New Developments in Livestock Systems based on Crop Residues in China

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Abstract

Since 1992, when livestock based on crop residues was included in the State Agriculture Comprehensive Development Project, significant progress has already been made.

A. A number of State-level demonstration 'counties' with cattle-raising based on crop residues have been established. By 1996, the number had reached 147 counties. Some concentrated and adjoining areas have already developed into demonstration 'prefectures'.

B. Demonstration projects expanded to include sheep-raising, also based on crop residues. Between 1995 and 1996, the State ratified 20 demonstration counties with sheep-raising based on crop residues.

C. Large scale extension campaigns have been carried out on the crop residue treatment technique. In 1995, crop residue silage (anaerobic fermented and preserved corn or sorghum straw whithout heads and ears) reached 75.1 million tons nationwide and ammoniated crop residues, 21.5 million tons. Together they saved about 19.8 million tons of feed grain. 7 million farming households adopted the ammoniated crop residue technique.

D. There has been a large increase in beef and mutton production. In 1995, beef production reached 4.1 million tons, an increase of 25.1% compared to 1994, fulfilling the Eighth Five Year Plan target by 275%, and becoming the most rapidly

growing item in livestock products. For 1996, beef production is forecasted to exceed 5 million tons, and mutton to reach 2.6 million tons, with a continuing high growth rate.

E. Livestock systems based on crop residues provide 1 billion tons of organic fertilizer, which can support 20 million hectares of farmland, not only lowering grain production costs, but also promoting the development of sustainable agriculture.

KEY WORDS: Crop residues, cattle, sheep, straw, urea, silage, manure, China

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Historical Origin

In the last ten years, China's grain production increased by only about 1% annually, but the growth of animal production averaged about 10%. It is obvious that China's grain production can definitely not bear the rapid growth of livestock. The only option is to utilize feeds other than grain, and to establish a grain-saving livestock structure. In the mid 80's, the Ministry of Agriculture (MOA) began establishing demonstration sites for the utilization of crop residues as feed and, in 1987, FAO implemented the TCP project in China for the utilization of crop residues as feed. Both were successful.

In 1990, Guo Tingshuang and 13 other specialists submitted a statement to the Central government, proposing the development of livestock systems based on crop residues to ease the problem of insufficient grain supply in China, to greatly increase beef and mutton production and to partly replace pork. Previously pork made up 80% of consumer meat supply. Beef and mutton would also improve the meat supply structure of the population. This proposal received great attention and approval. In 1992, the State Council ratified the implementation of a demonstration project for cattle raising based on crop residues and 10 State-level demonstration counties were established. This undertaking developed rapidly. By 1996, the number of demonstration counties increased to 147 in 29 provinces.

In 1995, the State extended the successful experience with cattle rearing to the sheep sector. In the same year, the first batch of 6 State-level demonstration counties with sheep (or goat) rearing based on crop residues were established and another 14 were set up this year. Thereafter, sheep production began to develop rapidly in cropping areas. A census showed that, in the first nine months of this year, the total production of mutton reached 1.2 million tons, 34.4% higher than for the same period last year. From now on, both cattle and sheep will be included in the project. In October 1996, the State Council has officially issued the National Development Programme for Livestock based on Crop Residues 1996-2000 and it is now not only the responsibility of the MOA but also an established national policy.

From 1992 onwards, the State Council entrusted the MOA to convene four national conferences to implement the work. 200 million yuan were allocated by central and local governments to be used for the project. At the same time, funds raised by farmers for the same purpose reached well over 10 billion yuan. Urea and polyethylene film were also provided to support this work. FAO and UNDP attached great importance to these projects and supported the work with experts and material resources. In 1993 and 1995, FAO (in cooperation with MOA) convened two International Conference on Increasing Animal Production from Local Resources in China and some FAO specialists and consultants were sent to China to give instruction (Rene Sansoucy, F. Dolberg, E. Orskov, J.C. Chirgwin, F. Sundstol and others). With the efforts of FAO and the Chinese Government, great progress has been made in China.

Major Accomplishments

A. Increase in Beef and Mutton Supply

Between 1992 and 1995, beef production increased by 27.8% annually. By 1995, beef production reached 4.1 million tons, over-fulfilling the Eighth Five Year Plan target by 275%. For the first nine months of 1996, beef production increased by 29.6% compared to the same period last year, and is forecasted to reach 5 million tons by the end of the year. By extending the same principle to sheep (and goat) rearing, China has also increased mutton production which was previously stagnant. The annual growth was 9.9% in 1993, 17% in 1994, and 22% in 1995. In the first nine months of this year, mutton production increased by 34.4% compared to the same period last year.

By developing livestock based on crop residues, vast cropping areas have already taken the place of pastures, and are rapidly developing into China's main base for ruminant production.

B. Economizing on Feed Grain

China produces about 570 million tons of crop residues annually, of which about 25% is used as feed. In 1995, 75 million tons (fresh weight) of crop residue silage (anaerobic fermented and preserved corn or sorghum straw whithout heads and ears) were produced, together with 21.5 million tons of ammoniated straw and stover (Table 1), thus saving nearly 20 million tons of feed grain (calculation of grain-saving is based on the so-called "oat feed unit": 1kg of dry straw equals to 0.2 unit; 1kg of ammoniated straw equals to 0.4 unit; 1kg of fresh straw silage equals to 0.15 unit).

Table 1: Number of farmers treating straw and quantities of treated straw

Year	Farmers (millions)	Treated straw (million tons)
1990	0.8	2.6
1991	1.2	3.7
1992	2.3	7.1
1993	3.8	11.7
1994	5.3	15.9
1995	7.1	21.5

C. Integration of Livestock with Grain Production

Rearing cattle in cropping areas can provide 1 billion tons of farmyard manure which can support 20 million hectares of farmland. The extensive use of farmyard manure can reduce the use of chemical fertilizer, thus not only lowering costs but also improving soil conditions and promoting agricultural production. Fuyang in Anhui Province and Zhoukou and Shangqiu in Henan Province are areas with well established systems of cattle rearing based on crop residues. In recent years, their agricultural growth rate has been well above the national average. Formerly deficient in grain, they are now rapidly achieving grain surpluses.

D. Growth of Industry

The rapid development of cattle and sheep rearing has promoted the growth of the slaughter and meat processing industry, leather processing, and also bone, blood and viscera processing, giving impetus to the marketing of live animals and their processed products. The result has been to provide more jobs in the urban and rural areas, benefiting the farmers, increasing revenue to local governments and putting new vitality into the agricultural and village economy.

E. Disease Prevention and Reduction in Environmental Pollution

Many places along the Yangtze River are schistosomiasis endemic areas. Cattle grazing near the river (as well as lakes and water holes) become parasite hosts. Utilizing ammoniated crop residues to feed cattle, and moving from grazing to stall feeding, breaks the schistosome cycle and helps to control the spread of disease. Also, utilizing more crop residues helps to avoid atmospheric pollution from burning crop residue which is a problem in highly populated areas.

Development Prospects

Although the project of livestock based on crop residues has already achieved impressive results, from the point of view of the extent of resources and the vast market potential, the achievements gained can only be considered as a good beginning. Every year, 570 million tons of crop residues are produced. Up to now, only 25% has been used as feed. Last year, the per capita consumption of beef was only 3.42 kg and less than 2 kg for mutton. The aim is to speed up these developments. In October 1996, the State Council issued the National Development Programme for Livestock Based on Crop Residues 1996-2000 (Outline). Henceforth, the system of livestock based on crop residues became the responsibility not only of the agriculture institutions, but a basic national policy. We can forecast an even greater rate of development in the future.

There are now outline plans to establish 20 demonstration prefectures nationwide, and 400 demonstration counties (250 for cattle and 150 for sheep and goats).

The Outline provides that, by the year 2000, China's beef production will reach 7 million tons, or hopefully 10 million tons. Mutton production will reach 3 million tons, aiming to reach as high as 4 million tons. By then, the proportion of beef and mutton within the total meat production of China will be raised to 20% or so from the present 12%.

By the year 2000, the proportion of crop residues utilized for feed will be raised from the present 25% to about 40% (or 240 million tons). Crop residue silage will reach 120 million tons and ammoniated crop residue 60 million tons, together saving about 40 million tons of feed grain. The ammoniation technique will be extended to 20 million farming households.

By the end of the century, the number of cattle at the year end will reach 167 million head, with 300 million head of sheep and goats. Cattle, sheep and goats would produce 2 billion tons of organic fertilizer annually, which can be used on 40 million hectares of farmland. With the use of large quantities of manure, soil will improve and large areas of stable high yielding farmland will emerge.

Main References

1. Livestock Based on Crop Residues. Shanghai Science and Technology Publishing House, 1995.

2. A Statistical Survey of China (1996). China Statistical Publishing House, 1996.

Feeding Urea and Molasses on a Straw Diet: Urea Molasses Block

vs. Urea Molasses Straw

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Most of the cereal straws are very low in fermentable energy, protein and some macro- and micro-minerals. To optimize the rumen environment of straw fed animals in terms of the availability of readily fermentable carbohydrates, ammonia N and minerals, supplementation of urea and molasses in the form of block or as liquid feed is often suggested (Preston and Leng, 1987). In the Bangladesh Livestock Research Institute, a technique called UMS has been developed where straw is enriched with 3% urea and 15% molasses (on dry matter basis). The relative performance of cattle fed UMS was compared with that of the urea-molasses block (UMB) containing: molasses 55%, urea 10%, rice bran 13%, wheat bran 15%, calcium oxide 6% and salt 1%.

A feeding trial was conducted with 8 native (*Bos indicus*) bulls of approximately 256 kg live weight. Half of the animals were given ad libitum dry rice straw along with UMB (DSUMB) and the other half was given ad libitum UMS (dry rice straw 82%, molasses 15% and urea 3%). Average amount of brans daily licked by the block fed animals was also given to the animals fed UMS. In both groups, data on the rumen fermentation pattern (pH, ammonia-N, DM degradability), intake, digestibility, microbial N yield, growth rate and feed conversion ratio of the bulls were recorded.

Table 1. Degradation characteristics of a straw sample incubated in the rumen of animal fed either DSUMB or UMS.

Items	DSUMB	UMS	SED

Digestion rate (% per hour)	2.29	2.36	0.65
Extent of digestion (%)	49	59	9.8
48 h DM degradability (%)	32	34	3.3
Rumen pH	7.80	7.71	0.12
Rumen ammonia-N (mg/l)	101	173	22.1

Although not statistically significant (P > 0.05), both rate and extent of straw DM degradability were higher in the UMS than the DSUMB. Significantly (P< 0.05) higher rumen ammonia N concentration may partly be responsible for a better rumen environment for straw digestion in the UMS fed animals. Complete mixing of urea, molasses and straw probably provided more available fermentable energy, N and minerals to the microcolonies of bacterial cells attached to the fibre or in the fluid than those provided by the DSUMB.

Table 2. Digestibility (%) of different nutrients in animals fed either DSUMB or UMS

Items	DSUMB	UMS	SED
Dry matter	47	45	1.9
Organic matter	53	50	3.5
Crude protein	53	55	6.6
Acid detergent			

fibre	49	52	1.3

Digestibility coefficients of the different nutrients were not different (Table 2) but the intake of straw DM, digestible organic matter, metabolizable energy and digestible crude protein (Table 3) were significantly ($P < 0.05$) higher in the UMS than in the DSUMB. This is probably due to higher rate and extent of straw DM degradability (see Table 1) with the consequent reduction in the retention time of solid digesta in the former than the latter.

Table 3. Intake of different nutrients in animals fed either DSUMB or UMS

Items	DSUMB	UMS	SED
Straw DM intake (kg/d)	3.95	4.65	0.18
Digestible OM intake (kg/d)	2.16	2.61	0.21
ME intake (MJ/d)	34.1	41.2	3.32
Digestible CP intake (g/d)	279	341	35.3

Table 4. Microbial N yield and growth rate of animals fed either DSUMB or UMS

Items	DSUMB	UMS	SED
Microbial N yield (g/d)	23.8	23.8	3.20
Growth rate (g/d)	93	233	51.8

Feed conversion ratio (g feed/g LW gain)	58	26	22.8

The microbial N yield was similar for both DSUMB and UMS, but the growth rate and feed conversion ratio were significantly better in the latter than the former. These differences in the performances of DSUMB and UMS may not be explained by the differences in nutrient intake per se of the two groups of animals. One of the possible reasons could be that the continuous supply of molasses and urea mixed straw (UMS) may synchronize the supply of energy and amino acids at the tissue level which brings the necessary changes in the hormonal level for better growth and feed conversion efficiency. On the other hand during block preparation, molasses was heated above 70oC in the presence of urea which may lead to the formation of 4-methyl imidazole (4Me-I) causing hyperexcitability in cattle (Tillman *et al*., 1957; Perdok and Leng, 1987). Although bulls in the present trial ate about 600 to 750 g of block/d and did not show any symptoms of hyperexcitability, but 4Me-I may cause unavailability of Ca and Mg to the animals due to chelate with the minerals (Vosloo, 1985). This may also affect the overall performances of animal.

The idea of feeding urea molasses multinutrient block is unique in a sense that in addition to correction of nutritional imbalances of straw diets, transportation of molasses may be done through it. However, blocking of molasses and urea with other feed ingredients incurs costs of manufacturing and its preservation in a hot humid climate like Bangladesh needs the inclusion of preservatives. Thus UMB may not always be the effective method of correcting the nutritional imbalances of ruminants in a subtropical humid situation like Bangladesh. In one of our survey study (Huque, 1993), farmers stated that preparation and feeding of blocks are cumbersome process and possibility of its toxicity can not be ruled out if animals bite them. However, UMS found to be much easy, economic and acceptable method of feeding urea and molasses provided molasses is available to the farmers at a reasonable price.

References

Perdok, H.B. and Leng, R.A. (1987) Hyperexcitability in cattle fed ammoniated roughages. Anim. Feed Sci. Technol., 17:121-143.

Preston, T.R. and Leng, R.A. (1987) Matching Ruminant Production System with Available Resources in the Tropics and in the Sub-tropics. Panambul Books, Armidale, Australia.

Tillman, A.D. Gallup, W.D. and Woods, W. (1957) The utilization of ammoniated cane molasses by sheep. J. Anim. Sci. 15:25-35.

Vosloo, L.P. (1985) Onlangse ontwikkeling op die gebied van ruvoervoorsiening aan herkouers. S. Afr. J. Anim. Sci. 15:86-90.

Introductory paper

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Background

The first FAO electronic conference on Tropical Feeds and Feeding Systems was held in 1995 (Speedy, Dalibard and Sansoucy, 1996). About 200 participants took part from over 50 countries with more than three-quarters being from developing countries.

In this first conference, the evaluation of the nutritive value of tropical feeds for ruminants was reviewed by Leng

(1996) and extensively discussed by the participants. To summarize, there are many data on the chemical analysis and calculated nutritive value of animal feeds but the emphasis has been on grains and supplements used in temperate systems. Far fewer data exist on the less conventional feeds and forages, especially those found in the tropics. Yet, for example, Tanzanian farmers use some 200 species of fodder trees for their livestock (Komwihanilo *et al*., 1995). But even given sample data on alternative feeds, caution must be applied to their use in developing rations and feeding systems.

Firstly, samples of heterogenous materials like forages and fodders are subject to enormous variation. Plant age, component, location and season are among the many factors which may influence the composition. Even if the actual material were analysed, if the animal is given choice, it may select a part of the material which differs from the remainder which it refuses. Secondly, nutrients are NOT additive, especially in ruminant diets. Thus rice straw may have a very low feeding value on its own but when combined with a protein or simple nitrogen source such as urea, can give markedly improved animal performance. Urea treatment of straw can actually improve the availability of energy, which is not reflected in the chemical analysis. Thirdly, many plant materials contain compounds other than nutrients which influence digestion and metabolism of the feed. Non-nutritional factors, such as phenolic compounds, are of principal concern in the case of many tropical plants. They form complexes with proteins and carbohydrates, and in the former case, this includes enzymes. This may be, but is not always, detrimental to the digestion of nutrients.

In short, it was concluded that animal feeding trials are the only sure test of the value of a feed, within a defined system. And the whole ration must be considered, as there are optimal and sub-optimal mixtures of available plant materials, in terms of digestion, metabolism and animal performance.

These basic yet fundamental concepts have been stated by Leng (loc. cit.) but are not yet widely accepted among nutrition chemists who continue to rely on 'feed analysis'. For this reason, a more descriptive approach has been adopted in the FAO Tropical Feeds database (Gohl, 1981; revised Speedy, 1994), together with considerable reference to animal trials and published results.

Other papers in the first conference included those on the strategy for use of renewable natural resources, roughage intake, the treatment of poor quality roughages, use of molasses-urea blocks, forage trees, the African Palm, aqualculture feeds, and examples of feed information on a variety of plant materials. It was decided to extend the scope of the second conference by considering livestock feed resources in the context of integrated farming systems.

Integration vs. Specialization: Historical Context

In colonial times, traditional farming systems which combined crops and livestock production were replaced in many tropical countries by large scale plantations of export crops (cotton, sugar, groundnut, palm oil, rubber, etc.). They relied heavily on imported technologies and inputs, increasing the dependency on the countries which supplied them. Multinationals have now taken over control of the system, and many developing countries are caught in the vicious circle of requiring commercial production to generate the hard currency needed to pay for the inputs.

Agricultural education and training in both the developed and developing world put much more emphasis on specialization than on integration. Institutions separate crop and animal production at all levels (extensionists, researchers and decision makers), and the two groups ignore each other and struggle separately for power and budgets. They develop separate projects instead of cooperating with each other and exploiting the benefits of integration.

As the demographic pressure is increasing rapidly in the developing world, new priorities are emerging: food security, sustainable management of resources, slowing down the drift from the land and improving welfare of the rural poor. The commodity-oriented production system is now being called into question. Much more emphasis is put on integration within production systems and this is reflected in the new FAO Food Security Special Programme. Recently, World Bank projects aimed at strengthening the extension services in developing countries have begun to train general extensionists able to intervene in the different components of the farming systems: crops, livestock and forestry. Furthermore, participatory approach methodology is now adopted by most developers and greater emphasis is placed on indigenous knowledge and the needs of the rural population. New educational

programmes have focused on integrated systems (e.g., the SAREC MSc Programme on Sustainable Systems of Livestock Production in Vietnam), and many NGOs are following the same line as CIPAV (Centro para la Investigaci�n en Sistemas Sostenibles) in Colombia which has developed expertise in many components of integrated farming systems (from crop production, to animal production, energy, forestry and wild fauna).

Farming Systems

The emphasis in this conference is therefore on feeds as components of systems. It is essential to define 'the system' when reporting results and conclusions. Furthermore, it is concerned not just with the 'feeding system' but also with the feed plants as components of the 'farming system' which includes soil, water, crops, livestock and their interactions. The system may rely on external inputs (fertilizer, chemicals, etc.) or be self-sufficient (with minimal external inputs). The concept of 'sustainability' adds the dimension of time: whether the system can continue indefinitely without soil or environmental degradation. It is important to judge the system not only in terms of is self-sufficiency but also in terms of its long-term viability.

Caution must be applied to the definition of the system. For one thing, 'systems' may be defined within a wide range of boundaries. In this context, it refers to the whole farming system, and the land, labour and economics of that system. The boundaries of the system may be further extended to include the environment, market, economic and social factors. Such considerations are vital when considered in the context of 'sustainable development'.

There are many instances where 'improvements' are reported in terms of yield, performance or financial margins, resulting from genetic, dietary or management changes. But such 'improvements' must be questioned in the context of environmental, market and social effects (indicators of sustainability'). The classic case is the 'Green Revolution' in which high-yielding varieties of rice and maize were introduced, with major effects on production and food supply. But these varieties required high inputs of chemicals and fertilizers. And the additional supply had serious market implications so that the poor farmers, who did not have access to land, capital and chemicals needed to use the new crops, suffered reduced prices and incomes (Greenland, 1990).

Such effects also occur in livestock production. Many developed countries have achieved big increases in milk production from dairy cows by genetic and technical improvement, with high usage of grain and a high level of subsidy. The result is a reduction in the number of cows and dairy farmers and the need to apply production quotas to limit supply.

Also, the high performance systems now operating in Europe are causing serious pollution problems as a result of high concentrations of animals in small geographic areas, e.g. Belgium, Brittany, the Netherlands, etc. In these systems, the feed base is often completely dissociated from animal production, with imports of cereals, cassava and soya from other regions or countries. The expansion of production based on non-local feed resources has proved to be environmentally unsustainable.

Brazil has increased production and exports of pig and poultry meat by applying modern production methods and meat technology. This is in direct competition on the world market with supplies from France, USA, etc. Pig meat prices are currently (July 1996) low and small-scale production is uneconomic. Production is also based on corn and soya. The 'feed conversion efficiency' is good but corn prices have gone up and profits disappeared. The majority of producers are small and the risk is that more will abandon the rural areas and move to the cities. Furthermore, pollution from pig and poultry units is becoming a serious problem, as in many countries. Although this does not affect the economics of the pig enterprise, it has wide implications for human health and the environment. It represents an 'externality' which economists now take as a type of cost.

Much attention has also been paid by scientists to increasing beef production from extensive systems (by pasture improvement and improved management), especially in Latin America. Higher stocking rates mean higher profits per hectare. Economically, it benefits only the large cattle ranchers. And the world beef market is already saturated so increased supplies mean lower prices. It is also claimed to increase meat supplies to the cities. But the rich already consume protein in excess of requirement and the poor remain unable to buy beef.

So the consideration of 'livestock systems' which are environmentally, economically and socially stable must take account of factors beyond the farm level.They are likely to be environmentally non-destructive, not to contribute to

saturated markets (although they may provide other products which are currently required) and to account for family labour and satisfaction within the small-farm sector.

System Definition

The question arises of what constitutes an environmentally sustainable system. Such a system is likely to be as near to, and therefore a modification of, the natural ecosystem of the area. This is proposed as a fundamental principle of environmental sustainability and should be borne in mind throughout the discussion. In the various agro-ecological zones, the following systems would apply:

- pasture-tree systems in arid or semi-arid savannah
- multi-layer perennial (tree) systems in humid forest environments
- pasture-palm systems in wet savannah
- multi-layer pond systems in wetland areas

These systems are polycultures rather than monocultures and involve trees and/or nitrogen fixing species. Food crops and animal feed resources can be chosen which replace the natural species but fulfill a similar role in the ecosystem. However, annual crops like maize and beans are unlikely to constitute sustainable options on tropical soils with a low cation exchange capacity (CEC) and where nutrients are mainly held in the organic matter (Weischet and Caviedes, 1994).

