An Investigation into a Low-Input Pig-fish System Appropriate for the Mekong Delta, Vietnam

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The use of pig manure as an input to freshwater fish culture is a well established system in parts of Asia. The pig production wastes, which may include urine and waste food in addition to faeces, may be used to provide nutrients for stimulating the growth of natural food organisms such as phytoplankton, zooplankton and detrital-bacterial aggregate. These feeds, present in both the water column and sediments of ponds, are consumed by suitable herbivorous and omnivorous fish species.

Research into integration between pigs and fish to date has been based on the wastes from modern pig production systems utilising nutritionally balanced feeds. Fish yields are related to the level and quality of nutrients in waste; the data from high input pig production therefore cannot be extrapolated to backyard, small-scale systems. These tend to utilise local feeds which are typically nutritionally inferior and produce wastes that are also less nutrient rich. The choice of fish species also has impacts on yields since phytophagous fish such as Nile tilapia (*Oreochomis niloticus*) are likely to optimise yields in eutrophic water. Their tendency to breed in the system may be either a benefit, if progeny can be marketed locally as 'seed', or a problem if their recruitment is uncontrolled leading to stunting of stocked fish. The use of suitable predatory fish to control excess progeny may therefore improve performance.

An experiment in which all the production wastes from fattening pigs fed a diet available to Vietnamese farmers was used to fertilise a monoculture of Nile tilapia or a polyculture of the same species with hybrid clarias catfish (*Clarias macrocephalus* x *Clarias gariepinus*). All the wastes from pigs housed in stalls were loaded daily into a series of six earthen ponds (200m^2) over a period of 90 days. A ratio of 50 pigs/ha pond area was used, based on the normal numbers of pigs fattened per household and typical fishpond size in the target area. No other inputs were used except for an initial basal fertilisation of 75 kg/ha urea and 90kg/ha triple superphosphate during pond preparation.

Pigs (hybrid Large White x Landrace x Duroc) were fed a cooked mixture of rice bran, obtained from village rice mills in north-east Thailand, and chopped water hyacinth (*Eichhornia crassipes*) twice daily. Rice bran and water hyacinth were fed on a basis of 5% and 4% (wet weight) of the live weight of the pigs, adjusted monthly. The pigs used were modern hybrids obtained from a commercial farm at a mean size of 55.3 kg and raised over a period of 3 months, reaching a average marketable size of 88.9 � 3.2 kg.

Net yields of the monoculture and polyculture of fish were not significantly different at 14-16 kg fish/pond (extrapolated yields of 2.9 and 3.3 MT/ha/year respectively). Stocking hybrid catfish as a predator to control tilapia breeding was ineffective. Large numbers of tilapia fry were harvested from both systems, although the polyculture had significantly less.

The simulated value of the harvest varied with local market opportunities for tilapia fingerlings or hybrid catfish. The use of the tilapia fingerlings as a supplementary pig feed is a potential option; yields of small fish (total length=<10 cm) varied between 5-8 kg per pond over the three month trial.

The energy requirements to prepare the pig feed were also accounted within a framework of woody biomass produced from *Leucaena leucocephala* in which the leaf was fed to small ruminants. Rotational cutting of a boundary fence (178m long, 1m wide) would satisfy the energy needs to produce feed for one fattening pig throughout the experimental period.

Effect of Cropping Patterns on Egg Production of HYV Hens in a

Semi- Scavenging Poultry Model in Bangladesh

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Abstract

A study was made with 1272 pullets of 6 months age under semi scavenging conditions to compare the egg production in three agro-ecological zones with different cropping patterns. The cropping patters were grain dominant in low lying 201% cropping intensity (Manikgonj), grain / fibre (Jute) in medium high land 207% cropping intensity (Jessore) and Sugarcane / grain in high land 159% cropping intensity (Rajshahi). Cropping pattern significantly influenced age of first egg and total egg production. Average age at first egg was 31, 34, 34 weeks in the grain, grain/fibre and sugarcane/grain cropping patterns respectively. The average egg production/hen/year were 157, 154 and 103 respectively and the results varied significantly. It was interesting to observe that the highest egg production and early egg laying were associated with the lowest level of supplementation by the farmers in the grain dominant cropping patterns (130Kcal and 6.4g protein/bird/day). The results indicated that HYV hens can be an efficient utilizer of grain based crop residues as scavenging feed resources and the egg productivity seems to be much higher than the existing non descriptive native chicken under same nature of management.

Introduction

The native chicken in the existing traditional scavenging system of Bangladesh produces 45 eggs per hen per year (Ahmed and Hasnath, 1983) and constitutes about 80% of country's chicken population. Some experiments have been conducted concerning introduction of exotic breeds of hen (HYV) and their crosses to determine potentials and limitations in the scavenging and semi scavenging system (Ahmed *et al*., undated; Quader *et al*., 1989; Hossain *et al*., 1992; Sazzad, 1992; and Rahman *et al*., 1995).

The Directorate of Livestock Services (DLS) and the NGO Bangladesh Rural Advance Committee (BRAC) have developed a unique semi scavenging system (BRAC, 1994) in which exotic chicken are reared in confinement during the first 8 weeks age after which the birds scavenge part time for some days and gradually shifted to the semi scavenging system of rearing.

The feed resources for small flock of birds in traditional scavenging system are agricultural crop residues in and around homestead /or after harvest near by crop fields, kitchen and dinning wastes, grazing of green grass /small plants, earthworms, insects and small amount of supplemented feed ingredient(s) offered by the flock owner. The agricultural cropping patterns of Bangladesh which varied from one region to another are said to contribute as major feed resources for scavenging chicken. This study was undertaken; 1) to know the egg production of HYV hens under semi scavenging system of rearing in three agro ecological zones with different cropping patterns, and 2) to estimate the energy and protein content of feed ingredient(s) supplemented to the birds by flock owner.

Methodology

A total of 1272 selected HYV pullets from 4 batches of 11 weeks interval were at the age of six months placed by 297 rural women farmer (key rearer - beneficiaries of BRAC) kept for a period of one year. Number of pullets per key rearer ranged from 3 to 6. The distributions of pullets/key rearer were 375/98 for grain dominant (Manikgonj), 408/98 for grain/fibre (Jessore) and 489/101 sugarcane/grain (Rajshahi) cropping areas. The experimental locations with cropping patterns are shown in table 1.

Table 1. Cropping patterns of sites during experimental period

Particulars	Grain dominant (Manikgonj)	Grain/fibre (Jessore)	Sugarcane/grain (Rajshahi)

Agro-ecological zone	Low Ganges	Medium high river flood plain	High Ganges flood plain
Seasonal flood	Yes	No	No
Cropping intensity	200.6 %	207 %	159 %
Major cropping patterns	1.Rice(B.Aman +B.Aus)-Onion (T.Aman)	1.Rice(B.Aus) /Jute-Rice	1.Sugarcane - Lentil
	2.Rice(B.Aman +B.Aus)-Mustard	2.Rice(B.Aus) /Jute-Rice (T.Aman)-Wheat/Pulse/ Oil seed	2.Sugarcane - Onion/Garlic
	3.Mustard-Rice (Boro)	3.Rice(B.Aus) - Rice(T.Aman) -Rice(Boro)	3.Rice(B.Aus)-Wheat
	4.Rice(Boro) - Rice(Local) - B.Aman (transplanted)	4.Rice(B.Aus) /Jute-Wheat/ Pulse-Oilseed/ vegetables	4.Rice(B.Aus)-Lentil/Mustard

	5.Rice(B.Aus+ B.Aman)/Jute - Khesari		5.Rice(B.Aus)- Potato
	6.Rice(B.Aus+ B.Aman)- Wheat/Potato/ Mustard		6.Rice(Boro)
	7.Rice(B.Aman) -Ground Nut		7.Rice(T.Aman) -Wheat
	8.Rice(B.Aman) - Sesame		8.Rice(T.Aman) -Vegetables

The key rearers were offered a short training on HYV chicken management before started. Birds were allowed to scavenge in and around homestead and adjacent crop fields during day time and kept in shelter at night and during unfavorable weather conditions. Feed ingredients, like wheat, wheat bran, paddy, broken rice, cooked rice, balanced diets for laying hens etc. were supplemented as single or a mixture of 2 or 3 ingredients to the birds by farmers. Birds were housed in a bamboo shelter when offered supplemented feed. There was continuous supply of drinking water in the bamboo enclosure and birds had easy access during scavenging period of the day. Laying nest was placed in night shelter areas. Birds were dewormed every two months and vaccinated against Newcastle and Fowl pox diseases according to a program. Data regarding egg production, mortality and supplemented feed were recorded twice a week. The protein and energy content of the supplemented feed were calculated on the basis of book values. Data were analyzed by the least square principle using the SAS programming package, SAS (1988).

Results and Discussions

The performance data of the hens up to 18 months of age are presented in table 2. Birds from grain dominant

Manikgonj area started early egg production (31 weeks) compared to other locations (34 weeks) and the difference was significant.

The average hen day egg production / hen was highest in grain dominant area (157) followed by grain/fibre (154) and significantly lower in sugarcane/grain (103) cropping patterns. Mortality was observed very high in all the locations and the most suspected reason was bacterial diseases against under nutrition condition of the birds. The seasonal flood in grain dominant Manikgonj area and water logging condition in grain/fibre Jessore area could be the other reasons for higher significant mortality than sugarcane/grain based cropping patterns of Rajshahi. Mortality due to predator (wild animals) loss were found significantly higher in the sugarcane/grain cropping area compared to other locations and the reason was that wild animals hunt experimental birds from their sugarcane fields hideout adjacent to scavenging areas.

The energy content of supplemented feed was observed lowest in grain dominant cropping area and found significantly lower than grain/fibre area.

Table 2. Performance of experimental birds reared under semi scavenging conditions at three locations

PARAMETERS	PERFORMANCE (Least square mean)		
	Grain (Manikgoni)	Grain/fibre (Jessore)	Sugarcane/grain (Rajshahi)
Age of first egg (wk)	31a	34b	34b
Eggs/hen (hen day)*	157a	154a	103b
Mortality % (excluding	43.9b	12.3a	19.8a

predatory loss)			
Mortality % due to predator loss	0a	0.3a	6.3b
Supplemented energy Kcal/bird/day	130a	146b	134a
Supplemented protein (g)/bird/day	6.4b	8.3c	5.6a

Figures with same letter in a row are not significantly different (P<0.05)

*** Corrected for 12 months production period from first egg production**

The amount of supplemented protein were found lowest in sugarcane/ grain area followed by grain dominant and grain/fibre areas and differed significantly. However, irrespective of locations the amount of supplemented protein and energy seems to be around 30 and 40% of daily requirement of commercial hens in captivity.

In grain dominant cropping pattern (201% cropping intensity) area, it was observed the highest egg production and early egg laying while the birds received the lowest amount of energy and protein supplementation. On the other hand, the egg productivity of birds in grain/fibre cropping area (207% cropping intensity) receiving higher amount of energy and protein supplementation might not come up like in the grain dominant area because of the presence of the fibre crop in the cropping patterns.

The results indicated that the HYV hens used to manage good amount of feed by scavenging various resources, especially the grain based crop residues widely scattered in and around homestead or nearby after the harvest in the crop fields. The amount of scavenged feed seems to be 60 - 70% of total feed consumed by a scavenging bird

which has practically no cost involvement. The higher egg productivity over native chicken indicated that HYV hen could be an efficient utilizer of various scavenging feed resources including the grain based crop waste of Bangladesh.

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The Role of Scavenging Ducks, Duckweed and Fish in Integrated Farming Systems in Vietnam

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Abstract

There are some 30 million ducks raised annually in Vietnam. Most are scavengers raised seasonally in rice fields during the early growth of the crop and immediately post-harvest; and in backyards or gardens of farm households throughout the year. Duck and fish production has been expanding and contributes to increased income and improved living standards of the farmers, especially for poor farmers in the remote rural areas.

Trials on using duckweed cultivated as a partial or complete replacement of protein supplement for feeding crossbred and Muscovy ducks gave encouraging results. The practice of using scavenging ducks to control insects and weeds in the rice fields contributes to decreased investment and brings more benefits for the farmers. Duckweed grown in the integrated farming system is also a high quality feed for fish.

KEY WORDS: Ducks, local, scavenging, rice fields, duckweed, fish

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Introduction

The duck industry in Vietnam is of long standing and plays a considerable role in providing meat and eggs in the diet of the people (Men *et al*., 1991). Ducks are raised throughout the country but are concentrated in the Mekong and Red River Deltas, but also in suburban areas of the big cities.

Unlike the Northern countries, duck egg and meat consumption is expanding in Vietnam and they provide important and nutritious protein foods for people in both cities and rural areas, especially the poor farmers in the remote regions. The products are usually sold at a reasonable price that the poor can afford and they can be processed into many different traditional dishes and even special dishes in the restaurants of the big cities.

The farmers use many traditional systems for raising ducks, of which the rice-duck system is the most common. In this system rice production is enhanced due to the ability of the ducks to control insects and weeds and at the same time excrete manure which provides nutrients for the growth of the rice plants. There are als

o environmental benefits as chemical control of insect pests and weeds is not needed. Along with the improvement in rice, the farmers derive more profit from the ducks because they forage themselves on natural feeds and left-over rice in the fields which decreases the need for supplementary feed. Ducks are also commonly allowed to scavenge in the backyards or gardens of households in small flocks, receiving household waste or rice to supplement what they obtain by scavenging.

Today, ducks are also raised in partial confinement, either for table eggs in coastal areas where shellfish gathered from the sea are good mineral and protein sources for ducks, or in areas where they are bred for meat during the dry season in an integrated fish-duck system. Duck production makes good use of available labour in rural areas and increases the income of poor farmers, especially the landless. However, duck producers have experienced problems since the introduction of high yielding rice varieties because the time available for duck flocks to scavenge is limited. Also, the price of feeds, especially protein supplements, has greatly increased. Consequently, although consumer demand for duck products is increasing, the income for farmers is reduced by the high input costs.

Duckweed (*Lemna* spp.), which is common throughout the country, is a tiny water plant that grows very well on the surface of stagnant ponds all the year round. It can tolerate high nutrient stress and is able to survive extremely adverse conditions, and appears to be more resistant to pests and diseases than other aquatic plants in tropical areas. It has a high content of nutrients in the DM, especially protein and carotene, which are necessary for growing animals. Duckweed is popular in Vietnam as a feed for fish and poultry, so it seems a useful candidate for development as a year-round feed resource for ducks and fish within the integrated farming system.

Scavenging Ducks

Breed

Several breeds of ducks are raised in the country. The two different species are the common breed and the Muscovy duck.

The common breed is estimated at 80% of the duck population of the country (Phuoc *et al*.,1993). They consist mostly of local and improved breeds and a few exotic strains (Cherry Valley).

Of the local breeds, the first type is the "Tau" or "Co" breed (grass ducks). This is a laying type that reaches mature body weights of 1.3 - 1.5kg for females and 1.5 - 1.8kg for males. Drakes can mate at 120 days of age. The females begin to lay at 140 days old and achieve an average of 180 eggs per layer per year with egg weights in excess of 60 g. This breed tolerates hard conditions of nutrition and management, so they are well suited to egg and meat production in the remote rural areas. Also, they are very good at foraging for food such as insects, water creatures and plants. The mating ratio of males to females is 1:20-25, but this achieves highly fertile eggs (over 90%) with high hatchability in traditional hatcheries in the rural areas, even without electricity. The prices of table eggs, ducklings and duck meat from these ducks are usually lower than those of other types because of lower production costs.

The second group, called "Ta" or "Bau" ducks, is a meat type that achieves a mature live weight average of 2.5

kg. This breed is low in reproductive ability and gives low profit to the producers so the population has been decreasing.

The local Pekin has been imported for a long time and is genetically poorly defined. It has degenerated into a dual purpose breed. They achieve live weight gains and finishing weights slightly higher than the "Tau" or "Co" ducks and the number of eggs laid appears to be equivalent to the "Co" breed.

There are several crossbred types which are a combination of the local and exotic breeds. These are used for meat purposes.

The exotic Cherry Valley type has been imported from Europe and gives high meat performance but, given the conditions in which they are bred and raised, productivity and profitability has declined and the population is decreasing. At present they are raised for crossing and for meat around some cities. The Khaki Campbell breed is a laying type imported from Asian countries which achieves poor performance under the conditions in Vietnam and the yield of eggs appears to be equivalent to the local laying type (personal observation).

Muscovy ducks are estimated at some 20% of the population and numbers have expanded throughout the country. These include both local and exotic types, and their crosses. The local breed achieves mature weights from 3-3.5kg for males and 1.8-2kg for females. The female lays on average 40-60 eggs per year and hatches them herself under extensive conditions. The Muscovies are suitable for smallholders with small flocks because they are easy to manage and can consume different feeds in the farming system. Also, the ducklings or table ducks are usually sold at a higher price than common ducks.

Scavenging Ducks in the Integrated Farming System

Duck Raising Along with Growing Rice

The ducks selected for this purpose are commonly the local laying type or local Pekin breed due to their small body size. They do not harm the plants, are active and forage well when herded. In the brooding stage, after the first

week of age, the ducklings are driven into the rice fields from 20 days after transplanting until the plants begin to flower. In the young rice fields, the ducklings can catch destructive insects such as white or brown hoppers, leaf insects, mosquito larvae, spiders, small shellfish and fish. During scavenging, the ducks consume weeds and stir and loosen mud around the rice roots with their beaks without harming the rice plants. In addition, they excrete manure to fertilize and stimulate the growth of the rice. Insecticide and herbicide inputs are rendered unnecessary, and labour for weeding is reduced. The reduction in chemicals is beneficial to the environment.

The ducks are supplemented with feed consisting of by-products of rice or rice grain, 3-4 times daily depending on feed availability in the rice fields.

After the rice plants start flowering, the ducks are driven from the rice fields to the canals, ditches, lakes and swamps to forage in the water. The duck raising season usually lasts for 3 months producing males for meat and females which continue to lay eggs in the post-harvest rice fields. The culled ducks are sold in the market.

Duck Raising in the Post-harvest Rice Fields

Along with laying ducks, the table ducks or ducks for meat are reared in the rice fields post-harvest. Generally farmers purchase ducklings from the hatcheries 3-4 weeks before the rice harvest. The ducks usually selected are the native meat type, local Pekin, crossbred local x Cherry Valley or Cherry Valley.

After 3 weeks of age when the ducklings can consume whole rice grains, they are permitted to enter the newly harvested rice fields. They forage the whole day on leftover or fallen rice grains, insects, shellfish, small frog and fish, and water plants. In the late afternoon, they are moved to pens or sheds on the dikes near the household until next morning. The ducks raised at this time are usually finished at 2.5-3 months of age, and achieve live weights of 1.6-2.0kg for the crossbred Cherry Valley.

Now, most varieties of high yielding rice are planted and harvested within a short period with only a limited time available for the duck flocks to scavenge, so this traditional system is becoming less feasible. In order to solve the problem, a trial was recently carried out, feeding a supplement of broken rice and crushed, dried fish (CDF) to

crossbred meat ducks (Cherry Valley hybrid x local Pekin) herded in rice fields post-harvest, in order to shorten the time to finish and improve the meat quality. Three supplements of 50g/duck/day of a mixture of broken rice (80%) and CDF (20%), 50g/day broken rice or 20g/day of CDF were given each evening to the ducks, and compared with no supplementary feed. The live weights at 70 days of age were 1855, 1749, 1659 and 1592g (P<0.001) and daily live weight gains 34, 30, 28 and 27g, respectively (Men *et al*.1995).

The results of the trial show that supplementation with broken rice alone or a mixture of broken rice and crushed-dried fish to scavenging crossbred meat ducks significantly improved the daily gain and carcass quality, and would shorten the time to market. This trial demonstrates a strategy for improvement of the traditional method of the farmers in order to meet the increasing demands of consumers for high quality duck meat, and is consistent with today's rice cultivating conditions in the country.

