestock in the tropics will increasingly differ from that practised in temperate countries.

The available and potentially available non-cereal grain feed resources can be divided into two categories:

- Feeds low in fibre and rich in oil, sugars or starch.
- Feeds rich in protein.

In the category of energy-rich feeds are:

- The products and by-products derived from sugar cane (FAO, 1988).
- The products and by-products derived from the African oil palm.
- Fruits from mainly leguminous trees (e.g., *Prosopis* spp.).
- The by-products from certain food and cash crops (e.g., reject and/or surplus bananas, plantains and sweet potatoes, cassava bran and fines, whey) (FAO, 1992).
- Recycled organic food waste recovered from homes and institutions and from points of storage and sale of agricultural food crops.

Almost without exception all these feed resources are very low in protein (usually less than 5% and closer to 1% for sugar-based feeds). Most (exceptions are sugar cane molasses, the oil-rich pressed fibre from oil palm processing and fruits of *Prosopis* spp.) have a high moisture content at the point of harvest or production. By way of contrast, the

cereal grains used in temperate pig production are relatively high in protein (8-10%) and are harvested with relatively low moisture content.

Since it is expensive in time and energy to dry plant material, feeding systems using tropical resources will increasingly require transport, storage and distribution of the feed in the fresh state (e.g., palm fruits) or as liquids or slurries.

The soluble fractions of sugar cane (juice and molasses), which are rich in sugars, are the feed resources which are steadily having increased impact in pig production in the tropics. However, new possibilities are seen in the African oil palm tree - which combines high productivity, a perennial growth habit and products and by-products of high energy density - and the sugar palm tree. Most of the research with cassava has been directed towards producing a dry meal which could be exported (e.g., from Thailand to the European Union) or incorporated into mixed feeds. Less attention has been given to developing systems for the small-scale farmer.

### **SUGAR CANE FOR PIGS**

The two most important feeds derived from sugar cane are sugar cane juice and molasses. They have special characteristics which must be taken into account when using them as the basis of feeding systems.

- They have a lower energy concentration, compared with cereals, and the main energetic substrate is not starch but a mixture of sucrose, glucose and fructose. Fructose is a poorly studied substrate in pig metabolism.
- They contain no fibre and no lipids, and are practically free of true protein. Additionally they contain variable and imbalanced amounts of minerals and vitamins.
- Molasses has physical properties (e.g., high osmotic pressure, high density, complete solubility) which have consequences from the nutritional and physiological points of view and also in its technological manipulation.

The agro-industrial process of extraction of sucrose (heating, clarification and centrifugation) results in the production of substances

whose chemical composition is not well characterized (for convenience they are described as "non-identified organic matter" (NIAM) and, in the light of practical findings, are not well metabolized by pigs. These substances appear in the sugar cane molasses in proportions which may be as high as 30% in final molasses.

Older pigs (>3 months) are able to extract the juice from chopped sugar cane stems and even from whole stems (Bien-aimé and Denaud, 1989). However, growth rates are only some 60% of what can be achieved when the pigs are fed with juice extracted mechanically (Molina, C., personal communication). There is probably a role for chopped cane stalks for pregnant sows that will benefit from being offered low-energy-density feeds (see Chapter 3). The principle of fractionating sugar cane to secure its most efficient use by livestock and for production of fuel can be applied at a practical level in three ways:

- in the industrial sugar mill (Figure 7.3),
- in a "trapiche" (a crusher with 2, 3 or up to 5 rolls) (artisan system) dedicated to making "gur" or "panela", or
- in a "trapiche" crusher dedicated to livestock (and fuel) production (Figure 7.4).

Pig production systems have been developed for each of the three alternatives described above.

### **High test, "A", "B" and final ("C") molasses**

The grinding of the cane stalk, filtering, clarifying and concentrating the juice and crystallizing the sucrose, are the processes which give rise to molasses (Figure 7.3). There are four types of molasses in the sugar cane industry:

- Concentrated cane syrup (high-test molasses) which has been partially inverted to avoid crystallization of sucrose during storage and distribution.
- "A" molasses produced after extracting 75% of the total recoverable sucrose.
- "B" molasses produced after some 85% of crystallizable sucrose has been recovered.
- "C" or final molasses considered as a by-product in view of the fact that further sucrose recuperation is not feasible.

Normally "A" and "B" molasses are not produced as products; they are re-processed in order to extract more sucrose. The chemical composition of the different types of molasses is essentially the same as the cane juice differing in that, as the technological flux to crystallization and sucrose separation advances, the biomass is submitted to alkali and steam treatments which increase the percentage of reducing sugars. In these processes, non-sugar organic substances are produced and concentrated. The other important difference between molasses and sugar cane juice is that the former has a high dry matter percentage (approximately 80%), which facilitates storage and distribution.

**Table 4.1. Chemical composition of different types of Cuban sugar cane molasses (Source: Figueroa and Ly, 1990).**

High-test	A	Molasses B	Final	
DM	85.0	77.8	78.1	83.5
(As % DM)				
Nitrogen	0.26	0.29	0.38	0.44
Ash	2.8	4.6	7.2	9.8
Total sugars	86.1	75.9	69.5	58.3
Sucrose	28.6	63.4	57.1	40.2
Glucose	29.3	6.4	5.2	8.9
Fructose	28.2	6.1	7.2	9.2
NFE	95.6	93.0	90.4	87.4
Non-identified OM*	9.5	17.1	20.9	29.1
Gross energy				
(MJ/kg DM) 15.0	14.9	14.7	13.5	

\* Nitrogen-free-extract minus total sugars

In Table 4.1 is the typical composition of the different types of molasses (High-test, "A", "B" and final). It should be noted that the concentration of total sugars decreases, and the ash and non-sugar organic matter increases, in the progression from high-test (concentrated, clarified, partially inverted cane juice) to final molasses. In a sugar cane mill where the efficiency of sucrose crystallization is low, the final molasses may resemble in composition the "B" molasses in Table 4.1. Molasses characterization is an essential step in deciding on the strategy for using it. In fact, it is precisely the composition of molasses which determines animal performance and which indicates whether it is best fed to monogastric or ruminant animals.

The different grades of molasses are essentially similar in their chemical composition. They contain sugars, nitrogenous substances and a "non-identified organic matter" fraction. This latter fraction varies significantly between the types of molasses. The other important characteristics of molasses are:

- It contains neither lipids nor fibre.
- The nitrogen content is low (<0.5%; about one third is in the form of free amino acids).
- The ash varies from approximately 3% (in dry matter) for high-test molasses to 10% for final molasses.
- The principal energetic source is a mixture of soluble sugars (as sucrose, fructose and glucose), the concentration of which increases from <58% in final molasses to 86% in high-test molasses.
- The proportion of total sugars to reducing sugar varies. It is less in high-test molasses due to a process of partial inversion to avoid sucrose crystallization.
- The gross energy of molasses is approximately 20% lower than that of any typical cereal grain.