In such areas, the maintenance of soil organic matter and fertility are primary concerns. The integration of livestock itself may help the cropping system to become sustainable through the use of residues, animal power and recycling of nutrients. But if the cropping system is based on inputs of fertilizer and chemicals from outside the system and subject to long-term reduction in soil fertility, then the whole system, including the livestock element, should be regarded as unsustainable. Much attention has been paid in the past to crop byproducts, treatments (e.g.

urea) and supplementation. Materials such as straw, husks, cakes, etc., are available and may be used for animal production but the integration of livestock per se does not guarantee the principle of long-term sustainability. More emphasis is likely to be placed on alternative perennial crops and multi-strata systems which conserve and replace the soil organic matter.

Even on fertile soils, there should be more attention paid to mixed farming systems (where byproducts are used), including integrated systems with legumes (especially multi-purpose trees), mixed livestock and return of nutrients through nitrogen fixation and use of manure.

Descriptions of feed use within systems must therefore be justified in terms of the environmental, as well as the economic and social sustainability of the system, together with the feeding value and animal performance.

The Programme

Papers were requested within the following subject categories:

1. Integration in small-scale farming systems.

2. The poultry component in integrated farming systems.

3. Integrated farming systems with a major fodder crop component.

4. Integrated farming systems with a major tree/shrub component.

5. Feed resources from cereal production.

6. Feed resources from large scale plantations.

7. Alternatives to industrial exploitation of plantations.

8. Fertilizer and energy components in integrated farming systems.

9. Networking for circulating information on integrated farming systems and promotion of these systems.

In addition, a number of short communications were requested and it was expected that participants would contribute to the discussion with data, experience and further contributions. Following from experience of the last electronic conference, a number of changes were made. The conference was fully moderated and all contributions and discussions wereconsidered by the moderators before release.

It was hoped that contributors would add information on feed and feeding systems that are not currently included in FAO Tropical Feeds. Such information should include full description, as well as brief exemplary chemical analysis and, where possible, animal performance results. Details of farming systems are particularly important and contributions should take account, as far as possible, of indicators of sustainability: environmental, social and economic.

Additional Information

FAO Tropical Feeds may be obtained on diskette by application to:

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E-mail: rene.sansoucy@fao.org

or from the world-wide-web.

The Proceedings of the First FAO Electronic Conference on Tropical Feeds and Feeding Systems can be obtained on diskette at the above address or from the www.

There are many articles on sustainable livestock systems and feed resources available from the electronic journal Livestock Research for Rural Development. A full list of papers will be sent to participants on request. The journal can be obtained in the same way as the above.

A special www site was set up where these can be obtained.

References

Gohl, B. (1981). Tropical Feeds. FAO, Rome. (Revised by Speedy, A.W. (1994) as FAO Tropical Feeds, 4.2 mB on diskette).

Greenland, D.J. (1990) Agricultural research and Third World poverty. In: Developing World Agriculture. Speedy, A.W. (Ed.). Grosvenor Press International, London. pp. 8-13.

Komwihangilo, D.M. *et al*. (1995). Indigenous knowledge in utilization of local trees and shrubs for sustainable livestock production. Livestock Research for Rural Development 6:3 Paper 7.

Leng, RA. 1996. Evaluation of Tropical Feed Resources for Ruminant Livestock. In: Proceedings of the First FAO Electronic Conference on Tropical Feeds and Feeding Systems.

Speedy, A.W., Dalibard, C. and Sansoucy, R. 1996. Proceedings of the First FAO Electronic Conference on Tropical Feeds and Feeding Systems.

Weischet, W. and Caviedes, C.N., 1994. Persisting Ecological Constraints of Tropical Agriculture. Longman, London and New York.

Integrated Animal Production in the Oil Palm Plantation

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Abstract

The oil palm industry offers a number of opportunities in terms of feed resources which can be utilised for animal production. These feed resources range from forages in the inter-rows to the by-products from the oil palm. Many of these by-products, e.g. palm kernel cake and oil palm fronds, are rich in nutrients and have been proven to be feeds of high quality. Integrating animals with oil palm plantations will ensure long-term profitability as well as sustainability of the agriculture industry in a very competitive environment.

KEY WORDS: African oil palm, by-products, forages

Introduction

Oil palm cultivation is rapidly expanding within the tropical zone and South-East Asia is the leading producer of palm oil, accounting for more than 80% of the world's output. Palm oil, with a 20% market share, has emerged as one of the dominant vegetable oils, second only to soya bean oil. During the past three decades, the production of palm oil grew at the fastest rate (8% per year) compared to rape seed oil (7.2%), soya bean oil (4.5%), and sunflower oil (3.7%). Palm oil production is expected to increase further with the expansion of oil palm cultivation and improved cultivation techniques. The oil palm industry, with diverse products and by-products, offers two opportunities for the promotion of animal production. Firstly, the products and by-products from the industry are valuable feed resources with the potential to be utilised for expanding animal production. Secondly, the forages in the inter-rows can be consumed by ruminants. Integrating animal production with oil palm plantations should take into account all the available resources, i.e. the products and by-products of the industry as well as the

forages grown in the inter-rows.

Palm Oil By-products

Palm oil is available in about 15 different grades, ranging from crude to semi-refined, refined, crude fractionated, refined fractionated oil and refinery by-products. Palm oil is currently the main fat source in feeds for monogastric animals, but it is not commonly fed to ruminants because it can result in rumen disorders, metabolic problems and reduced milk fat content (Palmquist, 1995). However, calcium soaps of palm oil origin, given to dairy cattle to increase energy intake, produced many positive effects of an energy supplement (Palmquist, 1995). This is attributed to the high level of unsaturated fatty acids (primarily oleic acid) which escape rumen degradation, leading to enhance digestibility. This makes calcium soaps of palm oil origin a good source of by-pass energy.

Oil Palm By-products

Palm press fibre

Palm press fibre (PPF) is a fibrous residue of oil palm fruits after oil extraction. The potential of using PPF for ruminant production is enormous but, due to its bulkiness and low feeding value, the amount consumed and digested is inadequate to support production at an economic level. Therefore, the use of PPF could be enhanced by improving its nutritive value by chemical treatment and by manipulating the ration to optimise rumen fermentation.

Treating PPF with chemicals such as sodium hydroxide, urea and ammonium hydroxide has shown varying degrees of improvement in feed intake and biodegradability. For example, DMD increased from 43.3% to 58.0% when PPF was treated with 8% sodium hydroxide (Jelan *et al*., 1986). Buffalo could be induced to increase voluntary intake of PPF (360 g/head/day) which was sprayed with molasses and supplemented with fish meal. Animals fed urea-treated PPF had significantly higher voluntary feed intake when energy and protein were supplemented compared to those receiving only protein or energy. This is a clear indication that PPF is limiting in both energy and protein. A feeding system based on PPF needs to be carefully balanced with supplements in order to ensure optimum

production.

Palm Kernel Cake

In Malaysia, more than 60,000 tonnes of palm kernel cake (PKC) are produced annually. The world production of PKC far exceeds the stated amount. PKC has a fairly high nutritive value and is being used extensively for fattening steers in feedlots. Crude protein content of PKC ranges from 7.7 to 18.7% depending on processing methods and the degree of impurities such as shell content. At 70% DMD, PKC is readily consumed. Hutagalung (1985) reported that cattle fed 6-8 kg PKC combined with small quantities of feed additive (e.g., minerals and vitamins) produced daily growth rates of 0.7-1.0 kg/animal. Similar results were obtained under farming conditions by Jelan *et al*. (1986).

There are two intrinsic problems in the utilisation of PKC, namely, the high oil residue and the copper content. The oil content in certain cases can be as high as 20%, which can cause rancidity and rejection by the animals. Palm oil is extracted by expeller or solvent. The former process is rather inefficient resulting in large quantities of oil residue in the PKC. The high copper content can cause toxicity in small ruminants, particularly sheep. To a certain extent, copper toxicity can be alleviated by the addition of zinc molybdate. The extent of copper toxicity in larger ruminants is somewhat unclear because feeding PKC over a long period to either cattle or buffalo has not resulted in retarded growth or mortality. Furthermore, steers fed high level of PKC were found to have normal concentrations of rumen metabolites, glucose, urea, alkaline phosphate and glutamate oxaloacetate transaminase. A more recent study by Hair-Bejo *et al*. (1995) showed that buffalo fed 100% PKC had twice as much copper and zinc in the liver and adrenal cortex compared to buffalo fed a normal diet. However, high mineral contents in these two organs did not cause any mortality.

Oil Palm Fronds

Oil palm trees require regular pruning to facilitate harvesting of mature fruit, thus yielding large quantities of fronds (leaves and petioles), which at present are not utilised for feeding animals. Oil palm fronds (OPF) with

nearly 15% crude protein is a potential ruminant feed (Abu Hassan, 1995). However, it cannot be economically utilised unless processed into pellet form. Cattle fed OPF pellets measuring 9 mm in diameter and 3-5 cm in length with 33.3% total digestible nutrients gained 0.93 kg/day (Asada *et al*., 1991).

Empty Fruit Bunch

Empty fruit bunch (EFB) can also be processed into ruminant feed as pellets. Very little work has been done to utilise EFB as ruminant feed but there should not be serious problems in developing appropriate technology to improve the feeding qualities of EFB.

Forage Cover Crops

The inter-row spaces found in all oil palm plantations promote the growth of at least 60 plant species - usually considered as weeds (Chen and Dahlan, 1995). In intensive oil palm plantations, chemicals are used regularly to control weed growth so that the competition for plant nutrients is minimal. The cost of weeding is quite substantial and can be easily eliminated if the forages in the inter-rows are utilised for animal production. In addition, soil and environmental pollution is minimised. Integrating animals in the plantation can also reduce fertilizer application since the nutrients returned to the soil from the animals are quite substantial. Reducing chemical fertilisers in the long-run will not only reduce production costs but, more importantly, will minimise further deterioration in soil fertility. It is a known fact that constant application of chemicals will alter the ecological profile of the soil. With reduced biodiversity in the soil, plant growth can be affected.

Cover crops such as *Centrosema pubescens, Desmodium audifolium, Pueraria phaseoloides, Calopogonium caeruleum*, etc., found in the inter-rows in most plantations, are legumes with a high nutrient content. As the palm matures, the canopy increases and limits light penetration, which in turn will reduce forage production in the inter-rows. It has been estimated that after the second year of planting, the light intensity declined by an average of 10 - 15%. Forage DM yield for the five years after planting ranges from 2000-3000 kg/ha to as high as 7000-8000 kg/ha DM depending on the extent of weeding done (Chen *et al*., 1991). After five years, DM yields declined to

between 500 and 1000 kg/ha.

The stocking density has to be adjusted to correspond with the forage yield. The carrying capacities and liveweight productions of cattle grazing under immature oil palm are comparable to those found in ranch operations in Malaysia, which is about 138-285 kg/ha/year (Chen and Dahlan, 1995). The carrying capacity under mature oil palm is only 0.3 head/ha which is low. The carrying capacity can be sustained at a higher level if all the available biomass (including the by-products) are utilised. However, a production system which fully integrates livestock utilising forage and other biomass has not been developed.

Grazing Systems

Forage production in the inter-rows can be substantially increased even under mature palms provided the planting density is reduced. Reducing planting density does not necessarily mean lower fruit bunch production. On the contrary, production of fruit bunch is maintained because the reduction in planting density is compensated by increased production from individual trees. Under reduced planting density there is greater light penetration resulting in increased forage production.

Chen and Dahlan (1995) suggested that a rotational grazing system at 6-8 weekly intervals is ideal since it allows routine work to be done. They also recommended that the interval of grazing be adjusted depending upon forage availability. The stocking rate for cattle varies from 0.3-3.0/ha and in the case of sheep, from 2.0-14.0/ha. The large variation is due to the inconsistency in forage availability. Animals should be relocated after 60% of the forage is grazed when it meets both objectives of weeding and forage regeneration.

Integrated animal farming can be further intensified if the system incorporates the utilisation of by-products. The by-products from the oil palm industry are easily available at competitive costs. There is no reason why a viable animal production system cannot be developed in conjunction with the oil palm plantation. In fact, the oil palm industry is the only basis for animal production in the tropics since conventional grazing alone is uneconomic.

Conclusion

The concept of integrating animals with oil palm plantations is a feasible and practical proposition as demonstrated by many studies conducted in Malaysia over the past two decades. The only impediment towards implementing the concept is the attitude of the plantation management which lacks the expertise in animal husbandry and is unable to see the benefits derived from such a farming system. Future plantation managers should be competent in both crop and animal production. At present, plantation management cannot ignore the need to optimise all available resources for two reasons. Firstly, with the rapid expansion of oil palm cultivation worldwide, ensuring profitability solely from extracting oil has become somewhat uncertain. Secondly, demand for animal products has exceeded supply because of improved standards of living and affluence. Finally, a paradigm shift is needed in the way the oil palm sector is managed. This is only possible through new policy directions and availability of training packages to advance the concept of animal/crop integrated farming system.

References

Abu Hassan, O. 1995. Utilisation of oil palm trunks and fronds. In Proc. 1st Int. Symp on Integration of Livestock to Oil Palm Prod. Kuala Lumpur, Malaysia. pp. 129-138.

Asada, T., Konno, T., and Saito, T. 1991. Study on the conversion of oil palm leaves and petioles into feeds for ruminants. In Proc. 3rd. Int. Symp. on the Nutrition of Herbivores. Penang, Malaysia. pp. 104.

Chen, C. P. and Dahlan, I. 1995. In Proc. 1st Int. Symp. on Integration of Livestock to Oil Palm Prod. FAO, Rome. pp. 35-49.

Chen, C. P. H. K. Wong and Dahlan, I. 1991. In Recent Advances on the Nutrition of Herbivores. Y. W. Ho et. al (Eds.) Malaysian Society and Animal Production. pp. 233-246.

Hair-Bejo, M., Liang, J. B. and Alimon, A. R. 1995. Copper tolerance in buffalo: The potential toxic effect of copper in buffalo fed palm kernel cake. In Proc. 17th Malaysian Society of Animal Production Ann. Conf. Penang, Malaysia. pp. 246-247.

Hutagalung, R. I. 1985. Nutrient availability and utilisation of unconventional feedstuffs used in tropical regions. In Proc. Feeding Systems of Animals in Temperate Areas. Seoul, Korea. pp. 326-337.

Jelan, Z. A., Jalaludin, S., and Vijchulata, P. 1986. In Final RCM on isotope-aided studies on non-protein nitrogen and agro-industrial by-products utilisation by ruminants. International Atomic Energy Agency, Vienna, Austria. pp. 77.

Palmquist, D. L. 1995. By pass energy from palm oil for cattle. ln Proc. 1st Int. Symp. on Integration of Livestock to Oil Palm Prod. Kuala Lumpur, Malaysia. pp. 123-128.

The Role of Feeding System Based on Cereal Residues in Integrated Farming Systems in Sub-Saharan Africa

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Abstract

The traditional practice of transhumance in the African Sahelian countries has been severely hit by the droughts. The combined effects of recurrent droughts and declining pasture availability have both resulted in major changes in livestock ownership and production systems. Transhumant pastoralists are increasingly settling in cropping

zones, growing mainly sorghum and millet as staple food grains. The rise in human population and livestock numbers, decline in pasture availability and the expansion of cultivated areas have greatly increased the pressure on available land resources and led to declining soil fertility which is already very fragile.

The above factors have inevitably accelerated the process of integrating livestock into crop production, as crop residues and manure are becoming increasingly valuable, the former for animal feed and the latter as fertilizer. However, the challenge of assuring the sustainability of the integrated farming system is how to integrate animal production with crop production so that it contributes to an intensification of both food production and cash income and encourages the maintenance of soil fertility in the Sahelian regions of Africa. These principles have been applied successfully in the FAO-UNDP project in Niger (FAO-PNUD/ NER/89/016: Extension de la Methode de Traitement a l'Uree des Fourrages Grossiers), where it has been shown that the improvement in the ruminant feeding system based on urea treatment of crop residues is rapidly and enthusiastically received by resource-poor farmers. The technique of urea treatment is very simple, inexpensive and suitably adapted to Sahelian crop farmers. The advantages are undeniable greatest for feeding large and small ruminants during the dry season. The nutritive value of crop residues, namely sorghum and millet stovers, is greatly improved (nitrogen content, digestibility and consumption are significantly increased) and they are far better utilized since the edible proportion is increased.

This improvement of the animal feed, based on better utilization of crop residues not only led to better maintenance of live weight and other animal performance but extended to greater integration of crop and livestock production systems through improvements in draught animal power and increased availability of organic manure. Fields are ploughed more efficiently and rapidly. Nitrogen content in dung is sharply increased when animals are fed urea-treated forages compared to untreated forages (7 to 8.3 percent instead of 4.5 to 5.8 percent), which is extremely significant for soil fertility. As a result, yields of millet and sorghum are increased by roughly one-fifth to a third, improving the food security and income of farmers, decreasing the rural exodus and reducing the pressure on soils. The technique contributes also to reducing the animal pressure on the environment.

KEY WORDS: Feed, ruminant, Sahel, straw treatment, urea, millet, sorghum, soil fertility, integration

Introduction

The Sahel countries, which comprise Chad, Gambia, Mali, Mauritania, Niger, Senegal and Guinea Bissau, are characterized by their arid climate, low soil fertility, low annual rainfall (100 to 400 mm) with one long dry season of eight to nine months and recurrent droughts. This subject is introduced by reference to studies and observations mainly made in Niger.

Factors Changing Traditional Farming Systems and Their Consequences

The traditional farming systems in the Sahel have been based on an adaptation to low and variable rainfall, poor and fragile soils and widely available land (Speirs and Olsen, 1992). Over the past decades, the Sahel has had to face an increasingly difficult economic situation. Recurrent drought and temporal variation in rainfall are considerably changing farming systems and the socio-economic conditions of Sahelian farmers. For example, the practice of transhumance has been severely hit by the drought and many transhumant pastoralists were obliged to abandon their traditional dry season grazing areas and move to the south in higher rainfall zones where both pasture and crop residue outputs are greater (Dalibard, 1995). This phenomenon had resulted in major changes in production systems:

a. Transhumant pastoralists are increasingly settling and cultivating in cropping zones,

b. The high rate of population growth (average 3% per annum), the increasing settlement of nomads, the increase in the number of livestock in arable zones, the increase in cultivated area and the reduction of fallow periods have greatly augmented the pressure on available land resources and reduced soil fertility,

c. Land available for grazing animals is becoming increasingly scarce and of poor quality, as more and more is occupied by crop cultivation. In many zones, conflicts between crop farmers and pastoralists over access to land have therefore become more frequent and serious.

d. There have also been major changes in the pattern of livestock ownership: an increasing proportion of stock in the Sahel is now owned by crop farmers and many merchants have profited from low livestock prices during droughts to acquire more animals from poor farmers and pastoralists.

The above factors have inevitably accelerated the gradual evolution from separate crop and livestock production systems in the Sahel towards integrated mixed farming systems (Speirs and Olsen, 1992; Lhoste, 1987). As land becomes ever more scarce, crop by-products (residues) and manure from livestock are becoming more valuable, the former for animal feed and the latter as fertilizer, and playing a key role in promoting a beneficial integrated farming system.

The Role of Feeding Systems Based on Cereal Residues in Integrated Farming Systems in the Sahel

Crop production is characterized by a few cash crops such as cotton and groundnuts, and cereal crops for domestic consumption. The main cereals grown are millet and sorghum, intercropped with cowpeas in some zones and, to a much lesser extent, paddy rice, mainly in irrigated areas. Millet and sorghum are the predominant staple food grains and there is little rotation of crops. Because of declining soil fertility, yields of millet and sorghum are extremely variable and generally low; 500 kg/ha is often recorded as an average yield. Many farmers do not produce enough cereals to meet their domestic requirements.

In addition to crop cultivation, farmers practise animal husbandry (cattle, small ruminants, draft animals, dromedaries) and the livestock contribution to household income is increasing with the deterioration in the terms of trade of agricultural products from the Sahel, notably groundnuts and cotton (Club du Sahel and CILSS, 1989). As pasture production has declined, ruminant animals in the Sahel have become more dependent on crop residues which assume a progressively greater proportion of the total diet, and have become the basic feeds for animals belonging to the traditional crop farmers, as well as to the newly settled pastoralists. They are mainly used during the dry season. The collection of crop residues from fields sown with millet, sorghum, rice, groundnuts, cowpeas and pigeon peas is increasing as a larger proportion of livestock is maintained near to the household and an intensive fattening system has been introduced in many projects.

Unfortunately the feeding system practised in the Sahel is based on cereal crop residues of poor quality with low nitrogen, energy and mineral contents. In addition, the edible proportion of sorghum and millet stovers is low and rarely exceeds one-third of the biomass. Therefore, most of animals lose weight, become weak and are more susceptible to disease by the end of the dry season.

Effect of Improved Feeding Systems Based on Cereal Residues on Greater Integration of Livestock Into Crop Production Systems

The feeding of urea-treated cereal residues (sorghum and millet stovers, and rice straw) to large and small ruminants in Niger since 1991 (FAO-PNUD/ NER/89/016: Extension de la Methode de Traitement a l'Uree des Fourrages Grossiers) has greatly improved animal productivity and it has also been shown that this technique can be a way to strengthen the capability of farmers to run integrated crop-livestock systems while improving food security and the well-being of farmers.

Urea treatment is a simple method

Urea treatment of cereal residues, as developed in Niger, is a simple technique based on the use of locally available materials in villages. Sorghum and millet stovers, savannah grasses and rice straw are treated with urea (5 kg urea dissolved in 50 litres water to 100 kg dry residues) and made into a stack using the traditional storage method and locally available air-tight system in the village: silos made from sekos (Andropogon gayanus) or banco (briquettes made from clay and straw). Air-tightness was successfully ensured by tying with braids made from Andropogon gayanus and no plastic was used. Urea-treated forage was well preserved, showing a dark brown colour, with a strong smell of ammonia and a softer consistency. The treatment was effective and the nutritive value of poor quality forage was greatly improved, as confirmed by analysis (table 1): dry matter digestibility is significantly increased after treatment (an average increase of 20%) and the nitrogen content is more than doubled. In addition, most of the introduced urea is hydrolyzed (at least 78%) to ammonia gas which is the essential chemical product for upgrading cellulosic materials in forages.