Scavenging Ducks in the Backyard Or Garden

The system is common to most smallholders. Small flocks of ducks from 5-50 head, producing eggs for the table or fertile eggs for meat production or combining both, are allowed to run loose in the backyards and gardens, and are fed household wastes or rice 2-3 times per day and obtain other feeds from scavenging in the ditches, canals, ponds or part of the rice fields near the home. This system is very suitable for home consumption of the products by the poor farmers.

Duckweed (*Lemna minor*)

Duckweed is a small floating aquatic plant that grows very well on stagnant ponds and is commonly found throughout the country. It has a high content of nutrients, particularly protein and carotene, and tolerates adverse conditions such as nutrient stress and attacks by pests and diseases. Duckweed gives a high biomass yield as a result of rapid reproduction and growth. When effectively managed, yields of 10 tonnes DM/ha/year are possible (Preston, 1995).

Duckweed can be collected daily when grown on ponds manured with effluent from biodigester systems and home waste, and produce an average of 100g (38.6% CP of DM) fresh weight per square metre (Men, 1995). Duckweed protein has a better composition of essential amino acids than most vegetable proteins and closely resembles animal protein (Culley, 1978).

Duckweed has long been used in poultry diets (Lautner, 1954). Fresh duckweed (26.3% of DM) was used to replace soya beans at levels from 19-27% in diets for fattening ducks at Cantho University in Vietnam. There were no adverse effects on health, but the reductions in growth rate and feed conversion efficiency were considerable when duckweed replaced more than 20% of soybean protein (Becera *et al*.1994).

Recently, an experiment was carry out on crossbred ducks fed roasted whole soya beans replaced by duckweed (38.6% CP in DM) at levels of 0, 30, 45, 60 and 100% in the diet (Men *et al*., 1995). Daily gains of ducks fed duckweed were higher than those of ducks fed a conventional diet because the duckweed , which was grown and managed well, had high nutrient concentrations, especially of CP and carotene.

If duckweed is grown and collected by household farmers, the feed cost could decrease 48%. However, feed conversion ratios tended to be poorer on the diets with duckweed due to their low energy compared to the control diet. In another experiment, local Pekin were fed fresh duckweed ad libitum (40% CP in DM) in limited broken rice diets at levels 80 and 60g/day compared to *ad libitum* feeding (Men *et al*., 1995). Results obtained showed that the ducks with live weights of 1.5-1.6 kg can consume an average of 870g fresh duckweed per day in the growing stage. The final weights and weight gains of the ducks fed 80g broken rice were slightly lower than those fed rice *ad libitum*, but the difference was not significant.

Muscovy ducks are known to like duckweed very much. In 1994, a trial was carried out on growing exotic female Muscovies at Cantho University, where 15 and 30% of the dietary protein was replaced by fresh duckweed from 28 to 70 days of age and compared to a conventional diet (Men *et al*., 1994). At finishing, daily gains were 37, 36 and 34g (P<0.001) and feed conversion rates were 3, 3.3, 3.5, respectively. Correspondingly, the cost of feed decreased by 15 and 26% compared to the control diet.

In another trial, Men *et al*. (1995) fed local female Muscovies on duckweed *ad libitum* with a limited amount of broken rice at levels of 80 and 60g/day compared to ad libitum feeding from 28 to 70 day of age. Results achieved showed that local female Muscovies consumed fresh duckweed less than the local Pekins (325 vs 817g) and daily gains were 25, 20, 18g, respectively.

Fish in the Integrated Farming System

Fish is a common food for Vietnamese people. Wild freshwater fish are caught in many ways. At present, because of indiscriminate exploitation, environmental damage caused by overuse of agricultural chemicals and serious pollution caused by humans, the precious food source is becoming impoverished.

In order to solve the problem, many farmers raise fish profitably in ponds, even rice fields, in the integrated farming system. The main feed sources for fish continues to be based on natural aquatic creatures and plant feeds that grow and develop themselves in the pondwater. In some regions, farmers raise fish on feeds such as grass, weeds, leaves, by-products from agricultural processing or animal manure and obtained good results with fast growth of the fish. However, the feeds only contribute about 20% of the requirements of the fish (personal observation).

Duckweed As A Feed for Fish

Many trials have been carried out using duckweed as the major feed to raise fish, with good results (Journey *et al*. 1991), but, so far, this is fairly rare in Vietnam. The farmers in the Mekong and Red Deltas and around Ho Chi Minh city use duckweed as a partial or complete feed for growing fish and get excellent results. The farmers in the Mekong Delta feed duckweed to breeding fish to increase reproductive performance.

Most of the fish species living in fresh water are known to like to eat duckweed very much, especially Tilapia, carp, catfish, Mekong catfish, gourami, etc. Duckweed is convenient and fairly easy to manage because it is grown in the ponds on stored waste water. It utilises the nutrients and contributes to a clean environment. Children or women in

the households can take part in managing and collecting duckweed to feed fish. The farmers can control the amount of feed to the fish easily by observation and prevent excessive growth, thus protecting the fishes' environment (personal observation).

Conclusions and Suggestions

There is no doubt about the role of scavenging ducks, fish and duckweed in the integrated farming system in Vietnam today. They produce truly sustainable economic benefits to the smallholder farmers. The results achieved in the experiments and practices show that the development is based on scientific logic under natural and social conditions that avoid damage to the living environment and improve living standards of the people, of which 80% are working in the agricultural domain.

Development of scavenging ducks and fish, based on renewable local feed resources such as duckweed in integrated farming systems, is an actual revolution and is consistent with the strategy to eliminate hunger and reduce poverty in the country. However, in order to make further progress, the detailed parameters of using scavenging ducks and their influence on the environment, soil fertility, and other effects, need to be investigated. There is also a need to look at which species of fish are most suited to feeding on duckweed.

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Sugarcane for Beef and Pork Production

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Abstract

Tropical countries have a great comparative advantage due to the intensity and regular availability of solar energy which may be exploited through plant photosynthesis. Sugarcane is a C4 plant which has a greater capacity to utilize high light intensities with reduced water requirement and hence produce as much as 3.8 times more biomass per hectare than cereals. Total biomass yields of 255-480 T/ha are reported.

Sugarcane has been used as the basis for meat production systems in the tropics, with the aim of maximizing output per hectare. Fractionation of cane, using traditional artisanal mills (50% extraction) yields juice for fattening pigs, and pressed cane stalk and tops for feeding cattle. Trials were carried out on the farm.

In this study, sugarcane juice, with or without palm oil, and 500 g protein supplement was fed to pigs from 20-80 kg and achieved average daily gains (ADG) of 633 and 666 g/day respectively. A second trial (30-80 kg) showed gains of 565 g/day, with or without palm oil.

Bull calves fed on pressed cane stalk and tops, with *Gliricidia sepium*, multinutritional blocks (20% urea), rice bran and poultry manure grew at 526 g per day, compared to cattle on a similar diet but with integral sugar cane replacing the pressed cane stalk and tops which had an average daily gain of 767 g per day.

Comparison of beef production alone with an integrated pig and beef system favoured the integrated system. Direct production from cane was 3,458 kg beef per hectare compared to 5,870 kg per hectare from pigs and bull-calves together.

These figures compare to a maximum potential production of 1500-2000 kg meat per hectare from one hectare of star grass (*Cynodon nlemfluensis*) with fertilizer and irrigation, under the same climatic conditions. The integrated systems also provided more employment.

KEY WORDS: Livestock, sugarcane, integration, meat production

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Introduction

Farming production systems in tropical countries must take as much advantage as possible of the use of the soil, the water, the air and the solar energy. The integration between different animal and vegetal species must ensure production on the long term that warrants the improvement of the soil, the water and the air purity as well as protecting biodiversity that prevails in tropical areas.

From all the energy sources, the most renewable and under-used is the solar one. This is a great comparative advantage for the tropics (Preston, 1992) where it is widely available. Its most logical use is by plants through photosynthesis (Preston and Murgueitio, 1993). The biodiversity and high productivity of tropical ecosystems is due to the major and more regular flow of energy throughout the year (Preston and Murgueitio, 1993). Classical data show that in the tropics, net productivity of energy is twice the one obtained in temperate areas in all ecosystems.

But it is necessary to select the comparative advantages of the same genetic potential taking into account that some plants have an exceptional capacity to use the solar energy when luminosity and temperature are high (Preston and Murgueitio, 1993). These are the C4 plants which can produce more biomass with minor water requirements. Sugarcane is a C4 plant and for this reason, it produces several times more biomass than other

grasses as pangola (*Digitaria decumbens*) even without irrigation or added nitrogen (Rodriguez and Ruiz, 1983).

The yields of various varieties of sugarcane are shown in Table 1.

Table 1: Production of biomass from 6 sugarcane varieties (first harvest at 15 months)

Variety	Tops (ton/ha)	Canes (ton/ha)	Total Biomass (ton/ha)
MZC-74275	70	235	305
V-7151	45	210	255
RD-7511	90	310	400
Co-421	130	350	480
POJ-2878	60	245	305
CC-8475	90	310	400
Average	81	277	358

Sugarcane yields per year and per hectare are much higher than those of any other traditional crop. From sugarcane juice or A molasses, 3.8 times more energy is obtained than with a secondary cereal (Figueroa and Ly, 1990).

The farming systems should include the production of food, fuel and organic fertilizers, integrating different animal and crop species. They should be more efficient through the optimized use of the components of the tropical

wealth: the people, the earth, the water and the solar energy (Preston, 1988).

This paper intends to demonstrate the advantages obtained from meat production systems based on sugarcane, using different animal species and aiming at an increased meat production per hectare in tropical regions without depending on cereals. To reach this objective, it was chosen to feed pigs with the liquid component (sugarcane juice) and cattle with the fibrous component (bagasse and tops) of the sugarcane as the basis of their diet.

The study was conducted in the farm "El Hatico", located in the municipality of El Cerrito in the department of Valle del Cauca in Colombia. The climate and soil conditions are:

Average temperature: 24 C
Relative humidity: 75%
Annual rainfall: 750 mm
Altitude above sea level: 1000 m

Soil:
pH: 6.5 to 7.5
Texture: largely clayey
Organic matter content: 2.5 to 3 %
Phosphorus content: 30 p.p.b.

Since 1988, this farm has been conducting research on the integral use of sugarcane (chopped canes and tops) for feeding cattle while increasing the carrying capacity of the land (Molina *et al*., 1992). The results have been satisfactory from the biological point of view, with Average Daily Gains (ADG) reaching 800 g. Nevertheless, the analysis of the profitability shows that the cost of supplementation is rather high, as sources of by-pass proteins and energy and non protein nitrogen are needed (Molina, 1994).

Therefore, research was re-oriented in the farm in order to integrate cattle and pig production with the aim of

optimizing the sugarcane for meat production per hectare.

Background

It is necessary to take advantage of the specific physico-chemical characteristics of sugarcane in a proper way in order to optimize its use for animal feeding. This plant has been genetically selected and industrially processed for many decades with the only aim of producing sugar. Sugarcane is basically composed of two fractions, one of soluble simple sugars, essentially sucrose, and other insoluble fractions made of structural components as cellulosis, hemicellulosis and lignin. The protein content is very low. Furthermore, lignification, crystallization index of cellulosis and its level of polymerization are responsible for the cane rigidity. Taking into account these physical and chemical factors, it is necessary to process sugarcane in order to optimize its use for different animal species (Figueroa, 1990).

The soluble fraction of sugarcane is easy to extract through crushing which permits to reach extraction rates as high as 97% in the sugarcane industry and about the half through the traditional artisanal sugarcane mills. This fraction, the sugarcane juice (16-20% DM) is composed of sucrose and reduced sugars. It is a liquid feed which is rich in energy but difficult to preserve because of its tendency to rapidly ferment (Figueroa and Ly, 1990).

Mena (1981) started research in this field in Mexico on station and on farm. Ferm�n (1983) and Fern�ndez (1984), in the Dominican Republic, carried out several experiments with the use of sugarcane juice and obtained similar results to those of this work and other works done in Colombia (Table 2) published by Sarria (1994).

Table 2: Results from fattening pigs with a diet based on sugarcane juice and soya cake in different locations in Colombia

(kg)	(g)	(g/day)	Conversion	Reference
25-91	200	640	3.8	Quiroga and Preston, 1987

20-77	200*	580	3.1	Solano, 1989
21-90	200	730	3.2	Solano, 1989
19-92	300	755	3.2	Solano, 1989
27-98	200	625	3.0	Sarria *et al*., 1992
27-78	200**	590	3.7	Sarria and Preston, 1992
28-81	200	631	4.0	Sarria *et al*., 1992a
23-80	200**	455	3.7	Sarria *et al*., 1992b
24-91	200	681	3.3	Ngoan, 1994
25-90	200	482	4.7	Becerra *et al*., 1990
	200	720		Fern�ndez CIPAV, 1990
13-90	200	790		Mu�oz, 1989

Materials And Methods

Pigs

Two independent experiments were carried out in order to assess the potential of sugarcane juice, in association with small quantities of palm oil (from African oil palm, *Elaeis guineensis*) as the source of energy in the diets of pigs growing from 20 to 80 kg.

The aim was to study the alternative energy sources in order to increase the flexibility of the use of sugarcane juice. Nevertheless, the results are not sufficiently comprehensive to reach any conclusions with reference to the

oil in the diet.

So far, it was considered very hard to reach the same levels or higher level of production in the tropics such as those in temperate countries where diets are based on cereals. The experiments carried out by Ocampo (1992) proved that it was not only possible to reach these levels, but even to exceed them with palm oil as source of energy.

The quantities of palm oil used were:

Pigs (kg)	Palm oil (g)
20 to 40	90
41 to 60	120
61 to 90	180

The oil was given twice a day in association with the source of protein.

The sugarcane used for the extraction of the juice was from the variety Mayaguez Colombia 74275, 12 months old, yielding 180 tonnes per hectare (135 tonnes of canes and 45 of tops) and producing a juice of 20 degrees Brix.

The trials were conducted in 4 barns (11 pigs in each) with a cement ground (15 m2) and fences of bamboo.

The results showed in Table 3 concern pigs 'berracos' originated from paternal lineage (Pietrain, Hampshire, Duroc) whereas the results showed in Table 4 concern pigs originated from boars from maternal lineage (Large white, Landrace, Yorkshire). This is important in order to interpret the differences in ADG between the two groups.

The initial weight of the animals were between 17 and 22 kg and they were weighed every 30 days before feeding them. Every treatment was repeated twice with 11 pigs in each.

Protein supplementation consisted in 500 g of a mixture of soya cake, vitamins and minerals (40% protein) per pig per day, given in two meals.

Cattle

Cattle was included in the trial in order to assess its capacity to use the fibrous residue left after crushing the sugarcane to get the juice. A trial was also conducted on bull-calves in order to compare the use of the integral sugarcane (chopped canes and tops) with the use of bagasse and tops.

Two corals were used: each included 200 m^2 of earth with 3 trees for shadow and 20 m^2 of cement grounds near a trough 4 m long (0.8 m per animal). In order to ease the management of the animals, and to keep the natural immunity given to them by grazing on the pastures, they were released during the week ends in pastures of star grass (*Cynodon nlemfuensis*).

The two groups (integral sugarcane; bagasse and tops) were identically supplemented:

- **Gliricidia sepium (3% of the live weight on fresh matter basis) as the source of protein (Preston and Leng, 1987).**
- **Multinutrient blocks given *ad libitum* and including 20% urea as a source of non protein nitrogen, 15% cotton husks, 40 % molasses C, 10% rice bran, 5% salt and 10% lime.**
- **Rice bran as a source of by-pass energy, rich in long chain fatty acids: 500 g per animal per day.**
- **Poultry manure as a source of non protein nitrogen, minerals and protein: 500 g per animal per day.**

The bagasse was obtained from the sugarcane crushed to get the juice for the pigs through an artisanal mill powered with animal draught and with an extraction capacity of 50% of the cane weight as juice. Therefore this bagasse is still rather rich in sugars. It was daily chopped with a Brazilian chopper (Nogueira 12 A) powered by a tractor Fordson Mayor of 65 HP (capacity of chopping 1 ton per hour). The thoroughly chopped bagasse (fragments 1 to 2 cm long) were transported to the trough on carts draught by mules.

The cane tops, which represents 25% of the biomass of the sugarcane, were chopped on the spot with the same equipment and were also transported by mules.

The diet of the control group of Table 5 consisted in integral sugarcane (chopped canes and tops) processed and transported as the tops above mentioned.

The animals used for these trials were from the Lucerna breed (Colombian breed) originating from a triple crossbreeding between the European breeds Holstein, Dairy Shorthorn and the Colombian creole breed Harton del Valle which has inhabited the region for more than four centuries.

Results

Pigs

In the first trial with pigs (Table 3), ADG are 33 g higher with the treatment including African oil palm and sugarcane juice (666 vs 633); taking into account the lower juice consumption (0.7 litres per pig per day), and the intake of 117 g of oil per pig per day, the difference amounts to 1,000 pesos (US$ 1.17) per pig after fattening is completed.

Table 3: Fattening pigs with sugarcane juice and African oil palm

Parameter	Unit	Juice and oil	Juice

Groups	-	2	2
Pigs/group	-	11	11
Duration	days	90	90
Initial weight	kg	21	21
Final weight	kg	81	78
ADG	g	666	633
Standard deviation		0.104	0.112
Intake			
Sugarcane juice	litres	7.7	8.4
African oil palm	g	117	0
Protein Supplement	g	0.500	0.500

In the second trial with pigs (Table 4), there was no difference in ADG between the group fed with sugarcane juice and oil and the group fed with only juice (565 vs 565). It was also observed that in this assessment, the difference between juice intake was maintained: 0.7 litres less per pig per day for the animals receiving an average of 134 g of palm oil per day per pig. In this case, the pigs that received juice and oil had an additional cost of 4,256 pesos (US$ 5) to complete fattening with comparison to the pigs that received only sugarcane juice.

Table 4: Fattening pigs with sugarcane juice and African oil palm

Parameter	Unit	Juice and oil	Juice
Groups	-	2	2
Pigs/group	-	11	11
Duration	days	92	92
Initial weight	kg	30	30
Final weight	kg	82	82
ADG	g	565	565
Standard deviation		0.170	0.118
Intake			
Sugarcane juice	litres	6.8	7.5
African oil palm	g	134	0
Protein Supplement	g	0.500	0.500

The minor ADG found in Table 4 with reference to Table 3, are due to the genetical difference between the animals. The average intake of sugarcane juice for the assessments of Table 3 and 4 are between 7.5 and 8.4 litres

per pig per day.

Cattle

As shown in Table 5, the bull-calves used had an average initial weight of 276 kg. The trial lasted for 133 days. The ADG of the group receiving integral sugarcane, Gliricidia sepium, supplemented with multinutrient blocks (20% urea), rice bran and poultry manure were 250 g higher than those of the group receiving bagasse, tops and the same supplementation. The ADG were 767 g and 526 g respectively.

Table 5: Rairing/fattening Lucerna bull-calves with bagasse/sugar-cane tops vs integral sugarcane

Parameter	Unit	Bagasse and tops	Integral sugarcane
Animals	-	5	5
Duration	days	133	133
Initial weight	kg	276	277
Final weight	kg	346	379
ADG	g	526	767
Standard deviation		0.071	0.057
Intake			

Integral sugarcane	kg	0	23
Bagasse	kg	10	0
Tops	kg	6	0
Blocks 20% urea	kg	0.682	1.080
Gliricidia sepium	%LW	3	0
Rice bran & poultry manure	kg	1	1

Multinutrient block intake was 400 g higher for the animals receiving integral sugarcane compared to the animals receiving bagasse: 1080 and 682 g respectively. This might be interpreted by the higher requirements for ammonia concentration in the rumen for the animals receiving more fermentable sugars in their diet (Preston, personal communication, 1994).