The soluble fractions of sugar cane (juice and molasses) which are rich in energetic compounds are the feed resources which are finding increasing application in the feeding of pigs in the tropics. Their nutritive value in the pig diet will be determined by:

- Adequate protein supplementation.
- The efficiency with which the soluble sugars are utilized (sucrose, glucose and fructose).
- The mineral and vitamin content with the need to provide supplements to balance those in molasses.
- The role in digestion and metabolism played by the fraction of non-identified organic matter.

Typical results with growing-fattening pigs fed "C" (final), "B" or "high-test" molasses or a cereal grain control diet are given in Table 4.2. Growth rates on high test molasses were comparable with those obtained on cereal grain; results for the "B" molasses were slightly inferior and more so when "C" molasses was used. Feed intakes were always higher

on the molasses diets and therefore feed conversion rate was always poorer than with cereals. But this is not so critical when the price of molasses is less than that of grain.

**Table 4.2. Pig performance on high-test, "B" or final molasses compared with a maize/soya bean control; initial weight was 30 kg (Source: Figueroa and Ly, 1990).**

	Maize SBM	H-test	Molasses "B"	"C"
Final wt (kg)	104	103	98	96
LWt gain (g/d)	643	682	635	619
DM intake (kg/d)	2.21	2.55	2.61	2.56
DM conversion	3.19	3.74	4.11	4.14

Similar results have been obtained with molasses-based diets in pregnant and lactating pigs. In the case of lactating sows however, there are indications of better performance (more fat in the milk and better growth of piglets to weaning) on high-test molasses than on cereal grain (Table 4.3).

**Table 4.3: Performance of lactating sows fed high-test molasses and torula yeast (Source: Figueroa Vilda, 1991, personal communication)**

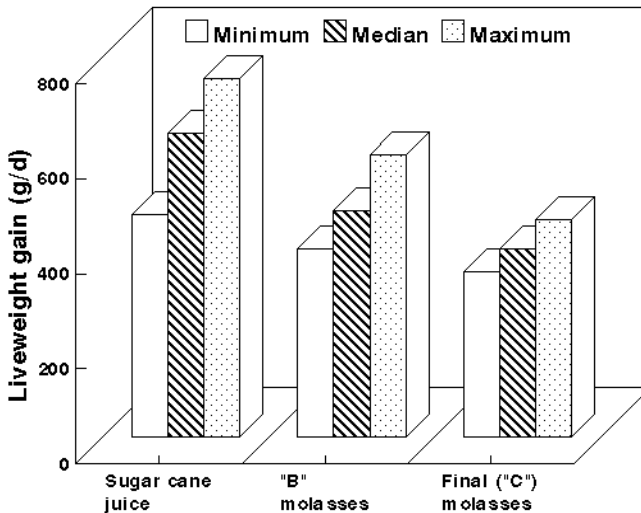
	Cereal	Molasses
Feed intake:		
Dry matter (kg/d)	4.1	4.5
ME (MJ/d)	56.0	53.8
Energy output in milk (MJ/d)	26.0	30.8
Litter weight (kg)*	58.5	63.2
Sow weight loss lactation (kg)	20.5	14.5

\* Weaning at 33 days; piglets fed sow's milk only

The differences between raw cane juice (high-test molasses is concentrated, partially inverted cane juice) and "B" and final molasses in trials done in Colombia (Figure 4.1) were much more pronounced. The poorer performance on the two sources of molasses possibly reflecting the advantages of higher purity cane juice (more sucrose, less reducing sugars) in Colombia (the industry is situated at 1000 m above

sea level and the difference in day and night temperatures maintains high sucrose content in the juice throughout the year) and higher factory extraction rates of sucrose, with correspondingly less sugar in the molasses.

**Figure 4.1. Comparison of sugar cane juice, and "B" and "C" molasses as basal diets for fattening pigs in Colombia (Source: Sarria *et al.*, 1990).**



It is evident that the energy concentration and the nutritive value of the molasses are favoured as long as it is a major product (High-test, "A" and "B") and not simply a by-product (final molasses). But such "higher" grades of molasses compete with sugar production. In the traditional sugar industry which produces sucrose for local and preferential export markets, it will rarely be economical to produce high-test or "A" molasses but under some circumstances, it could be economically feasible to modify the normal industrial process to produce "B" molasses and "A" and "B" sugar. The economics of this will depend on the relative value of the "C" sugar for human use and of the "B" molasses for livestock feed.

### Sugar cane juice

The soluble fraction of sugar cane is easily extracted at farm level by passing the stalk through a "trapiche" or crusher. In these machines, the maximum extraction rate is between 60 and 80% (expressed as percent of total sugars extracted) equivalent to 40 to 53% of juice as a percentage of the weight of the cane stalk. In the industrial mill, with repeated washing and crushing (up to 5 times), extraction can be as high as 97% of the total sugars.

This soluble fraction, called "sugar cane juice" will contain from 16 to 23% of soluble solids (DM), mainly consisting of sucrose and reducing sugars. It is thus a liquid, energy-rich feed and difficult to conserve due to its rapid fermentation.

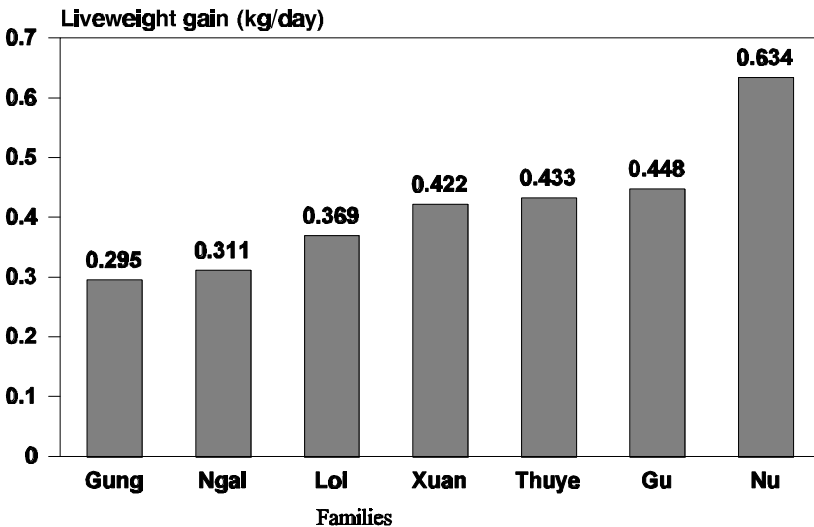
Sugar cane juice contains between 15 and 23% of total solids of which approximately 80% are soluble sugars, mainly sucrose. Sugar cane juice is not exposed to prolonged drastic alkali treatments and high temperatures (as is the case with molasses in the sugar factory). As a result the original chemical composition of the soluble sugars is preserved without the appearance of undesirable secondary chemical compounds, especially non-sugar polymers. Furthermore, there is no flocculation and extraction of the plant proteins as occurs during the clarification process in the sugar factory so the juice is richer in amino acids, minerals and vitamins than is molasses. The low solids content facilitates de-composition by a very rapid fermentation (8-12 hr), which can cause difficulties in the management and distribution of the cane juice in the piggery. The inclusion of formaldehyde, ammonium hydroxide or sodium benzoate permits the preservation of sugar cane juice for periods of from 3 to 7 days (Bobadilla and Preston, 1981). However, this has rarely been used in practice.