Table 1: Effect of urea treatment on improving the nutritive value of sorghum stovers, rice straw and savannah grasses in Niger (treated forage is stored according to the traditional storage system using local covering materials) (5 percent urea in 50 litres water to 100 kg dry residues)

Forage		N x 6.25	*In sacco* digestibility	Residual urea
Sorghum stover	untreated	5 � 2	38 � 7	
N=18	treated	10 � 4	47 � 4	0.78
Rice straw	untreated	4 � 2	39 � 5	
N=28	treated	11 � 3	50 � 6	0.92
Savannah grasses	untreated	4 � 2	36 � 3	
N=20	treated	10 � 3	45 � 2	0.86

Positive Results Are Obtained in Animals

a. Urea-treated forage is appetizing. The intake is much increased and refusals decreased considerably, especially in the case of millet and sorghum stovers. Quantities distributed to animals can be reduced by a third when the forage is treated. About 70 per cent of treated stovers is edible while the usual edible proportion is only 30 to 40

per cent with untreated stovers. Their is therefore less wastage. Water intake is also increased (by about 30 per cent) as a consequence of higher dry matter intake (Table 2).

b. Improvement of animal performance: The consumption of treated forages during the dry season is often accompanied by an improvement in body condition of the animals and maintenance of live weight; they are also more resistant to disease and their coat is improved (brighter hair). Thin and weak animals recuperate rapidly. Farmers have noted a positive effect on animal fattening. The fattening period is reduced with a consequent saving in concentrates. Furthermore, selling of fattened animals is made easier, especially at the end of dry season when there is a shortage of animals with good conformation. Finally milk from dairy cows is significantly increased, allowing a better growth of the suckled calf, an increased amount for household consumption and the sale of the remainder. Dairy recording, undertaken over 4 months, confirmed this important increase (280-350 litres instead of 150).

c. Improvement in the capacity of draught animal power and the improvement in the quantity and quality of dung have been noted by the majority of peasants as the two essential points of the technique. Farmers in Niger have given priority to feeding treated forages to draught animals during working periods, as well as at the end of their working cycle when animals are fattened and sold.

The Role of the Improved Feeding System in Strengthening the Integration of Draught Cattle Power Into Crop Production Systems

The use of draught cattle (oxen) is common and increases in the Sahel because of the extension of the cropping zones and settlement of the pastoralists, and this plays a major role in the development of integrated systems. In addition, they have a key socio-economic function in the Sahel by increasing the opportunities to earn non-farm income with the use of animals in the transport sector to carry a variety of goods such as wood, water, building materials, crop residues, manure to the fields, products and farmers to and from markets and so on. Draught animals also make a significant contribution to household income, mainly through the end value after their working life when they are sold for meat production.

Almost all farmers who fed urea-treated forages to oxen had carefully observed that, during the dry season, animal body condition was improved and they did not lose live weight during the ploughing period. In addition, animals work harder and longer, compared to those fed on untreated straw and stovers. It is often reported that animals plough 1.5 to 2 hours more per day. Some on-farm trials undertaken in Cambodia and Laos are closely comparable with these results (table 2). This is particularly crucial, since field ploughing is undertaken at the end of the dry season and beginning of the rainy season, when feed resources are scarce and of low quality. Draught animal power is therefore weakened, even before starting work, compromising the sowing of crops. However, when draft animals are fed treated forages, fields are ploughed efficiently and rapidly, more land can be cultivated and crop yields are greatly improved. Because ploughing is more rapidly completed, several peasants have rented their animals to neighbours and raised their cash income.

Table 2: Effect of feeding urea-treated straw on straw intake, water consumption and thoracic perimeter measures in Laos (February, Mars and April 1996) (Kayouli, 1996)

Animals	Intake/head/day				Thoracic perimeter	
	Untreated straw kg	Water litres	Urea-treated straw kg	Water litres	initial cm	final cm
Cattle						
1	3.5	25	3.5	35	149	151
2	3	22	4	31	137	140
3	3	25	4.5	32	130	132
Buffalo						

1	3.5	28	5	38	165	166
2	4	30	6	40	168	172
3	4	31	6	42	160	163
4	3	20	4	30	91	95
5	3	25	4	34	105	107
6	4.5	35	6	42	182	186

Role of the Improved Feeding System in Integrating Livestock Into Crop Production Systems Through Better Manuring of Fields

Draught animals are often constantly maintained at or near the households or the settlement, where they are fed on crop residues and collected savannah grasses. These animals are the basic producers of manure, which is increasingly used as fertilizer on crop fields prior to sowing (Orskov, 1995; Powell and Mohamed-Saleem, 1987). Farmers in the Sahel are aware that the main limiting factor responsible for the lower crop yields is the quality of soils: organic matter is reducing and the fertility of soils is continually declining as a results of the reduction or abandonment of fallow periods. The key problem of maintaining or improving crop productivity per unit area in the Sahel is how to enrich the soil. The quantity of manure produced per household is often insufficient to sustain soil fertility (Speirs and Olsen, 1992). This issue is further accelerated since the manuring of fields practised in the past by transhumant herds in exchange for crop products (manuring contracts) is diminishing because crop residues are increasingly collected by crop farmers to feed their own animals or for sale.

The feeding system based on urea-treated stovers and straw in Niger and elsewhere has been accompanied by positive, and sometimes unexpected, effects. Dung is more abundant: a higher output of faeces which was of a wetter consistency and darker colour, and of high quality as fertilizer. These results emerge from numerous on-

farm trials and findings of farmers. Laboratory analysis indicated that nitrogen content in dung is sharply increased when animals are fed urea-treated forage compared to untreated forages (7-8.3 per cent instead of 4.5-5.8 per cent; Sourabie *et al*., 1995; Sansoucy, 1995). Similar results have also been recorded elsewhere with animals fed urea-treated rice straw (table 3). The urea or ammonia treatment generates an increase in the nitrogen excreted in the dung. This increase results from: (I) nitrogen fixed to indigestible cell walls ,(ii) microbial nitrogen coming from fermentation in the large intestine and not able to be digested (Chenost and Besle, 1993); (iii) it is also expected that the microbial protein in the rumen, which contain about 20% indigestible nucleic acids, is significantly increased after intake of urea-treated forages since there is more energy and nitrogen in treated forages which stimulate rumen microbial growth.

Table 3: Influence of alkaline treatment on nitrogen content of dung of ruminants (mean values � standard deviation; as per cent of faeces dry matter)

Cereal residues	n	N x 6.25	Reference
Wheat straw			
Treated (3.5% NH3)	7	15.6 � 2.6	Chenost & Dulphy, 1987
Treated (5% urea)	4	13.8 � 0.9	France.
Control	7	9.5 � 0.6	
Millet stover			
Treated (5% urea)	5	9.4 � 2.1	Kayouli, 1994. Niger.
Control	9	5.9 � 1.1	

Rice straw			
Treated (5% urea)	10	8.5 � 2,4	Kayouli, 1996. Laos.
Control	10	6.3 � 0.9	

Comparison between fields fertilized with dung produced by animals fed treated forage with those fertilized with traditional dung shows that the former improves soil texture fertility and crops are greener, more productive and more vigorous. Crop yields are therefore significantly increased. This improvement is highly significant in Niger where soils are naturally poor, with very low organic matter content. For example, some peasants have reported increases of 40 to 50% in the production of cereals, despite a reduction of half of the quantity of urea used on the fields. Farmers in Laos, who traditionally use dung as fertilizer in paddy fields, have also perceived with much interest that the best quality of manure is produced by animals fed urea-treated rice straw, improving soil fertility and thereby rice yield. Table 4 shows a significant increase of production per hectare varying from 15 to 24 percent.

Table 4: Effect of dung (as a fertilizer) produced by animals fed urea-treated rice straw (UTRS) on the paddy rice yield in Laos (Kayouli, 1996).

Province	Paddy production (sacks*)		Observations
	Before	After	
	feeding UTRS**		
Vientiane	60	70	3 ha. 4 t UTRS. 15 animals
Pakse	28	32	1 ha. 1 t UTRS. 2 animals
Saravanne	50	62	4 ha. 3 t UTRS. 5 animals

*** 1 sack = 75 kg.**

**** UTRS = urea-treated rice straw**

Conclusion

The improvement of animal feeding based on better utilization of crop residues not only led to better maintenance of live weight and improved animal performance but led to greater integration of crop and livestock production systems through improvements in draught animal power and increased availability of organic manure. The use of crop residues is indeed enhanced after urea treatment. Yields of millet and sorghum, which are the staple foodgrain, are increased by one-fifth to a third, improving the food security and income of farmers, decreasing the rural exodus and reducing the pressure on soils. The technique contributes also to reducing the animal pressure on the environment as reported by Dalibard, 1995.

Bibliography

Chenost, M. and Dulphy, J.P., 1987. Amelioration de la valeur alimentaire (composition, digestibilite, ingestibilite) des mauvais foins et des pailles par les differents types de traitement. In C. Demarquilly, ed., Les fourrages secs: recolte, traitement, utilisation. I.N.R.A., Paris, 199-230.

Chenost, M. and Besle, J.M., 1993. Ammonia treatment of crop residues via ureolysis: some reflection on the success of the treatment and on the utilization of the treated material. Proceed. internat. Conf. on increasing livestock production through utilization of farm and local resources, Beijing, China, 18-22 october 1993, 153-171.

Club du Sahel and CILSS. 1988. Livestock activities in the Sahel. D(88)314, Club du Sahel/CILSS, OECD, Paris.

Club du Sahel and CILSS. 1989. Regional cereals markets in West Africa - a compilation of studies on Sahelian

agriculture, regional trade and world markets. Club du Sahel/CILSS, OECD, Paris.

Dalibard, C. 1995. Livestock's contribution to the protection of the environment. FAO Word animal review 84/85, 1995/3-4.

Kayouli, C., 1994. Rapport de mission, Projet FAO - PNUD / NER/ 89/016 Niger: Traitement a l'uree des fourrages grossiers. FAO, Mai 1994.

Kayouli, C. 1996. Increasing utilization of locally available feed resources for cattle and buffaloes. Terminal Statement FAO - TCP/LAO/4451.

Lhoste, P. 1987. L'association agriculture-elevage - evolution du systeme agro-pastoral au Sine-Saloum. Etude et syntheses de l'IEMVT, 21. Institut d'Elevage et de Medecine Veterinaire des Pays Tropicaux. Maisons-Alfort.

OECD, 1988. The Sahel facing the future-increasing dependence or structural transformation. OECD, Paris.

Orskov, E.R. 1995. Contribution of livestock to sustainable resource management in crop livestock systems. In Proceeding of the 2 nd international conference on increasing animal production with local resources. Zhanjang China, 1995.

Powell, J. and Mohamed-Saleem, M. 1987. Nitrogen and phosphorus transfers in a crop-livestock system in West Africa. Agricultural Systems, 25.

Sansoucy, R. 1995. Livestock - a driving force for food security and sustainable development. FAO Word animal review 84/85, 1995/3-4.

Sourabie, K.M., Kayouli, C. and Dalibard, C. 1995. Le traitement des fourrages grossiers a l'uree: une technique tres prometteuse au Niger. FAO Word animal review. 82(1).

Speirs, M. and Olsen, O. 1992: Indigenous integrated farming systems in the Sahel. Word Bank Technical Paper Number 179, Africa Technical Department Series.

The Sugar Palm Tree As the Basis of Integrated Farming Systems in Cambodia

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Abstract

The sugar palm tree (*Borassus flabellifer*) plays an important role in the small integrated farming systems in Cambodia. The sugar palm is considered to be a multi-purpose tree and provides different products such as juice, sugar, leaves, timber, fruits, underground seedlings and roots. The juice from the sugar palm is rich in highly digestible carbohydrate (sugars) which is an alternative energy source for animal feeding in the rural areas. The impact of the sugar palm on the farming system is increased when the excreta from the animals is recycled through biodigesters to provide gas for household cooking and effluent to fertilize the pond which can produce fish or water plants, the former for the household and the latter for the livestock.

When sugar palm juice is used for pig feeding, rather than the making of sugar, it is better from both the economic and environmental points of view, because sugar production requires large amounts of firewood that makes the cost

of production very high. It is even less profitable and extremely harmful to the environment when palm trees are used as fuel in order to produce the sugar.

KEY WORDS: ***Borassus flabellifer*, palm juice, palm sugar, fuel, environment, biodigester, sustainable production**

Introduction

In Cambodia, 85 per cent of the total population is dependent on agricultural activities. Most of their annual income comes from agriculture. The farming system comprises rice cultivation, sugar palm production, livestock farming, and vegetable growing. Livestock make many contributions to the farming activities, such as draught power, meat, milk, eggs, organic fertilizer, fuel, social status, etc. In order to maintain these important contributions, livestock have to be adequately fed, well managed, and properly cared for. However, there must be a clear division between what is human food and what is animal feed. As Preston and Sansoucy (1987) have suggested, one way to achieve a sustainable animal production system is to match livestock with the available local resources. In this case, there are resources which can be used for animal feed such as multipurpose trees, aquatic plants, agricultural products and by-products.

The sugar palm tree, which is called "Thnot" in Khmer, is a source of income in different seasons of the year. In addition, it provides good materials for house construction such as leaves, leaf branches and trunk, when juice production is not carried out. The palm tree commences to produce inflorescences (maturity) in 15-20 years depending on soil fertility. There is no relevant literature which describes the productive life of the tree, although there are examples of trees today which have been used to produce juice for more than 70 years. Borin Khieu *et al*. (1996a) reported that the juice can be collected for 3 months of the year from the male tree and 5-6 months from the female tree. The average yield was 5 kg of juice per day per tree with an average brix value of 13.5% (sugar content). In 1995, the sugar palm population was estimated at 8 million trees in different provinces in Cambodia. The trees are found mostly on sandy soils with a pH of 5.5. The sugar palm trees are capable of producing 160,000 tonnes of juice or 21,600 tonnes of sugar (sucrose) per year per hectare. This is a great potential feed resource

that can be used as an alternative to cereal grains for feeding monogastric animals. The preferred animal species are pigs and ducks which adapt readily to "unconventional" high moisture feed resources. However, it may also be used as a supplement for draught animals.

The system is based on the sugar palm which provides the carbohydrate feed (juice). The other multipurpose trees and water plants supply protein in addition to the important role that the trees play as a sink for carbon dioxide, in nitrogen fixation, in controlling erosion and as a source of biodiversity. Sugar palm trees are integrated into the farming activities.

The Role of Sugar Palm Trees

The sugar palm tree is considered a multipurpose tree since it demonstrates great potential by providing different products for humans, as well as for animal feeding. The role of sugar palm trees in the mixed farming system is as follow:

- To provide sugar, fruits, germinated seeds and juice for human consumption and animal feeding.
- To use as the green fence around the household, as well as on the bunds of rice fields.
- As the sugar palm tree has a deep root system (up to 15 m), it can be used also to control erosion.
- The leaves of the sugar palm tree can be used as a nest for bats which provide manure as a good source of fertilizer. The bats can provide 0.5 to 1 kg of manure per day which could be sold to the city for flower gardens.

The Production of Sugar Palm Tree

The sugar palm tree does not require any management for biomass production. But the leaves should not be harvested when trees are kept for juice collection. Farmers believe harvesting the leaves has a great influence on the yield of juice. The juice from the sugar palm tree is normally collected once a day. However, there are high production trees (20-25 kg of juice per day) which should be collected from twice daily. The yield and the brix value (sugar content) vary from tree to tree, farmer to farmer and time of production. Some skillful farmers can manage to get juice with high brix value that is good for sugar syrup production because it requires less firewood for boiling the juice. Potentially, trees (especially females) can produce juice throughout the whole year.

The composition of the syrup samples (Table 1) showed considerable variation among farmers and between harvest periods. Seasonal variation in composition is shown in Table 2. Sucrose as per cent of total solids in the juice ranged from 66 to 94% in the samples taken in January and from 51 to 88% in April. In contrast, glucose and fructose levels in juice increased. The levels of glucose ranged from 2.1 to 9.6% in samples taken in January and from 3.5 to 18.2% in April. The fructose levels ranged from 2.6 to 11% in samples taken in January and from 4.6 to 24.5% in April.

The constraint on sugar palm production is the fuel consumption. The estimate of firewood consumption is 460 kg per tree per year which is equivalent to 3.68 millions tonnes of firewood required for sugar production annually in the country. However, rice husk can be used as an alternative fuel to boil juice but it is still a problem to get sufficient quantity for this purpose. The other way to achieve better utilization of the sugar palm tree is by diverting juice from sugar production to animal feeding.

The Use of Sugar Palm and By-products in Animal Feeding

There is no relevant literature which describes the real amount of sugar palm and its by-products given to domestic animals in the country. But it has certainly been used as a livestock feed supplement in the rural areas.

Ruminant Feeding

The main feed for cattle and buffaloes during the dry season is rice straw. In this period, most of the animals become very thin because of the poor quality feed supply. However, some of the animals which get a supplement from sugar palm products and by-products have good performance or at least maintain weight. The juice from the

sugar palm is sprayed over the rice straw and kept for some minutes and then fed mainly to draught animals. This also makes rice straw more palatable.

Table 1. Chemical composition of sugar palm syrup (as % of dry matter)

	DM	Ash	Sucrose	Glucose	Fructose	Total CHOs
16 Jan.1995						
Hay Yang	84.8	1.4	65.8	9.6	10.6	86.7
Huy Kiel	86.5	1.3	85.7	5.8	6.6	98.0
Pring Huy	84.3	1.7	74.1	9.4	11.0	94.8
Map Chreb	82.7	1.2	88.2	4.8	5.5	98.6
Sim Hen	87.8	1.0	93.1	2.1	2.6	97.9
Pauv Pauv	84.1	1.4	81.7	5.7	7.5	95.5
Tha Khorn	88.1	1.5	94.3	2.1	3.3	99.7
Thorn Punn	89.9	1.8	74.3	6.8	8.3	91.1
Yem Khnol	84.2	1.8	72.9	9.1	10.6	93.6
Chan Mak	88.4	1.0	93.1	2.5	2.9	98.5
Thorn Chreb	78.6	1.7	85.7	4.8	2.9	96.9
15 Apr. 1995						
Hay Yang	85.8	1.7	69.8	7.3	12.5	89.6

Huy Kiel	88.9	1.5	68.5	11.2	13.4	93.5
Pring Huy	82.9	1.6	51.0	18.2	24.5	91.2
Map Chreb	82.3	1.5	57.4	15.7	18.1	92.7
Sim Hen	85.0	1.3	74.9	8.7	9.9	96.2
Pauv Pauv	79.7	1.6	68.0	10.6	12.2	92.2
Tha Khorn	82.2	1.1	87.6	5.5	5.9	99.0
Thol Onn	86.9	1.2	73.5	8.0	11.0	92.6
Thorn Punn	87.4	1.5	87.1	3.5	4.6	96.1
Yem Khnol	92.0	1.5	62.6	9.4	15.8	90.0
Thorn Chreb	75.6	1.6	76.4	9.8	9.5	95.7

Table 2. T test analysis of changes in sucrose, glucose & fructose (reduced sugar)and ash in sugar palm juice with advance of harvesting season.

	16 Jan 1995	15 Apr 1995	Mean diff	t value	Prob.
Sucrose	81.6	70.4	11.2	2.79	0.021
Glucose	6	10	-4.0	-2.78	0.021
Fructose	7.2	12.3	-5.1	-3.56	0.006

Ash	1.4	1.4	-0.02	-0.19	0.86

Sugar palm syrup can also be used as an ingredient to make multi-nutritional blocks. Experience from FAO Project TCP/CMB/ 2254 "Emergency Plan for Livestock Security" has shown that multi-nutritional blocks are a good potential supplement for draught animals in the dry season. The formula used for a hundred kg of mixture was: rice bran 40 kg, sugar palm syrup (80% DM) 15 kg, urea 7.5 kg, salt 7.5, lime 5, cement 5, clay 20 kg. The animals have good performance, a bright coat and stop licking urine from others animals.

The fruits from sugar palm are chopped and given to animals after having taken the soft part and kernel for human consumption. The mature fruits are soaked in water and the wiry fibers sucked out. The solution of yellow pulp is given to the draught animals or lactating cows. During the dry season, it has been observed that the leaves from the young palm trees are eaten by cattle.

Monogastric Animal Feeding

The common monogastric animals kept in the rural areas are pigs, chicken and ducks. The population of monogastric animals is growing very fast because of the quick turnover of capital and the available market. A scavenging system is the common practice. The animals are sometimes supplemented with kitchen waste or cereal grains. Another important feed is the solution which is obtained after cleaning the pan from making palm sugar. The solution is mixed with rice bran and fed to pigs. Pigs show good performance compared to the ones which are fed rice alone.

Starting in 1993 with the introduction of TCP/CMB/2254 and later on with SAREC, research has demonstrated that the sugar palm juice can be used as a source of energy supply for pigs. The trials were adapted and tested in different villages in Cambodia. When the monogastric animals are fed a basal diet derived from tropical feed resources such as sugar cane, cassava, bananas, sweet potatoes or palm oil, the supplementary nutrients needed are protein, lipids, minerals and vitamins (Preston, 1992).

The first idea was to use the scum from making sugar palm syrup to feed pigs. But the reaction from the farmers was to use fresh juice for pig feeding instead of the scum. In 1995, there was a trial involving 72 pigs divided between 12 families in Kandoeung Commune, Takeo Province, Cambodia. The objective of the research was to evaluate the juice of the sugar palm tree as a sole energy feed for pigs. The result was reasonably good compared to sugar palm syrup production. The average live weight gain was 356 g per day per pig with only 156 g CP supplement. In fact, the most important feature is the economic impact of feeding juice to pigs. Elliott and Kloren (1987) reported that the use of fibre-free energy sources such as raw sugar or sugar cane juice permits greater use of cheaper vegetable and aquatic protein sources which are not usually included to a great extent in conventional diets because of their high fibre content. Therefore, the use of sugar palm juice in monogastric feeding, especially for pigs, will provide opportunities to farmers for better utilization of their own locally available feed resources as protein supplements and the cost of production will be reduced.