Indeed, the low nitrogen content of the sugarcane and its by-products clearly indicates the need to provide supplements in order to increase the levels of ammonia in the rumen. This is done by the urea but this might also be achieved through other sources of fermentable ammonia as poultry manure or fodders with high contents of soluble protein. The requirements are between 20 and 30 g of nitrogen per kg of fermentable carbohydrate in the diet.

Because of the rapid degradation of a high proportion of the fermentable carbohydrates, it is necessary to thoroughly mix the urea with them in order to ensure the proper availability of ammonia from urea while the

sugars are fermenting. In diets rich in fibers and sugars, the strategic use of the urea consists in maintaining high levels of ammonia in the rumen, when the fermentation of sugars ends, and the degradation of fibre starts (Leng, 1988).

It was also shown in Table 5 that the standard deviation for the two treatments was very low, 0.071 and 0.057 for the treatment with bagasse and the treatment with integral sugarcane respectively. This shows the confidence in the results that are expected with these two diets.

Conclusions

As shown in Tables 3 and 4, pigs that are fed sugarcane juice *ad libitum* during rairing-fattening and supplemented with 200 g of net protein per pig per day have an ADG of 600 g.

The potential of integral sugarcane (chopped canes and tops), in the fattening of bull-calves supplemented with *Gliricidia sepium* (3% of liveweight on fresh matter basis), multinutrient blocks (20% urea), 0.5 kg of rice bran and 0.5 kg of poultry manure is to produce ADG of 750 to 800 g per animal per day.

The integration of the cattle to take benefit of the crushed sugarcane (bagasse) from which only 50% of the sugar has been obtained, permits to reach ADG of 500 g with a supplementation including protein, non protein nitrogen and a source of by-pass energy (large chain fatty acids).

The present work shows the advantage of the integration of the pigs and cattle for using more efficiently the sugarcane in order to increase meat production per hectare. In Table 6, there is a comparison between the exclusive use of sugarcane for cattle (chopped canes and tops) and the integration between the pigs fed with the juice and the cattle fed with the bagasse and tops.

Table 6: Two alternatives for using sugarcane

Parameter	28 kg integral sugarcane	28 kg fractionated sugarcane

	[illegible]	[illegible]	
	Bull-calf	Bull-calf	Pig
Integral sugarcane	28 kg		
Bagasse		10 kg	
Tops		8 kg	
Juice			10 l
Gliricidia	9 kg	9 kg	
Multinutrient block	1.1 kg	0.7 kg	
Rice bran & Poultry man.	1 kg	1 kg	
Prot. suppl.			0.5 kg
ADG	765 g	500 g	600 g

To analyze this trial, it is considered that the voluntary intake of sugarcane for a bull-calf of 350 kg in total confinement, amounts to 80 g of fresh sugarcane (canes and tops) per kg of liveweight, which means an offer of 28 kg per animal per day. The fractionation of these 28 kg gives 7 kgs of tops and 21 kg of canes. The crushing of these 21 kg of canes in an artisanal mill extracting 50% of juice, will give 10.5 kg of sugarcane juice and 10.5 kg of bagasse.

Taking into account what was mentioned previously, it is concluded that with the quantity of integral sugarcane needed to feed a bull-calf of 350 kg and to obtain ADG of nearly 800 g, it is possible to feed the same bull-calf with only the bagasse and the tops with ADG of 500 g and with their respective protein supplementation.

In Table 7, the economical analysis shows that the alternative of feeding only the cattle avoids a loss of 281 pesos (US$ 0.33) of lost per animal per day, whereas the association with pig production produces a benefit of 366 pesos (US$ 0.44) per day.

Table 7: Economic analysis of the two alternatives for using sugarcane

System	Integral sugarcane for fattening bull-calves		Fractionated sugarcane (Juice and bagasse)			
Species	Cattle		Cattle		Pig	
ADG (g)	765		500		600	
Value/kg	Pesos	US$	Pesos	US$	Pesos	US$
live weight	900	1.12	900	1.12	1700	2.0
Gross income	689	0.73	450	0.53	1020	1.2
Gross income/ system	689	0.73	1470 Pesos		1.73 US$	
Costs	970	1.14	649	0.76	455	0.5
Net income	-281	-0.33	-199	-0.23	565	0.7
Net income/ system	-281	-0.33	366 Pesos		0.43 US$	

The benefits from the production of organic fertilizer from the pig and cattle excreta should be added to these figures. In the case of the cattle, it is estimated that 17 bull-calves of 350 kg of liveweight (carrying capacity per hectare) can produce 21 tonnes of fresh matter of manure per year, which represents an additional income of about 100,000 pesos (US$ 118) per hectare. In the case of the production system using fractionated sugarcane, pig

manure is obtained with its specific properties in relation with the production of energy (methane production) and as a fertilizer.

The potential of production of meat per hectare of sugarcane (yielding 180 tonnes of biomass per hectare) is 4,940 kg in the case of the use of integral sugarcane for bull- calves. When pig and cattle production are associated, it is possible to obtain 2,900 kg of beef and 4,800 kg of pork, which means a total of 7,700 kg of meat per hectare. This meat production is not entirely related to the effect of the sugarcane, as the animals receive a supplementation. Considering the percentage of sugarcane on dry matter basis in the diet, the productions would be:

Bull-calves fed with integral sugarcane	3,458 kg
Integrated production system:	
Bull-calves:	2,030 kg
Pigs:	3,840 kg
Total:	5,870 kg

The previous figures are more striking if we take into account that one hectare sown with star grass (*Cynodon nlemfluensis*) with a high level of fertilization and irrigation in the same conditions of climate and soils as mentioned at the beginning of this paper, has a maximum potential of production of 1,500 to 2,000 kg of meat per hectare per year.

Furthermore, from the social point of view with reference to the employment opportunities, this production system of cattle fed integral sugarcane and the integrated system of cattle and pig production based on fractionated sugarcane, generates respectively 4 to 6.5 times more employment than the intensive pasture production system. This is particularly crucial in developing countries often densely populated and with

insufficient sources of employment.

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The Outcome of Networking 24 Latin American and Caribbean Countries on Integrated Use of Sugar Cane and Local Resources in

Animal Feeding (The CIPAV Experience)

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Abstract

In 1993, FAO instigated a cooperation agreement for the establishment of the Information Network for Tropical America and the Caribbean on the utilization of the sugar cane and other locally available resources for animal feeding. The Network funded by France includes Antigua and Barbuda, Barbados, Belize, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, and Venezuela. The objectives of the Network are:

I) to promote, the exchange of technical information, practical and theoretical experience, and training methods, within and between countries.

ii) to organize practical demonstrations of the most appropriate techniques under local conditions in the countries with limited experience of the new production systems.

iii) to promote the evaluation and production of local plant genetic resources, which complement rations based on sugar cane, through the exchange of appropriate plant genetic material among the countries of the Network.

In order to fulfill these objectives, FAO has commissioned the Colombian NGO "The Centre for Research in

Sustainable Systems of Agricultural Production" (The CIPAV Foundation) to be the Central Organization, with 10 years' experience in the generation of agricultural technologies based on the use of sugar cane, forage trees and organic residues for animal feeding, decontamination of water and gas production by means of continuous-flow-plastic-biodigesters, and pioneer in the production of a computerized scientific journal.

KEY WORDS: integrated systems, sugar cane, supplementation, protein forages, publications, network, international cooperation, Latin America

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Background

Since the 1970s, scientists from different parts of the world, investigating technical proposals for the agricultural development of tropical countries, have found that many technologies developed in temperate countries and transferred to the tropics have had little success in social terms for the agricultural sector of these countries.

In most cases they are based on the import of packages involving production of high-yielding cereals, with intensive mechanization and high inputs derived from oil (fuel, fertilizers and pesticides).

Most of the cereal production, together with imports from temperate countries, is used to feed imported animals with "maximum genetic improvement", whose nutritional requirements can hardly be satisfied under the natural conditions of the tropics (wet and dry).

All the technological elements are, of necessity, imported from the north and consequently require foreign currency which increases the operating costs. This, together with the low yields (compared with those of the countries of the temperate zone), results in minimal financial benefits and, at the same time, they have lead to the degradation of the ecosystem and a decline in traditional production systems.

In the search for solutions, since the 1980s, scientists like Drs Ronald Leng, Thomas Preston, Vilda Figueroa and Rena Perez (among others) have devoted efforts to research that aims at seeking alternatives for agricultural

production in the tropics and sub-tropics, based on the hypothesis that "the primary production strategy in the tropics must be based on the efficiency of plants to transform solar energy into concentrated energy sources (sugars, starches and oils), as well as protein production for animal feeding".

With this objective, they demonstrated, initially in Cuba, that it was possible to totally replace cereals as the energy source for animal feeding, with the use of molasses (A molasses, B molasses and final molasses) from the sugar industry, supplemented with unconventional protein sources (yeasts, organic wastes and protein pastes) for pig fattening, without detriment to animal performance. Since 1986, projects were established in Colombia by CIPAV with the advice of Dr. T.R. Preston, where the evolution of research and the commercial application of the technologies have demonstrated that:

- **Fattening pigs from 20 to 90 kgs liveweight, using sugar cane juice ad libitum and a restricted protein supplement (200 g/animal/day) based on soya grain or cake permits at least 500 g/animal/day live weight gain.**

- **The use of forage from trees and aquatic plants as part of the protein supplement for pregnant sows (1 to 2 kg/animal/day on a fresh base) permits litters from 8 to 10 pigs at birth and weaning, with live weight of 1200 g at birth and 9 kg at weaning at 45 days.**

- **The strategic feeding of dual-purpose cattle with sugar cane bagasse and sugar cane tops or fibrous crop residues, supplemented with leaves of forage trees, poultry litter, rice bran and multi-nutritional blocks, prevents loss in weight and improves the reproductive performance of the herds, even during the dry season and, under good climatic conditions, permits daily gains higher than 600 g/animal/day in the males and average production of 10 to 12 litres of milk/cow/day.**

- **An appropriate nutritional strategy for dual-purpose cows, allows both milking and restricted suckling which leads to increases in milk production of over 25% and the improvement in the post-weaning growth of the calves.**

- **The use of females for animal traction (cows and buffalo) in agricultural activities permits an annual saving of the equivalent of 45% of the energy used by an electrical motor, and, at the same time, generates annually 1.73 tonnes of milk, 0.182 tonnes of meat (1.3 calves), 13 tonnes of manure and 1.82 tonnes of waste forage which can be used as a fertilizer.**

- **Sugar cane with a spacing of 0.7 - 1 m between rows (the sugar industry in Colombia uses 1.5 m) gives a total biomass production of around 250 tons/hectare/year without the use of agricultural chemicals.**

- **Fractionation of sugar cane for animal nutrition, allows the incorporation of different species into integrated systems of sustainable production, where the sugar cane tops and bagasse are used for ruminants, organic fertilizer and energy production and the juice is used for monogastric nutrition and for the production of molasses for the family. The animals are supplemented with forage trees (which are grown together with the sugar cane), aquatic plants (established in waste ponds), multi-nutritional blocks (for ruminant and rabbits) and soya grain or cake (for monogastrics).**

- **The integration of biological water de-contamination systems using continuous-flow-plastic-biodigesters and ponds with aquatic plants has enabled the generation of methane gas to be used instead of non-renewable fuels, protein for animal feed and nutrient recycling.**

- **Different investigations carried out with other scientists from Colombia, Cuba, Venezuela, Nicaragua, Vietnam, Tanzania, United Kingdom, Sweden, Denmark and Australia have shown that there are many plant species in the tropics and the sub-tropics which have great potential for animal and human nutrition. Known species which have a high efficiency in the transformation of solar energy into other forms are sugar cane (*Saccharum officinarum*), bananas (*Musa* spp.), cassava (*Manihot* spp.) and the African palm (*Elaeis guineensis*). With regard to protein production, some of the trees and shrubs which deserve mention are *Gliricidia sepium, Erythrina poepigiana, E. fusca, E. glauca, E. edulis, Prosopis juliflora, Trichanthera gigantea, Morus* sp., *Urera* sp., *Tithonia***

diversifolia, Malvaviscus penduliflorus, Canavalia* sp., and the aquatic plants *Azolla* spp., *Lemna* spp. and *Salvinia natans.

With the practical and scientific demonstration of the hypotheses by the pioneers researchers and continuing investigations, it has been possible to generate, over the last 10 years, technological proposals which, at the same time, have been taken and transformed by farmers in different tropical countries. In 1993, FAO decided to establish the Information Network for Tropical America and the Caribbean on the utilization of the sugar cane and of other locally available resources for animal feeding.

Sugar Cane Network Fao-america

The CIPAV Foundation (Cali, Colombia) was designated as the Central Organization which, under the patronage of the FAO, coordinated the "Information Network for Tropical America and the Caribbean on the utilization of the sugar cane and of other available local resources for animal feeding" (FAO project GCP/RLA/116/FRA funded by the French Government). In each country, a committee has been created as the responsibility of an organization which provides a National Coordinator, who is the principal facilitator of the activities of the National Committee, the permanent liaison between countries, and the direct contact with the CIPAV Foundation, which at the same time liaises with FAO and another Network in Asia. To activate the Network, CIPAV, through short duration missions to each country, has accomplished different activities:

- **Training and advice to the National Coordinators, National Committees, other technicians and farmers through field days, demonstrations, tours and conferences.**

- **Advice to the National Coordinators, National Committees and other technicians in the design of experiments and information analysis.**

- **Training on the use of software for investigation and communication (spreadsheets, word processors, graphical packages, compression and converters programs, E-mail tools, etc.), documents produced** in electronic form (Livestock Research for Rural Development (LRRD), books in Windows Help Format) and templates for presentation and publication of printed books and electronic documents containing information generated in the research.

CIPAV produces technical and scientific material which is distributed between the different country members of the Network, and invites local researchers to write articles to be published in LRRD.

The Sugarcane Feeds Centre (SFC), Trinidad, implemented similar activities for the English-speaking Caribbean countries. This institution was selected as it has a long experience in the use of sugarcane and other local resources as animal feeds in the Caribbean islands and as it also conducts a wide range of on-going experiments and demonstrations concerning these topics. Three international workshops have been organized by the SFC for the Caribbean countries. Furthermore, the SFC director carried out short missions in Guyana, Saint Vincent, Saint Lucia, Dominica and, Antigua and Barbuda, in order to increase liaison with Ministry officials and support and encourage the National Coordinators to strengthen the impact on farmers.

Outcome of the Network

Publications

a) Material on sustainable agricultural technologies has been published both in Spanish and English, in different formats (computerized journals, posters, proceedings, manuals, books and videos), and distributed between the country members of the Network. These include more than 1,000 copies of 19 issues of LRRD (each one containing 10 articles); all the articles can be obtained through FTP or the World-Wide-Web, in versions for DOS and Windows. In addition there are the computerized journals: "Non-Ruminant Small Herbivores" (CENDI, Venezuela) and "Pig Production" (Instituto de Investigaciones Porcinas, Cuba).

b) 1,200 copies of 5 primers: "Sugar cane", "Feeding of Cattle for Small Farms", "How to Raise Pigs with On-Farm Resources", "Training of Working Animals" and "The Cipres Production System" (the last two only in Spanish) and some copies of the primer "The Rope Pump to Extract Water".

c) More than 50 packages of the poster collection "The Bag of Trees to Eat".

d) Copies of the proceedings: "Forage Trees as Sources of Protein", "Sustainable Systems of Agricultural Production for Small Farmers", "Nacedero (*Trichanthera gigantea*): an Integrated Production Species" (all in Spanish).

e) 120 copies of the Manual "Continuous Flow Plastic Biodigesters: generation of gas and bio-fertilizer from waste water".

f) 240 copies of 4 books: "Strategy for Sustainable Livestock in the Tropics" (Preston T.R., Murgueitio R.), "Matching Ruminant Production Systems with Available Resources in the Tropics and Sub-Tropics" (Preston T. R. and Leng R.), "Forage Trees and Shrubs Used in Animal Feeding as a Protein Source (CIPAV)", "Pig Production with Tropical Plants and Nutrient Recycling" (Figueroa V.); and some copies of the books "Sustainable Agricultural Systems for the Tropical Mountains (CENDI - CIPAV)" and "Fauna Investigation and Management for the Development of Sustainable Systems (CIPAV)". The first four are printed on paper, the rest were published both on paper and electronic form (Windows Help Format).

g) The video "Didimo's Sweet Pigs" in English and Spanish.

Events

The representatives of CIPAV have held technical conferences for more than 1,500 persons, demonstrations with the participation of more than 500 persons, and training workshops in project design, analysis and data handling with more than 100 persons (technicians, students and farmers). They have participated in technical study tours and evaluation to more than 50 farms (private and state).

The National Coordinators and the National Committees have organized their own training events for groups of farmers, students and technicians.

The National Coordinators of Costa Rica, Honduras, Cuba, Venezuela and Colombia, with the collaboration of their respective National Committees and FAO, have organized international seminars on Integrated Systems of Agricultural Production, with the participation of National Coordinators of different countries and the participation of more than 1,300 persons (technicians, students and farmers).

In 1995, an NGO that works in El Salvador (Veterinaires Sans Frontieres - VSF) organized, with the involvement of other national organizations and a representative of CIPAV, a national event on Integrated Systems of Agricultural Production with 100 participants (farmers and technicians).

Exchanges

Some National Coordinators, members of National Committees or Institutions of the Central American countries and CIPAV have begun the exchange of technical information, technologies and material:

- **tours among neighboring countries (Honduras, Costa Rica, Nicaragua, El Salvador), or to CIPAV (Nicaragua, Costa Rica, Honduras).**
- **live material of californian red worm (*Eisenia phoetida*), nacedero (*Trichanthera gigantea*) and *Azolla* sp, from Colombia to Honduras and Costa Rica and from Honduras to Costa Rica, Nicaragua and Belize.**
- **8 continuous-flow-plastic-biodigesters taken from Colombia to Nicaragua, Honduras, El Salvador and Costa Rica.**
- **local exchanges of sugar cane varieties resistant to drought and with easy management.**

Research, Transfer and Technical Proposals

In several member countries of the Network, the National Coordinators and the National Committees have

developed some sort of research activity, and transferred or developed new technologies. Some examples are:

- **In Guatemala, the Science and Technology Institute (ICTA) and the Veterinaires Sans Frontieres work in the agricultural characterization, reproduction and use of local forages of the Altiplano and small mountains, for small ruminant nutrition (goats and ewes) with indigenous communities.**

- **In El Salvador, the National Coordinator and the organization Center of Agricultural Technology Transfer (CENTA) are carrying out research into the reproduction and establishment of Erythrina verteruana, and at the same time they are starting work on the use of this forage as a protein supplement for milk production; they have also begun trials on feeding hens with californian red worms. The NGO's VSF and FASTRAS have established, with different groups of small farmers, different components of the system (sugar cane, forage trees, soya and earthworms for feeding native hens, pigs and cattle, and plastic biodigesters).**

- **In Honduras, the National Coordinator and the National Committee are carrying out serious research on establishment and resistance to drought of sugar cane and forage trees, pig feeding with sugar cane juice supplemented with different protein sources (soya cake and shrimp meal), grazing of pregnant sows, establishment of a dual-purpose cattle herds, buffalo production, plastic biodigesters and aquatic plants.**

- **In Nicaragua, the technical personnel of the World Food Programme have set up projects for training and technology transfer on strategies for cattle feeding in the dry season (sugar cane, fibrous residues and multi-nutritional blocks). A technician from the National Institute of Agricultural Technologies (INTA) is working on the adaptation of the dual-purpose cattle system to the severe drought zone of Chontales and he has organized an event with the exclusive participation of farmers, to present the results of the projects on their farms.**

- **In Costa Rica, the National Coordinator and the National Committee have established different**

investigations into the use of residues of banana production for animal feeding and multi-nutritional block production, establishment of silvopastoral systems and dual-purpose cattle management, and are starting projects on animal traction.