The research leading up to the development of this technology has been described by Mena (1989) and Sarria *et al.* (1990). The most important step was the demonstration that, when the protein was provided by soya bean meal, the levels could be reduced to 200 g/day with minimal effects on performance but important economic advantages (Mena, 1983; Sarria *et al.*, 1990).

Cane juice is now employed commercially as the basis of pig feeding on farms in Colombia (Sarria, 1994), Cuba (Perez, R., 1994, personal communication), Vietnam (Nguyen Thi Oanh, 1994) and Philippines

(Moog, F., 1994, unpublished data). Typical results on smallholder farms in a mountainous village in Vietnam are shown in Figure 4.2.

**Figure 4.2. Liveweight gains of growing-fattening pigs (local breed) on smallholder farms in Binh Dinh village in Vietnam. The protein supplement was 300 g/day of groundnut cake; minerals and vitamins were supplied from sweet potato vines and water plants (Source: SIDA-MSc, 1994).**



### THE SUGAR PALM AS A SOURCE OF FEED FOR PIGS

It is estimated there are about 1 million trees of sugar palm (*Borassus flabellifer*) in Cambodia where it is traditional practice to make palm sugar from the juice. The tree is also found in neighbouring countries: in Thailand, Vietnam, Myanmar, India and Bangladesh. The season of production of palm sugar is for 6 months (from December to June) and the rate of production (% of total/month) is 5, 15, 25, 30, 20, 5 for months 1 through 6. The juice is collected twice daily in the morning (about 2 litres) and again overnight (12-14 hr; 2.5 to 4 litres) from the flower of both male and female trees. It begins to invert quite quickly. Traditionally a piece of wood (popél) is used that produces an extract that slows down the inversion.

The juice contains about 13% of sucrose and production of "*masse cuite*" is on average 150g per litre of juice. Average yield is 4 litres juice/tree/day = 600 g of *masse cuite*. A serious constraint is the need for fuel. 1 kg of crude sugar (*masse cuite*) requires: 3-4.5 kg wood or 4.2- 5 kg of rice husks.

An average household in Cambodia will harvest the juice from 20 trees giving a total production in 180 days of 3600 kg. This is equivalent to a production of 1 kg of *masse cuite* per tree per day (peak time of the season).

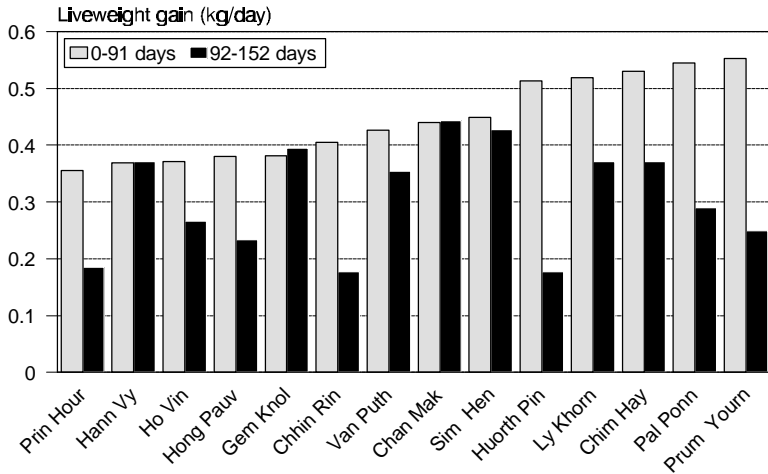
Potential feed sources for pigs are the scums skimmed off the boiling juice. The scums are composed of the juice enriched with the proteins and minerals which flocculate and float to the surface due to denaturing of the protein when the juice is heated. From 20 trees, the daily production of scums from the evaporation of the palm juice is likely to be about 5 to 10 litres. This would supply the energy needs of 1 pig.

The fresh juice can also be used. The daily yield from two trees would be sufficient to feed one pig. There is increasing interest in Cambodia in this option due to the shortage and increasing price of firewood needed to make the sugar.

Results from a series of demonstrations in villages in Cambodia are shown in Figure 4.3. The juice was fed fresh and was supplemented with 300 daily of soya beans that had been boiled for 30 minutes after overnight soaking in water. Salt and green vegetable were also given.

Growth rates during the 4 months from January to April (days 0-91) were good (almost 500 g/day) when the palm juice was fed as the basal diet. From 91 to 152 days there was insufficient palm juice (end of the season) and the farmers used the traditional diet of rice bran. In almost all cases the growth rate decreased on the rice bran indicating the superior nutritional value of the palm juice diet.

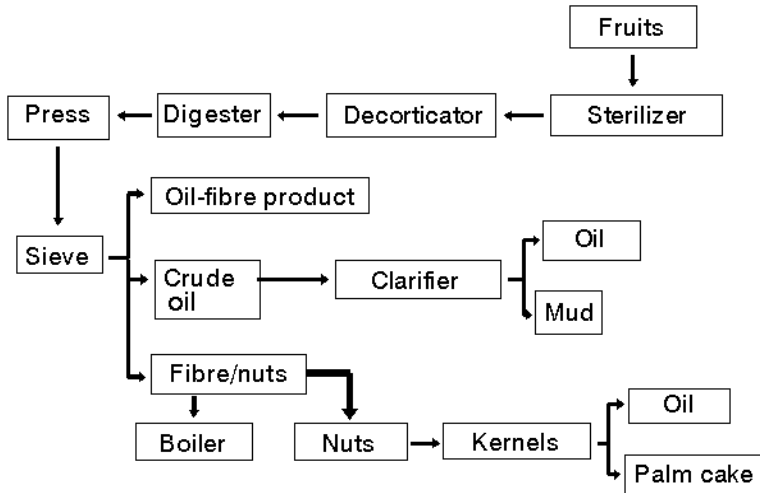
**Figure 4.3. Liveweight gains of pigs fed sugar palm juice and boiled soya beans (0-91 days) and later (92-152 days) rice bran, on farms in villages in Cambodia (FAO/TCP, 1994b).**



### THE AFRICAN OIL PALM AS THE BASIS OF INTENSIVE PIG PRODUCTION

The first attempts to use the products and by-products of the African oil palm (*Eleais guinensis*) in pig feeding were focussed on incorporating the dried sludge in relatively low concentrations in conventional mixed feeds (Ong, 1992). Ocampo *et al.* (1990a,b) were the first to show that the oil-pressed fibre (30% oil) could completely replace cereals in diets for growing-finishing pigs. These researchers subsequently extended their studies to the use of both the crude oil (Ocampo, 1994a), and the fresh fruit (Ocampo, 1994b), as complete replacements for cereal grain in all phases of the production cycle. The flow of biomass, products and by-products in a typical oil palm factory are shown in Figure 4.4.