Economic Aspects of Sugar Palm Tree

Sugar palm production has been one of the main sources of income for rural families. The number of trees ranged from 10 to 30 per family which results in 1 to 3 tonnes of sugar palm syrup (approximately 80% DM) in the 6 month production period. However there are farmers who can collect juice from the female trees for the whole year. The price of the syrup varies from 400 - 600 Riels during the production period (dry season) to 1,000 - 1,200 Riels afterwards (rainy season). Sugar production still continues to be a source of income for the people who have access to free firewood.

It was shown during the study (Borin Khieu *et al*., 1996b) that when firewood was purchased for condensing sugar palm juice, some farmers lost an average of 20 Riels per tree per day. There is another alternative source of fuel, rice husks, which can replace firewood. This system requires a new kind of stove that was adapted by a French organization, the GRET. The income from sugar production using rice husk is comparatively better than with firewood. However, there is still insufficient fuel for cooking because the yield of husk from a hectare of rice is approximately 240 kg which provides only 4.5% of the total fuel consumption for condensing the juice of 20 trees. If opportunity cost of labour is taken into consideration, it greatly increases the cost of production because one to

two persons are permanently assigned to take care of boiling juice.

Using palm juice for pig feeding has proved to be an effective and sustainable method of production. Several trials showed that, from the economic point of view, the profit from using palm juice for pig feeding was much higher than for sugar production. The net profit was 140 Riels per tree per day, compared to only 10 Riels from sugar production (Borin Khieu *et al*., 1996b).

The sugar palm tree may produce 8-15 bunches of fruits with a total of about 80 fruits per year from female trees which are not exploited for juice. The price is 3,000 to 3,500 Riels per 40 kernels which are extracted from 15-20 fruits. Therefore, each tree provides approximately 12,000-14,000 Riels annually. In addition, the leaves also contribute other income or at least they can be used to thatch the houses. Finally when palm trees are over 10 m (70-100 years old), it is difficult to use them for juice collection. They are cut and sawn for house construction.

Constraints on Sugar Production

At present, the densest population of sugar palms is found in highly populated areas. This is leading to the disappearance of the trees because of the high demand for land for cultivation to satisfy the needs of the people. Another important reason could be that there is a need for timber for construction materials and a need for fuel for household cooking and for boiling juice. Many sugar palm tree are used every year as fuel to condense sugar palm juice. As an example, in 1995, it was estimated that 10-15 sugar palm trees were cut to supply part of the firewood requirement by the sugar producers in Tumnop Thom Commune, Punhea Leu District, Kandal province.

It should be noted that by using juice for pigs, 3.68 million tonnes of firewood will be saved each year. Therefore this system will contribute to the reforestation programme which is taking place at present in Cambodia.

Alternative Integrated Farming Systems

It has been calculated that the sugar palm trees in the country may produce enough juice to feed 3-4 million pigs or 14 million ducks. This shows great potential for replacement of cereals for animal feeding which is very important

for a country like Cambodia which has not produced enough cereal grain to feed its population since 1979. As the population grows rapidly, there will be a demand, not only for cereal, but also for meat. Pigs and ducks are the first choice as they grow fast and are in high demand by the people.

When low protein basal diets such as sugar cane and sugar palm products and by-products are fed to monogastric animals, the total protein needed is reduced considerably. This is because the ratio of essential amino acids is close to the optimum when the animal is supplemented with tree foliage and water plants such as Nacedero (*Trichantera gigantea*), duckweed (*Lemna* ssp.), water spinach (*Ipomea aquatica*) and azolla (*Azolla anabaena*) (Preston, 1995 and Leng *et al*., 1995). All these sources of protein are available in the ponds or around the households which are fertilized with the effluent from the plastic biodigester.

This integrated farming system provides an environmentally friendly solution, where the biodigester is playing an intermediate role in the system. Biodigestion enables the farmers to recycle waste and excreta from animals as well as humans. The number of biodigesters is growing very fast in Cambodia; up to now, there have been 450 digesters installed in different provinces of Cambodia. The popularity of the biodigester is connected to that of the human latrine and the need to solve the firewood problem. In addition, when pigs are raised in confinement, they produce waste and manure as a substrate for the digester which has not been the case in the past when they were mostly kept in a scavenging system. The biodigester does not produce only gas (methane) for household cooking but also provides fertilizer for rice fields and vegetable gardens which is better than the fresh manure. Farmers participating in the FAO GCP/RAS/143/JPN and Lutheran World Service (LWS) projects demonstrated that the biodigester provided great value by cutting down the expenditure on chemical fertilizer. The slurry from the digester is safe and it can be used as feed in the fish pond. It is also very important that the housekeepers (wives) are happy to participate in the system because it provides a clean environment in the kitchen, as well as the whole house, and it gives her more time to perform other work or participate in social activities.

Strategy for Animal Production Based on Sugar Palm

The development of livestock production in Cambodia will be based on small-scale farmers and the utilization of

local resources. The free range system is the common practice for all kinds of animals. But now there is a need to utilize available land for crop production in order to satisfy the demands of the growing population. The sustainable way to keep the system working and to solve these problems is to raise animals (especially cattle, buffaloes and poultry) in a semi-scavenging system. For instance, sugar palm products and by-products can be used as the energy basal diet with the protein supplement from the leaves of multipurpose trees like *Gliricidia, Acacia, Leucaena, Trichanthera*, etc. and water plants such as duckweed, *Azolla*, water spinach and so on. This should be the alternative way for livestock production in Cambodia. In the same strategy, pigs are proposed to be confined because of their propensity to destroy crops like sweet potato and vegetable gardens. By keeping pigs in a pen, they will also provide additional income as mentioned above.

Perspectives

In order to further develop this integrated system, more involvement from farmers is vitally important. A credit programme is needed for the poorer farmers who do not have money to start. It is crucial that both women and men participate in the discussion, in planning as well as implementing. The role of women in these activities is very important because the woman is the one who feeds the animals and spends most of her time looking after the farming system. However, the man does the rest of the activities such as climbing the sugar palm tree, ploughing the land, digging the pond, etc.

The majority of farmers are interested in raising fattening pigs but very few keep sows which makes the system unbalanced. Therefore the price of the piglets (15-20 kg) is 100,000 Riels, relatively high compared to the finishing pigs (90-100 kg) which cost about 330,000 Riels. The strategy for long term and sustainable development is to establish the reproduction system which can provide piglets in the villages so that they are more adapted to the native environment and local conditions. In this case, the indigenous pigs such as Chrouk Domrey, Chrouk Hainam, Chrouk Kandor, etc., are likely to be the best for prolificacy and efficient use of poor quality feed.

In the tropics there are many plant species that can be utilized better for animal feeding from the economic and environmental points of view than imported concentrate feeds. They are excellent components of the integrated farming system and part of the local ecological context. The plants which produce energy-rich feed are sugar cane, sugar palm trees and all palms yielding juice (*Coco nucifera, Arenga pinnata, Borassus species, Caryota urens, Nypa fruticans*, etc), palm oil, cassava, etc. However, in all livestock feeding, the most expensive ingredient is protein. In fact, on the small farm in remote areas, the availability of protein is restricted to what can be grown on the farm and the by-products available in the areas. In these cases, it is crucial to introduce multipurpose plant species that could be used as animal feed and which have a better amino acid balance.

Conclusions

In Cambodia, it is important to diversify the use of sugar palm trees for animal production in order to maintain these trees as part of the farming system because sugar production will not survive any longer in the provinces due to the firewood problem.

The multipurpose sugar palm trees have played an important role in an integrated system. They are very efficient utilizers of solar energy and may not require any fertilizer inputs. They provide high energy feeds, low in fibre but with very low protein contents. This allows the optimum use of on-farm products and by-products as protein sources for monogastric nutrition. These include leaves of Nacedero (*Trichantera gigantea*), sweet potato leaves, water spinach, silage of cassava leaves, duckweed, azolla, etc.

References

Borin Khieu, Preston, T. R. and Lindberg,J. E. 1996a. Juice Production from the sugar palm tree (*Borassus flabellifer*) in Cambodia and the performance of growing pigs fed sugar palm juice. (MSC thesis in Sustainable Tropical Animal System, Swedish University of Agricultural Sciences, Uppsala). pp 1-11.

Borin Khieu, Lindberg, J. E. and Preston, T. R. 1996b. A study on the multipurpose tree (*Borassus flabellifer*) and its products for animal feeding in Cambodia. (MSc thesis in Sustainable Tropical Animal System, Swedish

University of Agricultural Sciences, Uppsala). pp 1-10.

Elliott, R. and Kloren, W. R. L. 1987. The use of sugar in diet for monogastric. Recent Advances in Anim. Nutri. in Australia. pp 164-169.

Leng, R. A., Stambolie, J. H. and Bell R. 1995. Duckweed - A potential high-protein feed resource for domestic animals and fish. Livestock Research for Rural Development. Volume 7, number 1, October 1995. (16kb).

Preston, T. R. 1995. Tropical Animal Feeding: A manual for research workers, FAO Animal Production and Health Paper, No. 126. Chapter 3: Nutrition of non-ruminants. pp 35-49.

Preston, T. R. 1992. The role of multi-purpose trees in integrated farming systems for the wet tropics. In: Legume trees and other fodder trees as protein sources for livestock (Proceedings of the FAO Expert Consultation help at the Malaysia Agricultural Research and Development Institute (MARDI). FAO Animal Production and Health Paper No. 102. pp 193-208.

Preston, T. R. and Sansoucy, R. 1987. Matching livestock system with available feed resources. In: Proceeding of FAO Expert Consultation on the substitution of the imported concentrate feed in animal production system in developing countries. FAO Animal Production and Health Paper No. 63. pp 32-41.

Rice-based Livestock Systems in Northeast Thailand - Strategies for the Integration of Fish Culture

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Abstract

An analysis of production and distribution of rice products within a village, Ban Thap Hai, in Udorn Thani, Northeast Thailand suggests that current patterns of utilisation constrains use in integrated fish culture. Most rice bran (80%) is used by the rice miller to feed pigs. The remaining 'grower's share' is split between use as a supplementary feed for scavenging poultry and for fish. The extent of, and constraints to, integration between livestock and fish in the current situation are discussed. Potential fish production through direct use of ricebran and from livestock wastes is modelled based on data from on-station and on-farm research. The impact of changing distribution and use of surplus rice paddy and rice bran in the village on livestock and fish production is then considered. Feeding management for scavenging poultry has an important effect on productivity of both poultry and, subsequently, the amount of wastes available for fish culture. Inorganic fertilisation increases fish yields from feeding limited amounts of ricebran directly to fish or via poultry by over 100%. Retention of rice byproducts by the growers could have a major impact on total poultry and fish production in the village, potentially doubling the amount of fish that can be produced. The importance of off-farm factors in constraining smallholders' use of rice byproducts for livestock and fish will continue to increase.

KEY WORDS: Rice bran, fish, feed, integration, livestock, waste, recycling, manure, pig, poultry

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Introduction

Monogastric livestock are a traditional component of farming systems in Indochina. Their future role on smallholder farms, however, is threatened by the forces of modernisation affecting even the poorer, rural areas of the region. The importance of pigs and poultry in the household economy, as a bank and source of readily available 'feast food' has been recognised. Resource-poor farmers may attach greater value to these attributes than productivity *per se*. Typically raised in small numbers, pigs and poultry were traditionally allowed to scavenge for a significant part of their diet, thus obviating the need for nutritionally complete diets. In Northeast Thailand rice paddy and it's byproducts are the major feeds used; nowadays pigs are typically penned and fed concentrate in addition to ricebran and broken rice but poultry may only be fed a little paddy grain to supplement scavenging. Poultry are normally managed as mixed flocks of native chickens and muscovy ducks, raised mainly for meat, together with egg-laying strains of domestic duck. Modernisation has led to increased availability of both 'improved' breeds and feeds. Intensification of livestock production has resulted, although typical rice growing households do not appear to have benefitted. Indeed these changes may have stimulated a dichotomy of production (Little, 1995), in which smallholders in Northeast Thailand are increasingly excluded from livestock production. Part of this appears linked to macroeconomic changes in which the balance of rural livelihoods shifts towards urbanisation and specialisation. Thailand's steady economic development may have prevented the reversals of this process that have been observed in other parts of the World where external inputs have become limiting (e.g. Rodrigues, this conference, Ibrahim and Abdu, 1996).

A significant step in the effects of modernisation on rural livestock production in Northeast Thailand has been the change from manual to machine milling of rice. The convention has developed that the rice byproducts are ceded to the miller in lieu of a cash milling fee, a practice that inevitably results in the concentration of rice bran and broken rice in the hands of the rice miller, and poorer availability to the farmers who grew the rice. This is in contrast to some parts of Indo-China where rice growers pay a milling fee and keep their rice bran for their own livestock. Access to rice bran is particularly important if other feeds have not been traditionally fed to livestock, such as in Northeast Thailand. This contrasts with areas with more diversified cropping systems, such as the Red River Delta of North Vietnam, where a variety of feeds are purposefully cultivated for pigs.

Increasing the productivity of livestock systems could be a major strategy for increasing outputs of cultured fish.

Ponds in Northeast Thailand, which are often stocked with young fish, typically lack nutrients and produce low fish yields (Edwards *et al*., 1991). Although the use of livestock wastes for fish culture is traditional in other parts of Asia, such practices are relatively new to this, the poorest part of Thailand. Until recently wild fish had provided for peoples' needs but now, fish pond construction and the production of fish is being actively promoted and adopted by rice growing farmers. More fish culture could affect the village rice bran economy. Rice bran is currently the most common supplement fed directly to fish in farmers' ponds and rice fields (Edwards *et al*., 1991). Most of this rice bran is obtained from mills within the village, perhaps resulting in competition with livestock for this limiting resource.

Several factors could increase the rice growers' livestock numbers and productivity, both to improve returns and to enhance the quantity and quality of waste available for fish culture. More on-farm feeds could be used to 'spare' the limited amounts of rice products available to rice growers. Alternatively feeds or additives could be purchased from off-farm sources. The introduction of improved strains or breeds of livestock into rural areas might utilise better diets more efficiently but be unsustainable unless overall management is changed to suit their requirements. Integration of livestock and fish may have an important role under conditions of nutrient scarcity, such as most rural areas of Northeast Thailand. Where nutrients are limiting, re-use in fish culture could improve overall efficiency and support a more diversified food production system. In contrast, when nutrients are locally super-abundant, such as around livestock feedlots, fish ponds can 'treat' the waste and reduce their impact on the local environment.

Objectives

This study attempts to investigate the effects of availability and use of rice bran from village rice mills and surplus rice paddy on livestock and fish production using a dynamic model. Using data derived from experimentation and observation of farmers' systems we will attempt to improve our understanding of livestock production systems in relation to these feed resources. The effect of different livestock feeding strategies on fish yields will be compared. It is hoped that the impacts of rice milling practices on livestock and fish culture can be illustrated and used in comparisons with other systems in Indochina.

Materials and Methods

The main sources of data for this model are from an analysis of paddy rice production and utilisation in two villages of Udorn Thani, Thailand (Thomas, 1989). Additional data for the current utilisation of rice byproducts for pig production was obtained recently in the same area (AIT Aquaculture Outreach, data). Household paddy utilisation in Northeast Thai villages was taken from Chayaputhi and Kongkajandr (1977) as cited by KKU-FORD (1982).

Input/output data for poultry-fish systems was obtained from research on and off AIT campus (AFE, 1992 and AASP, 1996-IDRC). Data concerning smallholder and commercial-scale pig-fish production systems are from Long (1995) and Poudyal (1990) respectively. The model was developed using STELLA (Systems Thinking, Experiential Learning Laboratory with Animation) II version 3.0 on the Macintosh computer.

Scenarios have been based on a wide variety of livestock and fish production systems (Table 2). The poultry used for on station trials were mainly Muscovy ducks (Cairina moschata) and domestic egg-laying ducks. Input/output data was obtained from controlled experimentation in earthen ponds and extrapolated from concrete tanks, for 180 day periods. This duration mirrors water availability in seasonal ponds in Northeast Thailand. The model assumes that poultry and pig wastes are used as far as is practical, i.e. pigs are penned and all the wastes (including urine) may be channelled and used for fish production. The wastes from poultry scavenging throughout the farm and its margins are assumed to be collected from night-time confinement and used the following day for fish production. The fish species cultured is the Nile tilapia (Oreochromis niloticus, stocked at densities of 2-4 fish/m^2).

Description of the Systems

The two villages studied, an irrigated lowland village, Ban Kan, and a rainfed upland, Ban Thap Hai, are representative of the range of rice growing conditions in the region. A single rice crop is grown in both villages; the greater planted area and higher rice yields in the irrigated area (2.6 MT/ha cf 2.25) increase the amount of paddy and, subsequently rice bran in the village. Rice millers retain most of the rice bran in both villages (80%). The greater quantities of rice bran from rice grown and milled in the village, together with additional amounts

purchased by both millers and growers increase the total available in the irrigated area village. Thus, whilst in rainfed Ban Thap Hai only rice millers raise pigs, in irrigated Ban Kan pigs are also raised to some extent by rice growers. Typically pigs are fed rations in which purchased concentrate and broken rice is mixed with the rice bran.

In rainfed Ban Thap Hai, the remaining rice bran is purchased back by rice growers and used as supplementary feed for scavenging poultry (>80%) or fish (<20%). The size of poultry flocks appears to be most limited by the availability and price of this feed (Little *et al*., 1992).

Farmers also use part of their unmilled rice paddy crop for feeding poultry, particularly chickens and egg-laying ducks. They may also improve the quality of the supplementary feed using purchased concentrates but this practice is most common for chicks and laying ducks and rare for growing/fattening birds.

Table 1 Comparison of two villages in Udornthani, Northeast Thailand in terms of rice production and byproduct distribution.

Village	Ban Kan	Thap Hai
Type of land	Irrigated lowland	Rainfed upland
Number of village household	250	162
Rice production (kg/rai/yr)	416	360
Land per household (rai)	13	13
Distribution of rice bran rice miller (%)	78.8	78.6

rice grower (%)	20.5	21.4
outside village (%)	0.6	0
Purchased rice bran by rice miller (kg/yr)	8,100	0
Purchased rice bran by rice grower (kg/yr)	1,670	0
Rice bran recovery (1) (%)	12.6	11.3
Result from model (180 days)		
Available rice bran for rice miller (kg/day)	332.8	155.3
Available rice bran for rice grower (kg/day)	85.4	42.3
Total rice bran in village (kg)	70,960	35,574
Available rice bran for rice miller (kg)	55,973	27,961
Poultry activity (kg)	1,078	56
Fish activity (kg)	419	419
Pig activity (kg)	58,470 (Outside 3994.5)	27,486

Available rice bran for rice grower (kg)	14,561	7,613
Poultry activity (kg)	6,993	6,188
Fish activity (kg)	2,336	1,425
Pig activity (kg)	6,056 (outside 430.9)	0

(1): % of paddy grain as rice bran

Almost all pigs are sold for slaughter outside of the village whereas most poultry products are consumed in the village and, very often, in the household. Fish is both consumed by the household and sold locally.

Options for Change

The range of scenarios modelled is given in Table 2 is based on Ban Thap Hai, the rainfed village more typical of the region. The table reflects the possible strategies to use the currently available rice bran in which rice growers retain only 20% of the total produced.

The scenarios relate to various feeding strategies to increase livestock numbers, rather than productivity per se, in order to increase livestock waste for fish culture. In particular, the effect of restricted feeding (case 1-3) and substitution of village rice bran by a mixture of sun-dried cassava root, leaf meal and ground rice husk were tested (case 4-8).

Also considered is the use of rice bran directly as a supplementary fish feed, with or without inorganic fertilisation of the fish pond (case 10-12). The use of rice bran or surplus paddy rice is also considered for egg-laying ducks. The use of rice bran for pig fattening is considered in cases 13-14.

The area of fish pond in which a given level of nutrients is added also affects the amount of fish that can be produced; more fish will be produced in a larger pond receiving the same amount of wastes than a smaller pond (Tables 3 and 4).

Table 2. Case Description.