- **In Cuba, the National Coordinator and the National Committee are making progress in the establishment of forage trees and production systems with cooperative farmers, and the installation of continuous-flow-plastic-biodigesters.**

- **In Venezuela, the National Coordinator and a group of collaborators established an integral farm and are studying different animal species: feeding with multi-nutritional blocks; characterization, behaviour and management of native stingless bees; conservation of wild species in danger of extinction; and systems such as the 'alpargata forrajera', for the fresh forage supply to the animals.**

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Constraints to the Promotion of Integrated Farming Systems in Small Island States

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Abstract

Over the last 50 years when agricultural modernisation was attempted, farmers were encouraged to forsake mixed farming for monoculture systems aimed at achieving high technical efficiency and with the expectation of increased income. In the highly "monetised" though small economies of the islands, this was taken as being a valid approach for agricultural development. Integrated farming, the traditional agriculture of both larger and smaller farmers, was not encouraged.

The new systems resulted in increased production and improved quality of product. Being based on imported feed, the devaluations which occurred in the value of local currencies, with consequent increase in prices of imported inputs, have resulted in higher costs to the producer and ultimately higher prices to the consumer. The options seemingly available have been to seek high technical efficiency of production, seek alternative feed inputs from local sources, or to get out of production.

Some smaller farmers are increasingly dependent on production methods based on a mixture of new and traditional practices. These include utilising local natural feeds, recycling waste, integrating their livestock with cropping activities, limited aquaculture production, etc. The technical parameters are not as high, but the economic returns are satisfactory and the systems are apparently more sustainable. The more "commercial", medium-sized farmers are attempting to purchase only essential inputs, while growing and utilising what they can create or obtain as feed from their holdings.

The climate is such that some islands experience relatively low rainfall, 1,100 mm in Antigua and Barbuda with drier year-round conditions, while some at the other extreme have levels as high as three times this. This influences

the growth, availability and quality of the forages, products and by-products useful for feeding. But these are problems that could be solved technically.

The limit of land availability dictates that integrated, intensive methods of production with recycling of effluent to soils, most of which have been heavily exploited, eroded and denuded from centuries of commercial export agriculture, must be preferred. Systems will have to be based on the economic and social environment in which agriculture operates. This presentation hopefully raises some of the issues beyond those that are only technical.

KEY WORDS: Integrated Farming System, island, Caribbean, modernisation, extension, imported feed, local feed, feeding system, sustainability

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Introduction

Over the centuries, agriculture in the small island states of the Caribbean has been dominated by export crops such as cocoa, cotton, coconut, coffee, citrus, bananas, nutmeg, etc. Up to the middle of this century, "agriculture" was therefore taken to mean "export crop" agriculture. Crops such as bananas and sugar are still very important at the present time in specific countries. Bananas are important in Dominica, Jamaica, St. Vincent, St. Lucia and Grenada; sugarcane in Barbados, Jamaica, St. Kitts and Trinidad; cocoa and nutmeg in Grenada; coconuts in Dominica, Jamaica, St. Lucia, and Trinidad; and, citrus in Dominica, Jamaica and Trinidad.

While these commodities were exported, the territories imported much of their food needs. Yet food was produced for local consumption. There was dichotomy in agriculture as mainly small farmers, landless peasants and estate workers were engaged in such production. Food crops were allowed on the estates as long as they did not interfere with or reduce resources allocated to the "main" crops. Production of local food was not given recognition in terms of statistics on agriculture, so that it would have been difficult to assess levels of poultry or eggs, mutton or root crop production. There were however integrated systems of production, crops with animals as shown below:

(i) Prior to the widespread use of inorganic fertilizers, inter-planted crops of cocoa, nutmeg, citrus and bananas

were fertilised mainly with manure from pens of zero-grazed cattle. Animals were tied to stakes in the fields and fed legumes such Leucaena, Glyricidia, Spondias spp., and grasses such as Brachiaria mutica, Pennisetum spp. and guinea grass, and crop or agro-processing wastes. The organic matter, after a period of curing, was used on the crops.

(ii) Sugarcane cultivation was carried out on both estates and small farms with animals - water buffalo, zebu or creole cattle - providing traction/haulage and also, manure, meat and milk. Animals utilised molasses, cane tops, grasses and legumes as the main feeds.

(iii) Coconut plantations had either estate or worker/peasant- owned cattle, small ruminants and pigs tethered between the trees. These controlled the under-storey vegetation at low cost, allowing a more complete harvest of fallen nuts. On larger estates, herds of cattle were (and are still) kept. Often, the importance of the coconuts was diminished as trees aged, with little replanting or maintenance. This has been due to competition from soya bean oil with the coconut oil. Soya bean is imported and processed in the region.

(iv) The small landholder, squatter or landless peasant practised mixed farming on small holdings, growing mixtures of fruit trees, annual plants, vegetables, etc., and rearing free-range poultry for eggs and meat, and tethered pigs, sheep, goats or cattle on roadsides or open lands. Pigs were also fed mainly on household wastes, sometimes collected from neighbours or institutions.

This general situation of integrated farming practices has been mainly reversed and there are at least three aspects to this:

- **the search for modernisation of agriculture;**
- **pressures of the wider economy on agriculture and resource use; and**
- **the failure to recognise and deal with agriculture for local consumption.**

Modernisation of Agriculture

The plans of the larger Caribbean states in the 1960's were to encourage economic development with modernisation and industrialisation of agriculture. These involved "improved technology". There were some influential factors:

(a) Being situated close to North America and its agriculture with yields based on high levels of technology, equipment, pesticides, irrigation, etc., this model was adopted.

(b) Even though the islands had limited land with small and fragmented agricultural holdings, "economies of scale" parameters were promoted. Poultry, pigs, milk and, to a lesser extent, beef production were encouraged as monoculture operations. (State assisted farms were forbidden to engage in any secondary enterprises).

Imported feed ingredients - corn and soya bean meal - were fed to imported, ill-adapted breeds of cattle. Backyard poultry and pigs were deemed unacceptable. The new feeding systems ignored traditional mixed crops/livestock farming.

(d) The replacement of animals with tractor power started in the 1950's and spread to even the smaller farmers. Today, livestock production by the sugar companies is separated almost entirely from the cultivation of the crop.

(e) "Modern" agricultural education reinforced the above developments. Technical efficiency became the goal with efficiency of general resource use and sustainability ignored. Monoculture economic models of production were promoted and accepted.

Pressures of the National Economy

A national economy is made up of several sectors with agriculture being one and livestock production as a sub-sector of agriculture. The other sectors heavily influence agriculture from many points of view such as return on investment, labour status, alternative land and resource use (opportunity cost), etc. In all these, agriculture comes

out second best. Labour is attracted to public works, light industry, hotels and tourism, and the service sector, i.e. to virtually any non-agricultural activity.

This either leaves land idle or it makes the farmer a part timer with crop production abandoned and animals kept on systems such as "uncontrolled grazing". Animals are let out in the morning to forage where they wish and return to the owner's holding in the late afternoon to be secured. Milk production is no longer promoted (too time-consuming) and there is only occasional slaughter and sale of meat. Manure use declines. There may be some element of forage harvesting by the owner of the animals for night feeding or, especially in the dry season, on his way home from work.

In the drier areas of the islands and particularly on the coast, the "natural" land for livestock is being diverted into housing, hotels and related facilities (golf courses, etc.). The value of land earmarked for such purposes far exceeds its value for agriculture, so more and more land is lost in the absence of land utilisation plans or laws or, where they may exist, enforcement.

Dealing with Local Consumption

It has been noted that production for local use, with the notable exception in recent decades of vegetables and root crops, has been largely ignored and under reported. That was the case for meat and milk but change has come about with the attempted modernisation in pig, poultry and dairy farming. Even in these cases, the official statistics still ignore production that does not officially enter into processing. For example, Trinidad and Tobago milk production statistics are generally given as the milk intake of the single large milk processor. Yet this is variously estimated to be 1/2 to 2/3 of actual national production.

Feed Production, Cost and Feeding Systems

Feed manufacturing developed rapidly in response to the livestock development thrust. Most mills had working relations with or parent companies in the USA or Canada. In Trinidad and Tobago, there were as many as 15 mills by 1980. Initially, feed provided to the farmer was heavily subsidised by the national government to encourage farm

production and "development". Subsidies were removed and, with successive devaluations of local currency and increase in international commodity prices, the quantity of feed manufactured there has declined markedly. Between 1985 and 1994, prices of dairy, pig and poultry feed to the farmer have doubled, tripled and doubled, respectively (Table 1). Manufactured feed use has likewise decreased. The efficiency of feed use has increased on the fewer, larger, more capital-intensive units that remain in production. The other farm units, mainly the middle-sized pig units, small poultry units and dairy large units, have dropped out of production. Some information on these trends is provided below.

Table 1 :Production of dairy, pig and poultry feed in Trinidad and Tobago ('000 tonnes) and unit cost per 45 kg bag ($TT) 1985 to 1994

FEED YEAR	DAIRY		PIG		POULTRY	
	Tonnage	Cost	Tonnage	Cost	Tonnage	Cost
1985	48.8	25.6	27.6	27.2	168.3	37.8
1988	28.3	28.9	23.8	34.9	148.5	43.8
1991	18.9	37.1	20.4	49.1	139.3	58.0
1994	10.2	50.7	5.7	72.4	107.6	81.6

Source: CSO

Dairy:

Annual production of milk as reflected by sales to the major processor has been approximately 10 million litres annually between 1985 to 1994, in spite of increasing feed prices. Increasingly this milk is attributed to production

from smaller, mixed farms using more forage and by-products with little manufactured feed.

The bigger producers, with over 100 head, went out of production by the early 1980's. Even the 266 specialised 10-hectare pasture grazing units are now either more integrated farms, with mixed cultivation, or a few are very specialised but high cost producers, or the farms are out of production altogether. The smaller, integrated, zero-grazing farms with cross-bred stock (some are probably ill-advisedly upgrading their cattle with North American semen) are now producing more milk than the 10 hectare units.

A look at two dairy farms known to the author reveals the following:

FARM RESOURCE		FARM A	FARM B
1.	Size (ha)	10	10
2	Grasses	Improved + off-farm cut grass	Partially improved, no cut grass
3	Water Resources	No pond	Pond
;4.	No of milk cows (yield-litres)	30 (15 - 18)	25 (10 - 13)
5.	Other Products:		
a)		Heifers/bulls	Heifers/bulls

b)		-	Fish (Cascadura)
c)		-	Pumpkin/Melons
d)		-	Pigs
e)		-	Ducks
f)		-	Common fowl/eggs: (home use or sold)
g)		-	Manure (sold)
h)		-	Dahee
i)		-	Fruit (home use)

RESULTS FARM A	RESULTS FARM B
a) Higher milk income	a) Mixed income
b) Higher cash outflow for feed, medication, etc.	b) Lower milk income
c) More "dependence", lower sustainability	c) Lower cash outflow
	d) Smoother cash inflow

	e) More sustainable

Pigs:

Pig sales increased from 50,000 head to 79,000 head between 1988 and 1989, but returned to the former level by 1993 (CSO, 1994). While, in mid-1988, a total of 17,000 pigs were on farms of 21 to 500 head, by 1994 the number in this size range was 5,263. Farms with less than 20 and more than 500 head increased their population, indicative of the dichotomy in the industry. The smaller farms use less purchased feed, the larger are vertically integrated. The few large units have integrated feed manufacture, pig production, processing and marketing (and export) for high technical efficiency. Small pig farmers have reverted to farm by-products, household waste, waste from agro-industrial processing, forages, offal from poultry slaughter, etc.

Broilers:

The broiler production statistics are also of interest. Table 2 shows that, while total liveweight production of chicken has remained steady, the percentage produced by "contract farmers" who are part of the integrated feed miller/hatchery/ producer/processor/sales complex, as compared to that of "independent" non-contract farmers, rose from 55.5 to 89.3% between 1988 and 1994. Efficiency of feed use and marketing of products are important factors in this development. The small, independent poultry producers with integrated farm operation and limited use of manufactured feed (but using forages, waste grains, etc.) is making a come-back (with some free range production).

Table 2: Broiler production in Trinidad and Tobago by contract and non-contract farmers 1988 to 1994 ('000 tonnes).

Year	Total	Contract farms	Non-contract	Contract % of total

1988	25.6	14.2	11.4	55.5
1990	28.5	18.0	10.5	63.2
1992	24.3	19.6	4.7	81.4
1994	26.3	23.5	2.8	89.3

Source: CSO 1994

These indications are still not readily accepted by "officialdom" for reasons given in earlier sections. There is admittedly more recent interest in integrated farming and its validity is gradually being accepted and recognised by traditionally trained economists.

The Problem

The Caribbean region should be seeking to improve its agriculture and particularly its livestock production. A few reasons include:

- **the need to provide for some measure of "food security";**
- **the need to use the resources of soils, climate, etc. to provide employment and economic activity;**
- **the need to increase inland fish production, given the water resources available and static world fish output and that the rapidly developing sub-sectors of the economy (e.g. tourism) are not only fragile but can ultimately be self-destructive if not carefully handled and also dramatically increase food importation;**
- **with the new world trade situation of reduced farm and export subsidies, the cost of imported food (and feed) is rising; and**

- **developed, "modern" agriculture is not necessarily energy-efficient agriculture.**

With all the modernisation Trinidad & Tobago imports approximately TT$ 1.5 billion worth of food ($1US = $6TT) for a population of 1.2 million persons. In islands with "well-developed" tourist industries, the situation is even more dramatic.

Grenada, with less than 100,000 total population but tourist arrivals of over 200,000 persons, imported EC$ 21 million ($1US = $2.70 EC) of milk products in 1995. For Trinidad and Tobago, a development economist has noted that the index of food imported (1973 = 100) rose to over 470 by 1983 and in 1990 was 247 (Ifill, 1993). Food imports as a percentage of total imports rose from 10.3% in 1973 to 20.4% in 1990.

The macro-economic policy of devaluation and later the open liberalised economy are appearing not to work for the development of agriculture. In fact the liberalised agricultural regime is expected to have negative output and reduced employment implications. Countries of the region are, however, committed to such policies.

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The Integration of Fodder Shrubs and Cactus in the Feeding of Small Ruminants in the Arid Zones of North Africa

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Abstract

In the arid and semi-arid zones of North Africa, animal feed resources are fluctuating and insufficient. Small ruminants are basically fed on rangelands. During the last three decades, the contribution of rangelands to the needs of livestock decreased from 80 to 30%. Therefore, to reduce the increasing deficit of feed resources and to preserve the rangelands, large scale plantations of spineless cactus (*Opuntia ficus indica*, var. *inermis*), *Acacia* (*Acacia cyanophylla*, Lindl.) and *Atriplex* (*Atriplex nummularia* and *A. halimus*) were established recently (400,000 hectares in Tunisia).

The benefits of these species include high biomass yield, evergreen character, drought resistance, tolerance to salinity and soil adaptability.

These plantations were first established mainly on communal lands but recently more and more were established on mixed crop/livestock farms and private land.

***Opuntia* and shrubs are planted in wide rows allowing cereal cropping (mainly barley) in between. Animals may therefore graze the increased herbaceous biomass between the rows during spring, and stubbles during the summer time. The seasonal supply of feed is then better adjusted to the animals' needs, and livestock feeding is based more on farm resources than on commercial feeds. Indeed livestock farmers, and especially small herd owners, face dramatic difficulties during the frequent drought seasons. They are often forced to sell a large number of their flock in order to buy either rarely available expensive straw and hay or imported cereal-based feeds.**

Nutritionally, the above mentioned species complement each other. *Opuntia*, rich in water and carbohydrates, gives sufficient energy, *Atriplex* provides protein and *Acacia* is a fibre source.

Nutritional characteristics of these species and their use in combination with other farm resources such as treated straw will be discussed.

***Opuntia* pads have low crude protein (20 to 50 g/kg DM) and crude fibre (80 to 150g/kg DM) contents. However, they have high contents of water (800 to 900 g/kg fresh weight) and ash (150 to 250 g/kg DM). Cactus helps to meet the animals' water requirement. In addition, cactus pads are rich in vitamin A (almost the only source under harsh conditions) and in readily available carbohydrates. However, they need to be supplemented with nitrogen. On the other hand, poor quality diets may be correctly supplemented with cactus. Our work showed that the intake of straw increased significantly with the amount of cactus in the diet. Moreover, cactus is a good supplement to ammonia- or urea-treated straw because it provides the carbohydrates needed for the efficient use of non-protein nitrogen. Other trials clearly demonstrated that energy and nitrogen requirements of sheep may be met using cactus-based diets supplemented with *Atriplex* sp. Indeed, it is possible to get good performances by feeding animals cactus and *Atriplex* ad libitum with limited amounts of hay and barley. Such diets are recommended during drought years in arid and semi-arid zones.**

Diets based on limited amounts of straw (17%) and various amounts of *Atriplex nummularia* (24 to 59%) and spineless cactus (21 to 56%) can cover 165 to 180%, and 165 to 230% of the sheep's maintenance requirements, in energy and digestible crude protein terms, respectively. Such diets, using low inputs of cereal grains and forage crops, are recommended to cope with the feed deficiency prevailing in the North African arid and semi arid areas.

***Acacia cyanophylla* Lindl. is a leguminous fodder tree that is widespread in North Africa. *Acacia* leaves are high in crude protein (14% DM), lignin (ADL, 16% DM) and condensed tannins (4,5% DM catechin equivalent). Their nitrogen is poorly digested by the animal because of the condensed tannins. Air drying or polyethylene glycol (PEG 4000) treatment help to overcome this problem. PEG may be added in drinking water or included in feed blocks in order to efficiently increase the performance of animals fed *Acacia* leaves.**

Trials were carried out with sheep to investigate the effect of air-drying and polyethylene glycol (PEG) treatment of *Acacia* leaves on intake, digestibility and growth. A decrease in condensed tannin content was observed when Acacia leaves were air-dried or treated with PEG. Drying and PEG treatment significantly increased nitrogen utilization. Crude protein digestibility of *Acacia* averaged 18.6, 17.2 and 68.8% for fresh, air-dried and PEG-treated leaves, respectively. The beneficial effect of PEG treatment was also supported by growth trials.

KEY WORDS: *Opuntia*, prickly pear, nopal, *Acacia cyanophylla*, *Atriplex*, PEG, North Africa, feed, small ruminant

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Introduction

The North African climate is characterized by an extreme irregularity both in space and time (succession of rainy and dry years, high thermal amplitude, long dry season, etc.). Drought is a frequent phenomenon that must be coped with it.

The key problem of the arid and semi-arid zones in North Africa may be summarized as follows (Oram, 1995):

i. The increasing degradation of rangelands in the steppe zones and the consequent decline in feed supply for ruminants.

ii. The continuing increase in the number of small ruminants, especially sheep, despite widespread indications of declining productivity of the natural grazing.

iii.Uncertainties about the rights to graze animals on the range, arising from changes in the traditional tribal regulation mechanisms consequent on privatization of the range and settling of migratory peoples.

iv.Demographic changes and increasing population pressure on natural resources, both directly through competition of people for land and water and indirectly through rising demand for meat and other animal products.

v. The limited availability of technology for improving sustainable range productivity. This is because of the lack of support for range research, inexperience of management of range flora, and a "reservation-type" rather than a participatory approach by government officials to establishing and utilizing forage shrub plantations.

Fodder Shrubs: An Attractive Alternative for Rangeland Improvement

Experience with fodder shrubs started in the early 60's and even earlier in some countries (Tunisia), with various degrees of failure and limited success. Their impact is difficult to assess, since monitoring and evaluation processes are lacking most of the time.

In Tunisia, for example, according to a recent survey, rangelands cover some 5,413,000 ha distributed in forest and forest pasture (970,000 ha), *Stipa tenacissima*-based steppe (743,000 ha), communal and state rangelands (2,500,000 ha), and private rangelands (1,200,000 ha).

National strategies for rangeland rehabilitation were initiated in most countries. The most important components of these strategies are plantations of shrubs. The main species used are spineless cactus (*Opuntia ficus indica* var. *inermis*), *Atriplex* sp. (mainly *A. nummularia* and *A. halimus*), *Acacia cyanophylla* and *Medicago arborea*. Species or varieties of shrubs were not selected for each particular environment and production system.