**Figure 4.4. Flow diagram of African oil palm factory showing products and by-products (Source: Ocampo *et al.*, 1991a,b).**



### The by-products

The three by-products of potential use in livestock production are:

- The oil-impregnated fibre (oil-press fibre) recovered after filtration of the crude oil.
- The mud which remains after the oil has been clarified and centrifuged.
- The palm kernel cake.

The first product has only 5% moisture, 24% of oil and 15% fibre (dry matter basis). In contrast, the mud contains over 90% moisture although the dry matter is rich in oil (51%) and relatively low in fibre (12%). Yields are 5 and 29% respectively of the weight of fresh fruit harvested. The palm kernel cake is relatively high in fibre and has only 20-25% protein. It has a limited role as a protein supplement for monogastric animals.

With a fruit yield of 15 tonnes/ha/yr (data for the Meta Department of Colombia; Ocampo, A., personal communication), the availability of the oil-press fibre and the mud is 0.76 and 0.44 tonnes dry matter equivalent/ ha/year, respectively. It has been demonstrated that:

- The oil-press fibre can be a complete replacement for cereal grain in the diet of the growing-finishing pig (Ocampo *et al.*, 1990a).
- There is no advantage of giving more than 200 g/day of supplementary protein (as soya bean meal) for fattening pigs in the range of 20 to 90 kg liveweight (Ocampo *et al.*, 1990b).

The effect of supplementary protein level on performance of pigs fed the oil-press fibre is shown in Table 4.4. With a dry matter intake of palm oil residue of 2.6 kg/animal/day, it takes 135 days to fatten a pig from 20 to 90 kg liveweight and uses 350 kg dry residue equivalent. Thus 1 ha of oil palm plantation should generate, on average, enough oil-rich residue (oil-press fibre and mud combined) that potentially could grow and finish 3 pigs. However, there are no reports on the use of the mud or "sludge" as the basis of the diet for pigs. This is an obvious area for further research.

**Table 4.4. Mean values for performance traits of pigs fattened with oil-press fibre and reduced levels of protein (Source: Ocampo *et al.*, 1990b).**

	Supplementary protein level (g/day)			
	280	256	230	200
Number days	121	126	124	135
Liveweight, kg				
Initial	22.7	22.8	22.8	22.1
Final	90.2	90.0	90.4	90.3
Daily gain	0.56	0.53	0.55	0.51
Intake, kg/day				
Soybean meal	0.70	0.64	0.57	0.50
Oil residue	2.33	2.44	2.22	2.56
Conversion (DM)	4.8	5.2	4.6	5.4

### Crude palm oil

The African oil palm has become an important crop in Colombia now established on approximately 120,000 ha of which 80% is currently in production. The recent (since 1993) removal of guaranteed producer-support prices, and the reduction of import tariffs in Colombia, led to a fall in the internal price of crude palm oil to close to the world free market price (about US\$450/tonne). This made the crude oil competitive on an energy basis with imported cereal grain (about US\$200/tonne), and was the stimulus for initiating research with the crude oil as the basis of

the diet of growing-fattening pigs (Ocampo, 1994a). An advantage from using oil as the energy resource is its high caloric density and the absence of fibre. This creates opportunities for using unconventional sources of protein such as tree leaves (Preston and Murgueitio, 1987) and water plants (Van Hove, 1986; Lumpkin and Pluckett, 1982; Becerra, 1991) whose fibre content would normally be a limitation in a conventional cereal grain diet.

The data in Table 4.5 show the effect of feeding a diet with 50% of the dry matter in the form of oil to growing-fattening pigs, and of replacing up to 30% of the soya bean meal protein with *Azolla filiculoides*. The results for growth and feed conversion suggest that, even at such high levels in the diet, the oil is efficiently utilized, and that there are apparently no detrimental effects on carcass quality.

**Table 4.5. Growth performance of pigs fed crude palm oil and different levels of *Azolla* replacing soya bean meal (Source: Ocampo, 1994a).**

	Replacement of soya protein by <i>Azolla</i> protein, %			
	0	10	20	30
Live weight (kg)				
Initial	28.8	29.4	28.8	28.9
Final	87.8	92.3	88.8	79.6
Daily gain	0.526	0.561	0.535	0.452
Feed intake, kg/day				
Supplement	0.500	0.450	0.400	0.350
<i>Azolla</i>	0.0	1.17	2.0	2.10
Oil	0.57	0.55	0.54	0.5
Rice polish	0.110	0.110	0.110	0.110
Total DM	1.11	1.10	1.0	1.0
Conversion DM	2.1	1.98	2.0	2.2
Carcass yield, %*	85	84	84	88
Backfat (cm)*	3.7	3.5	3.6	3.4

\*Means for 3 pigs per treatment obtained 1 hr after slaughter

The results also indicate that *Azolla* can replace successfully up to 20% of the soya bean protein in oil-based diets. Practical observations suggested that the presence of a small amount of carbohydrate (from rice polishings) in an oil-based diet was beneficial. A trial to evaluate the effect of level showed that there was no advantage in exceeding 100 g/day of rice polishings (Ocampo, 1994c, personal communication).

Several commercial producers in Colombia are now using the crude palm oil, supplemented with soya bean meal and rice polishings, as a replacement for cereals in all phases of the pig production cycle (Ocampo, 1994a; Ocampo, A., unpublished data; Rodriguez and Cuellar, 1994).

### Fresh oil palm fruit as the basis of pig diets

The use of the fresh whole fruit of the oil palm as the basis of intensive pig production makes it possible for the farmer-producer to diversify the end-uses of the crop through integration with pig production. This will have favourable effects on the sustainability of the farming system, since the manure from the pigs will serve as fertilizer for the trees. Farmer self-reliance will be increased by the creation of alternative end uses for the fruits thus reducing dependence on sale to the oil palm processing factories. The hypothesis that the pig would be able to extract the oil and other nutrients from the whole fruit was confirmed as can be seen from the data in Table 4.6. However, there was a reduction in growth rate, apparently related with a fall in intake, when the replacement of sorghum by the palm fruit exceeded 50%.

**Table 4.6: Performance of pigs fed whole fruit of oil palm as replacement for sorghum grain (Source: Ocampo, 1994b).**

	Replacement of sorghum, %			
	25	50	75	100
Duration trial, d	98	98	126	126
Liveweight, kg				
Initial	26.1	27.0	26.7	27.0
Final	89.3	85.7	90.2	85.7
Daily gain	0.625	0.596	0.503	0.466
Intake, kg/d				
Supplement	0.5	0.5	0.5	0.5
Sorghum	1.3	0.86	0.20	0.0
Palm fruit	0.54	0.97	1.68	1.59
Total DM	2.02	1.94	1.68	1.59
Conversion (DM)	3.2	3.2	3.3	3.4

Part of the reduced intake on the 100% fruit treatment was thought to be due to deterioration in fruit quality, when occasionally it had to be stored

for periods exceeding the recommended 7 days (Ocampo, 1994c, personal communication). Despite the slower growth rate, the economic analysis (under local conditions in the southern plains of Colombia) favoured the treatment with complete replacement of the sorghum by the palm fruit. This latter treatment would also be favoured by an analysis taking into account the indicators of sustainability.