Case	Description
1	Scavenging Muscovy ducks confined and fed village rice bran ad libitum at night; wastes collected and used to raise fish over a range of loadings (Ratio of duck: water from 1,500-2,500 ducks/ha); fish stocked at 2/m^2 in 5 m^2 concrete tanks.
2	Scavenging Muscovy ducks confined and fed a restricted ration (75 % of voluntary intake) of village rice bran at night; wastes collected and used to raise fish over a range of loadings (Ratio of duck:water from 1,500-2,500 ducks/ha; fish stocked at 2/m^2 in 5 m^2 concrete tanks)
3	Scavenging Muscovy ducks confined and fed a restricted ration (50% of voluntary intake) of village rice bran at night; wastes collected and used to raise fish over a range of loadings. (Ratio of duck:water from 1,500-2,500 ducks/ha; fish stocked at 2/m^2 in 5 m^2 concrete tanks)
4	Scavenging Muscovy ducks confined and fed a supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran] ad libitum at night; wastes collected and used to raise fish at a high rate (62.5 Kg DM/ha/day); fish stocked at 2 fish/m^2 in 5 m^2 concrete tanks
5	Scaveging Muscovy ducks fed with supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran], allowed to feed ad libitum and wastes collected during overnight confinement of Muscovy ducks loaded at a low rate (32.7 Kg DM/ha/day) with urea (0.5 KgN/ha/day) and TSP (0.32 KgP/ha/day) ; Monoculture Tilapia (2 fish/m^2 in 5 m^2

	concrete tanks)
6	Scavenging Muscovy duck fed with supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran], allowed to feed restricted (levels of 50 % the voluntary intake rate) and wastes collected during overnight confinement of Muscovy ducks loaded at a high rate (62.5 Kg DM/ha/day); Monoculture Tilapia (2 fish/m^2 in 5 m^2 concrete tanks)
7	Scavenging Muscovy duck fed with supplementary feed [50 % cassava (a mixture of dried cassava leaf and root meal and ground rice husk) and 50 % village rice bran], allowed to feed restricted levels of 50 % the voluntary intake rate) and wastes collected during overnight confinement of Muscovy ducks loaded at a low rate (32.7 Kg DM/ha/day) with urea (0.42 KgN/ha/day) and TSP (0.31 KgP/ha/day); Monoculture Tilapia (2 fish/m^2 in 5 m^2 concrete tanks)
8	Scavenging Khaki campell (laying duck) fed with supplementary feed (village rice bran) ad libitum; stocking density 500 ducks/ha (water area); Monoculture of Nile tilapia at a stocking density of 2 fish/m^2 in 200m^2 earthen pond, also loaded with urea (1.7 KgN/ha/day)
9	Scavenging Khaki campell (laying duck) fed with supplementary feed (paddy rice) ad libitum; stocking density 500 ducks/ha (water area); Monoculture Tilapia with 2 fish/m^2, pond add urea to get Nitrogen loading at 1.7 KgN/ha/day
10	Direct village rice bran fed to Tilapia and Mrigal (25 Kg DM/ha/day) : fish stocking rate (Tilapia 3 fish/m^2 and Mrigal 1fish/m^2)
11	Direct village rice bran fed to Tilapia and Mrigal (25 Kg DM/ha/day) : fish stocking rate (Tilapia 3 fish/m^2 and Mrigal 1 fish/m^2); add urea 1.5 KgN/ha/day and TSP 0.75 KgP/ha/day)
12	Direct village rice bran fed to Tilapia and Mrigal (25 Kg DM/ha/day) : fish stocking rate (Tilapia 3 fish/m^2 and Mrigal 1fish/m^2); add urea 3.0 KgN/ha/day and TSP 1.50 KgP/ha/day)

13	Hybrid pigs fed a mixture of cooked village rice bran and water hyacinth (*Eichhornia crassipes*) at rates of 4% and 5% Body wt/pig/ day respectively on a fresh weight basis. All wastes loaded daily into earthen ponds (200m^2) at a ratio of 50 pigs/ha. Mixed sex Nile tilapia and hybrid clarias catfish stocked at rates of 2 and 0.25 fish/m^2; 3 month culture period.
14	Hybrid pigs fed a mixture of rice bran (14%), dried cassava chips (35%),maize (20%), concentrate (31%) by a commercial farm. Pigs raised at a ratio of 123 pigs/ha fishpond. Fish yields of 20 Kgs/ha/d from a tilapia/carp polyculture in 0.3 ha earthen ponds managed by 3 month partial harvest .

Table 3 Potential poultry and fish production of rice growers using different rice-based feeding strategies based on current availability of paddy and rice bran to rice growers in Bang Thap Hai, Udornthani (180 day production).

Case	Management	Type	Fish inputs	No. ducks
1	*ad libitum*	rice bran	-	300
2	75 % *ad libitum*	rice bran	-	482
3	50 % *ad libitum*	rice bran	-	675
4	*ad libitum*	50 % rice bran + 50 % cassava	-	433
5	*ad libitum*	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	433
6	50 % *ad libitum*	50 % rice bran + 50 % cassava	-	903

7	50 % *ad libitum*	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	903
8	*ad libitum*	rice bran	add inorganic fertilizer (2)	220
9	*ad libitum*	paddy rice	add inorganic fertilizer(2)	1,182
10	-	-	only rice bran	-
11	-	-	rice bran + low inorganic rate (3)	-
12	-	-	rice bran + high inorganic rate (4)	-

(1) Urea 0.108 g/m2/day and TSP 0.160 g/m2/day;

(2) 1.7 KgN-ha/day ;

(3) 1.5 Kg N and 0.75 Kg P/ha/day;

(4) 3.0 Kg N and 1.5 Kg P/ha/day

Table 3 Potential poultry and fish production of ricegrowers using different rice-based feeding strategies based on current availability of paddy and rice bran to rice growers in Bang Thap Hai, Udornthani (180 day production). (continued)

Case	Kg of flock or No. of	Net fish yield	Pond area

	eggs	(kg)	(m^2)
1	865	310.7-428.5	1,501-2,001
2	1,067	458-636	1,927-3,214
3	1,264	574-672	2,701-4,497
4	731	244	1,673
5	731	522	2,789
6	988	449	3,615
7	988	921	6,023
8	6,448 eggs	1,225	4,396
9	63,402 eggs	3,311	23,639.9
10	-	732	2,878.9
11	-	1,270	2,878.9
12	-	1,580	2,878.9

Table 4: Potential poultry and fish production using different rice-based feeding strategies based on retention of rice bran by rice-growers in Ban Thap Hai, Udorn Thani (180 day period).

Case	Management	Type	Fish inputs	No.

				ducks
1	*ad libitum*	rice bran	-	1403
2	75 % *ad libitum*	rice bran	-	2252
3	50 % *ad libitum*	rice bran	-	3154
4	*ad libitum*	50 % rice bran + 50 % cassava	-	2021
5	*ad libitum*	50 % rice bran + 50 % cassava	add inorganic fertilizer(1)	2021
6	50 % *ad libitum*	50 % rice bran + 50 % cassava	-	4221
	50 % *ad*	50 % rice bran +	add inorganic	

7	*libitum*	50 % cassava	fertilizer(1)	4221
8	*ad libitum*	rice bran	add inorganic fertilizer (2)	1027
9	*ad libitum*	paddy rice	add inorganic fertilizer(2)	1182
10	-	-	only rice bran	-
11	-	-	rice bran + low inorganic rate (3)	-
12	-	-	rice bran + high inorganic rate (4)	-

(1) Urea 0.108 g/m2/day and TSP 0.160 g/m2/day;

(2) 1.7 KgN-ha/day ;

(3) 1.5 Kg N and 0.75 Kg P/ha/day;

(4) 3.0 Kg N and 1.5 Kg P/ha/day

Table 4: Potential poultry and fish production using different rice-based feeding strategies based on retention of rice bran by rice-growers in Ban Thap Hai, Udorn Thani (180 day period).(Continued)

Case	Kg of flock or No. of eggs	Net fish yield (kg)	Pond area (m^2)
1	4,041	1,452-2,002	7,015-9,349
2	4,985	2,139-2,974	9,002-15,021
3	5,905	2,681-3,139	12,622-21,014
4	3,416	1,140	7,820
5	3,416	2,440	13,033
6	4,619	2,098	16,892
7	4,619	4,306	28,143
8	30,132 eggs	5,725	20,540
9	63,402 eggs	3,311	23,640

10	-	3,420	13,452.6
11	-	5,935	13,452.6
12	-	7,383	13,452.6

Pigs

Most pig production is based on the feeding of a dry mash of freshly milled rice bran, broken rice and purchased concentrate. Traditionally, before concentrates from feed mills were available, rice bran was fed together with leftover human food and weeds.

If pig feed is prepared by cooking rice bran with water and vegetables, approximately 50 pigs can be supported on rice bran from a village of 162 households such as Ban Thap Hai. At a ratio of 50 pigs/ha of pond, over 1-1.2 MT of fish could be produced over a period of 180 days.

The use of concentrates and other ingredients can increase the herd size for a given amount of rice bran considerably. A reduction of rice bran to around 14% of a least cost, nutritionally balanced feed used by larger operations in the area allows a theoretical increase in standing herd size to over 400 animals and fish production to over 12 MT. This eight-fold increase in pig numbers is based on the use of rice bran together with maize and soya bean, which are imported into the village and dried cassava root chips which could be obtained within the village. Increases in waste quantity and quality are offset to some extent by higher ratios of pig:pond area.

The purchasing of concentrate to mix with broken rice and rice bran is the normal current practice for rice miller/pig raisers in the region. Based on a typical ration, a mean herd size of 59 pigs is maintained on rice bran available to rice millers in Ban Thap Hai. This suggests that rice millers feed their pigs fairly inefficiently, a practice perhaps encouraged by the availability of cheap rice byproducts.

Poultry

The efficiency of rice growers using smaller amounts of rice bran for scavenging poultry is clear. Although the amount of rice bran used for poultry is a fraction of that fed to pigs by the millers, relatively large amounts of poultry and fish can be produced despite the amounts of bran and flock size being small. The poultry scavenging for natural foods over a large part of the day also makes a proportion of wastes uncollectable. Based on the total amount of rice bran available for rice growers in Ban Thap Hai a total of around 300 muscovy ducks can be raised on rice bran alone and over 400 Kg of fish produced if the waste was used as an input to fish culture. If the amount of fish produced from feeding the small amounts of rice bran directly to fish is added, over 1 MT of fish can be produced in the village derived from the small 'grower's share' of the rice bran.

Amounts of poultry waste can be increased in several ways. In practice scavenging poultry are often fed limited rations rather than ad libitum. This allows a larger flock (>100%) to be raised from the same amount of rice bran, increasing the pressure for the birds to scavenge natural feeds. Growth of individual birds is slower (Table 3, case 1), but overall flock yield is higher. The slower individual growth may synchronise better with the main demand for fattened poultry occurring between rice harvest and Thai New Year (Little *et al*. 1992). Also, after rice harvest, a seasonal abundance of rice bran allows for fattening prior to slaughter. Moreover, the area of pond that can be fertilised and amount of fish produced also increases as individual feed levels are restricted and flock size increases. Whereas ad libitum feeding of poultry could produce an estimated 428 Kg fish, limiting feeding to 75% and 50% of these levels increases fish production to 636 Kg and 672 Kg respectively.

Flock size, and wastes available for fish production, can also be increased by 'sparing' rice bran with cassava byproducts, commonly grown on the farm. Using this measure, together with restricted feeding, flock size can be increased by a factor of 3 using the same absolute amount of rice bran (cf cases 1 and 6, Table 3). There appears to be no advantages to fish production, however. Digestibility and nutrient release studies suggest that little of the nitrogen in the cassava leaf may be available for either ducks or uptake by phytoplankton (AFE, 1992).

Use of rice bran as a direct supplementary feed, particularly in fertilised ponds, is the most efficient means to produce fish for the village. Only 5% of the rice bran produced was fed directly to fish in Ban Thap Hai but use of inorganic fertilisation to increase the levels of natural feed in the pond would improve its efficiency of use

considerably. Fertilisation of ponds increased yields to 1270 Kg and 1580 Kg (@1.5KgN/ha/d and 3 KgN/ha/d respectively; N:P =2) compared to 732 Kg without fertiliser. A FCR of 1.77 of feeding rice bran directly to fish compares favourably to more than 9 if the amount of rice bran to produce fish via poultry is considered.

Supplementation with inorganic fertilisers boosts fish production from the waste of poultry fed the same amount of rice bran by over 100% (cf cases 4 and 5; 6 and 7, Table 3).

Current rice bran use could have greater impact on fish production in the village as a whole if ponds received inorganic fertilisers. In Ban Thap Hai, even with the limited availability of bran for ricegrowers to raise poultry and fish, approximately 5 MT of fish could be raised per year from this source in perennial ponds (e.g. case 7, Table 3) which is equivalent to around 30 Kg/household.

The direct use of rice paddy surplus to feed small numbers of scavenging egg-laying ducks is also common among ricegrowers; the wastes of these birds can also produce significant amounts of fish. The number of ducks raised by rural households relates to their paddy surplus compared to consumption needs, the desire for home-produced eggs and the value of paddy rice on the market. If the amount of rice paddy surplus to consumption and other requirements (seed, exchange, debt service, wages etc; KKU-Ford, 1982) is utilised as supplementary feed for scavenging egg ducks, a total flock of 1182 birds, producing more than 2 eggs/household/day, can be supported. The collectable wastes from these birds can, with minimal levels of inorganic fertilisation, produce over 100 g fish/household/day. These levels contribute substantially towards household consumption requirements (Mekong Committee,1992).

Scenarios

The following situations were simulated to estimate the effect of changes in rice bran utilisation on fish production in Ban Thap Hai. Scenarios 1 and 2 reflect the current control of rice and its byproducts in the village, but that the wastes of the livestock are utilised for fish production. Scenario 2 is based on the rice growers diverting all rice bran to fish and none for poultry.

Scenarios 3 and 4 indicate possible fish yields if rice growers retain control of all the rice bran produced in the village either using it for poultry and fish at the same ratio as currently (3) or using all of the extra rice bran for fish and maintaining poultry at current levels (4). The scenarios are characterised by the ratio of the millers share, mainly fed to pigs (M), to the amount fed by the grower to poultry (GP) to the amount fed by the grower to fish (GF).

(1) current (80:16:4)

This assumes that rice bran is used at current rates by ricemillers and growers for feeding pigs and poultry respectively and that all these wastes are used for fish culture. Additional fish is produced from direct feeding of rice bran and the range reflects the level of inorganic fertilisation. It also assumes that surplus rice paddy is used to feed egg-laying ducks, the waste of which is also used in fish culture.

(2) give up feeding rice bran to poultry and use all the rice bran that they can purchase (i.e. current growers share of all rice bran) for fish culture (80:0:20)

This option would lead to an estimated 6 fold increase in the fish produced by rice growers over levels in which all poultry wastes are used for fish culture. Mean fish production, assuming all the growers rice bran was used in this way, would vary between 52-114 Kg/household/year, depending on the level of inorganic fertilisation used in the fish ponds.

(3) purchase back all their rice bran and then use it for poultry and fish production at current ratios (0:80:20)

This would produce a similar range of fish yields as (1) and (2), but all of the fish would be produced by the ricegrowers rather than a large proportion by the miller.

(4) purchase back all their rice bran, maintain poultry at current levels and use the extra for fish production (0:20:80)

This scenario indicates the levels of fish production that might be possible if rice growers gained access to all of the rice bran produced and used most of the bran for fish culture. Assuming that they maintain poultry at current levels and integrate the wastes with fish culture, it is clear that this would support only a minor part of potential fish production. Yields approaching 40 MT/over a 6 month season are possible if most of the rice bran produced in the village is used as a supplement in fertilised fish ponds. Up to 9 hectares total of ponds would be required for such a scenario, which is nearly 30% of the planted rice area. In practice, fish production would likely be constrained at much lower levels by lack of perennial water and suitable sites. Only a fraction of this pond area (about 1 ha) was available at the time the survey was carried out. However the scenario does suggest the impact that local feed resources could have on local fish production.

Table 5 Potential range of fish production in Ban Thap Hai based on number of livestock and fish fed rice based feeds for 4 different scenarios of byproduct utilization (ratio of miller's share (M): growers & poultry (GP): growers & fish (GF))

Scenario ratio M:GP:GF	Feed	Route to	Fish production (kg/180days)		
			Miller	Grower	Total
1.Current 80:16:4	rice bran	livestock waste	1,686-12,228	244-1,225	
	rice bran	direct feed	215-465	732-1,580	
	paddy rice	livestock waste	-	3,311	

			1,901-12,693	4,287-6,116	6,188-18,809
2. 80:0:20	rice bran	livestock waste	1,686-12,228	-	
	rice bran	direct feed	215-465 8,440	3,910-3,311	
	paddy rice	livestock waste	-	3,311	
			1,901-12,693	7,221-11,751	9,122-24,444
3. 0:80:20	rice bran	livestock waste	-	1,140-5,725	
	rice bran	direct feed	-	3,420-7,383	
	paddy rice	livestock waste	-	3,311	
				7,871-	7,871-

		-		16,419	16,419
4. 0:20:80	rice bran	livestockwaste	-	244-1,225	
	rice bran	direct feed	-	15,093-32,581	
	paddy rice	livestockwaste	-	3,311	
		-		18,648-37,117	18,648-37,117

Table 6 Area of ponds (m^2) required for fish production by rice millers and growers in Bang Thap Hai for 4 different scenarios of rice bran.

Case	Ratio	Miller	Grower	Total
1.	80:16:4	9,954-34,485	1,231-4,497	11,155-38,982
2.	80:0:20	9,954-34,485	15,380-23,640	25,334-58,125
3.	0:80:20	-	5,614-28,143	5,614-28,143
4.	0:20:80	-	1,201-	1,201-

			59,370	59,370

Note : in 1988, Area of culture pond was 1.1 ha (11,000 m^2)

Constraints to Use of Millers' Pig and Growers' Poultry Manure for Fish Culture

Currently, the linkages between the rice millers' pigs, village poultry and fish are weak. A recent survey indicated that only 3 out of 25 mills used their pig manure to raise fish; much of the rest was utilised to some extent for rice fields, vegetables or given to neighbours. Cultural aversion to the use of livestock wastes, particularly pig manure, in fish culture exists but does not seem to be a major factor in preventing integration in most cases. Lack of labour and water for raising fish and the distance between pigs and ponds constrained integration. Twenty per cent of rice millers didn't use their manure for fish culture because they used their pond water for domestic purposes and didn't want 'dirty' water (AAOP data).

The likelihood of the rice millers' pigs becoming a significant source of nutrients for fish culture look unlikely for a variety of reasons. Currently, a good deal of potential fish production is lost through poor use of pig wastes by rice millers. The central location of rice mills in the village and the need for constant attendance probably limits the efficiency of its use by these actors. The lack of waste recycling into fish culture reflects the millers' main business foci and their higher-than-average economic status. Aquaculture has been found to be of both interest to middle-income households (AAOP data). The high proportion of millers that give waste away to their neighbours (>50%) suggests that some waste may finally be used for fish culture, although the urine, which is rich in both nitrogen and phosphorous, would be likely lost. Its use elsewhere in food production is also likely to be sub-optimal; seasonal aridity constrains the efficient use of manures in the rainfed cropping systems of the region and probably a major proportion of the nutrient value is lost.

The ponds of rice growers have also been found to be unintegrated with poultry production and various factors, particularly the distance between fish and poultry operations, are believed to be important constraints (Little, 1995). Recent on-farm trials, however, suggest that rice growers will collect the waste of their scavenging poultry

from overnight pens and use it in their fishponds (AASP, 1996). In general, little sustained interest for intensification of backyard poultry was found among individual farmers who are mainly motivated to raise poultry to satisfy household needs (AASP, 1996). This may be explained partly by the marginal financial returns, risk of loss from disease and an increasing reliance on off-farm income. However, the continued interest by many households in raising a small mixed poultry flock for social and cultural reasons together with the control of most of the rice crops byproducts by rice millers probably prevents the potential rise of 'medium-scale' producers from obtaining enough rice bran. The sustainability of poultry systems in their current form looks linked to the future of village life generally. The high opportunity cost of labour has been a major factor in changing rural lifestyles; the rapid replacement of other livestock, such as water buffalos by mechanised tillers is explained partly by this factor. Raising poultry requires little labour and the typical small flock can be managed by older family members close to the home provided some rice bran can be purchased back from the mill.

The use of 'surplus' rice paddy for feeding egg-laying ducks is a common practice. The relatively small surplus does appear to restrict the practice to small flocks (<15) serving to producing eggs for household consumption; retention of larger amounts of paddy to raise ducks for selling eggs is not worthwhile. As a high proportion of duck eggs are consumed by children in school packed lunches, this may have strategic nutritional impact. Integration with fish culture could improve the overall returns of duck egg production based on rice paddy. The potential impact of using more inorganic fertilisers, with or without rice bran or rice bran-derived wastes, for fish production are great (Edwards *et al*.1991, Edwards, 1993). Farmers have accepted the supplementation of ruminant manure with small quantities of inorganic fertilisers, but current trials suggest that the higher levels used in this study are also adoptable and effective under village conditions. The use of inorganic fertilisers in the fish pond, as opposed to elsewhere on the farm, is a critical issue. Current use of inorganics on rice and other crops is low, partly because of the unpredictable response on the infertile and rainfed conditions (Ragland and Boonpuckdee, 1988).

The role of inorganic fertilisers, patterns of outmigration and habitation in the village and their impacts of mechanisation and labour utilisation all affect rice yields and the availability of byproducts. Further, fundamental changes in average land holding and strategies for maintaining output (Surinteraseree,1996) will all affect levels of rice production and maybe the marketability of poultry and fish products.

Conclusion

The control of rice byproducts after local processing has a major impact on the livestock and fish production of rice growers. The use of rice bran as a supplementary feed for scavenging poultry or part of the ration of feedlot pigs, could support significant fish production if the activities were integrated. In practice, although many factors limit livestock waste re-use for fish production under Northeast Thai village the dominance of rice bran use by rice millers is a major constraint. Lack of rice bran and its high price is a critical barrier to farmers producing more monogastric livestock, particularly poultry, and their integration with fish. The model illustrates the benefits that more control of rice bran by the rice growers could bring to their poultry and fish production. Moreover, such changes would likely improve the efficiency of nutrient use and efforts to diversify by rice growers.

Other mechanisms exist to increase synergism between activities including attention to poultry feeding strategies and the use of more non-rice ingredients. The feeding of paddy grain surplus to egg-laying ducks has potential to support household needs of eggs and contribute substantially towards fish consumption needs. More direct use of rice bran for fish culture optimises fish yields but would reduce the availability of feed for poultry production. Inorganic fertilisation improves the effectiveness of both poultry manure and rice bran as inputs to fish culture. Trends in production and consumption in the village, which are linked to macroeconomic changes, may have fundamental impacts on poultry and fish production.

References

AFE, Agricultural And Food Engineering, 1992. Final Report- Muscovy Duck Project : The development of economic feeding systems for Muscovy ducks (Cairhina moschata) in duck/fish integration in Thailand (15 May 1988-31 December 1991) . Agricultural And Food Engineering, Asian Institute of Technology, Bangkok, Thailand. 36 pages.

AASP, Agricultural and Aquatice Systems Program, 1996. Final Technical Report -IDRC : The development of

feeding systems for fish and an integrated duck-fish system (30 December 1991 - 31 April 1996). Agricultural and Aquatic Systems Program, School of Environment, Resources and Development, Asian Institute of Technology. 41 pages.

AASP,Agricultural and Aquatic Systems Program, 1996. Final Report-ODA suppport for aquaculture at the Asian Institute of Technology (December 1992 - May 1995) and Aquaculture support project (June-November 1995). Agricultural and Aquatic Systems Program, School of Environment, Resources and Development, Asian Institute of Technology. 126 pages.