The cost of establishment is often high. For Tunisia, the approximate cost of establishment (including the maintenance and subsidies to farmers during the first 3 years) is about 750 US$/ha for cactus and 1000 US$/ha for other shrubs .

Current Management of Shrub Plantations

Since the beginning, shrub plantations were established on communal lands under the supervision of forestry departments. Most plantations are kept ungrazed by forestry people, who are more interested in soil conservation, or exposed to uncontrolled communal grazing which frequently leads to their degradation. Thus, several constraints appear rapidly and are due to poor management.

Numerous questions arise when considering the use of introduced shrubs:

i. How should introduced shrubs be used by the animals (cut-and-carry vs. grazing)?

ii. How frequently can they be grazed?

iii.What stocking rate can shrublands support?

iv.For how long can shrublands be grazed without permanent damage?

v. Should plants be completely defoliated or would they recover better if only partly defoliated? etc.

In the absence of a well-defined management strategy, continuous grazing is the prevailing management system. Lands are permanently exploited to their maximum potential with no compensatory input.

Unfortunately, little effort has been devoted to defining convenient strategies for the management of introduced shrubs. Once planted on communal, state or private rangelands, shrubs have to be maintained for at least three years before their use by animals. Subsidies, as feed (concentrate, hay, alfalfa pellets), are given to farmers to replace outputs of the improved rangelands during the maintenance period (first three years). After three years, introduced shrubs are supposed to be properly used as recommended. Under Tunisian climatic conditions, shrubs are used from two to five years following their establishment, depending on the zones (north or south regions) and on rainfall. In Tunisia, the use of shrubs is based on field experience of farmers and technicians. No adequate seasonal or annual calendars have yet been recommended to farmers.

***Acacia cyanophylla* trees are used by animals every two years. Plants are grazed one year and browsed the following year. Leftover branches and leaves are cut and distributed to the animals.**

Cactus plantations are never grazed directly. The cut-and-carry technique is the common practice. Using such techniques, the loss of feed is virtually nil and the risk of over-utilisation is considerably reduced. The cut-and-carry

technique is, however, costly in labour and the grazing layer of herbage remains unavailable to the stock.

Saltbushes (*Atriplex* spp.) are grazed during the summer season. Plants are rarely cut for regeneration.

Meanwhile, shrubs are used in different ways depending on the users' preferences. On private rangelands, shrubs are well managed and properly used. Their use is confined to the farmers' needs to fulfill seasonal animal feed demands according to technical advice. Nevertheless, these shrubs are subject to over-use during dry years and, consequently, plants hardly survive. On communal land and on rangelands under forestry department control, the use of established plants is dictated by the forestry technicians. Plants can be used shortly after their establishment (but not before three years). However, the use of rangelands (either rehabilitated with shrubs or not) by farmers' flocks is allowed only during dry years. To use improved and/or protected rangelands, farmers have to pay a fixed fee which varies between 0.3 and 0.4 US$ per animal. Meanwhile, most protected forest and communal rangelands are often not used by animals for many years. Such practice leads to early aging of shrub plants which become woody and less productive in terms of browsing. Their periodic cutting will favour the growth of new shoots and leaves and results in an increase in the production of fodder.

Better Adoption and Better Management of Shrubs on Private Lands

Within the WANA region, Tunisia may be considered as a leader in promoting the establishment of shrubs on private farms and their integration into the current feeding calendar.

From 1990 to 1995, the Rangeland and Livestock Office (OEP) initiated the establishment of some 50,000 ha of cactus and 7,400 ha of various shrubs (*Acacia, Atriplex, Medicago arborea*) on 20,000 private farms. Most of these plantations were located in central Tunisia (arid zones) where there is a permanent feed shortage (table 1).

Table 1: Area of shrubs established by the Pasture and Livestock Office on private farms during the last five years (1990-1995)

Zones	Spineless cactus (ha)	Other fodder shrubs (ha)*
North-east	1669	1623
North-west	2772	1449
East central	9674	1495
West central	33099	528
South	2712	2265
Total	49926	7360

***Main shrub species are: *Acacia cyanophylla* Lindl., *Atriplex nummularia* and *Medicago arborea*.**

It can be noted from Table 2 that spineless cactus is the main species used for rangeland rehabilitation. The largest areas of cactus plantations are located in the west central region of Tunisia (governorates of Sidi Bouzid, Gafsa and Kasserine). Using cactus pads for feeding animals has been a common practice for a long time. Cactus, a low protein, bulk foodstuff, is regarded as an emergency feed and is cultivated as such in Tunisia as part of the drought evasion strategies for livestock. Moreover, cactus feeding considerably reduces the drinking water requirement as it contains 80 to 90% of water (Ben Salem *et al*., 1996).

In contrast to the other fodder shrubs, cactus establishment is accepted without problems by the farmers since they are familiar with this species. At the farmer level, cactus may serve as a fodder resource and also for human consumption of the fruits. However, the benefit expected from the other fodder shrubs is limited and the absence of a strategy for their management is the main constraint to their acceptance by the farmer as a tool for rangeland rehabilitation. In addition, it should be stated that the number of shrubs used for rangeland rehabilitation in the national strategy is too small to allow for better selection of species adapted to the micro-climate of each region.

Integration of Shrubs in the Production System - Some Promising Results

Spineless Cactus : A Strategic Fodder for Arid Zones

The benefit of integrated use of cactus is discussed in the following examples and case studies.

EXAMPLE 1: Nutritive value of diets based on spineless cactus (*Opuntia ficus indica* var *inermis*) and *Atriplex* (*Atriplex nummularia*) (Nefzaoui and Ben Salem, 1996).

Barbarine wethers were randomly allotted to 3 equal groups and fed diets based on cactus (*Opuntia ficus indica* var. *inermis*) and *Atriplex* (*Atriplex nummularia*) (80% of the diet). Restricted amounts of wheat straw (180 g/d) and commercial mineral and vitamins supplement (30 g/d) were distributed.

Dry matter intakes (DMI) were similar for all the groups (930 to 983 g DM/d or 70 to 73 g DM per kg $LW^{0.75}$). The relative intakes of Atriplex and cactus in the diets were 59 and 21%, 41 and 38%, and 25 and 56%, respectively for diet 1, diet 2, and diet 3. Digestibility coefficients of organic matter (OMD) and crude protein (CPD) of the 3 diets were relatively high, averaging 68 to 74%, and 75%, respectively. In contrast, fibre digestibility was low, probably because of the soluble carbohydrate content of cactus which depressed rumen cellulolytic activity. Nitrogen retentions were 4.1, 3.9, and 4.1 g. nitrogen per day for diet 1, diet 2, and diet 3, respectively (table 2).

The diets provided about 170% of the sheep's energy and digestible CP (DCP) requirements. Diet 1 provided 1.65 and 2.3 times the energy and DCP requirements of the sheep, respectively. Thus, it has an excess of nitrogen and may be supplemented with an energy source like barley grain. Diet 2 is relatively well balanced in both energy and nitrogen, while diet 3 has an excess of energy and needs to be supplemented with a nitrogen source (non protein nitrogen, like urea).

Voluntary intake of cactus was high (6.8 kg/d or ~550 g DM/d). No digestive disturbance was observed on any of

the diets. Organic matter (OMD) and crude protein (CPD) digestibilities of the 3 diets were high. Nitrogen retention was positive for the 3 diets and may indicate the relative good quality of nitrogen supplied by *Atriplex*.

In conclusion, cactus is a good source of energy and *Atriplex* a good source of nitrogen. Energy and nitrogen requirements may be matched by using diets based on these two feeds. The level of cactus in the diet may reach 55% on a DM basis, without digestive disturbances. A small amount of fibrous feed (straw, hay) has to be fed to the animals before feeding cactus. More efficient use of the diets could be achieved if the mineral balance is improved.

Table 2: Nutritive value of diets

Diets	D1	D2	D3
Total intake g DM/d*	941(70)	930(72)	983(73)
Cactus intake	197	353	550
Atriplex intake	554	391	236
Straw intake	160	159	167
Diet OMD, %	67.7	69.3	74.4
Diet DCP, %	74.5	76.6	75.5
Retained N, g/d			

*** the values ( ) correspond to intakes stated in g of DM per kg of $LW^{0.75}$**

EXAMPLE 2: Nitrogen supplementation of cactus-based diets fed to Barbarine yearlings (Nefzaoui *et al*., 1996).

The objective of this research was to investigate the effect of a nitrogen supplement (urea, soya bean meal, *Atriplex halimus* or *Atriplex nummularia*) on voluntary intake and growth of Barbarine yearlings fed cactus-based diets.

Four isonitrogenous and isoenergetic diets (D1 to D4) were offered each to 6 Barbarine yearlings for 60 days (summer 1995). On all diets, freshly cut cactus was fed ad libitum in addition to a limited amount of hay (170 g/d). Diets were supplemented respectively with 8 g/d urea (D1), 770 g/d *Atriplex halimus* (D2), 740 g/d *Atriplex nummularia* (D3), and 65 g/d soya bean meal (D4).

The relatively low intake of cactus and the poor nitrogen content of *Atriplex* sp. was due to the drought during the year of the experiments.

Results showed that cactus-based diets may be supplemented efficiently with *Atriplex nummularia*. Urea and *A. halimus* lead to low growth rates in comparison to soya bean meal or *A. nummularia* supplemented diets.

The voluntary intakes were 694, 844, 858 and 674 g DM per day for diets D1, D2, D3, and D4, respectively. The average daily live weight gains were 55, 58, 74 and 70 for D1, D2, D3 and D4 respectively (table 3).

Such diets, using low inputs of cereals (28% of the diet) and forage (17% of the diet), are recommended to cope with the feed deficiency in arid and semi-arid areas prevailing in North Africa.

Table 3: Feed intake and live weight gains

Diets	D1	D2	D3	D4
Feed intake (g DM/day):				
Cactus	241	252	241	228
Atriplex halimus	0	224.2	0	0

Atriplex nummularia	0	0	225.8	0
Soybean meal	0	0	0	57.6
Barley	308.8	243.6	243.6	243.6
Hay	149.0	142.9	147.5	150.6
Urea	8	0	0	0
Total intake	706.8	862.7	857.9	679.8
Average daily gains (g/day)	55	58	74	70

Spineless Cactus and Acacia

In this example, the widely introduced shrub *Acacia cyanophylla* was used to supplement cactus-based diets. Indeed, *Acacia* is rich in crude protein (about 13% in DM). For this purpose, 4 Barbarine sheep groups were fed various diets (R00, R21, R22, R23) (table 4). Hay, a scarce and expensive feed, was distributed in a restricted and limited amount.

The intake of *Acacia* was low (250 g DM/day) because of its high content of condensed tannins (7% DM). These tannins are also responsible for the low digestibility of the *Acacia* crude protein.

Table 4: Diets nutritive value

Diets	R00	R21	R22	R23

Feed intake, g DM/day				
Cactus	0	167	246	267
Acacia	241	373	211	177
Diet digestibility, %				
OM	67.7	76.5	73.9	74.6
CP	45.8	49.4	34.8	16.9
CF	62.8	80.5	77.4	79.9
Retained N., g/day	2.77	2.73	0.46	-1.07

With such diets, the energy requirement for maintenance is matched but a large nitrogen deficit remains and they need to be supplemented with an appropriate source of nitrogen.

Integration of Shrubs and Cereal Crop Residues

EXAMPLE 1: Effect of straw supplementation on intake and browsing of *Atriplex nummularia* (old man saltbush) by 'Segurena' ewes, under pen feeding and free grazing conditions (Correal and Sotomayor, 1996)

This example is taken from experiments conducted in Southern Spain (Murcia) where agro-climatic conditions are very similar to those in North Africa.

In the first autumn experiment under pen feeding conditions, dry Seurena ewes were fed for 6 weeks with two *ad libitum* diets (a) old man saltbush browse (mixture of leaves and young twigs) and (b) saltbush browse and barley straw. At the end of the experiment, the ewes from both feedlots ended up with higher live weights (LW) and

better body condition (BC), which suggests that both diets more than met the sheep's maintenance requirements. In the case of the saltbush/straw diet, ewes consumed about 2/3 saltbush and 1/3 straw. Average total intake was higher for the saltbush/straw diet than for the old man saltbush diet (102 and 88 g DM/kg metabolic weight respectively).

A second winter experiment was run with free grazing in a fenced old man saltbush plantation divided into two halves; in one half, a group of ewes had free access to straw and, in the other half, ewes were fed only on old man saltbush shrubs. The experiment finished when the shrubs were completely defoliated. In both subplots, ewes maintained BC and improved LW, but the straw supplement increased by about one-third the number of grazing days obtained from the saltbush/straw subplot compared to those on the saltbush subplot. The straw supplement also reduced by 33% the average diameter of the twigs browsed by ewes. In conclusion, the use of a barley straw supplement can improve the feeding value of old man saltbush plantations.

EXAMPLE 2: Effect of straw supplementation on the *Atriplex halimus* (saltbush) diet consumed by 'Segurena' ewes (Sotomayor and Correal, 1996)

Dry Segurena ewes were fed in pens for 4 weeks in summer with ad libitum amounts of three different diets: (a) saltbush browse (*Atriplex halimus* leaves and young twigs), (b) saltbush browse and barley straw, and (c) barley straw. Leaf and twig intake was measured daily (by difference between the offered and refused saltbush diets), and sheep live weight (LW) and body condition (BC) weekly. Ewes consuming a mixed diet of saltbush and straw ended up with higher LW and better BC, but those consuming only saltbush, increased LW and lost BC; finally, ewes fed with straw, lost LW and BC.

Saltbush leaves contained about three times more crude protein (18.5% CP) and minerals (29.7%) than stems (6.4% CP and 8.7% ash), and stems contained about four times more crude fibre (53.2%) than leaves (13.9% CF). The average leaf:stem ratio was 1.24 for the saltbush diet, and 2.23 for the saltbush/ straw diet; hence, with the straw supplement, ewes consumed more leaves (richer in CP) than without it and, in the absence of straw, ewes consumed more stems - probably in search of more fibre in an energy deficient diet. In conclusion, the combination

of saltbush browse plus barley straw met the sheep's maintenance requirement during summer.

EXAMPLE 3: Spineless cactus (*Opuntia ficus indica*, var. *inermis*) as a supplement for treated straw (Nefzaoui *et al*., 1993)

Research was performed to study the opportunity to use large amounts of cactus (*Opuntia ficus indica*, var. *inermis*) and also to assess the use of non-protein nitrogen from ammonia or urea-treated straw. Six groups of six Barbarine wethers were submitted to diets including cactus ad libitum and two levels (300 and 600 g) of untreated, urea- or ammonia-treated straw.

Cactus voluntary intakes were high (450 g DM) and were not affected when the amount of straw was increased from 300 to 600 g. Diets containing 64% of cactus were well eaten without any digestive disturbance (table 5). Data indicate that it is possible to provide the sheep maintenance requirements for energy from diets based on cactus given ad libitum with 300 g of straw per day. With a high level of straw (600 g/day), it is possible to achieve 1.7 to 1.9 times energy requirements. To cover nitrogen maintenance requirements, straw should be treated. Cacti may be used as a major component of diets containing cereal straws. Non-ammonia nitrogen provided by the treatment of straw is well demonstrated. However, it is necessary to add appropriate supplements in order to overcome the nitrogen deficiency and to give the fibre needed for normal rumen function.

Table 5: Straw supplementation with spineless cactus (Nefzaoui *et al*., 1993)

Level of straw	300 g/day			600 g/day		
	US	ATS	UTS	US	ATS	UTS
DM INTAKE, g						
Opuntia	445	447	425	432	462	439

Straw	254	242	249	494	466	486
IN VIVO DIGESTIBILITY,%						
OM	67.9	64.0	63.3	66.5	69.8	72.6
CP	41.1	48.0	43.3	45.9	61.0	77.1
CF	37.5	30.5	29.2	46.5	49.2	52.7
N RETAINED	-0.2	-0.2	-0.6	0.8	2.8	3.9

EXAMPLE 4: Supplementation of straw by *Acacia cyanophylla* (Ben Salem and Nefzaoui, 1993)

Previous studies showed that *Acacia* foliage had a relative high crude protein content. Taking into account this characteristic, it was thought that Acacia may be a suitable protein supplement for poor quality diets (straw, natural range lands, etc.). Ben Salem and Nefzaoui (1993) tested the effect of supplementing straw-based diets with graded levels of air-dried *Acacia cyanophylla* Lindl. foliage on digestion in sheep. Results obtained in this study, which are summarised in table 6., failed to support the above suggestion since there was no positive changes in the nutritive value of straw-based diets supplied by *Acacia*. Data on the crude protein digestibility of diets and the levels of ammonia nitrogen in the rumen fluid of sheep were indicative of an inhibition of rumen digestion. The presence of high levels of condensed tannins, which form insoluble complexes with *Acacia* proteins, seems to be the causative factor. Therefore, it was concluded that *Acacia* is less suitable as a protein supplement for poor quality roughages than might be expected from its high content of crude protein. Research is being carried out in our laboratory to dissociate the tannin-protein complexes of *Acacia* and preliminary results seem to indicate that polyethylene glycol (PEG 4000) had an affinity for Acacia tannins and thus improved the nutritive value (intake, digestibility, rumen fermentation and growth) of Acacia foliage.

Table 6: Effect of Acacia cyanophylla Lindl. foliage supply on intake, digestibility and rumen fermentation

parameters in sheep offered straw-based diets (Ben Salem and Nefzaoui, 1993)

	Level of *Acacia* supply (g DM/day)			
	0	75	150	225
Dry matter intake (g/day)				
straw	425b	431b	687a	350b
straw + *Acacia*	425b	506b	837a	515b
Total diet digestibility (%)				
Organic matter	51.6a	40.7b	48.7a	46.1a
Crude protein	-114.1b	5.1a	-4.0a	5.3a
NDF	60.1a	44.8c	56.7a	49.8b
Ruminal fermentation parameters				
NH3-N (mg l-1)	2.74	0.57	2.97	1.17
Total VFA (mmo-1)	60.5c	67.8b	74.2a	65.0bc

a,b,c: Data in the same line with different superscripts differ (P<0.05)

Conclusions

We discussed several examples showing that, in arid and semi-arid zones, shrubs, and especially cactus, play a significant role in providing valuable nutrients to small ruminants. In each example, conventional feeds (concentrates, hay or straw) are used in limited amounts because they are scarce and expensive.

Moreover, we recommend the following ideas:

(i) Encourage shrub plantations on private farms instead of communal rangelands. In other words, shrubs must be considered as a part of the production system and as a permanent fodder resource instead of a 'strategic' or 'reserve' fodder to be used only during drought. This option will facilitate the management of shrubs in a sustainable way.

(ii) Avoid planting a single shrub species. This will promote the availability of feeds during all seasons and will help to provide better balanced diets. Cactus can be used all year around and *Acacia* is mainly used during autumn and winter, while *Atriplex* can be exploited during the winter and summer seasons.

(iii) Plantations should be established in alley cropping where barley (the main cereal sown in arid zones) is planted between lines of shrubs. This will help to give better barley yields and will help to make better use of cereal crops. In fact, barley stubble may be grazed directly and supplemented with Atriplex (a protein source) or cactus (energy source).

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The African Oil Palm in Integrated Farming Systems in Colombia: New Developments

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Abstract

Recent work supports and extends the idea of using the African oil palm as a strategic resource within integrated tropical production systems.

The use of high-energy multi-nutritional blocks containing palm oil for beef cattle has been evaluated. Results show a significant increase in animal production especially in grazing systems based on the natural savannahs.

Pig production work has continued with the aim of refining the use of crude palm oil in the diet and increasing the use of protein rich forages like the leaves of *Manihot esculenta, Trichanthera gigantea* or *Azolla filliculoides* as replacements for soyabean meal. Also, a feeding and management system for grazing pigs has been designed with satisfactory results. This system, based on an integral approach, aims to improve the soil conditions of land which is destined for crop production.