### **SURPLUS AND REJECT BANANAS AND PLANTAINS**

In his review of bananas and plantains as animal feed, Batabunde (1992) pointed out that these would almost never be grown as a specialist crop for livestock, in view of their role as a staple in the human diet in most tropical countries. The exceptions to this rule are the commercial banana plantations producing fruit for export, where grading of the produce often results in rejections rates of 20-30% because of unsuitable characteristics (e.g., blemishes, over-size and over-ripeness). Many studies have been made on ways of using this material mainly for pig feeding. However, these rejects increasingly find their way into local markets and there are few instances of producers setting up livestock units to use these resources. The fruit of both plantains and bananas is largely composed of starch which gradually is converted to sugars during ripening. Because the fruits are low in protein (<4% in dry matter), the principle of the feeding system is the same as with sugar cane juice. A protein supplement is required but, as in the cane juice system, the amount can be restricted (see Chapter 3) to approximately 60% of the levels recommended by NRC (1988), assuming that the supplement chosen has a well-balanced array of essential amino acids. Ripe bananas generally support faster growth than green bananas (Hernandez and Maner, 1965), due it is believed to high "free" tannins in the unripe fruit. Cooking slightly improved the feeding value of the green bananas, but ensiling may be a more appropriate option (Le Dividich and Canope, 1975). The fact that there has been little research on bananas and plantains as animal feed during the past 20-30 years confirms Babatunde 's (1992) statement that these resources will almost always find a better market as human food.

Plantains are often grown as shade for coffee and, because of the

short shelf-life of the fruit and the distance from markets, their use as animal feed in these circumstances may be feasible (Espinal, R., 1993, personal communication). However, economic success will generally be obtained by minimizing costs rather than maximizing performance. Restricting the protein supply is an important strategy in this case.

## **CASSAVA**

Both the roots and the leaves can be used as feed for monogastric animals.

### **Cassava roots**

Processing (chopping and sun-drying) of the roots to produce cassava chips for animal feed is a major industry in several tropical countries, chiefly Thailand, Indonesia, Brazil and to a lesser extent in Colombia.

As with bananas and plantains, the decades of the 60's and 70's were the periods of active research into uses of cassava products in pig feeding when it was shown that fresh (the sweet varieties only), ensiled or dried cassava root chips could completely replace cereal grains in diets for pigs (see review by Gomez, 1992). Poultry appear to be less tolerant of cassava products, mainly because of the adverse effects of hydrocyanic acid (HCN) on intake and requirements for the sulphur-containing amino acids. Inclusion levels of dried root meal of less than 50% are recommended for broilers and no more than 40% in rations of layers (Khajarern and Khajarern, 1992).

The direction of the work eventually focussed almost exclusively on production of dried cassava root chips for export to Europe for mixed feed manufacture where, because they were classified as a by-product, they were subjected to a much lower tariff than imported cereal grain.

Some promising work on the feeding of fresh and ensiled cassava root chips, along with a protein supplement (Buitrago, 1964; Maner, 1972), a system that is appropriate for small-scale farmers, was unfortunately never followed up presumably because of the higher profits to be made in the short term from exports of the dried chips. The recent revision of the Common Agricultural Policy in the European Union and the consequences of the recently approved World Trade Agreement will almost certainly result in the market for cassava chips becoming less attractive. This will create opportunities for more sustainable mixed

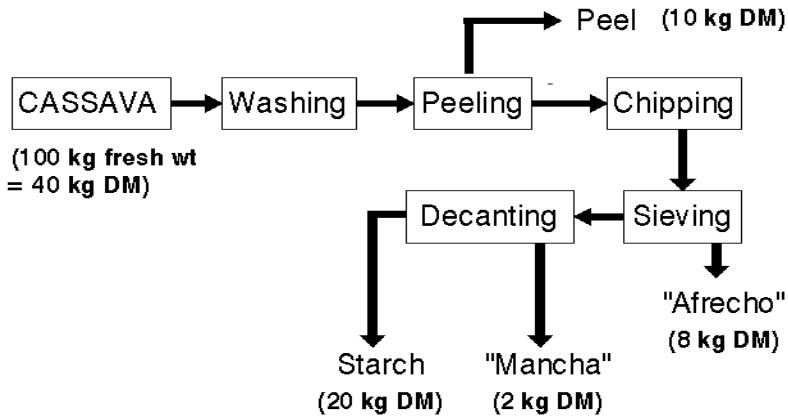
farming systems in which the cassava will be consumed by livestock on the farm where it is grown.

There are indications that this approach is being adopted in the tropical region of Mexico (Lopez *et al.*, 1988; Rodriguez, 1989), using ensiling as the the method of conservation. Manipulation of the protein supply will be an important feature of research to popularize cassava feeding at the small farm level (Ospina *et al.* 1994). When livestock are treated primarily as components of farming systems and not as specialized activities, emphasis shifts to optimizing the role of the animal in the system rather than maximizing individual performance. This has important economic consequences since it is in striving for maximum performance that creates requirements for expensive ingredients such as essential amino acids and vitamins. An example of this interaction can be seen in the work of Ospina *et al.* (1994) where performance of growing finishing pigs on a basal diet of cassava root meal increased linearly with protein supply (from soya bean). The maximum biological response was obtained with a daily intake of 350 g protein, but the economic optimum was with levels of only 200 g/day.

The advantage of cassava is that it can be grown in areas with extended dry periods. Where there are better conditions for plant growth, other crops are usually more profitable as sources of animal feed (Nguyen Thi Mui, 1994a). Certainly, cassava is an exploitive crop and growing it in monoculture leads to declines in soil fertility. Thus it should be grown in rotation with other fertility-restoring crops, and this is usually what is practised by small-scale farmers (Moreno, 1992).

An attractive end-use for cassava is for manufacture of starch. This can be done at an artisan level with minimum infrastructure; chippers/grinders to peel and break up the roots into chips and a washing machine to extract the starch. A flow diagram for such a unit as operated in the Cauca Valley of Colombia is shown in Figure 4.5. The two by-products from this process are "bran" (*Afrecho*) and "fines" (*Mancha*). The bran contains (dry matter basis): 1% protein, 15% fibre and 60% starch; corresponding data for the fines are 5, 1 and 64%. As is to be expected, cassava bran and fines are low in protein and thus the total protein in the diet, provided it is well balanced in essential amino acids, can usually be reduced in accordance with the recommendations in Chapter 3. Typical results using these feed resources for growing-finishing pigs are given in Table 4.7.

Figure 4.5. Flow diagram of artisan system of producing starch from cassava roots showing origin of by-products (Espinel, R., unpublished data).



The results are similar to what would be expected with traditional diets of cereal grains. There is an obvious potential in cassava starch by-products as feed particularly for pigs. However, the way forward will be to encourage farmers close to the plants to engage in pig production. This will avoid the need for sun-drying the cassava by-products (a tedious, time-consuming exercise). The pig excreta could then be combined with the organic-matter-rich wash waters from the plant to feed biodigesters and ponds which in turn could provide fuel (the biogas) for the families and protein (from water plants grown on the ponds) to be recycled to the pigs.