Edwards, P, K.E. Weber, Ed W. McCoy, C. Chantachaeng, C. Pacharaprakiti, K. Kaewpaitoon, S. Nitsmer, 1983. Small-scale fishery project in Pathumthani Province, Central Thailand: socio-economic and technological assessment of status and potential. Agriculture and Food Engineering Division and Human Settlements Development Division, Asian Institute of Technology, Bangkok, Thailand. 256 pages.

Edwards, P., H. Demaine, S. Komolmarl, D.C. Little, N. L. Innes-Taylor, D. Turongruang, A.Yakupitiyage, T.J. Warren, 1991. Toward the Improvement of Fish Culture by- Small-scale Farmers in Northest Thailand. J. Asian Farm. syst. Assoc. 1, 287-302. Edwards, P. 1993. Environmental issues in integrated agriculture-aquaculture and wastewater-fed fish culture systems, p. 139-170. In R.S.V. Pullin, H.Rosenthal and J.L. Maclean (eds) Environment and aquaculture in developing countries. ICLARM Conf. Proc. 31, 359 p.

Ibrahim, Mamman A. and Paul A. Abdu. 1996. Ethno- agroveterinary Perspectives on Poultry Production in Rural Nigeria. In Ethnoveterinary Research & Development. Constance M. McCorkle *et al*. (eds.) Intermediate Technology Publications, London, U.K., pp. 103-115.

KKU-FORD,1982. An Agroecosystem Analysis of Northeast Thailand. KKU-FORD Cropping systems project, Faculty of Agriculture, Khon Kaen University, Thailand. August 1982. page 88-89.

Little, David C., Khalil and P. Takaikaew, 1992. Development of Duck-fish Integrated Systems in Northeast Thailand. Sustainable Animal Production Proceedings of the Sixth AAAP Animal Science Congress, Vol.II., pp. 93-

106.

Little, David C., 1995. The Development of Small-scale Poultry-fish Integration in Northeast Thailand: Potential and constraints. In Seminar TSThe Management of Integrated Freshwater Agro-Piscicultural Ecosystems in Tropical AreasCC, Brussels, 16-19 May 1994, J. J. Symoens and J. C. Micha (eds.) Technical Centre for Agricultural and Rural Co-operation (CTA) Royal Academy of Overseas Sciences (Brussels) 00. 265-276.

Long, Duong Nhut, 1995. An Investigation into a Low Input Pig-fish System appropriate for the Maekong Delta, Vietnam. Master of Sciecne Thesis, Asian Institue of Technology, Bangkok, Thailand. 75 p.

Maekong committee, 1992. Fisheries in the Lower Mekong Basin (Review of the Fishery Sector in the Lower Mekong Basin) Main report. Interim commitee for Coordination of Investigations of the Lower Mekong Basin, May 1992. page 10.

Poudyal, Hem Raj. 1990. An on-farm study of a commercial integrated farm in Northeast Thailand. Master of Science Thesis, Asian Institute of Technology, Bangkok, Thailand. 168 p.

Ragland, John and Ladda Boonpuckdee, 1988. Soil Fertility Management in Northeast Thailand. NERADICS Technology Documentation Series, Paper No. T7, Northeast Rainfed Agricultural Development Project (NERAD), Northeast Regional Office of Agriculture, The Phra, Khon Kaen, Thailand. NERADICS PCE-4007-1031. 23 p.

Surinteraseree, P. 1996.Doing more with less:Impacts of non- farm employment on rice reduction in northeastern Thailand. PhD thesis. McGill University, 175 p.

Thomas, John., 1989. An asessment of the use of rice bran as a fish feed in four areas of Udornthani province in the Northeast Thailand. Master of Science Thesis, Asian Institute of Technology. 70 p.

Poultry and Fish Production - A Framework for Their Integration in Asia

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Abstract

A framework for the integration of poultry and fish production in the tropics and sub-tropics is proposed. Poultry may be integrated with fish culture in several ways and benefits extend to both. Both poultry production and processing wastes have value as nutrient inputs to fish and the water used for fish culture can be used for evaporative cooling of poultry and fertilization of crops. The conceptual basis of controlled eutrophication of fishponds using poultry manure for the production of herbivorous fish is compared to feeding of abattoir wastes to carnivorous fish. A comparison of poultry production systems in terms of their potential for integration with fish culture is made; the modern feedlot is compared and contrasted with traditional systems. The nature of poultry wastes is reviewed with respect to the effect of poultry strain/species, diet, and poultry and waste management. The impacts of the use of bedding materials, frequency of waste collection and contaminants are discussed. The use of poultry feedlot waste alone for fish culture is compared to the use of waste and additional fertilisers or feeds. The relative value of wastes from scavenging poultry alone or together with other inputs is analysed. The political economy of current poultry and fish production are considered in this article. The impacts on public health and the environment are also discussed.

KEY WORDS: aquaculture, fish nutrition, poultry, integrated systems, wastes.

Introduction

Fish raised in semi-intensive, freshwater systems provide the major proportion of farmed, global production (FAO, 1995). A high proportion of this aquaculture occurs in rapidly developing Asian countries, which are also experiencing sharply increased consumption of poultry. Semi-intensive systems are usually based on ponds fertilised with livestock manure and fed with low cost supplementary feeds. This type of integration can increase overall production intensity and economise on land, labour and water requirements for both poultry and fish. For example, one hectare of static water fish ponds can 'process' the wastes of up to 1500 poultry, producing fish in quantities of up to 10 MT/ha without other feeds or fertilisers. Also, since effluents are few, environmental impacts are minimal.

The importance of poultry wastes in aquaculture is relatively recent. In areas of traditional fish culture, ruminant and pig manure have predominated as pond fertilisers in the Indian subcontinent and China respectively. Poultry manure was not used to any extent probably because small flock size and extensive management precluded collection.

Livestock production systems, and opportunities for reuse of wastes and byproducts, are changing. Vertical integration of the poultry industry by agribusiness has been stimulated by the biology and widespread acceptability of poultry, particularly chickens. Global trends in livestock production indicate that poultry, particularly layer and broiler chickens, are increasing faster than any other (FAO, 1989, 1990, 1991, 1993). The intensive nature of modern poultry production and processing tends to concentrate high quality byproducts, and this has stimulated their reuse. A range of poultry byproducts are produced and reused in livestock feeds including feather meal, bloodmeal, poultry litter meal etc. (Muller, 1980), and poultry wastes are also used as fertilisers and soil conditioners. Economic growth is fuelling demand for both poultry and fish in many parts of the Asia Pacific region and a major question is the extent to which their integration should be promoted further here and elsewhere.

Table 1: Matrix of livestock waste qualities and suitability for use in aquaculture (* = high to * = low)**

	Factors increasing relative suitability for aquaculture				
Livestock type	Collectability	Acceptability	Nutrient density	Low opportunity cost	Lack of deleterious compounds
Poultry					
feedlot	***	***	***	*	***
scavenging	*	**	**	**	**
Pigs					
feedlot	***	*	**	**	***
scavenging	*	*	*	**	**
Ruminants					
feedlot	***	**	**	**	**
scavenging	*	**	*	**	*

Poultry production wastes have inherent qualities that make them particularly valuable for fish production compared to other livestock wastes (Table 1). Commercial 'feedlot' production leads to concentration of nutrient-rich waste which can be handled and transported cost-effectively. The small individual size of poultry also allows their confinement and production directly over fish ponds. Poultry manure has been used widely in both fresh and brackish water aquaculture. In the latter, penaeid shrimp, milkfish (*Channos channos*) and tilapia (*Oreochromis* sp.) have been the principle organisms raised. Inland culture systems in which poultry and fish such as the carps,

tilapias and catfish are raised in commercial and subsistence systems are the focus of this review.

Poultry manure is now widely used in commercial freshwater aquaculture. In central Thailand, use of livestock wastes is the norm in the production of cheaper herbivorous fish. In other areas, intensification of culture using high quality feeds has reduced the importance of poultry waste to fish production. Predisposing factors to intensification include shortages of land or water and high product prices, but ready availability and competitively priced quality feeds are also critical. Wohlfarth and Schroeder (1979) identified the relative price of feeds and manures as being critical to determining input strategies.

Most published data concern integration of fish culture with modern poultry systems which are typically inappropriate for resource-poor farmers. Village or backyard poultry systems predominate in areas where modern breeds and systems are absent, or co-exist in competition with them. Recent research indicates that integration of such poultry and backyard fish culture can also bring benefits at little extra cost.

Waste-fed Aquaculture

A proportion of the nutrient content of feed given to poultry is voided as excretory or faecal waste. These nutrients can be used to support fish culture by their action as fertilisers that stimulate production of natural food organisms, such as phytoplankton, and detritus. A variety of carps and tilapias can grow rapidly on such natural feeds alone.

Stable and high water temperatures and sunlight ensure year-round growth of both fish and their natural feeds. The tropics, in which average water temperatures remain above 25 deg C, are ideal for culturing fish using poultry waste as inputs, although it is also practised in sub-tropical and sub-temperate climates during suitable periods of the year (>20 deg C).

Poultry wastes and byproducts can provide the feed support of aquaculture across a range of intensities. Poultry wastes may act mainly (1) indirectly or (2) directly to support fish production.

Poultry manure can be used fresh, or after processing, to enhance natural food production in sun-lit tropical ponds.

Although some nutrition may be derived directly from the waste, natural feed produced on the nutrients released from the wastes is more important. Fish feeding low in the food web - the carps and tilapias benefit most from this type of management since they can utilise plankton, benthic and detrital food organisms effectively.

Several factors affect the level of waste loading and standing stock of fish that can be supported. Greater sensitivity to dissolved oxygen limits carps to standing stocks of <3 MT/ha whereas tilapias may be harvested at standing stocks of over 5 MT/ha. Water quality, particularly the level of dissolved oxygen in the early morning, therefore limit the amount of wastes that can used. Input levels in excess of 75 kg DM/ha/ day typically 'overload' the system over a typical fish culture cycle (4-8 months), causing early morning deficits of oxygen. Balancing the production of wastes from poultry and the requirement of the fishpond is a key aspect of management.

The quality of poultry wastes used in fish culture varies greatly. High levels of spilt feed, for example, increase direct feeding value. Nutrient composition may be a useful guide to value but the availability or release of nutrients to the food web may be more important.

Conventional feed ingredients have been 'replaced' with dried poultry wastes of various types, but low metabolisable energy and digestible protein levels limit their usefulness (Wohlfarth and Schroeder, 1979).

Poultry processing byproducts such as chicken bones, intestines and whole carcasses have greater value as 'direct' feeds and are normally used for higher value fish species raised more intensively. High fish standing stocks can be maintained and yields produced using this type of product and management. Processing wastes can be used fresh, or after further processing, as good quality supplementary, or complete, feeds.

Traditional Aquaculture

A lack of nutrients was a major constraint to traditional aquaculture and this remains true for much of the fish culture practised in the developing World. Yields from carp-based polycultures in China were limited until recently by the paucity of diets for pigs and grass carp (Ctenopharyngodon idella), and their manures, which provided a large portion of the nutrients entering the food web (Ruddle *et al.*, 1983; Guo and Bradshaw, 1993). Recycling and

reuse of nutrients on-farm has a long tradition born of necessity in the population-dense areas of Asia. However, the high outputs of fish and other products from integrated systems reported from China and elsewhere in recent decades are related to greater inputs from off-farm (Edwards, 1993).

Lack of nutrients and sub-optimal stock management remain major constraints to the production of fish on small-scale farms, as they are for traditional livestock management generally. Greater outputs of fish necessitate more nutrient inputs to be used than are available on typical resource-poor farms. Such inputs may be either direct fish feeds or feeds for livestock that in turn produce waste used in fish culture. Both need to be purchased from off-farm to supplement better reuse of on-farm wastes.

Factors Affecting Use of Poultry Wastes in Fish Culture

The type of poultry production system can greatly influence the amount of fish produced. Poultry systems producing nutrient-rich and collectable wastes are most valuable for fish production. A broad dichotomy exists between 'modern', normally intensive poultry production and 'traditional', extensive systems and this affects potential for integration with fish culture (Little, 1995). Edwards *et al*. (1983) describing the level of integration of poultry with fish in Central Thailand found large differences between small and large producers. Flock sizes of less than 100 birds were unlikely to be cultured with fish but larger flocks (>400) were usually integrated. Modern 'feedlots' raise large flocks and are generally capital intensive, highly dependent on off-farm support and profit-orientated. Generally raised on optimal, processed feeds in 'feedlots', production cycles are rapid and all the high quality waste can be collected for use in fish culture. In contrast, Klausner (1966) observing traditional management in a Northeast Thai village said that 'the owners feel that there is not much point in taking pains and spending money in caring for chickens, when chickens seem quite capable of caring for themselves'.

Many factors appear to constrain close integration of traditional poultry and fish culture. The poor quality supplementary feeds usually given, and the fact that confinement is restricted to overnight, result in less and poorer quality manure being available for use in fish culture. Moreover, farm households may already be using the poultry waste which is collectable for other purposes such as fertilising backyard crops. Recent analysis of current poultry

production in small-scale farming households reveals a marginal but important niche.

Poultry Production Waste Characteristics

Poultry manures are nutrient-rich, but there is great variability in their quality at the time of use as fish production inputs. Although between 72-79% of the dietary nitrogen, 61-87% phosphorus and 82-92% of the potassium was present in feedlot egg-laying hens (Taiganides, 1978), the variability in terms of nutrients available (g nutrient/bird/ day) can be much greater. The impacts of the gradual improvements in food conversion efficiencies attained by modern breeds and feeds are probably overridden by other factors, especially diet. Poultry raised on a balanced ration produce a higher quality, more nutrient dense waste than those fed a supplementary feed (Table 2).

Species, size and sex of bird directly affect the quantity of manure produced. The amount of feed spilt during feeding and drinking also varies with these factors together with the nature of the feed and feeding practice. Generally, larger birds produce more waste than small birds; the waste production increases rapidly over the rearing period of modern broilers as a result. Layers produce more calcium and phosphorus-rich excreta than broilers and the waste of replacement birds fed restricted diets high in fibre is correspondingly poorer than laying birds.

In scavenging systems, manure quality is greatly affected by the quality and quantity of supplementary feeds, which in turn affects fish production. Egg-laying ducks fed paddy grain at night produced poorer quality manure than those fed rice bran. The amount of nitrogen and phosphorus in the manure was 50% and 25% respectively of that found in ducks fed relatively nutrient dense village rice bran (Table 2). Restricted feeding of rice bran during night-time confinement to Muscovy ducks (*Cairhina moschata*) scavenging during the day reduced both quantity and quality of collectable wastes. Nitrogen in wastes declined with the level of restricted feed given from 1.28 g N/duck/day, for birds fed ad libitum to 0.55 g N/duck/day for ducks restricted to 50% of *ad libitum* feeding levels. (AFE, 1992)

Table 2. Effect of feeding and management on waste characteristics of poultry.

	System		Feed		Production		Waste g/animal/day			
Poultry	Feed	Scavenging	Concentrate	Supplementary	Daily LWG	Laying	DM	N	P	Ref
Egg laying duck	Yes	No	Yes	No	1.88	46-58	44.7	1.97	0.49	a
Egg laying chickens	Yes	No	Yes	No	-	-	44	1.3	1.14	b
Broiler chicken	Yes	No	Yes	No	32	-	20	0.7	0.92	c
Egg laying duck	No	Yes	No	Yes	0.38	16.3	59.9	1.16	0.69	d
Egg laying duck	No	Yes	No	Yes	0.42	29.8	24.8	0.52	0.16	e
Muscovy duck	No	Yes	No	Yes	10.4-16	-	40-70	0.65-1.28	0.5-0.8	f

a) Edwards *et al*., 1983

b) Muller, 1980

c) Hopkins & Cruz, 1982

d) AASP, 1996 (Rice bran)

e) AASP, 1996 (Paddy rice)

f) AASP, 1992

Supplementary feeds of different types drastically affect waste characteristics and their value for fish culture. In a trial in which three different supplementary feeds (village rice bran, ground maize and ground sorghum) were fed to pekin and Muscovy ducks, both waste quantity and quality was affected. The degree of wastage, related to palatability and physical attributes of the feed, was an important factor (see below) but the intake and proximate composition greatly affected the value of waste for fish culture (Niang, 1990). Manure derived from maize-fed ducks was high in nitrogen, sorghum was intermediate and rice bran low, reflecting the composition of the feeds themselves. Total nutrients in the waste tended to be higher than in the feeds, suggesting the scavenged food tended to be of higher feed value than the supplement.

Spilled feed is a loss to the poultry system but a gain to the fish because of it's direct feeding value. The method of food presentation (timing, frequency, location) affects the amount of feed available directly for fish. Feedlot ducks fed complete diets appear to waste less than birds allowed to scavenge during the day and given access to supplementary feed at night. Feed processing can reduce spillage; up to 15 % of granulated feeds may be lost compared to 10% if the same duck feed is pelletised (Barash *et al*.,1982). Feeding behaviour and the nature of different feeds may increase the amounts of feed available directly for fish. Waste feed left in the waterer comprised more than 25% of the collectable dry matter from scavenging Muscovy ducks fed a supplement of village rice bran (AASP, 1996).

Poultry species, strain and environment affect the normal conditions of poultry management in tropical environments and these interact to determine the final characteristics of wastes available for fish culture. The density of birds in a given system and their method of confinement -in small cages or batteries (such as for chicken

layers) or in pens with bedding material (litter) affects the management of both the poultry and their waste. Confinement directly over fish ponds is used for both broiler and layer chickens but pens that give access to ponds stocked with fish for drinking and/or bathing are generally used only for ducks and geese.

Poultry house litter (PHL), which can be broiler, replacement or layer bird waste is produced from poultry raised in houses with bedding materials of various types. The type and management of these materials can affect nutrient content and availability for fish culture. Fermentation can result in losses of nitrogen, volatilised as ammonia, or becoming refractory and unavailable. Some vitamins may increase (vitamin B12) and some antibiotics (e.g. Chlortetracycline) decrease with duration of storage (Muller, 1980).

Table 3. Check list of factors affecting characteristics of poultry waste and its use for aquaculture (modified after Muller, 1980)

- **used fresh or collected, stored and transported**
- **nature of bedding materials (bulk density, particle size, moisture retention capacity, compressibility, penetrability, hygroscopicity, biodegradability)**
- **type of bird (size, growth rate, efficiency, sex)**
- **housing (open, closed)**
- **litter management (regular/irregular removal)**
- **nature of ingredients in poultry ration (digestibility, nutrient density and composition)**
- **type of storage (aerobic, anaerobic, exposure to temperature, rain, wind)**
- **quantity of bedding materials per surface unit (nutrient dilution, microorganism activity)**

Action of Wastes in the Pond

The rate of nitrogen and phosphorus release, particularly in the most available forms, (dissolved inorganic nitrogen, DIN; soluble reactive phosphorus, SRP) has been used as an indicator of wastes value for fertilisation of fish ponds. Laboratory leaching experiments indicated that DIN was rapidly released as ammonia-N, levelling off at 6 mg NH4-N/g DM chicken manure after 4-5 days (Knud-Hansen *et al*., 1991). Storage of duck wastes under aerobic conditions for a period of 4 weeks reduced both total nitrogen in the waste and the amount released subsequently as ammonia (Ullah, 1989).

The type of ingredients fed to poultry can affect the subsequent manure quality and release of nutrients for pond fertilisation. Substitution of a mixture of cassava leaf and root meal for village rice bran in complete diets of broiler Muscovy ducks resulted in a more nitrogen-rich manure but a similar cumulative release of nitrogen (5.5-6.7 mg/g DM). Release of DIN varied between 20-74% of the total in the waste. A greater proportion of phosphorus was released as SRP in all the wastes and the amount was inversely related to the level of cassava in the diet (AIT data).

Manure obtained from scavenging Muscovy ducks fed variable levels of a rice bran supplement (100, 75 and 50% of ad libitum) had different release characteristics. Significantly more DIN was released by ducks fed less supplementary rice bran suggesting that the protein in the natural feeds ingested during scavenging were less refractory than the nitrogen contained in village rice bran. SRP showed the inverse trend, with ducks fed ad libitum producing manure richer in phosphorus, of which more was released in the available form (AIT data).

Manures release other factors apart from nutrients that may have adverse effects on water quality and inevitably, fish production. Shevgoor *et al*.(1994) found that tannins and flavonoids were a major factor in the poor water quality observed in ruminant manure-fed systems. Substitution of cassava leaf for rice bran in complete diets for Muscovy ducks correlated with increased levels of tannin released from manure (AIT data).

The value of manures, including poultry manure, as a source of detritus and the role of detritus in the direct

nutrition of fish has been much debated (Schroeder, 1978; Colman and Edwards, 1987). The stimulation of bacterial production, both in the water column and sediments is known to be stimulated by addition of poultry waste (Moriarty, 1987). Animals that filter feed or graze on bacteria attached to detritus directly, or consume the grazers, are therefore likely to benefit directly through this mechanism. Both feed and dissolved oxygen are required to maintain high fish yields and phytoplankton, both alive and as detritus, is the most important source of both in fertilised ponds (Colman and Edwards, 1987, Knud-Hansen *et al*, 1993).

Classification of Poultry-fish Systems

A framework for poultry-fish systems is given in Table 4. Feedlot and scavenging poultry represent two ends of a continuum of systems (Little and Edwards, 1994). The type of producer and characteristics of the production system and waste collection methods are distinct. In both cases however, poultry wastes may be part of a range of inputs used to produce fish. The use of poultry processing wastes is distinct and considered separately, although this strategy is linked closely to feedlot broiler production.

Van der Lingen described the concept of increased carrying capacity and fish yields if more nutritional inputs are complemented with higher stocking densities (Edwards, 1986). Yields from fertilisation alone may be increased with the use of supplementary feeds. Further increases in density and yield rely on improvements in feed quality and quantity so that they become the primary source of nutrition to the fish. Poultry wastes are used across a range of intensities, and for different purposes. Poultry wastes, inorganic fertilisers and feeds are to some extent substitutable. Poultry waste can be used in place of inorganics or feeds, inorganics in place of manures or feeds, and feeds in place of either type of fertiliser. Thus if manures are in short supply, inorganics can be used to optimise nutrient loadings and feeds to further increase yields. Feed may be substituted, to some extent, with fertilisers.