The utilization of crude palm oil in the diet of broilers kept in a semi-confined system has resulted in similar performance to that of a confined system based on cereals, as well as permitting the inclusion of significant levels of protein-rich forages.

High-energy blocks have also been used with good results in African hair sheep production.

These systems offer new alternatives for small and medium-sized farmers to increase profitability, make better use of local resources, reduce dependence on external inputs and exploit the biodiversity of the natural ecosystem.

KEY WORDS: African oil palm, livestock, integration, *Elaeis guineensis*

Tropical Beef Production

The nutritive value of grasses is a major limitation to beef production in the tropics (Escobar, 1991). They are low in energy (especially in non-structural carbohydrates and lipids), protein and minerals. They are high in fibre which limits intake. The presence of secondary compounds in forages, particularly legumes, has very variable effects on the animal. The quality of forages themselves is very variable, both locally and seasonally, as a result of agro-ecological factors such as climate, soil, nutrient availability, topography, etc. These factors determine to a large part the productivity of tropical beef production, which is generally low when no action is taken to correct these

limitations. This does not mean that the production potential is low. On the contrary, by understanding the limitations, it has been possible to design different strategies to significantly improve animal performance, including the provision of non-protein nitrogen, mineral supplementation, the use of pasture legumes and particularly legume trees, and health management.

Recently, Huertas (1996) conducted an analysis of feed efficiency in Colombian cattle production (Table 1), showing evidence of the same low levels of productivity as measured by the feed conversion ratio in extensive or semi-intensive systems based on grass pastures.

In terms of efficiency, there has not been any improvement from the practice of replacing natural pastures with introduced species, known as 'improved pastures'. But on the contrary, the introduction of legumes has succeeded, giving an important improvement in efficiency.

The cultivation of African Palm has the potential to offer various production alternatives, different products and by-products that can be utilized in the energy supplementation of cattle, improving efficiency and productivity.

Energy Strategy Using Multinutritional Blocks

The advantages of the use of multi-nutritional blocks, in diets based on crop by-products or pastures of typical low quality, are well known in terms of providing adequate non-protein nitrogen in the rumen, improving both function and efficiency, which is reflected in higher voluntary intake by the animal and better digestibility of fibre.

Table 1. Feed efficiency of cattle in Colombia

Ecosystem	Live weight kg	Ratio kg forage/1 per kg live weight gain	
			Grass

		Grass	+ legume
Natural conditions	120	10:1	
Eastern Llanos	200	22:1	
	300	25:1	
Valle del Sinu	250-280	20:1	15:1
	300-350	22:1	18:1
Magdalena Medio	250-280	20:1	-
	300-350	22:1	-
Ladera Antioquena	230-260	22:1	18:1
	300-460	24:1	18:1
Piedemonte Llanero	220-260	22:1	18:1
	300-450	25:1	18:1

1/calculated on the basis of dry forage

Source: Adapted from Huertas (1996).

Work is in progress with blocks not just to supply nitrogen but as a way of offering additional energy using fat from palm oil and solubilized fatty acids.

The block being used contains 10% urea, 10% rice polishings, 40% molasses, 15% quick lime, 10% rice husks, 5% mineral salt and 10% crude palm oil or solubilized fatty acids. The content of crude palm oil can be raised to 15%, reducing the amount of rice husks to 5%.

In recent work, Ocampo *et al*. (1996) have supplemented cull cows with multi-nutritional blocks using two levels of crude palm oil, 10 and 15%, following the formula described above. The 30 cows with an average weight of 290 kg were on short pasture of Brachiaria decumbens, at an average stocking rate of 1 animal/hectare and three treatments: two with blocks and one control. The results are summarized in the following table.

Table 2. Average performance of female cattle following treatments (90 days experiment).

	Control Block	Block	
		10% oil	15% oil
Initial LW kg	300.6	288.6	290.5
Final LW kg	349.5	345.7	353.3
LWG g/day	544	634.4	697.7
Block intake g/d	0	111.1	123.3
Additional LWG from block g/day		90.4	153.7

Cost of block consumed USD		0.023	0.027
Value of extra LWG in USD		0.106	0.117

The animals that received blocks gave the best results, in both economic and biological terms. It is very important to emphasize the low intake of blocks, the response to which was significant to the animals, resulting mainly from the additional supply of energy.

Note how the difference between 0.023 USD and 0.027 USD daily represented an additional gain in production of meat that ranged from 0.106 USD to 0.117 USD, making it very worthwhile. It is not usual to encounter gains at pasture of 543 g/day, as shown in the control group, which was an indication of the good condition of the pasture. Nevertheless, the response to the effect of blocks was good. This shows that the use of energy blocks works not only in the dry season but that it is worth using throughout the whole year, improving the return per unit area of the smallholding or farm.

Very interesting results were obtained in the analysis of rumen degradability of the block, being approximately 50% at 6 hours for both blocks, 65% at 24 hours and 76% at 72 hours. The nitrogen content of the blocks had a degradability of 40% at 6 hours, 63% at 24 hours and 79% at 72 hours. Similar results were found with the NDF content. It can be concluded that supplementation with energy blocks improved overall animal performance, demonstrating that the effect of additional fat as a source of energy is viable.

Further work carried out in the Puerto Gaitan area, Departamento del Meta, Colombia evaluated the response to energy blocks by fattening cattle, with 45 steers per treatment lasting 67 days, and an initial average live weight of 250 kg. There were 4 treatments: one on Brachiaria decumbens without block, another on natural savannah

without block and two on natural savannah (Axonopus purpussi) with blocks containing 10% crude palm oil or solubilized fatty acids (SFA).

The results which are reported in the above table show once more the validity of the energy strategy using multi-nutritional blocks.

It leads to an interesting discussion of the production achieved on natural savannah of Axonopus purpussi compared to that on Brachiaria decumbens. The daily LWG is practically the same and the only difference is in carrying capacity which resulted in greater annual meat production per hectare from the improved pastures'. However, the latter depends on converting the local ecosystem by removing the natural pasture, adapted over many years and with a high capacity for persistence. In addition, the costs of establishment and maintenance of the introduced pasture implies a very great cost in order to achieve the levels of production reported.

The increase in production achieved on the natural savannah is highly significant, with minimal inputs and a high rate of return. To increase production to 90 kg/ha/year solely by introducing the block system is a very interesting finding and raises the issue of the politics of substitution of the natural ecosystem with introduced pasture, which is currently considered as the only way of increasing productivity.

Table 3. Multi-nutritional blocks with palm oil or solubilized fatty acids for fattening cattle on natural savannah (*Axonopus purpussi*).

Variable	Savannah without block	Block 10% oil	Block 10% SFA	*B. decumbens* without block
Initial LW kg	218	241.9	238.0	
Final LW kg	227.8	270.0	267.7	

LWG g/d	146.2	420.0	443.2	450.0
Additional LWG cp. savannah		237.8	297.0	
Block intake g		215	218	
Cost of block USD		0.045	0.047	
Additional gain USD		0.284	0.356	
Stocking rate/ha	0.22	0.6	0.4	0.8
Meat production kg/ha/month	0.965	7.6	5.3	10.6
Meat production kg/ha/year	11.6	91.2	63.6	129.6

The Savannah System of Pig Production

This work was carried out in the Municipality of Puerto Gaitan, Departmento del Meta, Colombia in the ecological zones of savannah plains and the banks of the river Meta, an area of tropical rainforest with an average annual temperature of 28 deg C, annual rainfall of 1800-2300 mm/year and an altitude of 200 m a.s.l.

Three trials were carried out; each trial corresponded to one phase or cycle of the pigs (Penuela *et al*., 1996).

Each phase was carried out in an area of 1 hectare, surrounded by a wooden fence with wire netting, divided into 4 equal parts (0.25 ha each) with feeder and water pipe in each corral. Each corral was provided with 16 sq m of shade. The number of animals in each trial varied from 40 to 60 depending on the stocking rate to be evaluated.

The treatments (diets) were designed with 2 replicates and 10 animals per replicate.

The treatments applied were (g/animal/day):

	T1	T2
Fortified soya cake[1]	500	500
Rice polishings[2]	200-300	200-300
Crude palm oil[3]	300-500	500-600
Sugar cane (crushed)	*ad lib.*	-------

[1] 945 g of soya cake + 50 kg tricalcium phosphate + 3 kg salt + 2 kg vit/min premix

[2] 200 g from 20-60 kg LW and 300 g from60 kg until they reached 90 kg

[3] 300 g from 20-60 kg LW and 500 or 600 g from 60 kg until they reached 90 kg

For phase 1 and 2, an adjustment was made to the diets by adding 100g/pig/day of rice polishings and 100g/pig/day of crude palm oil for each treatment respectively.

In the study area (1 ha), the botanical composition and existing soil fauna were examined before the entry of the pigs and once following the completed cycle, as well as monitoring the physical and chemical characteristics of the soil and the performance of the pigs.

The results obtained reflected the biological and economic performance of the pigs at pasture, their behaviour and

the changes in soil and botanical characteristics of the study area.

Biological Performance of the Pigs

The results obtained during the three phases of the investigation are summarized in the following table:

Table 4. Average results for fattening pigs

	T1	T2
No. of animals	27	27
Number of days on trial	117	117
Live weight kg		
Initial	36.0	33.3
Final	87.6	85.8
LWG (g/day)	440	448
Intake (kg/day)		
Soya bean meal	0.500	0.500
Palm oil	0.420	0.620
Rice polishings	0.326	0.587
Sugar cane	2.3	0.0
Total DM intake (kg/day)	1.74	1.23

Feed conversion (DM)	3.6	2.7

Source: Penuela *et al*., 1996.

The average biological results are positive and acquire additional value when it is realized that they were obtained under an open field system (pasture). It could be said that it is difficult to find positive results for fattening pigs in these conditions. The main reason for these good results is due to the use of fatty acids contained in the palm oil, responsible for a high percentage of the energy provided in the diet. It would be difficult to achieve this with cereals as the source of energy.

It is interesting to compare the production of meat from pigs and cattle per unit area under savannah conditions, still with reference to a cattle system based on *Brachiaria decumbens* pastures.

From the experimental results, the production of pig meat per hectare in one cycle is 1,958 kg. If a minimum of two cycles are considered per year, the meat produced rises to 3,916 kg/ha/year. In similar savannah conditions, using improved pastures (*Brachiaria*), cattle produce around 130 kg meat per year.

These results show that there is a much greater range of potential for the use of savannahs, without having to transform all the characteristic conditions of the ecosystem.

Ethology

The following account of the behaviour of the animals was observed:

- **At the introduction of the pigs to the experimental area, they began to explore the ground by moving around the whole area.**
- **The pigs stayed in a group, defined their social organization, established their rank: those which fed first and the lower rank ones which fed second.**

- **The pigs selected certain places for rooting and used the same place daily so as to convert it into a mud patch.**

- **Under these conditions, the body condition and health of the pigs was good. It should be noted that no form of medication was used throughout the trials.**

- **The consumption of water varied over time. On sunny days it was 12 litres/animal/day and 6 litres per day on dull days.**

- **The pigs consumed various plant species that were available in the experimental field, including mainly: *Salvia palaefolia, Anturium* spp. and *Pueraria phaseloides*.**

Monitoring of Physical and Chemical Conditions of the Soil

The physical and chemical conditions of the soil were monitored over a period of 16 months, the time which carried it to the end of three phases of the trial.

Soil analysis showed that the texture was maintained in the range of less than 20% clay and more than 60% sand. The increase in soil organic matter (although small) is significant, considering the short monitoring time and the soil conditions in the region. The tendency is to increase organic matter, a condition which would favour water retention and reduce the impact of the dry season on the soil and production.

With respect to minor nutrients, there were deficiencies of copper and zinc, although the tendency is to increase with time; manganese was within the acceptable range and iron was normal for this type of soil (oxisol). The pH tends to reduce, possibly due to the increase in organic matter.

In general, it can be said that the changes recorded in the experimental area are favourable, however small because of the short timescale, and tending to improve with time.

Biological Activity of the Soil

In order to monitor biological activity of the soil, samples of the invertebrate population were taken periodically throughout the same 16 month period.

Very interesting results were observed in the changes in the invertebrates (Table 5), showing notable differences in the number and diversity of species present in the experimental site, monitored before and after the presence of the pigs, and also according to the season (summer/winter).

More than 9 different species of invertebrates associated with the soil in the experimental area are reported.

To show comparative effects, a control site was established outside the experiment. After a series of samples were taken at the same time as in the experimental area, no associated invertebrates were found.

In general terms, the presence of the pigs increased the biological activity in the study area, in response to the physical disturbance of the soil by the rooting of the animals and a greater supply of organic matter.

Table 5. Invertebrate populations (per sq m)

	1/95	6/95	9/95	12/95	3/96
Earthworms	0	7	99	37+e	102+e
Scarabid larvae	41	20	53		
Adult Scarabids	0	0	0	0	4
Centipedes	0	1	10	6	62

Ants	+	+	++	+++	+++
Termites	0	0	++	+++	+++
Coleoptera	0	0	14	6	91
Hemiptera	0	0	5	0	12
Carabid larvae	0	0	6	4	71
Adult carabids	0	0	0	0	3
Lepidoptera larvae	0	0	7	1	9
Elaterid larvae	0	0	0	0	6
Adult cicindellidae	0	0	0	0	3
Asilid larvae	0	0	0	0	2

+e = earthworm eggs

The results are variable depending on the time of year. In the first sample (January-Summer), no biological activity was found in either the experimental zone or the control site. Different results were found in December, also in summer, when biological activity was shown in the experimental site but not in the control area. The difference appears to depend on the presence of the pigs in the experimental area and the growing biological changes that this initiates in the soil. The greatest biological activity was found in the rainy season (July-September and May) which

favoured soil moisture and living organisms in the soil.

Economic Analysis

The profitability per pig in phases 1 (USD 19.3-24.6) and 2 (USD 20.0-26.2) was good. In phase 3 (USD 4.7-8.3), the results were not so favourable as a result of the low level of prices in Colombia which failed to meet the costs of production, possibly due to the market crisis caused by imports of pigmeat from other countries, a problem which was critical to all pig producers at the time.

The biological and economic results are highly relevant, because it is difficult to find such results with out-door pigs. There is an urgent need to confirm the recommendations for this system.

It must be noted that, although the reported profitability is good with respect to pigs alone, it also provides an alternative method of pasture management that does not require high initial capital for installations. Furthermore it does not indicate the other economic and environmental advantages conferred by the presence of pigs. These include the improvement of soil conditions, increase in biological activity, the encouragement of desirable species and the effect on subsequent production.

Pig production based on the system described also plays an important role in furthering the processes of regeneration of pasture and greater capacity for seed development of the species present in the area: the pigs exert a scarifying effect on the seed, increasing its viability. The direction in which this leads suggests a dynamic increase in productivity starting with pigs production, through the greater organic activity which it stimulates to achieve additional benefits in pigmeat production, as well as greater vegetation cover.

Currently, work is in progress to collect the data on agricultural production in areas previously exploited by pigs, and to construct a model for the integral use of natural savannah soils. This will involve crops that are exclusively managed within the concept of organic farming, with a view to implementing a sustainable system with integrated use of resources. The proposed rotations are: pigs-maize- cowpea; african palm-cowpea; and pigs-cowpea-maize-palm. During the establishment of the african palms and throughout their productive life, cowpea and soya are

produced in the alleys; the design for this involves the planting of 100 palms per hectare. It is also possible to consider other perennial crops besides palms, with the criterion that they produce biomass which may be included in the pigs' diet.

New Advances in Pig Production

With the help of FAO, two experiments have recently been carried out on the feeding of fattening pigs, incorporating forage sources in the diet as partial substitutes for the protein normally provided by soyabean meal. The diets used have crude african palm oil as the principal source of energy.

The first experiment evaluated the partial replacement (20%) of the protein (200 g/day) by *Azolla filiculoides* and leaves of *Trichanthera gigantea*, as well as offering crude palm oil either ad lib or restricted. Sixteen animals per treatment were used over the complete fattening cycle (126 days).

Table 6. Average results for pigs fed diets with *Azolla filiculoides*, *Manihot esculenta* (cassava) and *Trichanthera gigantea*.

	T1	T2	T3	T4
Live weight kg				
Initial	23.6	24.5	24.2	24.4
Final	86.6	87.5	83.4	87.4
LWG g/day	0.500	0.500	0.470	0.500
Intake kg/day				
Soya bean cake	0.500	0.350	0.350	0.350

T. Gigantea	0.0	1.2	0.0	0.0
Azolla	0.0	0.0	3.0	0.0
Manihot esculenta	0.0	0.0	0.0	1.5
Palm oil	0.450	0.450	0.450	0.450
Rice polishings	0.175	0.175	0.175	0.175
TOTAL	1.125	2.18	3.98	2.48
DM	1.04	1.2	1.05	1.14
FCR (DM)	2.08	2.4	2.23	2.28

Animal performance was slightly better when they were offered leaves of Trichanthera gigantea as a substitute for the protein provided by soyabean meal, a very interesting result in relation to the design of integrated production systems in which the tree component plays an important role.

This experiment showed that supplying a higher level of energy from african palm oil (T1 and T4) did not lead to a large response by the animal, but it significantly raised the costs, reduced the quality of the carcass by producing a large amount of fat and affected the feed conversion efficiency. It appears that pigs respond better to an adequate balance of the sources of energy (fatty acids and carbohydrates) that is well provided by the medium treatments (T2 and T3) and the relation between the content and quality of the protein in the diet.

Another experiment, evaluating three forage protein sources as substitutes for 25% of the soya protein (200 g/day) by means of giving Azolla filiculoides (DM 5%, CP 25%), Trichanthera gigantea (DM 25%, CP 18%) or cassava

leaves (DM 16%, CP 22%) in a diet based on crude palm oil and a strategic input of rice polishings, demonstrated the viability of introducing forages in diets where the source of energy was principally provided by crude palm oil.

Table 7. Average results for pigs fed diets containing *Azolla filiculoides* and *Trichanthera gigantea*.

	T1	T2	T3	T4
Live weight kg				
Initial	23.9	23.1	23.5	26.2
Final	89.1	80.1	82.8	93.1
LWG g/day	0.517	0.453	0.470	0.530
Intake kg/day				
Soya bean cake	0.400	0.400	0.400	0.400
Azolla	1.6	1.9	0	0
T. gigantea	0	0	1.0	1.0
Palm oil	1.3	0.450	0.450	1.3
Rice polishings	0.200	0.200	0.200	0.200
TOTAL	3.3	2.95	2.05	2.9
DM	1.85	1.06	1.21	2.02
FCR (DM)	3.5	2.33	2.57	3.82

Animal performance was not affected by substituting 25% of the traditional protein. It is particularly attractive to

use the leaves of cassava which can be done as an integral use of this resource during the growing stage of the crop.

In all cases, excluding feed conversion efficiency, the results were as good as those given by the standard recommendations for pigs based on cereals and traditional sources of protein, with total inputs far higher than those reported here. In this sense, the concentrated input of energy in the form of fatty acids (african palm oil) performs a strategic role in the feeding system that is proposed.

These alternatives permit the pig producer to achieve a good level of integration of production and, at the same time, a greater independence from external factors and inputs to the system, which allows greater economic sustainability and productivity. This tendency can be even better when the production of the oil palm is included as the central energy component of the production unit, achieving a higher level of autonomy in the production cycle and allowing a growing level of integration.

Finally, it is important to point out the simplicity of the proposed feeding system, which can be implemented by any producer without the need for special equipment or machinery. Also, when offering this kind of diet, it is possible to carry out the management operations on the pigs in the morning only.