**Table 4.7. Performance of pigs fed coarse and fine by-products from cassava processed for starch (Source: Ospina, L. and Espinel, R. 1992, Unpublished (data)).**

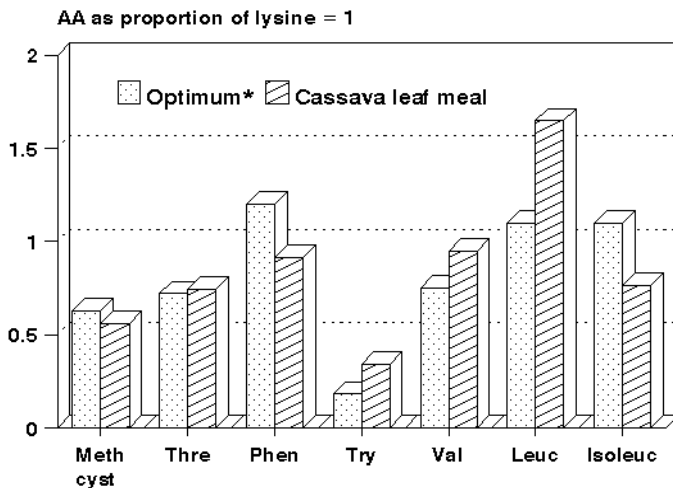
	Coarse	Fines (50:50)	Coarse:Fines
Liveweight (kg)			
Initial	38.5	41.5	38.1
Final	92.0	91.5	90.5
Daily gain	0.660	0.534	0.443
Feed intake (kg DM/d)			
Cassava by-product	2.1	2.04	1.75
Supplement	0.45	0.45	0.45
Total DM	2.55	2.49	2.20
Conversion	3.86	4.66	4.97

### Cassava leaves

When leaves are harvested at the same time as the roots, yields are in the range of 1 to 4 tonnes dry matter/ha (Ravindran, 1992). Leaf production can be enhanced by partial defoliation during the growing season. Ravindran and Rajaguru (1988) obtained almost 7 tonnes of leaf dry matter/ha by defoliating once during a 7-month growing season and reported a reduction in root yield of only 12%. It was claimed that, with adequate irrigation and fertilization, cassava cultivated only for leaf production will persist over several years with average annual dry matter yields of over 20 tonnes/ha (Montaldo, 1977). However, there are no reports of this practice being adopted by commercial farmers.

Fresh cassava leaves can be fed directly to ruminants but must be dried or ensiled for monogastric animals. The effects of drying and ensiling on the HCN content are shown in Table 4.8. Ensiling appears to be the best method for reducing HCN content. However, little is known about the effect of this process on the digestibility and availability of the amino acids. The nutritive value of the leaves is similar to that of alfalfa with respect to fibre levels and the amino acid profile (Figure 4.6).

**Figure 4.6. Amino acid profile of cassava leaf meal compared with optimum (Source: Ravindran, 1992; Wang and Fuller, 1989).**



**Table 4.8. Effect of drying and ensiling cassava leaf meal on HCN content (Source: Bui Van Chinh, 1993, Unpublished data)**

	HCN (mg/kg DM)
Fresh	863
Dried in shade 2 days	274
Sun-dried for 4 hours	261
Sun-dried meal	80
Ensiled	33

### Sweet potatoes

An advantage of the sweet potato crop is its short growing season (100 to 150 days). Both the tubers and the vines are traditionally fed to pigs by small-scale farmers. There is evidence that cooking improves the feeding value of the tubers for pigs and especially poultry as it reduces trypsin inhibitors and improves starch digestibility (see review by Dominguez, 1992). As with other tropical carbohydrates sources, the economics of using sweet potato tubers in pig feeding will depend on the source and quantity of protein that is given. There appear to be no data

on growth responses to varying protein levels which makes this a priority area for research. Soya bean meal levels were reduced to 390 g/day (200 g/day of protein) when the fresh vines of sweet potato were also fed in a pig diet based on cooked sweet potato tubers (Table 4.9). However, little is known about the digestibility of the protein in the sweet potato vines.

**Table 4.9. Sweet potato vines as replacement for soya bean meal in diets based on cooked sweet potato tubers (Source: Dominguez, 1990).**

Intake, kg/d				
Soya bean meal	0.72	0.54	0.39	0.54
SP vines	0.0	2.4	5.1	0.0
Cooked SP9.5	8.6	8.1	0.0	
Maize	0.0	0.0	0.0	2.8
Liveweight gain, kg/d	0.77	0.69	0.64	0.77
Feed conversion (DM basis)	3.51	3.81	3.01	

## **PIG PRODUCTION SYSTEMS BASED ON RECYCLED HOUSEHOLD AND INDUSTRIAL ORGANIC WASTE**

Cuba developed an unconventional model for its national pig production strategy based on the integration of its principal agricultural crop - sugar cane - with the utilization of wastes and by-products from restaurants and canteens and from agricultural and industrial activities. In this way, the traditional dependence on cereal grains for the pig industry was avoided.

### **Collection and utilization of organic wastes**

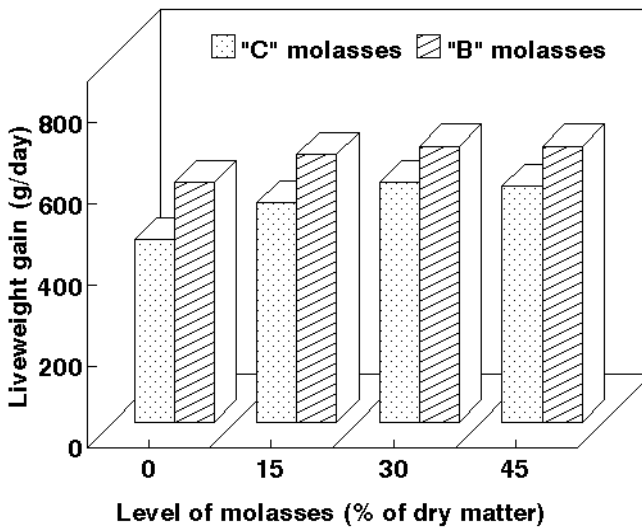
All organic wastes with potential for use in pig feeding are collected and transformed into a liquid feed termed "processed wastes". The recovery of these materials is done systematically in tanker trucks which follow established routes throughout the country. In 1990, there were 205 such routes and the average amount of organic waste collected on each one was 7.7 tonnes, giving a total of 1,578 tonnes daily, or nearly half a million tonnes annually. The wastes are delivered to industrial plants designed specifically for the purpose of processing the wastes (Del Rio *et al.*, 1980), where they are submitted to selection, grinding, sterilization and mixing with sugar cane molasses, before being conveyed by pipeline

to pig fattening units (usually of some 12,000 head) situated adjacent (usually within 200m) to the processing plant (see Figure 7.2).

Analysis of this processed organic waste, prior to mixing it with molasses, shows that it contains: 13.5-18.8% dry matter, 7.9-16.7% ash, 18.6-22.2% protein, 6.6-10.8% lipids and 6.5-12.6% fibre (Dominguez, 1991).