Table 4 Input and output of poultry-waste-fed-aquaculture

	INPUTS (g/m^2/day)		
	POULTRY WASTE	OTHER	

	POULTRY WASTE			OTHER			
SYSTEM	DM	N	P	DM	N	P	Ref
FEEDLOT							
Egg-laying ducks	6.71	0.3	0.07	-	-	-	a
Broiler chickens	10.0	0.4	0.46	-	-	-	b
Layer chicken	14.3	0.4	0.3	-	-	-	c
Layer chickem	1.07	0.03	0.018	-	0.47	0.23	d
SCAVENGING							
Muscovy duck	9.7	0.15	0.10	-	-	-	e
Egg-laying duck	3.0	0.23	0.03	-	0.17	-	f
Egg-laying duck	1.24	0.20	0.01	-	0.17	-	g

		OUTPUT				
SYSTEM	Fish	(g/fish/m^2/day	System			Ref
FEEDLOT						
Egg-laying ducks	Tilapia	2.82	200m^2 ponds, 6 months			a
Broiler chickens	Tilapia, common	2.87	400m^2 ponds, 3 months			b

	carp			
Layer chicken	Tilapia	1.33	1000m^2 ponds, 5 months	c
Layer chicken	Tilapia	2.75	220m^2 ponds, 5 months	d
SCAVENGING				
Muscovy duck	Tilapia	1.38	5m^2 tanks, 3 months; duck fed 75% ad libitum	e
Egg-laying duck	Tilapia	1.21	200m^2 ponds, 4 months	f
Egg-laying duck	Tilapia	1.21	200m^2 ponds, 4 months	g

a) Edwards *et al*., 1983

b) Hopkins & Cruz, 1982

c) Green *et al*., 1994

d) Knud-Hansen *et al*., 1991

e) AFE, 1992

f) AASP, 1996 (Rice bran)

g) AASP, 1996 (Paddy rice)

Feedlot Systems

Most of the poultry-fish systems described in the literature use waste from feedlots. Modern breeds of poultry raised on balanced feeds give the most nutrient-rich waste and produce the most fish, but systems are frequently sub-optimal, resulting in inefficient waste or space usage. Poultry manure is used either directly on-site, through the siting of poultry houses over ponds, or after collection, storage and transport to the site of fish culture.

Construction of the poultry house over the pond allows waste to drop directly in, saving labour costs. Also, in the peri-urban, flood-prone land often used, the cost to fill land for poultry housing, and the opportunity cost of land itself, are reduced. Confining poultry next to, or over, water can also improve their productivity under tropical conditions. Evaporative cooling can reduce heat stress in broilers (Theimsiri, 1992) and access to water improves feather quality of ducks, although growth may suffer (Edwards, 1986). Ducks free ranging over ponds in large numbers can damage dykes and cause water quality problems, restriction of the ducks to the water and pen prevents this problem (Edwards *et al*., 1983). However, evidence from on-station research and farmers suggests that access to complete feeds and some degree of scavenging optimises egg production in Khaki-Campbell ducks (AIT, 1986).

Fish species is a critical factor in determining loading rates of poultry waste since there is a range of sensitivity to dissolved oxygen among the commonly cultured fish species. Air-breathing fish, such as clarias catfish and the silver-striped catfish (Pangasius hypothalmus), can tolerate the highest input levels and, at the high stocking densities normally raised, also require extra feed to sustain growth. These fish species are also probably inefficient at using the phytoplankton-dominated food web. In contrast, the microphagous Nile tilapia is more sensitive to low dissolved oxygen in the early morning but thrives at numbers of poultry between 1000 and 1500 egg-laying ducks/ha without other inputs. Using poultry manure alone, net extrapolated yields of up to 12 MT, or standing stocks of 5-6 MT/ha, appear possible in monocultures of tilapia.

Polycultures of carps are often considered most efficient in waste-fed ponds but greater sensitivity to dissolved oxygen necessitates lower input levels. Hopkins and Cruz (1982) found a poor survival of the more sensitive common carp in a tilapia-dominated polyculture, and Yakupitiyage *et al*. (1991) recorded poor survival of large silver barb (Puntius gonionotus) under similar circumstances. Research using more sensitive Indian Major carps has

normally been undertaken at lower loading rates (<100-500 poultry/ha; Jhingran and Sharma, 1978, 1980).

Temperature regime affects the level of wastes that can be used in ponds and this is reflected in the lower stocking densities in eastern Europe (Edwards, 1986). Low temperatures reduce the amount of waste that can be processed by a given area of fish ponds. The fish kills reported in Hong Kong (Sin, 1980) are related to a continued build up of waste during the cool season, causing a subsequent bacterial and plankton boom as temperatures rise. This phenomenon, equivalent to a massive overloading, quickly removes oxygen from the water.

The dynamics of poultry flocks can make management of the waste for fish culture problematic. Direct use of egg-laying poultry for instance, in which the birds are of constant weight and produce fairly constant levels of waste, are easier to manage than broilers in which waste availability is cyclical (Hopkins and Cruz, 1982). The timely availability of replacement stock, veterinary support and market demand may be critical to maintaining both poultry and their waste production.

Higher loadings of waste necessitate water exchange or mechanical aeration to maintain dissolved oxygen. Green *et al*. (1994) significantly improved yields of Nile tilapia at high loading rates of chicken manure (1000 kg DM/ha/week) using mechanical aeration to ensure a high survival rate of fish. Additional aeration at levels of 10% saturation were sufficient to improve yields by 20% over unaerated ponds. Regular exchange of water to reduce phytoplankton biomass can alleviate water quality problems from overloading. In a well designed system, this would be avoided as effluents reflect inefficient nutrient reuse and negative impacts on surrounding environment.

Overloading of poultry waste can also be avoided by housing poultry over concrete or earthen floors, rather than directly over ponds, and regular manual or mechanical addition. This option may reduce construction costs considerably and also enables farmers to sell manure surplus to their requirements.

Supplementation of Feedlot Wastes

Various factors may limit the size of a poultry flock that a farmer can manage and integrate with fish culture,

reducing wastes to levels below optimum. Edwards *et al*.(1983) found that problems of marketing duck egg, and high feed costs constrained small-scale farmers from maintaining even 30 ducks over small ponds (200m^2) as feedlots. Farmers with limited numbers of poultry for their pond area need additional nutrient inputs to optimise productivity.

Inorganic fertilisers may be a cheaper form of nitrogen and phosphorus than purchased poultry manure in many situations (Table 5), and highest yields may be achieved with relatively low loadings of poultry manure. The optimal level of poultry manure in ponds fertilised with high levels of inorganic fertilisers (5 kg N/ha/d) was found to be around 75 kg/ha/week for a monoculture of Nile tilapia in Thailand (Knud-Hansen *et al*.,1991). These low levels reflect the subtle balance of dissolved oxygen and food production in a highly eutrophic pond. Green *et al*. (1994) recorded similarly high yields (>20 kg/ha/day) of Nile tilapia using higher levels of chicken manure in combination with inorganic fertilisers. There are indicators however that, compared to tilapia, carps raised at lower nutrient loading rates perform better when fertilised with organic manures in addition to inorganics (AASP, 1996). Also, high levels of inorganics may be constrained by their availability or opportunity cost.

Supplementing the use of poultry manure with cheap and available direct feeding of fish is an alternative strategy. The impact of supplementary feed on yields of fish in ponds fertilised with poultry waste is affected by many factors. The level of natural feed to some extent affects the effectiveness of the supplementary feed; more natural feed allows greater feeding of a high-energy supplement to 'spare' the protein requirements and support the growth of more fish. The optimal levels for feeding supplementary feeds are complicated by the variable levels of waste poultry feed mixed with the manure.

Strategic use of additional feeds such as rice bran can boost yields of a Nile tilapia monoculture receiving egg-laying duck manure by between 10-150% (AIT, 1986), but their use may not be cost effective. One trial clearly demonstrated the 'law of diminishing returns' when a low feeding rate (1% body weight/ day) increased yields profitably by between 28-40%, depending on duck manure level, but a further doubling (2% body weight /day) increased yields further by a mere 4% or reduced them by 16% respectively (Yakupitiyage *et al*. 1991).

This suggests that overall dry matter loadings into ponds receiving both feeds and fertilisers should be considered. The variable response of different fish species within the polyculture also illustrates that supplementary feeding should be strategic. Although manure level and rice bran acted independently to boost overall yields, Nile tilapia responded most to duck density and silver barb only to feeding rate, indicating the role of supplementary feeding in polycultures of fish with different feeding niches.

Table 5. Economic comparison of different fertilizers with respect to available nitrogen (N), phosphorus (P), and carbon (US$ = 25 Baht), (Knud-Hansen, 1993)

Fertilizer	Cost (baht/50g)	Available N (baht/kg)	Available P (baht/kg)	Available C (baht/kg)
Chicken manure	20/a	76/b	194/c	7/d
Urea	240	10	-	24
TSP	450	-	45	-
$NaHCO_3$	1000	-	-	140

a/Wet weight

b/Assumes 40 % dry weight of total N is available (Knud-Hansen *et al*. 1991).

c/Assumes 10 % dry weight of total P is available (Knud-Hansen *et al*. 1993).

d/Assumes 50 % dry weight of organic C oxidizes to DIC.

Supplementary feeding of fertilised ponds is only necessary if the carrying capacity is exceeded. Green *et al*. (1994) found no benefits to yields in poultry-manure fertilised ponds also receiving high quality pelleted feed, probably

because, at the low fish stocking densities (2/m^2) used, growth could be supported by natural feed alone. Yields may also be constrained by other factors such as seasonally low temperature and dissolved oxygen levels. The relatively low yields reported in Hong Kong (1.5-4.7 MT/ha/year; Sin, 1980), despite supplementary feeding of carp polycultures fertilised with duck manure, appear to be related to such water quality factors. Green *et al*. (1994) also reported poorer yields in supplementary-fed, poultry waste-fertilised ponds during cooler periods.

The reduction in feeding costs of more intensive systems by fertilising ponds with poultry manure is another strategy that has attracted attention by farmers and researchers alike. Clearly, the fish species raised need to be suitable for culture in plankton-rich, waste-fed systems. Green *et al*. (1994) found that the tambaqui (Colossoma macropomum), in contrast to the Nile tilapia, grew poorly in fertilised systems without supplementary feed.

Liao and Chen (1983) reported that Nile tilapia in Taiwan are raised in duck manure-fed, mechanically aerated ponds and also fed pelleted feed; yields of up to 18 MT/ha are the norm. Hepher and Pruginin's (1981) description of commercial polycultures in Israel indicates that fertilisation is an essential component of their high-yielding, semi-intensive systems.

Feed costs may also be reduced by feeding only in the later stages of the culture period, when the nutritional needs of the fish exceed the level supported by natural feed alone. Green *et al*. (1994) found that, at densities of 1 fish/m^2, tilapia could be raised on poultry waste alone for the first 3 months of an 137 day production without any differences in final yield.

Scavenging Systems

The use of scavenging poultry wastes in aquaculture is rare; few systems have been described in the literature in anything but qualitative terms. The variability of such systems must be expected to be greater than conventional poultry-fish systems; the production function between waste level and fish production, for example, is far more variable. The relationship between number of poultry and fishpond area is less clear cut when the wastes from scavenging birds are used. Waste collection is normally limited to overnight to allow enough time for the poultry to

obtain natural foods, but absolute amounts of waste collected may still be high (Table 2). If feeds are given ad libitum and all wastes are used for fish culture (see above), dry matter levels/bird may be higher than those produced in feedlot systems. Overloading of these wastes can have clear negative impacts on water quality and fish yields.

Developing fish culture based solely or partly on the wastes of current poultry production requires an understanding of feed constraints. In north-east Thailand, the main supplementary feeds, village rice bran and unmilled paddy rice, are available only in limited quantities. Feeding restricted amounts of feeds to a larger flock of poultry can result in more poultry and fish from the same amount of rice bran (AASP, 1996).

The quality of the scavenging environment might be expected to affect the requirement for supplementary feed and the final quality of wastes produced. Natural forage is frequently seasonal and crop harvests may produce short-lived abundances of residues (dropped paddy, spilt maize) that will affect waste composition.

The relatively low nutrient density of wastes from scavenging poultry fed supplementary feeds explains the rationale for using them as partial inputs into fish culture. Farmers understand this limitation; in a study of farmer practice in Udorn Thani, farmers tended to use a variety of inputs in addition to poultry manure including plant leaves, ruminant manure and rice bran (AASP, 1996).

The quality and quantity of supplementary feed is the key factor in waste characteristics (see above) and subsequent fish yield. Feeds high in cassava products generally depressed fish yields, possibly due to the levels of tannins and unavailability of nutrients. Rice bran, corn and sorghum-fed ducks produced highly dissimilar wastes and subsequent fish yields based on similar numbers of ducks were very variable (Naing, 1990). Egg-laying ducks allowed to scavenge and fed either supplementary rice bran or paddy rice at night showed that tradeoffs may be involved. Egg yields were higher,(Table 2) but fish yields barely half that from ponds in which ducks were fed rice bran (Table 4; AASP, 1996).

Inorganic fertilisation can have a major impact on yields (up to 100%) of microphagous fish such as Nile tilapia in

ponds receiving scavenging poultry wastes. In small ponds, the relative amounts required are also affordable, given the value of the fish produced (Edwards *et al*, 1996).

Poultry Processing Wastes

Boneless chicken meat is now an international commodity that resource-rich developing countries, with vertically integrated poultry industries, compete to produce and market. Low labour and feed costs and good infrastructure are necessary preconditions to develop the business that can produce large amounts of high quality byproducts suitable for intensive fish culture.

Poultry slaughterhouse wastes are in great demand for feeding hybrid clarias catfish (Clarias macrocephalus x Clarias garipinus) in Thailand. Heads, viscera and thigh bones are the main byproducts fed fresh after simple on-farm grinding and mixing with a binder. Food conversion ratios of 4-5 (wet:wet basis) are attained under farm conditions (Little *et al*., 1994), similar to levels reported by Prinsloo and Schoonbee (1987) for the use of chicken offal and dead whole chickens fed to Clarias gariepinus.

Benefits - the Political Economy of Poultry-fish Systems

Modern agribusiness control over production and marketing of poultry products is in great contrast to the fish component of integrated farming. Agribusiness companies control the breeds, the feeds and the marketing of broiler chickens in central Thailand and for hen eggs in Northeast Thailand (Engle and Skaldany, 1992). In contrast, the fish stocked are purchased from local entrepreneur breeders (Little *et al*., 1987), fed on poultry and other wastes and marketed directly or through local middlemen and markets. Farmers are willing to contract-grow broiler chickens over their fishponds for minimal return in order to gain the benefits of high cultured fish yields. This has resulted in long term declines in the price of both chicken and freshwater fish over the past decade.

Changes in production and demand for poultry and fish stimulate new opportunities for their integration. Increasing proportions of chicken consumed and exported as boneless products has spurred the use of slaughterhouse wastes

as feeds in Thailand, principally for a recently developed hybrid catfish which thrives under such culture conditions (Little *et al*., 1994). These forms of production however are concentrated in the hands of relatively few, richer farmers and entrepreneurs. Urban consumers benefit from lower prices for poultry and freshwater fish but rural small-scale production may be constrained through a lack of feeds and markets.

Environmental and Public Health Aspects

The concentration of nutrients that feedlot agriculture encourages can lead to pollution of surface waters. The controlled eutrophication of static water ponds stocked with herbivorous fish can act as on-site treatment and, providing water exchange is avoided, impacts on surface waters are minimal. Nutrient budgets indicate that, although only 15-20% of input nitrogen and 8-12% of phosphorus are recovered as fish, most of the nutrients accumulate in the sediments (Edwards, 1993). Loss of nutrients with drainage water (<10% of both N and P) and seepage are minimal (Boyd, 1985). Waste-fed aquaculture is therefore more likely to alleviate pollution from livestock production than cause it, although more intensive use of wastes and porous soils could increase nutrient losses to surface and ground water resources.

Public health concerns have been raised about the integration of poultry and fish production on several levels. The risks of direct pathogen transfer to humans in fishponds fertilised with manures, whether consumers, producers or intermediaries, have been most assessed (e.g. AIT, 1986; Buras, 1993). Although faecal bacteria and viruses are present in poultry manures, rapid attenuation of pathogens occurs in most stable, waste-fed ponds (Edwards, 1986, 1993). Clearly, the control of Salmonella and enteric bacteria capable of causing human disease is important and their maintenance in fish culture water below threshold levels that can lead to infection (Buras, 1993). The control of poultry disease, however, leads to the concern that poultry feeds containing prophylactic antimicrobials can encourages the emergence of antibiotic resistant strains of bacteria. The relative risks are likely to be insignificant compared to other causes such as direct human abuse (Dalsgaard,1993: personal communication) or chemotherapy of fish themselves (Austin, 1993).

There has also been implicit connections made between integrated livestock-fish systems and influenza pandemics

(Scholtissek and Naylor, 1988); this disturbing theory has led to widespread comment and discussion of the desirability and impacts of integrated farming (Edwards *et al*., 1988; Morse,1990; Skladany,1992). The theory maintains that integrated aquaculture encourages the raising of pigs and poultry together to provide manure for fish and that this in turn increases the risks of new forms of influenza developing. Pigs may indeed act as 'mixing vessels' for avian viruses that can transfer to forms more virulent to humans but fishponds have had little role in bringing pigs and poultry together on farms. Indeed, pigs, poultry and fish together are rare on both large and small-scale farms in Asia. Intensified poultry-fish systems are more likely to separate poultry from pigs and other livestock than traditional farms (Edwards, 1991).

The purposeful eutrophication of water, leading to blooms of toxic blue green algae, has also been raised as an issue (Maclean, 1993). The poisoning of mammals drinking water containing toxic strains of Microcystis aeruginosa is established in temperate climates and research has indicated that the Nile tilapia avoids ingesting toxic strains (Beveridge, 1993). Under practical conditions however, such fish grow fastest in ponds dominated by this same species of algae (Colman and Edwards, 1987). Although the possibility of poisoning of fish and mammals from poultry-waste fertilised water exists, their controlled use in fish ponds reduces the likelihood of pollution to other water bodies.

References

AFE, Agricultural and Food Engineering, 1992. Final Report-Muscovy Duck Project : The development of economic feeding systems for Muscovy ducks (Cairhina moschata) in duck/fish integration in Thailand (15 May 1988 - 31 December 1991). Agricultural and Food Engineering, Asian Institute of Technology, 36 pages.

AASP, Agricultural and Aquatic Systems Program, 1996. Final Technical Report-IDRC: The development of feeding systems for fish and an integrated duck-fish system (30 December 1991 - 31 April 1996). Agricultural and Aquatic Systems Program, School of Environment, Resources and Development, Asian Institute of Technology. 41 pages.

AIT, 1986. Buffalo/fish and duck/fish integrated systems for small-scale farmers at the family level. Agricultural and Food Engineering Division, Asian Institute of Technology. 138 p.

Austin, B. 1993. Environmental issues in the control of bacterial diseases of farmed fish. p.237-251 In R.S.V.Pullin, H. Rosenthal and J.L.MacClean (eds) Environment and aquaculture in developing countries. ICLARM conf. Proc. 31, 359p.

Barash, H, I. Plavnik and R. Moav, R.1982.Integration of duck and fish farming: experimental results. Aquaculture 27, 129-140.

Beveridge, M.C..M. and M.J.Phillips, 1993. Environmental impact of tropical inland aquaculture. p.213-236 In R.S.V.Pullin, H. Rosenthal and J.L.MacClean (eds) Environment and aquaculture in developing countries. ICLARM conf Proc. 31, 359p.

Beveridge, M.C. M., Baird, D.J., Rahmatullah, S.M., Lawton, L.A., Beattie, K.A., Codd, G.A., 1993. Grazing Rates on Toxic and Non-Toxic Strains of Cyanobacteria by Hypophthalmichthys molitrix and Oreochromis niloticus. Journal of Fish Biology 43:6, 901-907.

Boyd, C. 1985. Chemical budgets for channel catfish ponds. Trans.Am.Fish.Soc.114:291-298

Buras, N. 1993. Microbial safety of produce from wastewater-fed aquaculture.p.285-295. In R.S.V.Pullin, H. Rosenthal and J.L.MacClean (eds) Environment and aquaculture in developing countries. ICLARM conf. Proc. 31, 359 p.

Colman, J. and P.Edwards.1987. Feeding pathways and environmental constraints in waste-fed aquaculture:balance and optimization, p.240-281. In D.J.W. Moriarty and R.S.V. Pullin (eds). Detritus and microbial ecology in aquacultureе. ICLARM Conference Proceedings 14, 420 p. International Center for Living Aquatic Resources Management, Manila, Philippines.

Edwards, P., K.E Weber, E.W. McCoy, C.Chantachaeng, C. Pacharaprakiti, K. Kaewpaitoon,and S. Nitsmer. 1983. Small-scale fishery project in Pathum Thani Province, Central Thailand: a socioeconomic and technological assessment of status and potential. AIT Research Report No. 158, AIT, Bangkok, 256 p

Edwards,P. 1986. Duck/Fish Integrated Farming Systems. p 267-291. In D.J Farrell and P Stapleton (eds). Duck Production Science and World Practice.430 p

Edwards, P., C. Kwei Lin; K.Leong Wee; D.Little and N.L.Innes-Taylor., 1988. Nature. 333:505-506

Edwards,P. 1991. Integrated farming and influenza pandemics. World Aquaculture 22(3) 2-6

Edwards, 1993. Environmental issues in integrated agriculture-aquaculture and wastewater-fed fish culture systems, p.139-170. In R.S.V.Pullin, H. Rosenthal and J.L.MacClean (eds) Environment and aquaculture in developing countries. ICLARM conf Proc. 31, 359 p.

Edwards, P, H.Demaine,N. Innes Taylor and D. Turongruang. 1996. Suataianble aquaculture for small-scale farmers: Need for a balanced Model. Outlook on Agriculture Vol.25, No.1, 19-26 p.

Engle, C.R., Skladany, M., 1992. The Economic Benefit of chicken Manure Utilization in Fish Production in Thailand. CRSP Research Reports 92-45,Program Management Office, Pond Dynamics/Aquaculture Collaborative Research Support Program, USA. 8 pages.

FAO,1989. FAO yearbook: Production Vol.42:1988. FAO Statistics Series No.88. Food and Agriculture Organization of the United Nations Rome, page 241-252, 266-268.