Advances in Fattening Broilers

Having in mind the design of a feeding system for fattening broilers in semi-confinement associated with established perennial crops, a system has been evaluated which uses crude palm oil as the basic energy source together with fortified soyabean meal (soyabean meal 97.5%, tricalcium phosphate 2%, mineral/vitamin mix 0.3% and sodium hydroxide 0.2%) as the protein source (Ocampo *et al*., 1995; Ocampo *et al*., 1996).

The birds were managed in the traditional commercial way up to the third week, when they received a commercial concentrate, and were housed in confinement with heating. From the fourth week, they were offered the experimental diet and the birds went out to pasture between the trees.

Two types of diet were evaluated initially: diet A which consisted of a 1:1 mixture of crude palm oil and soyabean meal fortified with minerals and vitamins, with a maximum intake equivalent to 70% of the expected consumption on commercial diets (determined from 3 initial experiments) and diet B which included a 1:1 mixture, of which one part consisted of 80% palm oil and 20% rice polishings and the other part of fortified soya with minerals and vitamins, offered *ad libitum*.

Following a total period of 49 days, the results were as follows: Diet A - mean final weight 1,939 g, cumulative FCR 1.68, killing-out percentage 78.55, with average daily intake of 539 g; Diet B - mean final weight 2,016 g, FCR 1.64, KO% 75.4 and daily intake 604 g.

After that, *Azolla filiculoides* was included in the diet to appetite with the birds allowed to adjust their protein intake on a free-choice basis. Azolla was offered fresh after a period of draining for 3 hours after harvesting.

The diets A and B remained in the design and only the addition of Azolla was different. The results were as follows: Diet A - final weight 1,804 g, FCR 1.79, KO% 75, intake of supplement 500 g and intake of Azolla increasing from 40 to 163 g/bird/week; Diet B - final weight 1,963 g, FCR 1.77, KO% 76, intake of supplement 698 g and intake of Azolla from 39 to 176 g/bird/week.

The results with fattening broilers have been good, it being important to note that the birds were at pasture from the start of the fourth week, which is interesting from the point of view of integrated systems. As a result of the management given, the welfare of the animal was evident; the birds not only performed well in biological and economic terms but it was possible to achieve this with a happy chicken!

Results with Hair Sheep

Finally, it is interesting to relate the results of an investigation with hair sheep as the focus of the basic production system (Ocampo A, Monje S and Pineda C, 1996).

In order to understand the results, the components of the system are presented: the inputs, by-products and outputs

from the system.

***Components*: total area 4,828 sq m (3,264 sq m under shade and 1,564 open), duration of study 405 days, 54 trees of the species *Erythrina poeppigiana, Brachiaria decumbens* pasture, 10 ewes and 1 ram, a building and standard sheep management.**

***Inputs*: 860 kg high energy blocks (with 10% palm oil similar to those described for cattle), labour, 8900 litres of drinking water, and 3,240 kg rice husk bedding.**

***By-products*: 4,131 kg organic compost from the floor of the building, which had a contribution of organic matter of 1,367 kg, sheep manure 233.8 kg, plant material not consumed by the sheep 503.5 kg, biomass production from *Erythrina* leaves 629 kg (equivalent to 31.6 kg protein) and 2,230 kg of *B. decumbens*.**

***Output*: 286 kg sheep meat and their skins.**

If the meat producing capacity per unit area from the proposed system and the farm is analysed, the benefits are obvious: hair sheep system 42.3 kg/ha/month and 507 kg/ha/year; beef system 13.75 kg/ha/month and 165 kg/ha/year. The production is significantly higher with the hair sheep. This demonstrates the possibility that small and medium sized producers could really achieve high levels of profit from hair sheep and that it is made possible as a result of integration of the different components within the production unit.

Conclusions

There are good opportunities to achieve high levels of production in tropical countries based on the growing of oil palm, which particularly favours a high degree of integration within the production unit and with diversification as a basic factor.

This line of research is likely to lead to the incorporation of trees and perennial crops, and to the better utilization of biomass due to improved energetic efficiency and the exploitation of biodiversity and integration, allowing

tropical countries to capitalize on their comparative advantage and evolve more efficient production systems.

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Excess Feeding of Stovers from Sorghum and Maize for Small Ruminants and Cattle in Cereal-based Integrated Farming Systems in Africa

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Abstract

Surveys of small-scale farmers growing sorghum in Ethiopia and maize in Kenya showed that stover was used as livestock feed during the dry season. Feeding method generally involved offering crudely-chopped (i.e. machete), stover in large quantities, with refusals either re-offered to less valuable animals (eg. donkeys in Ethiopia), and/or used as fuel, mulch or compost with excreta. Experiments were undertaken to quantify the effect of varying extents of excess feeding on stover intake and livestock production; cottonseed cake and minerals supplementation was provided. In Ethiopia, using machine-chopped sorghum stover, sheep offered 25, 50 or 75 g stover/kg live

weight (M), daily (d), increased their intake and growth rate with increasing excess rate (intake, g DM/kg M.d: 22.1, 31.1 and 32.5; growth rate, g/d: 28.2, 54.1 and 62.2). With increasing excess rate, sheep consumed more leaf and less stem. Amount of stover refused also increased with excess rate (g/kg offered: 51, 318 and 526). Goats responded similarly. In another study, the effects of increasing the excess rate (25 vs 50 g/kg M.d) and chopping were additive in improving intake and growth rate of sheep. However, with cattle, chopping reduced intake of stover, but increasing the excess rate of unchopped stover improved performance. In a comparison of stover from a bird-resistant and non-bird-resistant variety, there was no difference in intake by sheep, but in the same trial, increasing the excess rate from 25 to 50 g/kg M.d increased intake. In Kenya, when mid-lactation, cross-bred cows were fed minerals and 3.2 kg DM/d cottonseed cake and offered 30, 60 or 90 g DM/kg M.d of unchopped maize stover, intake of stover (kg DM/d: 8.1, 11.3 and 13.2) and yield of milk (l/d: 10.0, 11.3 and 12.3) increased with increasing excess rate. The experiments demonstrate improved animal productivity from an excess feeding-rate strategy for sorghum and maize stovers. It is concluded that integrated farming systems involving excess feeding strategies now need to be modeled, so that interventions to improve the systems may be identified. However, to develop the models, it will be necessary to generate further input/output information, especially regarding strategies for utilising refused stover.

KEY WORDS: Excess feeding, straw, sorghum, maize, stover

Introduction

Farmer group surveys in sorghum-growing areas of Ethiopia (Nazret, Eastern Hararghe and Ada) showed farm sizes to range from 1.6 to 5 ha, with up to 54% of the cultivated area in sorghum (Osafo, 1993). Despite problems of grain damage by birds, farmers preferred local, non-bird-resistant varieties of sorghum to modern, bird-resistant ones, because of higher palatability of grain and more drought resistance. Sorghum stover and teff straw were major livestock feeds in the dry season, with draught oxen and milk cows having priority over small ruminants and donkeys, in access to crop residues. Stover feeding involved in situ grazing and stall feeding, the latter using either long stover, or crudely chopped (i.e. machete). Stems were used for fencing. Because of acute shortage of

fuelwood, uneaten stover was used as fuel, often mixed with cow faeces and tree leaves (e.g. Eucalyptus). There was little use of residues for mulching or composting.

Surveys (Methu *et al*., 1996; Wais, 1996) showed that smallholder dairying in Central Kenya Highlands (Kiambu) based on cut-and-carry feeding with exotic dairy breeds (mainly Friesian and Ayrshire), is a major enterprise on small-scale (2 ha) farms. Crops grown involve Napier grass (0.8 ha), maize (0.36 ha, two crops per year) and horticultural crops. Except in the dry season, napier grass is the major basal component of dairy rations. Maize stover (approximately 2.6 t DM/ha.year) could play a larger role in dry-season feeding if problems of low intake and low nutritive value were alleviated. Omore (1996) reported milk yields averaging only 5.8 kg/d over lactations extending beyond 24 months. Concentrate feeds from commercial dairy meals, cereal brans and oilseed cakes were purchased by over 70% of farmers, but concentrates were fed at very low levels.

In both Ethiopia and Kenya, there was no evidence of farmers adopting technologies such as urea-ammonia treatment of sorghum and maize stovers to improve intake and nutritive value. Farmers surveyed in Kenya were unaware of residue upgrading technologies (Methu *et al*., 1996). This confirms the earlier findings of Owen and Jayasuriya (1989) and the recent conclusions of Devendra (1996).

Research by Wahed *et al*.(1990) using barley straw, and Zemmelink (1980) using tropical grasses and legumes, showed that an `excess feeding' strategy resulted in increased intake of digestible organic matter. In view of this, a series of experiments was conducted with sorghum and maize stovers to investigate whether excess feeding would increase intake and productivity of ruminants. It was hypothesised that this approach would provide an adoptable and sustainable strategy for alleviating the problem of low nutritive value of stovers.

Experiments Undertaken

The Excess Feeding Approach

The method involved offering differing amounts of stover, on the basis of the live weight (M) of animals, such that

the proportion refused increased dramatically above the conventional ad libitum rate of 0.15 kg refused/kg offered. Except for one experiment (Osafo *et al*., 1993a), supplements of cottonseed cake and minerals were provided. Measurements were made of the quantity and quality (botanical fractions) of stover offered and refused.

Three experiments with sorghum stover were conducted at the International Livestock Research Institute (ILRI), Debre Zeit, Ethiopia and one with maize stover at the Kenya Agricultural Research Institute (KARI), Muguga, Nairobi.

Experiment 1: Effects of Amount of Chopped Sorghum Stover Offered in Goats and Sheep

The stover used (Seredo, bird-resistant variety) was coarsely chopped using a tractor-driven chopper (Alvan-Blanch Maxi chaff cutter). Both goats and sheep increased their intake of stover with increasing amounts of stover offered, and this was reflected in increasing growth rates (Table 1). As the amount offered increased, the content of leaf and sheath in the stover consumed increased and that of stem decreased, indicating selection for the more nutritious leaf and sheath components. Also clearly evident, was the increasing proportion of refused stover as the amount offered increased (Table 1).

Table 1: Effects of amount of chopped sorghum stover offered, in goats and sheep in Ethiopia (Aboud *et al*., 1993)

	Goat			Sheep		
Amount offered (g/kg M.d)	25	50	75	25	50	75
Number/treatment	7	7	7	8	8	7
Initial weight (M) (kg)	15.4	16.3	16.3	14.7	16.3	16.5
Stover refused (kg/kg offered)	0.15	0.43	0.57	0.05	0.32	0.53
Stover intake (1) (g DM/kg						

M.d)	19.9	26.3	29.1	22.1	31.1	32.5
Growth rate (1) (g/d)	9.4	23.4	31.6	28.2	54.1	62.2

(1) Measurements over 75 d following a 21-d preliminary period, supplements given: 150 g/d cottonseed cake and mineral licks; s.e.d. for stover intake, 1.09; s.e.d. for growth rate, 8.70

Experiment 2: Effects of Amount of Stover Offered and Chopping in Sheep and Cattle

The stover used was a non-bird-resistant variety (Dinkamash). Both sheep and cattle showed greater intakes when the amount of stover offered was doubled, and this was reflected in increased growth rates (Table 2). However, chopping increased intake in sheep, but decreased intake in cattle. This result has an important practical implication in view of the fact that chopping (albeit ill-defined) is widely advocated when feeding sorghum and maize stovers.

Experiment 3: Effects of Amount of Chopped Stover Offered and Variety of Stover in Sheep

Experiment 3 tested the hypothesis that stover from bird-resistant sorghum would be less nutritious than stover from non-bird-resistant sorghum because of the higher anti-nutritive factors in bird-resistant varieties (Reed *et al*., 1987). Table 3 shows that although digestibility was lower in the bird-resistant stover, intake was unaffected. This was probably due to the higher leaf-plus-sheath to stem ratio in the bird-resistant stover used.

Table 2: Effects of amount of stover offered and chopping, in sheep and cattle in Ethiopia (Osafo *et al*., 1993b)

	UNCHOPPED		CHOPPED	
Amount offered (g/kg M.d)	25	50	25	50
SHEEP (1)				

No. of pens (2)	4	4	4	4
Initial weight (M) (kg/pen)	51.8	51.0	50.4	51.2
Growth rate (3) (g/animal.d)	30.5	56.0	45.8	70.5
Stover offered (kg DM/pen.d)	1.25	2.56	1.23	2.60
Stover refused (kg/kg offered)	0.21	0.52	0.11	0.38
Stover intake (4) (kg DM/pen.d)	0.98	1.24	1.08	1.60
Stover intake (g DM/kg M.d)	18.9	24.3	21.4	31.3
CATTLE (5)				
No. of steers	8	8	7	8
Initial weight (M), kg	204	204	200	203
Growth rate (6) (kg/d)	0.25	0.43	0.36	0.44
Stover offered (kg DM/d)	4.9	9.5	5.1	9.9
Stover refused (kg/kg offered)	0.24	0.51	0.29	0.62
Stover intake (7) (kg DM/d)	3.7	4.7	3.6	3.9
Stover intake (g DM/kg M.d)	18.1	23.0	18.0	19.2

(1) Measurements over 56 d, supplements given: 310 g/d cottonseed cake and mineral licks;

(2) 3 rams/pen;

(3) s.e.d. 4.86;

(4) s.e.d. 0.100;

(5) measurements over 49 d, supplements given: 800 g/d cottonseed cake and mineral licks;

(6) s.e.d. 0.083;

(7) s.e.d. 0.22

Osafo (1993) found large variation in the leaf-plus-sheath:stem ratios between varieties of both bird-resistant and non-bird-resistant sorghums. Experiment 3 involved offering stover without supplementation to simulate farmer practice. It is notable that sheep offered the higher rate of stover maintained weight.

Table 3: Effects of amount of chopped sorghum stover offered and variety of stover, in sheep in Ethiopia (Osafo *et al*., 1993a)

Variety	Non-bird resistant (1)		Bird resistant (2)	
Amount offered (g DM/kg M.d)	25	50	25	50
INTAKE TRIAL (3)				
No. of rams	12	12	12	12
Initial weight (M) (kg)	20.0	20.1	20.1	19.9
Growth rate (4) (g/d)	-25.3	3.5	-16.1	-4.0

Stover offered (g DM/d)	548	1019	537	1011
Stover refused (kg DM/kg DM offered)	0.13	0.38	0.11	0.38
Stover intake (5) (g DM/d)	474	633	478	628
DIGESTIBILITY TRIAL (6)				
No. of rams	4	4	4	4
Live weight (M) (kg)	17.8	18.2	17.8	17.0
Stover offered (g DM/d)	622	1093	619	1067
Stover refused (kg DM/kg DM offered)	0.13	0.39	0.10	0.37
Stover intake (g DM/d)	544	670	558	676
OM digestibility (7)	0.58	0.56	0.53	0.54
NDF digestibility (8)	0.61	0.57	0.55	0.55

(1) Mixture of Dinkamash and 76T123 varieties), leaf-plus-sheath:stem, 0.82;

(2) Seredo, leaf-plus-sheath:stem, 1.25;

(3) measurements over 42 d, supplement given: mineral licks only;

(4) s.e.d 6.2;

(5) s.e.d. 16.0;

(6) measurements over 7 d, supplement given: mineral licks only;

(7) s.e.d. 0.024;

(8) s.e.d. 0.029

Experiment 4: Effects of Amount of Maize Stover Offered in Milk Cows

In both Latin squares, intake of maize increased as the amount offered increased, and this was reflected in greater milk production, though responses were non-significant (Table 4). The proportions of leaves and husks in the stover consumed were greater than in the stover offered, suggesting selection for these components as opposed to selection against stems and sheaths. As in Experiments 1 to 3, the proportion of stover refused increased markedly with increasing offer rate. The milk yields achieved in this experiment, from mid-lactation cows on a basal diet of maize stover, were substantial, although it is acknowledged that 3.2 kg DM/d cottonseed cake was fed.

Conclusions

The experiments confirmed the hypothesis that excess feeding of sorghum or maize stover is a method of increasing intake and productivity of small ruminants and cattle, thus alleviating the problem of low nutritive value of stovers.

At first sight, the large amount of refused stover generated by excess feeding would be conceived as unsustainably wasteful. However, as indicated by surveys in Ethiopia, residues uneaten by ruminants have a value as feed for donkeys or substitute for fuelwood.

Stovers refused in an in situ grazing system would be available for soil incorporation to increase organic matter (Powell *et al.*, 1995). However, refused stovers, which would tend to be dominated by the stem fraction, would

contain high C:N ratios. Not only are such residues slow to decompose under field conditions, but may also immobilise mineral nitrogen making it unavailable for plant growth.

In Kenya refused maize stover is used as bedding in zero grazing units. Farmers combine urine-soaked stover with cattle faeces in heaps or pits for composting prior to application to crops. Collaborative research being conducted by KARI and ILRI is currently examining how interactions between the quality of diets based on maize stover, bedding, manure management and composting techniques influence the quality of organic fertilizers produced.

Table 4: Effects of amount of maize stover offered, in lactating cows in Kenya (Methu *et al*., 1996)

	1994 stover (1)			1995 stover (2)		
Amount offered (g DM/kg M.d)	29	57	87	33	60	87
Live weight (M) (kg)	425	436	439	424	438	437
Stover offered (kg DM/d)	12.3	24.7	38.2	13.8	26.5	38.0
Stover intake (3) (kg DM/d)	8.3	11.5	13.2	7.9	11.0	13.2
Stover refused (kg DM/kg DM offered)	0.32	0.54	0.65	0.41	0.58	0.65
Milk yield (4) (kg/d)	11.2	11.3	13.0	8.8	11.2	11.5
Stover Offered (%)						
Stem	42	42	42	50	50	50
Leaf	17	17	17	12	12	12

Sheath	15	15	15	13	13	13
Husk	25	25	25	24	24	24
Stover Consumed (%)						
Stem	19	21	31	20	12	20
Leaf	24	28	29	18	19	17
Sheath	23	12	6	22	20	9
Husk	34	39	34	40	49	54

(1) 3 Ayrshire cows in 3x3 Latin square, 24 d/period, supplements given: 3.2 kg DM/d cottonseed cake and 150 g/d mineral premix;

(2) 3 Friesian cows in 3x3 Latin square, 24 d/period, supplements given: 3.2 kg DM/d cottonseed cake and 150 g/d mineral premix;

(3) s.e.d. for Ayrshires, 1.12, s.e.d. for Friesians, 0.46;

(4) s.e.d. for Ayrshires, 1.54, s.e.d. for Friesians, 0.71

Under the intensive farming systems practised in the highlands of East and Central Africa, excreta is a highly valued output of the livestock sub-system.

In Indonesia, excess feeding of indigenous forages is already practised by farmers with the main intention of maximising yield of manure-compost production made from refused forage and excreta (Tanner *et al*., 1996). In Indonesia, excess feeding therefore not only increases animal productivity per se, but also maximises outputs from the livestock enterprise which are of benefit to crops.

There is a need to model input-output relationships concerning the excess feeding approach and the use of supplements in order to optimise the sustainable use of sorghum and maize stovers in cereal-based integrated farming systems in Africa and elsewhere.

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Integration of Livestock in the Sugarcane Industry in Cuba

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Abstract

The Cuban sugarcane industry comprises a total of 1.8 million hectares dedicated to sugarcane for sucrose, produced in 156 sugarmills on the island. An additional 188 thousand hectares, is used to produce agricultural produce, milk, meat, poultry and eggs in order to help feed part of the half-million size workforce. For this, 94 thousand hectares are dedicated to food crops and animal feeds, while a similar amount of land is used for pastures and forests. The economic recession of the early nineties has stimulated the development of sustainable agricultural policies for producing livestock in the sugarcane-sector.

All of the sugarcane ground in the mills is produced in two types of cooperatives: 1) 1300 Basic Units of

Cooperative Production (BUCP), newly-formed in 1993 from the previous state-run and sugarmill- administered cane plantations, and 2) 400 Agricultural Production Cooperatives (APC), originally formed by private landowners into a cooperative organisation 20 years ago. Presently, 80% of all sugarcane entering the mills is produced by the 1300 BUCPs and 20% by the APCs and other private owners. In addition to the production of livestock in the 1300 newly-formed cane cooperatives, approximately 200 state-run farms, administered directly by the sugarmills and other sugarcane service industries, such as transport, construction and maintenance, also maintain livestock. Presently, in both areas, the cane coops and state farms, new emphasis is being placed on the use of sugarcane and its derivatives, soybeans, forage trees and multinutritional blocks for feeding livestock.