The protein is highly digestible but low in biological value at 58% compared with casein at 91%. It appears that the sulphur amino acids - methionine and cystine - are the most lacking. In view of the relatively high level of protein in the processed wastes, it has been standard practice in Cuba to mix them with molasses, initially with final "C" molasses and more recently with molasses "B". Results obtained with different levels of the two types of molasses are summarized in Figure 4.7.

**Figure 4.7. Growth rates of pigs fed processed organic waste mixed with "B" or "C" molasses (Source: Dominguez, 1991).**



It is apparent that the optimum limit of either type of molasses is of the order of 30% (dry matter basis) and that performance is always better with "B" molasses.

It appeared that pig performance on the processed wastes was improved when supplements of minerals (including copper sulphate), vitamins and methionine were added. Liveweight gains in one trial were increased by more than 100 g daily by the supplements irrespective of the type of molasses used Dominguez (1991). However, this refinement never became commercial.

### **Incorporation of citrus wastes**

Ensiling citrus wastes following extraction of the juice has advantages over traditional drying, in that less energy is used (dehydration is usually with fossil fuel) and there are improvements in the palatability, probably due to destruction of certain secondary plant compounds which give a bitter taste to both the dried and fresh product (Dominguez, P., personal communication).

Results from using ensiled orange wastes as a replacement for final "C" molasses are shown in Table 4.10. Liveweight gains were unchanged but feed conversion was improved when the citrus silage replaced the final molasses. These results show that the organic wastes from the citrus industry can be incorporated satisfactorily with other processed organic wastes for pig production, and can replace molasses.

**Table 4.10. Performance of fattening pigs given a basal diet of processed organic wastes and different proportions of final molasses and ensiled citrus pulp (Source: Dominguez, 1991).**

Ensiled orange waste	0	12	25	40	
Final molasses		49	37	24	9
Dry matter intake (kg/d)	2.8	2.9	2.6	2.45	
Weight gain (kg/d)		0.62	0.62	0.59	0.60
Feed conversion		4.54	4.64	4.37	4.08

### **Thermal destruction of animal and vegetable wastes**

Another feature of the Cuban programme of waste utilization has been

the design and development of an autoclave with mechanical agitation which processes adequately (130°C and 2 atmospheres pressure) not only vegetable wastes but also wastes from abattoirs and even dead animals. The advantage of this system compared with dehydration is the saving in fuel oil (3.7 tonnes less oil are used in wet processing compared with dehydration) and the lower investment cost of the equipment.

Conservation of the paste-like product has not proved to be a problem since addition of molasses has proved to be both effective and convenient. In any event the molasses is usually added to the final mixture of processed wastes. It is planned to equip all new waste processing units with the thermal-disintegrator system (Dominguez, P., personal communication) in view of lower investment costs and simpler operating procedures.

### **Conclusions**

The Cuban experience is unique in that it has shown that there can be an economical and ecological solution to the problem of organic waste disposal that is particularly appropriate for developing countries. The benefits of recycling organic waste as feed are many:

- In comparison with sanitary (?) land fills there is almost no production of methane and no risk of contaminating ground waters.
- The economic return from recycling the waste as feed is much greater than converting it into compost.
- Organic waste because of its high moisture content is not a suitable candidate for use as fuel in thermoelectric stations.
- If the wastes from the livestock units are themselves recycled through biodigesters and ponds, and sustainability indicators are applied, the overall balance will favour much more the recycling system, compared with any other method of disposal.

The constraints on the system are the dependence on fossil fuel for the vehicles required for the collection and transport of the raw material. On the other hand, this material has to be disposed of in one way or another, and it can be argued that the extra costs of delivering the organic waste to processing centres is justified by the saving in resources and the reduction in environmental contamination.

## ENSILED ANIMAL AND FISH WASTES

The ensiling of the animal and fish by-products, using molasses and crude syrups derived from sugar cane, is a simple and appropriate method of conservation (Perez, R., personal communication). The results of using this method to preserve mixtures of blood and shrimp heads in Vietnam are shown in Table 4.11. The shrimp heads were mixed with blood and molasses in the ratio (wet basis) of 5:3:2 and ensiled for 3 weeks. The pH fell to 4.5 at the end of the first week and remained at this level for the remainder of the ensiling period. The silage was used to replace fish meal at levels of 5 and 10% (diet dry matter basis) in a diet based on maize and rice bran in a fattening diet for pigs.

There were indications that the palatability of the silage was a constraint affecting intake and feed conversion at the 10% replacement level. It would be interesting to test the silage in completely mixed diets based on molasses or juice from sugar cane or sugar palm.

**Table 4.11. Mean values for growth and feed conversion of pigs fed silage of shrimp heads, blood and molasses as replacement for fish meal in cereal-based diets.**

		Control	Silage, %		SE
			5	10	
Liveweight, kg					
Initial	23.4	24.5	24.1		±9.4
Final	74.8	79.0	75.8		±2.6
Days on trial	102	100	107		±2.0
Liveweight gain, g/day					
Actual		506	532	483	±11
Adjusted*		502	531	489	±4.1
Dry matter intake, kg		1.93	1.92	1.80	±0.04
Dry matter conversion					
Actual		3.32	3.60	3.64	±0.21
Adjusted*		3.08	3.54	3.93	±0.052

\* By covariance for differences in initial weight and days on trial

## SUGAR CANE DERIVATIVES FOR POULTRY

### The general approach

Research in Cuba twenty years ago showed that raw sugar could replace the cereal grain in diets for all classes of poultry (Perez *et al.* 1968). However, the technology never became truly commercial. Raw sugar is

almost always too expensive to use in animal feeds. Molasses and cane juice are economically competitive with cereals but there are many factors that mitigate against their use for fattening and laying birds other than water fowl. For example:

- Large scale poultry systems are designed to use complete mixed and dry diets.
- The productive life of broilers is too short to permit them to adapt adequately to liquid diets.
- The mouth parts of birds are not designed for consuming liquid feeds. There is considerable wastage (whether it is cane juice or molasses) and the feed sticks to the plumage which is an inducement for cannibalism.

## LAYING AND FATTENING HENS

### Sugar cane juice

Use of the cane juice as a substitute for grain in broiler and laying hen diets has not been successful due mainly to the physical difficulties experienced by chickens in consuming a low-density liquid diet, and the stress caused by splashing of the sugar-rich juice on the feathers which can lead to cannibalism. Rates of growth and feed conversion have rarely exceeded 60-70% of genetic potential (Arango *et al.*, 1994).

Laying hens, particularly the heavier dual purpose strains, which have been raised on cane juice, have been maintained through complete laying cycles with satisfactory, although lower, egg production (about 65% laying rate) than would be expected with cereal diets (Vargas, J., unpublished data).