In December 1995, there were 72 thousand pigs, 188 thousand sheep, 4 thousand goats, 16 thousand rabbits, 6 thousand ducks, 21 thousand horses and 122 thousand head of cattle, including oxen. That same year a total of 8.7 thousand tons liveweight was produced, in addition to 1.6 thousand tons of fish and 20 thousand tons of milk.

KEY WORDS: Livestock, sugarcane, integration, Cuba

Introduction

The Cuban sugar industry, until the economic recession of the early 1990's, produced during 6 months of each year, from December to May, approximately 10% of the world annual production of crude sugar. For this, 70 million tons of sugarcane, harvested from 1.8 million hectares, were processed in 156 sugar mills into approximately 8 million tons of crude sugar and 2 to 2.5 million tons of final molasses. The basic division of all agriculture on the island is "cane" and "non-cane" and, in 1983, the government encouraged the "cane" sector, which employs 450 thousand workers or 12% of the entire active workforce, to set up crop and animal production systems to help feed the workers, and eventually their families. Ever since the introduction of this crop in the island, food for cane workers was mostly imported. By 1985, reproductive and productive livestock herds had been organized in all 156 sugar mills and other major service industries, to include: swine, rabbits, poultry, sheep, goats and cows (Table 1).

Until 1990, in addition to 450 sugarmill farms that produced crops and livestock, the sugar industry produced for the "non-cane" sector a total of 4.5 million tons of animal feeds, in 11 different products and when mostly needed, during the 6-month-long dry season. These included: 500.000 MT of 3% molasses-urea; 200.000 MT molasses-urea-bagasse; 325.000 MT hydrolysed bagasse pith; 400.000 MT each of B molasses and protein molasses, mostly for pigs, and 80.000 MT of Torula yeast. However, by 1995, due to a drastic nation-wide economic cutback, reflected in the lack of urea and caustic soda for hydrolysing and processing bagasse, and problems in transporting such highly fibrous feedstuffs to the feedlots, the production of most animal feeds was curtailed.

Table 1. Integration of livestock in the Cuban sugar industry

	1985		1990		1995	
	reprod.	total	reprod.	total	reprod.	total
Swine	9365	63646	12387	108231	10994	72244
Sheep	38731	87015	105050	228294	86058	187562
Goats	1593	3552	1702	3879	1507	3667
Rabbits	-	-	10167	41628	4046	16473
Ducks	-	-	-	2961	3028	5900
Horses	4017	34587	3817	30332	5547	20713
Cattle	2059	23069	14990	56655	30533	122641*

*** includes a total of 79 thousand oxen: 29,267 working pairs; 5879 pairs in full training and 6399 pairs beginning training (requirement: 33 thousand pairs)**

Land Tenure, Livestock and Food Production

Land Tenure

Due also to the economic recession, land tenure was drastically affected and most of the previously state-run agricultural enterprises, including the sugarcane plantations, were reorganized into cooperatives, called Basic Production Cooperatives (BPC). Formerly, 82% of all land in agriculture, including sugarcane, had been managed by the state, however, after the readjustment, this figure had dropped to 33 percent. Moreover, while the average size of the state-run sugarcane plantations had been between 12 and 13 thousand hectares, the 1300 newly-formed coops were assigned, each, slightly more than one thousand hectares (ONE 1994). Presently, 80% of all sugarcane entering the mills is produced by the BPCs and 20% by Agricultural Production Cooperatives (APCs) and other private owners. Livestock production is now in the in the hands of the newly-formed cane coops and in approximately 200 remaining farms which are managed directly by the sugar mills and other service industries, such as transport, construction, maintenance and the research institutes (Tables 2 & 3).

Table 2. Food program* of the Cuban sugar industry

Crops	Amount		Animal products	Amount	
	g/d	kg/yr		g/d	kg/yr
Rice**	115	36	Meat (w bone)	145	30
Beans **	58	18	Fish (cleaned)	150	8
Tubercles ***	500	156	Eggs	2/wk	104/yr
Fresh vegetables	170	35	Fat	20	6
Fresh fruits	230	48	Milk	1/4 l.	78

*** breakfast and/or lunch while at work; ** uncooked; *** unpeeled**

Livestock and Food Production

Two factors, which occurred almost simultaneously, caused a revamping of conventional agricultural livestock policies, towards the promotion of alternative or sustainable agricultural policies in the sugar industry. The first was: in order to develop livestock in the newly-formed cane coops, the government decided that most of the animals belonging to the former state cane plantations should be handed over to the coops. The new coops had little other than cane, consequently, they were receptive to new ideas related to using cane for feeding their livestock.

The second factor was that, when the sugarcane plantations were broken up, besides the sugarmill farms losing all of their cane and most of their animals to the coops, they no longer had sufficient sugarcane for their remaining livestock, and had to replant. And that is what they are presently doing, planting sugarcane. These farms might have relied more on molasses to feed their animals, but the economic recession meant less fertilizer and insecticides, therefore much less cane, resulting finally in the need to restrict molasses for use mostly in multi-nutrient blocks.

Table 3. Food production in the Cuban sugar industry (1990-95)*

	1990	1991	1992	1993	1994	1995
Crops, 000 MT	129	145	156	119	142	166
Livestock, MT	6671	6421	6173	5697	5803	6518
Fish, MT	-	268	457	849	1127	1600
Milk, MT	9830	12394	14846	15054	17704	19494

*** in addition, 450-500 t/yr. of cheese**

*** In addition, 450-500 t/yr. of cheese**

At present, in order to reduce basic food importation and feed better the workers, the coops need to produce more livestock. For that, they must use more cane for their animals, more efficiently. They need additional cane grinders and choppers. The remaining 200 sugarmill farms, that have more access to machinery, are re-planting sugarcane specifically as animal feed. A reconsideration of conventional agricultural policies towards alternative or sustainable agriculture is definitely the order of the day (Perez and Rabago 1996) and new emphasis is being placed on the use of sugarcane, soybean forage, protein trees and multinutritional blocks for feeding livestock in a technological package arrangement referred to as a "sugarcane village" for 300 workers (Table 4).

Table 4. Livestock objectives in a "sugarcane village" for 300 workers

Concept	Amount per capita	Reproductive herd	No. animals/day
Milk	1/4 litre/d	20 cows & progeny	30
Eggs	2/week	300 laying hens	300
Poultry	1 per 3 mo.	start 350 every 3 mo.	350
Rabbits	1 per 3 mo.	50 does and 6 bucks	125-150
Mutton	1/4 carcass/yr.	150 ewes and 6 rams	375-400
Pork	1/3 carcass/yr.	20 sows and 2 boars	200
Fish	2 kg per 3 mo.	5000 fingerlings/ha-yr.	-

Towards a Sustainable Agriculture Policy for Livestock in the Sugar Industry

Since the current economic cutback, the number one problem related to livestock production in the sugar industry

has been to provide animals a sufficient daily amount of energy and protein. Prior to the recession, the country imported annually, 1.9 million tons of cereals and protein supplements, and naturally some of these feeds eventually trickled down to livestock in the sugar industry. However, all that disappeared, feedstuff importations remain 30% of the pre-recessional period, and justly prioritized for livestock production in the "non-cane" sector of the country. Therefore, the new emphasis for feeding livestock in the sugar industry is with sugarcane, a crop that although it requires 16 months from planting to reach maturity, is a perennial crop that this country definitely knows, and, if "fractionated", could provide up to 80% of the daily energy needs of most livestock. As protein sources, the emphasis is now on soybean forage, sunflowers (mainly for oil) and protein trees. Multi-nutrient blocks (MNBs) are finally being promoted as a source of non-protein nitrogen for ruminants. The following is a brief description of the state of this program as it relates to a new chapter in the history of the Cuban sugar industry: livestock for half a million workers!

Sugarcane

The proposed "fractionation" of sugar cane for feed and fuel, first proposed in 1986 during an FAO Expert Consultation in the Dominican Republic (Preston 1988), has since then been promoted almost exclusively for animal production, where it has been shown that free-choice sugarcane juice and a restricted amount of a protein supplement can be used for pigs (Sarria *et al*., 1990) and ducks (Men and Su 1992). However, in order for sugarcane to constitute an economically viable livestock production system, the cane tops, 15%, and the pressed cane stalks, 40% of air-dry weight, need also to be used for animal production. For that, the "sugarcane fractionation system" requires little other than protein forage and free-choice MNBs. In support of the "cane fractionation system", is the following recent and fascinating farm study done in Colombia (Molina *et al*., 1995).

The farm study used as an example, an average amount of 28 kg of whole sugarcane, which was chopped and used solely as ruminant feed, or pressed to extract the juice for pigs before the stalks and tops were fed to a group of heifers. The pigs received a daily average of 0.5 kg of soybean meal and 10 kg of fresh cane juice. The heifers on the "leftover fibre diet", received a daily average of 12 kg of pressed stalks, 6 kg of cane tops, 9 kg of protein tree forage (*Gliricidia sepium*), 0.6 kg rice bran and 0.4 kg of poultry litter. They also consumed 0.7 kg of MNBs. The

control (whole cane) diet, also fed to heifers, consisted of 28 kg of chopped, whole sugarcane, in addition to the same ingredients fed to the heifers on the experimental ration.

The same 28 kg of whole cane, "fractionated", produced a total of 1100 g liveweight gain, 500 g with cattle and 600 g with pigs, almost double the 765 g liveweight gain produced on the whole cane heifer ration. This general concept, or strategy, is gaining momentum within the livestock program of the Cuban sugar industry. What has added a certain momentum, or strength, to the overall program, is the fact that farmers can now produce their own "protein", in the form of soybean forage.

Soya Bean Forage

In 1989-90, the Cuban sugar industry initiated a program to plant soybeans in rotation with cane, 5 thousand hectares for seed. It was a failure, due to many reasons: an incorrect planting schedule, lack of inoculants, herbicides and insecticides, and insufficient combines for harvesting, but perhaps more importantly, a lack of basic, farmer-friendly, grass-roots soybean technology. Several months later, and perhaps in part because the soybean program had failed, in a sugarmill in the eastern part of the island, pigs fed diluted B molasses, were offered as a source of protein, fresh soybean plants (PEREZ 1995). They began to grow faster and it was decided to plant soybeans periodically adjacent to the pig barn for this purpose. The idea quickly took hold amongst the other sugar mills of the province and freshly-harvested soybean forage is now being used in more than 150 sugarmill farms and cane coops throughout the entire island for pigs, ducks, rabbits and chickens, and to a limited extent for ruminants, particularly for milk production, until the protein trees are in production.

The technique consists in planting a 7-row plot of soybeans, weekly (Perez and Ochoa 1996). The length of the rows in the plots corresponds to the number of animals to be fed. The distance between rows is 35 cm, half the distance recommended for the production of soybeans for seed. The seeds should be inoculated and each plot requires weekly irrigation. After 8 or 9 plots have been sown, the first plot is ready for harvest. Harvesting must be carried out while the forage is still in the early milk-stage, otherwise, the anti-trypsin factor present in the formed seed, described as a defence mechanism against insects and birds, could affect non-ruminant performance. A

recently-performed, in vitro, digestibility trial of nitrogen in the whole soybean plant was 67% (IIP 1995), which compares favourably to that of soybean meal of 75%, and to forages in general of between 35 and 40 percent. Perhaps, this is a clue to one of the reasons for its success.

Protein Trees

At last, trees are beginning to be recognized as "protein trees" and farmers in both the cane coops and the sugar mills are beginning to refer to them as protein banks. Until recently, these trees, mostly *Erythrina* and *Gliricidia*, were used only for fencing and cut back once yearly, in the early spring. As earlier stated, traditionally, cane farmers were never livestock farmers. Having to produce one's basic needs was, and still is, an entirely new concept, since up until 10 years ago, most food for the cane sector was imported. And because "protein" for animals has been something one normally had to "plant" in the soil, the idea that tree leaves can contain up to 25% protein and be used for cattle is new and difficult to grasp (Perez 1996).

The "non-cane" sector continues to promote the use of *Leucaena* in the form of a swath at 5-metre intervals in pastures, while the "cane" sector, in addition to *Trichantera gigantea*, is promoting *Gliricidia* planted in a double-row arrangement, 0.5 x 0.5m, with a one metre wide band between double rows to facilitate hand cutting (Molina 1993). At present, in more than 70 different sites, this is occurring. Finally, the information that a Vietnamese student, studying in Colombia, fed oxen, in addition to their daily diet of bagasse, *Gliricidia* and MNBs, and got them to move more quickly (Thu *et al*., 1993), was widely disseminated here in a recent island-wide meeting on oxen in the sugar plantation. This information has begun to have wide-sweeping consequences on the use and propagation of protein trees and on the local manufacture of MNBs, and more importantly perhaps, for use in up to 80 thousand oxen in the coming 1996-97 cane harvest.

Multinutritional Blocks

Surely, because the cattle industry in Cuba used so much molasses/urea and other animal feeds, prepared in the sugar mills, MNBs were, for a long period, not promoted. The recession changed all that; in 1995, the production of

cane-based, animal feeds was approximately 10% of that of previous years. One outstanding incident changed the outlook on MNBs. In January of 1993, in the middle of the dry season, and a drastic 70% cutback on the importation of animal feeds, a 200-head dairy reported 101 animals in anestrus. The diet had been reduced to dry-season pasture, supplemented by sugarcane, nothing else. Multi-nutrient blocks were provided. Three months later, still in the dry season, only 8 cows remained in anestrus and the manager of the dairy reported that the animals were consuming more cane.

At present, in about 60 cane coops and sugarmill farms, MNBs are being made by hand, while in the "non-cane" sector, the interest is to perfect machinery for their centralized preparation and distribution. Although the most common formula refers to the use of molasses, one interesting development, particularly in the sugar mills, has been to use limited molasses, up to 50 or 60% fresh filter-press mud, 10% each of urea, minerals and calcium oxide or hydroxide, and no additional fibre.

Perhaps, one of the more eloquent examples of, firstly, the effect of MNBs, and secondly, the effect of MNBs, together with more locally-available feedstuffs, is the information presented in Table 5, obtained over a period of 16 months from a small sugarmill-owned dairy herd of approximately 15 milking cows. At the end of June, 1995, the herd was first exposed to MNBs and, in November, 1995, besides the MNBs, to a mixture of pressed cane stalks, chopped cassava stems, king grass and soybean forage. Milk production has practically doubled, and milking cows, expressed as a percentage of the total herd, has already increased from 57 to 70 percent.

Table 5. Average daily milk production during 16 months (litres/ day)

	J	F	M	A	M	J	J	A	S	O	N	D
1995	-	-	-	4.8	4.6	4.8	6.4	6.2	6.6	6.6	6.5	7.5
1996	7.5	7.9	8.1	8.3	8.1	8.4	8.9	-	-	-	-	-

Guideline to Livestock Feeding Systems

It is impossible to monitor 1300 cane coops and 200 sugarmill farms, all with crops and livestock, and accurately report the results of the recent introduction of alternative and/or more sustainable forms of agriculture. It will be a long process; perhaps, more precise information will be ready for FAO's Third Electronic Conference on Tropical Feeds! Meanwhile, the following is a brief guideline of the different production systems and diets being promoted according to the general livestock objectives set out in Table 4.

Pigs

The reproductive herd is managed at the coop or farm level. Each family receives two weaner pigs/year, one every 6 months, to be fattened mostly on table scraps and other local resources. The cane co-op, or the sugarmill farm, produces the weaners for the families and the pork, and lard, consumed in the collective dining area (Table 2). Energy sources can vary from fresh cassava, sweet potatoes, ripe bananas, cane juice or just plain ground cane, depending upon the time of year and/or available machinery. Protein sources are generally fish or fish silage, torula yeast, some saccharomyces yeast in cream form from the distilleries, but increasingly, whole plant soybean forage, about one metre freshly-cut forage per pig, per day.

Ducks

Surprisingly, ducks will eat the whole soybean plant and only leave the thicker part of the stem which then can be gathered and fed to pigs or sheep. Ducklings are started on one kilogram of dry feed, then switched over to soybean forage, one metre for every 5 ducks, the same amount for rabbits, approximately. As energy, the ducks are fed diluted molasses, cane juice or boiled tubercles.

Rabbits

They are kept in cages. Previously, macro-pellets (a type of MNB, without urea), made preferably with B molasses and a protein supplement, were widely used. However, the soybean forage feeding system is now overtaking the molasses blocks. In one farm, a trial was set up to compare: sweet potato vines, a mixture of sweet potato vines and soybean forage, or only soybean forage. It was impossible to obtain precise information for this report,

however, the farm manager reported best results with soybean forage.

Chickens

Fresh cassava roots and soybean plants, ground finely together in a ratio of 50:50 are beginning to give promising results.

Sheep

The sheep are left to graze mostly in the cane fields to mid-morning, and return in the cool of the afternoon. At night, they are kept in paddocks near the other animals. The farmers are beginning to use MNBs, and as soon as conditions permit, meaning the acquisition of more and simple machinery to chop and crush the cane, and the production of sufficient protein tree forage, hope to keep the productive herd inside in the dry season and feed them a mixture of 80% cane or tops with 20% protein forage, and MNBs. Inbreeding has now been largely controlled by binding tightly the testicles with a piece of rubber tubing at 5 days of age, within several days, they drop off.

Cows

With the creation of the cane coops, and a general movement of workers and their families from a sugarmill-oriented to a coop-style life pattern, there has been an increasing need to produce milk locally. Most of the larger dairies have been broken up into mini-dairies of up to 20-30 cows; at the same time, the government has promoted the sale of both heifers and cows to the newly-formed cane coops. Wire fencing is imported, therefore mostly unavailable to the cane sector; this has meant that the traditional pasture system has been increasingly pressured to use a dry-lot system, particularly in the dry season. Moreover, the interesting work carried out in one sugarmill dairy (Table 5), the fact that cows can produce 9 l/day of milk without imported concentrates and with only locally-available feed resources, is now being replicated in other sugarmill dairies in the remaining 13 provinces. All this has stimulated new interest in MNBs, and in protein trees. In fact, one immediate problem in need of solution is: can *Gliricidia*, which basically does not produce viable seed in Cuba, be started by stake, year round?

Conclusion: Concerns and Problems

In Cuba, because food for the entire sugar industry was mostly always imported, cane farmers for 400 years have only been cane farmers, not cane and livestock farmers. The overall problems that affect a better integration of livestock in the sugar industry in the context of the current Cuban situation, recently affected by a drastic economic recession, are:

1. The fact that, as most Caribbean nations, Cuba imported "temperate belt animal genetics" and did not develop a national feed resource base consistent with the nutritional demands of this type of livestock;

2. The fact that, the entire university agricultural training program must be revamped: a) to produce graduates in sustainable farming systems, and b) to learn to effectively extend positive experimental results to grass-roots level; 3. the fact that, neither the island, nor the sugarcane industry on the island, produces the required quantity nor quality of seeds, nor inoculant, nor sufficient fingerings required to optimize and/or accelerate this unusual and interesting activity. For this, the cane sector must necessarily develop specialized farms at either the provincial or sugarmill level for producing seeds and inoculant, and centres for producing fingerlings (cane sector has 4 000 ha of water); and 4. the fact that, there is insufficient simple machinery, such as, cane grinders and choppers, planters and harvesters, to face the immediate challenge of effectively and rapidly integrating livestock production in the 1300 newly-formed cane coops.

Finally, so as not to end on a pessimistic note, cane farmers, in 1995, received for the first time, a new Cuban sugar-industry-promoted magazine, "Canaveral", devoted to technical information for cane producers, including the production of livestock!

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