### Molasses

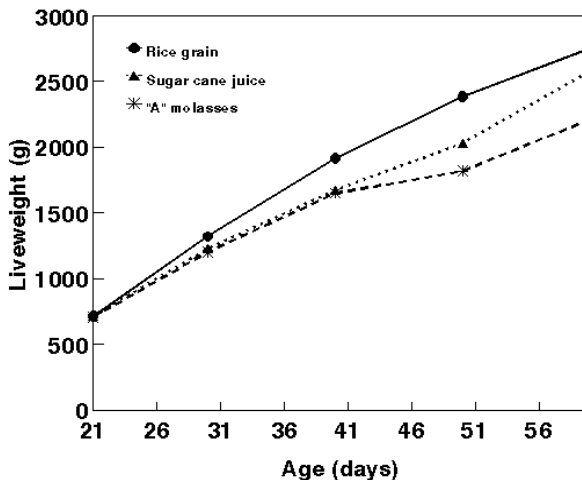
An interesting development has been reported from Cuba (Rodriguez *et al.*, 1994). It was found that ground sun-dried tropical forages, especially the leaves of sugar cane, were able to absorb up to twice their weight of "B" molasses. The molasses is first diluted with 20% of its weight of water, then mixed with the dry leaf meal and the mixture left to dry in the sun for 48 hr. The final product contains (DM basis): 70% "B" molasses and 30% dried sugar cane leaf meal. It is friable and easily mixed with

other dry ingredients. Its true metabolizable energy value was found to be 2.87 Mcal/kg DM. Up to 40% of this feed has been included in diets of laying hens with no loss of performance. The aim now is to replace the whole of the cereal grain with this alternative tropical feed resource.

## DUCKS AND GEESE

Recent developments in the feeding of cane juice to ducks are much more promising (Bui Xuan Men and Vuong Van Su, 1992; Becerra *et al.*, 1994). Ducks are well adapted to consuming liquid diets and, provided they have access to water for swimming, have no problems with the sugar juice falling on their plumage. It appears to be possible to reach at least 80-90% of genetic potential for growth (Figure 4.8).

**Figure 4.8. Ducks can be fattened on sugar cane juice with growth rates only slightly less than on cereal grain. (Source: Bui Xuan Men and Su Vuong Van, 1992).**



As with pigs, the absence of fibre in the cane juice permits partial substitution of conventional protein sources with water plants such as *Azolla filiculoides* (Becerra *et al.*, 1994). There appears to be real

potential here to develop low-cost, farm-based commercial feeding systems.

### **OTHER TROPICAL NON-CEREAL FEED RESOURCES FOR POULTRY**

Reject (from human consumption) cassava roots, sweet potato tubers and banana and plantain fruits, have long been fed to poultry managed as scavengers around the farm holding. There appears to be no reported research on the use of these feed resources as the basis of the diet in intensive on-farm feeding systems.

Scavenging for their feed continues to be the predominant system in the less-developed tropical countries. Nutritional improvements to this system have not been researched very well as it has not been a priority for most NARIs and not all for the CGIAR centres. In contrast, from the sociological standpoint, poultry are the most widely owned species of livestock and are particularly important for income generation for women.

There are reports from Bangladesh of economic gains by supplementing scavenging chickens with 25g of by-product feeds such as rice polishings (Dolberg, F., personal communication). It is likely that the choice of supplement will depend on the human and livestock pressure on available natural resources. Where pressure is high, protein is likely to be the first limiting factor as was shown in a study in Bangladesh where the contents of the crops of birds and ducks were found to have in the region of 9-10% crude protein in dry matter (Huque and Asaduzzaman, 1990). Where human and animal pressure is low, there may well be benefits from an energy-rich supplement. All of these observations indicate that there is need for much more research in this area.

### **TROPICAL NON-CEREAL FEED RESOURCES FOR RABBITS**

#### **Sugar cane**

The digestive system of rabbits requires that they be fed preformed amino acids (protein) that should preferentially be released in the small intestine. Although most non-ruminant small herbivores practise coprophagy, it is not efficient for protein to be recycled in this way since the pathway involves first fermentation to microbial protein. On the other hand the practice does permit cell wall carbohydrates to contribute

energy as volatile fatty acids. Rabbits also like to use their teeth to bite and chew their feed. The two approaches to replacement of cereal grains by sugar cane products which promise to have impact in farm practice are:

- Use of molasses incorporated into solid blocks along with other by-products.
- Use of sugar cane juice as an integral component of the fresh sugar cane stalk.

### **Molasses**

The idea of preparing molasses-rich solid blocks for rabbits was first proposed by Perez (Perez, R., personal communication). It was further developed in Vietnam (Dinh van Binh *et al.*, 1991), where it was shown that adequate growth and reproductive rates could be obtained with blocks containing 50% final molasses. In one trial, urea was incorporated at low levels (4%) but had no apparent effect. More recently in Colombia (Espinal, R., unpublished data), blocks made with 30% of final molasses and complemented with legume bean foliage have supported growth rates post weaning of 20 g/day. This is comparable with what can be achieved in the tropics with pelleted complete diets based on cereal grains.

### **Sugar cane juice and fresh "split" stalk**

Early attempts to replace cereal grains with sugar cane juice showed that it was technically feasible to adapt rabbits to consume liquid cane juice (from the same type of bottle used to dispense the drinking water), but growth rates were well below the genetic potential of the animals. More promising results have been obtained in Vietnam using lightly peeled cane stalk split down the middle (Nguyen Quang Suc *et al.*, 1994).

The rabbits relished the peeled, split cane stalk which was cut into lengths of about 15cm. For fattening of young rabbits, growth and feed conversion were best on the sugar cane stalk (Table 4.12). Reproductive performance was the same with the peeled sugar stalk as with the control fed cereal-based concentrates (Table 4.13). Feed costs were less for the sugar cane diet in both trials. It has since been found that peeling of the stalk is not necessary and it is enough simply to cut into short lengths and split these longitudinally (Nguyen Quang Suc and Perez, R., unpublished observations).

**Table 4.12. Mean values for performance of fattening rabbits fed concentrates or peeled sugar cane stalk (Source: Nguyen Suc *et al.*, 1994).**

	Concentrates	Sugar cane
Number of rabbits	20	20
Liveweight (g)		
Initial	459±41	468±53
Final	770±70	873±178
Daily gain	11.2	17.1
Feed intake (g/day)		
Concentrate	36.2	
Grass	124	
Peeled sugar cane stalk		91.9
Soya bean seed		23.9
Legume bean foliage		68.7
Total dry matter	53.6	62.9
Feed conversion	4.85	3.75

**Table 4.14. Mean values for reproductive performance of New Zealand White rabbits fed peeled sugar cane stalk, toasted soya bean seed and legume bean foliage (Source: Nguyen Quang Suc *et al.*, 1994).**

	Concentrate	Sugar cane
Number of does	9	10
Body weight change during lactation (kg)	-0.20	-0.31
Litter size at birth	5.4	5.1
Offspring weight (g)		
Birth	52.4	48.6
21 days	204	192
Feed intake (g/doe/day)		
Concentrate	94.1	
Guinea grass	548	
Sugar cane stalk		276
Soya bean seed		23.7
Legume bean foliage		421
Total dry matter	214	270
Total; N*6.25	17.3	19