FAO,1990. FAO yearbook: Production Vol.43:1989. FAO Statistics Series No.94. Food and Agriculture Organization of the United Nations Rome, page 241-251, 265-267.

FAO,1991. FAO yearbook: Production Vol.44:1990. FAO Statistics Series No.99. Food and Agriculture

Organization of the United Nations Rome, page 189-198, 212-214.

FAO,1993. FAO yearbook: Production Vol.46:1992. FAO Statistics Series No.112. Food and Agriculture Organization of the United Nations Rome, page 189-198, 202-214.

FAO Inland Water Resources and Aquaculture Service, Fishery Resources Division. 1995. Review of the state of world fishery resources:aquaculture. FAO Fisheries Circular, No.886. Rome, FAO. 127 p

Green, B.W., D.R. Teichert-Coddington and T.R Hanson. 1994. Development of semi-intensive aquaculture technologies in Honduras. International Center for Aquaculture and Aquatic Environments Research and development Series Number 39, Auburn University, Alabama, USA, 48 p

Guo, J.Y and A.D. Bradshaw. 1993. The flow of nutrients and energy though a Chinese farming system. Journal of Applied Ecology,30,86-94

Hepher, B. and Pruginin, Y., 1981. Commercial Fish Farming, with special reference to fish culture in Israel. John Wiley & Sons, New York. 261 p.

Hopkins, K.D. and E. M. Cruz, 1982. The ICLARM-CLSU, integrated animal-fish farming project: final report. Vol. ICLARM Technical Reports 5. Freshwater Aquaculture Center-central Luzon State University and International Center for Living Aquatic Resources Management, Nueva Ecija, Philippines. 96 p.

Jhingran, V.G. and Sharma, B.K., 1978. Operational research on aquaculture in West Bengal. Central Inland Fisheries Research Institute, Barrackpore, West Bengal, Bulletin No.27. Mimeograph.

Jhingran, V.G. and Sharma, B.K. , 1980. Integrated livestock-fish farming in India. (edited by R.S.V. Pullin and Z.H. Shehadeh) Proceedings of the ICLARM-SEARCA Conference on Integrated Agriculture-Aquaculture Farming Systems, ICLARM Conference Proceedings 4, Manila, August 1979, pp. 135-142, ICLARM-SEARCA, Manila, Philippines.

Klausner, W.J.1966. Reflections on Thai culture. Suksit Siam. Bangkok. 332 p

Knud-Hansen, C.F., Batterson, T.R., McNabb, C.D. and Kitjar Jaiyen, 1991. Yield of Nile Tilapia (Orechromis niloticus) in fish ponds in Thailand using chicken manure supplemented with Nitrogen and Phosphorus. In Eighth Annual Administrative Report (1 September 1989 to 31 August 1990). (Eds: Hillary S. Egna, Jim Bowman, and Marion McNamara) Pond Dynamics/Aquaculture CRSP, Oregon, USA, 54-62 p.

Knud-Hansen, C. F., Batterson, T.R., McNabb, C.D., Harahat, I.S., Sumantadinata, K. and Eidman, H.M., 1991. Nitrogen input, primaryproductivity and fish yield in fertilized freshwater ponds in Indonesia. Aquaculture, 94:49-63.

Knud-Hansen, C. F., Batterson, T.R., McNabb, C.D., 1993. The role of chicken manure in the production of Nile Tilapia (Orechromis niloticus). Aquaculture and Fisheries Management,24:483-493.

Liao, I. C. and Chen,T. P., 1983. Status and Prospects of Tilapia Culture in Taiwan. In International Sysmposium on Tilapia in Aquaculture, Proceedings. (EDS: Fishelson, L., Yaron, Z.) Tel Aviv University, Tel Aviv, Israel, page 588-598.

Little, D.C., M. Skladany and R. Rode. 1987. Small-scale hatcheries in north-east Thailand. Aquaculture and Fisheries Management,18:15-31.

Little, D.C., K. Kaewpaitoon and T. Haitook. 1994. The commerical use of chicken processing wastes to raise hybrid catfish (Clarias gariepinus x Clarias macrocephalus) in Thailand. Naga, The ICLARM Quarterly. 25-27

Little, D.C. and P.Edwards. 1994. Alternative strategies for livestock-fish integration with an emphasis on Asia. Paper presneted at the International Workshop on Integrated Fish farming, 11-15th October 1994, Wu-Xi, China

Little, D.C. 1995. The development of small-scale poultry fish integration in Northeast Thailand:Potential and Constraints. In J.J. Symoens and J.C. Micha (eds) Proceedings of a seminar "The management of integrtaed

freshwater agro-piscicultural ecosystems in tropical areas", Brussels, 16-19 May 1994.

Maclean, J.L., 1993. Developing-Country Aquaculture and Harmful Algal Booms. In Pullin, R.S.V., Rosenthal, H., Maclean, J.L., 1993. Environment and Aquaculture in Developing countries. ICLARM Conf. Proc. 31. 252-284 p.

Morse, S.S.,1990. Stirring up Trouble, Environmental Disruption Can Divert Animal Viruses into people. The Sciences Sept./Oct. page 16-21.

Muller, Z.O., 1980. Feed from animal wastes: state of knowledge. FAO animal production and health paper, Food and Agriculture Organization of the United nations, Rome. 190 p.

Naing, T. 1990. Potential of rice bran, corn and sorghum as supplements for scavengingmeat ducks. MSc thesis. Asian Institute of Technology. 71 p

Prinsloo, J.F.and H.J.Schoonbee. 1987. Utilization of chicken offal in the production of the African sharptooth catfish Clarias gariepinus in the Transkei. Water SA 13(2), 129-132

Ruddle, K, J.L Furtado, G.F.Zhong and H.Z. Deng. 1983. The mulberry dike-carp pond resource system of the Zhujiang Delta, People's republic of China :I Environmental context and system overview. Applied Geography,3:45-62.

Scholtissek, C. and Naylor, E., 1988. Fish Farming and Influenza Pandemics. Nature Vol.331 (21 January 1988). Page 215.

Skladany, M. 1992. People, Poultry, Pig, Fish and Social Viruses : The Integrated Aquaculture-Human Influenza Pandemic Controversy or "Give me a Fish Pond and I'll Either Feed or Infect the whole World". In Paper presented at the 8th World Congress for Rural Sociology, The Pennsylvania State University, Pennsylvania, U.S.A. 19 pages.

Shevgoor, L., Knud-Hansen, C. F., Edwards, P., 1994. An assessment of the role of buffalo manure for pond culture of tilapia. III, limiting factors. Aquaculture 126: 107-118.

Schroeder, G.L., 1978. Autotrophic and Hetrotrophic production of micro-organisms in intensely manured fish ponds, and related fish yields. Aquaculture 14:303-325.

Sin, A. W-C. 1980. Integrated Animal-Fish Husbandry Systems in Hong Kong with Special Case Studies on Duck-Fish and Goose-Fish Systems. In Proceedings of the ICLARM-SEARCA Conference on Integrated Agriculture-Aquaculture Farming systems, Manila Philippines, 6-9 Aug, 1979. (Eds: Pullin, R.S.V., Shehadeh, Z.H.) International Center for Living Aquatic Resources Management, Manila, and the Southeast Asian Center for Graduate Study and Research in Agriculture, College, Los Banos, Laguna, Philippines. page 113-123.

Taiganides, E. P., 1979. Wastes are resources out of place. Agricultural Wastes,1:1-9.

Theimsiri, S.1992. New concept on poultry breeder management in tropical countries 65-71. In Proceedings of Luang Suwan International Poultry Symmposium, the Sixth Animal Science Congress of AAAP, 27-28 November, 1992, Bangkok.129 p.

Ullah, M.D. 1989. Nutrient release characteristics of duck manure for Nile tilapia production. MSc. thesis. AIT. 67 p

Wohlfarth and Schroeder, 1979. Use of manure in fish farming-a review. Agricultural Wastes 1:279-299

Yakupitiyage, A., P. Edwards and K.L. Wee. 1991. Supplementary feeding of fish in a duck-fish integrated system.I. The effect of rice-bran, p. 143-157. In S.S. De Silva (ed.) Fish nutrition research in Asia. Proceedings of the Fourth Asian Fish Nutrition Workshop. Asian Fish. Soc. Spec. Publ. 5, 205 p. Asian Fisheries Society, Manila, Philippines.

The Use of Leguminous Leaves as Fish Pond Inputs

The following was the executive summary of a final report to USAID on a research project 'Use of leguminous leaves as fish pond inputs'. The authors of the report were David Little, Amararatne Yakupitiyage, Alma Castanares and Peter Edwards of AIT, and Leonard Lovshin of Auburn University.

The use of the leaves of four perennial leguminous tree species: *Cajanus cajan* (pigeon pea), *Gliricidia sepium, Leucaena leucocephala* and *Sesbania grandiflora* were studied for their value in aquaculture. A series of trials was designed to determine how such leaves could be used as on-farm inputs for fish ponds in the tropics where other inputs are unavailable or expensive. A series of experiments tested strategies to use the leaves directly as feeds or indirectly as fertilisers to enhance pond productivity. Their use as green manures or ruminant feeds, with subsequent use of ruminant excreta as pond inputs, was tested.

As fresh feed, the leaves were found to have negligible feeding value to four herbivorous fish species: Nile tilapia (*Oreochromis niloticus* L.), silver barb (*Puntius gonionotus*), grass carp (*Ctenopharyngodon idella*) and giant gourami (*Osphronemus gourami*). The presence of anti-nutritional factors was suspected to reduce palatability and intake but further research, after removal of the major anti-nutritional factors, suggested that poor digestibility was also a major factor.

The leaves may have some potential for use as green manure, although the labour requirements for leaf harvest will be a major constraint under many circumstances. Measurement of the amount and release rate of major nutrients (total nitrogen and phosphorus) in water indicated that 50% of nitrogen was released after a 25 day period. The relatively low nutrient density (high C:N) however, mean that the leaves cannot be used as a sole source of nitrogen in pond systems receiving optimum nitrogen levels (3 kg N/ha/d) as the dry matter loading

required leads to high oxygen demand and increased levels of tannic acid which decreases water transparency, fish survival and fish growth. Fish production comparable to inorganic fertilisation alone was achieved using legume leaf nitrogen to supply 50% of nutrients in both tank (*Oreochromis niloticus*) and earthen pond (*Oreochromis niloticus* and *Cirrhinus mrigala*) experiments. Potential exists for their seasonal use in multiple, lower input, carp-based polycultures.

The limited applicability of legume leaves as conventional feeds or green manures in ponds led to the study of the value of their nutrients after 'treatment' via a ruminant. Improvement of smallholder ruminant production in the tropics often involves upgrading the diet with legume leaves and its acceptability to farmers is proven. Previous research had demonstrated that faecal wastes are poor fertilisers but the current study showed that 100% of inorganic fertiliser-derived nitrogen can be substituted by goat liquid waste (urine plus floor washing). The main constraints to adoption are likely to be the relatively large numbers of ruminants and fodder required to provide significant inputs to the typical-sized fish pond. Up to 14 goats, and considerable labour and land, are required to provide optimal nitrogen levels for a single 200 m2 pond for example. This approach will have most value in situations where the ruminant system has been intensified, waste re-use is sub-optimal and fish ponds are located close by. Smallholder dairy production is expanding in many parts of developing Asia and fish culture may be an ideal integrated activity.

Whole farm analysis compared scenarios for inclusion of legume leaves into a food production system including fish and suggested that the wood fuel value of legume twigs derived from leaf production may be an important product. Fuelwood typically constituted as much to simulated incomes of the systems as fish production.

Legume leaves could have a subsidiary role in increasing nutrient inputs and fish outputs from smallholder ponds, particularly if intensified ruminant production has already been adopted. A high demand for fish, a lack of alternative pond inputs and a scarcity of on-farm fuel would encourage the production of legume leaves and their use for ruminant-fish systems.

On-farm Experiments in the Use of Local Resources for Pigs in Vietnam

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Abstract

In Vietnam, pig production plays an important role. There were 15 millions pigs in 1995, of which 95% were raised by small scale farmers. They are a very important source of income for the family. Protein is still a very important constraint in the traditional diet for pigs because of the high price. On-farm research has shown that protein intake is very low in traditional diets (94 - 98 g/pig/day).

On-farm feeding trials were conducted in two villages in Central Vietnam, Binh Dien and Xuan (which raise c. 2000 pigs annually).

Fourteen crossbred (Mong Cai x Large White) weaner pigs were fed traditionally and 12 similar pigs on a similar basal diet but given supplements of groundnut cake and fish meal to provide an additional 100 g/day/pig of crude protein. The mean daily live weight gain of pigs under the traditional feeding system was low (202 and 230 g/day in each of the two villages) but was significantly increased to 363 and 366 g/day (P<0.001) by giving the protein supplement. The net economic benefit after deducting the cost of the protein supplement was VND 800/day

equivalent to VND 135,000 for the 150 day fattening cycle.

Trials were conducted in the two villages to evaluate the effect of processing methods on pH and HCN content of ensiled cassava roots. The HCN content of the ground whole cassava root after ensiling for 60 days was reduced from 109 ppm to 64 ppm, while ensiling the chipped root reduced HCN from 111 to 71 ppm.

Further feeding trials examined the effect of different levels of A molasses replacing cassava root meal or ensiled cassava root on the performance of growing-finishing pigs. The optimum levels of A molasses to replace cassava root (ensiled or dried) in pig diets, with protein supply kept constant at 200 g/day, was from 15 to 20% in terms of live weight gain and economic return. Mean live weight gains were 465 g/pig/day for the cassava root meal diet and 453 g/pig /day for the ensiled cassava root diet replaced by 20% of A molasses. Feed costs/kg gain for the 20% molasses diet with dried and ensiled cassava root were 11% and 27% less than for corresponding diets without molasses.

Sugarcane juice was fed to 40 pigs on 20 farms in the two villages. The results from feeding sugar cane juice with 200 grams CP supplement derived from fish meal and ground cake in farm households in two villages were good.

KEY WORDS: pigs, local feeds, traditional diets, protein supplement, cassava root silage, "A" molasses, sugar cane juice

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Introduction

Cassava and sugar cane are the main crops in the upland areas of Central Vietnam. Cereal grains are needed for human consumption and cannot be spared for feeding pigs. Cassava and sugar cane, on the other hand, have several advantages compared with other carbohydrate sources. They give high yields under marginal climatic and soil fertility conditions, which results in a low cost raw material. The most under-utilized feed resource is fresh cassava root which is the cheapest feed in these areas. During the harvest season, the price of fresh cassava roots is only 180-280 VND per kg but it cannot be stored fresh.

The total production of fresh cassava root was 702,000 tonnes and of sugar cane 1.4 million tonnes in Central Vietnam in 1994 (Nguyen Sinh Cuc, 1995). The potential disadvantages of cassava roots are rapid perishability, their low protein content and the presence of cyanide in all root tissues. However, through simple processing, the disadvantage of perishability and cyanide can be overcome. The two most widely used processing methods are sun-drying and ensiling. In the humid tropics, especially in the wet season, sun drying is difficult and may result in the production of a low quality product with severe Aspergillus and related aflatoxin contamination. Artificial drying significantly increases the cost which makes the use of the root meal non-competitive with cereal by products such as broken rice and bran. Ensiling of the cassava root appears to be a more viable alternative.

Approximately 60% of the sugar cane crop is processed by artisan methods in the villages, giving rise to sugar-rich "A molasses" - the main by-product from artisan sugar manufacture. The total quantity of molasses resulting from the processing of the sugar cane has been estimated at around 35,000 tonnes per year. The prices on a dry matter basis of both fresh cassava root and "A" molasses are usually less than those of rice, maize and cassava root meal (Duong and Ngoan, 1993).

Protein is a very big constraint in the traditional diet for pigs because of the high price and lack of experience of using protein supplements.

Experiment 1

Effect of protein supplementation of the traditional diets on the performance of growing-finishing pigs

Materials and Methods

On-farm feeding trials were carried out from May to October 1995.

Animals, diets and management

a) The pigs were Mong Cai x Large White crossbreeds, belonging to the farmers. The farmers also provided their

normal management, drugs and vaccines. A total of 14 pigs owned by 5 farmer households (2 or 4 pigs on each farm) with initial live weights of 10.7 to 20.0 kg in the two villages (3 farmers in Binh Dien; 2 in Xuan Loc) were fed on a traditional (control) ration which consisted of 48% rice and rice bran; 45% cassava root meal and 7% vegetables (DM basis). Protein (N*6.25) concentration ranged from 5 to 7% in the DM.The amounts of the individual feed ingredients fed varied between farms and with time, depending on current availability and price. Details of nutrient intake are given in Table 1.

Table 1. Nutrient intakes on diets for Large White x Mong Cai crossbred pigs from 15 to 50 kg in Xuan Loc and Binh Dien villages.

	Standard*	Xuan Loc**	Binh Dien**
DM (kg/pig/day)	1.40	1.29	1.35
ME (MJ/pig/day)	18.1	17.2	17.6
CP (g/pig/day)	213	94	98

*** Source: Nguyen Van Thuong, 1992 ** Source: PRA survey in the two villages.**

b) Twelve pigs owned by 6 farmer households (3 in each village), but of similar genetic background and initial live weight from 9.6 to 23 kg, were fed on the traditional diet supplemented with 190 g/day of groundnut cake (39% N*6.25) and 60 g/day of fish meal (42% N*6.25). It was calculated that the supplement would raise the overall protein supply to 200 g/pig/day. The pigs were fed three times per day. The groundnut cake was soaked overnight and then mixed with the boiled basal feed. The fish meal was fed in the morning after being mixed with the rest of the dietary ingredients.

Data collection

The pigs were weighed in the early morning once a month using a 100 kg capacity portable scale with an accuracy of 0.5 kg. Feed intakes were recorded using a 20 kg capacity portable scale. These records were collected every two weeks, and additional random checks were also made. The major feed resources were identified and representative samples were collected and analyzed for dry matter (DM), crude protein (N*6.25), crude fibre (CF), ether extract (EE) and ash (AOAC 1985).

Results

The mean values for initial and final live weights and daily gains of the pigs on the traditional and supplemented diets, in each of the villages, are shown in Table 2.

Table 2. Mean values for initial and final live weight and daily live weight gain for pigs fed on traditional diets with and without a protein (groundnut cake and fish meal) supplement in Binh Dien and Xuan Loc Villages.

	Xuan Loc		Binh Dien		
	Traditional	Supplemented	Traditional	Supplemented	SE
Live weight,kg					
Initial	15.3	11.6	15.9	14.7	�2.0
Final	45.6	66.5	50.5	65.1	�4.2
ADG	0.202	0.365	0.230	0.363	�0.02

The results were similar in the two villages indicating little difference in the nutritive value of the basal feed resources. Protein supplementation increased live weight gain (adjusted for differences in initial weight) by 83%

from 204 to 375 g/day (P<0.001) and final weight from 46 to 68 kg over the 150 days fattening period.

The value of the additional 171 g/day live weight due to supplementation was estimated at VND 1,700 for an additional feed cost of the supplement of VND 800, giving a net benefit of VND 900 per pig per day (VND 135,000 per pig for the total fattening period).

There was some variation in growth rates of pigs between households. This phenomenon is quite common and has been reported previously from Vietnam by Dolberg (1993). The differences are normally ascribed to variations in management practices among households, which may warrant further studies in order to identify them and explain them more precisely. In the analysis of the management factor, Ostergaard (1994) points out that the interactions between farm households are an important aspect to consider, as the decisions about the management of biological or financial subsystems are strongly influenced by the social structure of the farm household and the cultural framework in which it exists. In this case, the trial intervention, which consisted of an equal supplement of protein with variation in energy supply between farmers may therefore be an important factor in explaining the differences.

Experiment 2

Evaluation of Processing Methods of Whole Fresh Cassava Root.

Material and Methods

Ensiled cassava root (ECR) was produced by washing and grinding (or chipping) the fresh roots and adding salt (0.5% of the fresh weight of the root). The material was ensiled immediately after processing, either in pits dug out of the ground, in a cement container or in plastic bags. These were filled with ground or chipped cassava root as quickly as possible and compacted properly to eliminate air, so as to minimise the loss of nutrients by oxidation. Usually a polyethylene sheet was used to cover the ensiled material, to create anaerobic conditions for fermentation. The time taken for preparation of the cassava roots and the ensiling process was recorded.

Chemical analysis

Samples of the freshly processed root were taken on the day of ensiling and after 30, 60, 90, 120, 150 and 180 days for analysis of DM, hydrocyanic acid (HCN), organic acids and pH in laboratories of the Animal Nutrition Department of Hue Agricultural University and the Biochemistry Department of Medical University. HCN was analysed by the method of Easley *et al*., (1970). Organic acids (acetic, lactic and butyric acids) were determined according to the method of Lepper *et al*., (1982).

Results and Discussion

The ensiled whole cassava root had an acceptable aroma for pigs with no mould growth and kept its white colour.

HCN in the root component after processing and before ensiling is shown in Table 1.

Table 1. Physical composition and HCN content of fresh cassava root,and preparation time for ensiling. Cassava Fresh weight DM HCN Preparation time

	% of fresh whole root	DM (%)	HCN (ppm)	Prep Time (minutes)
Fresh whole root	100	36	114 �5.2	104 �15(*)
Fresh thin peel	3.1 �0.49	21.5	212 �2.0	133�13 (**)
Fresh thick peel	13.6 �0.38	21	238 �3.6	350 �32 (***)
Fresh pulp	83.3 �0.80	38	91 �2.6	

(*) The time taken to pull up, cut , wash and grind 100 kg of whole fresh cassava root and mix with salt. (**) if the thin peel is removed the process takes 133 minutes more , (***) while removing the thick peel takes an additional 350 minutes

The HCN content was highest in fresh thick peel (238ppm) and lowest in fresh pulp (91 ppm). Tewe and Lyayi (1989) analyzed Nigerian cassava and found that the HCN contents of fresh thick and thin peel were much higher (364-815 ppm), while HCN in fresh pulp was only 34-301 ppm (air dry basis). They considered that these differences of HCN were probably due mainly to the variety and the time of harvest of the cassava. They further showed that the concentration of HCN in the cassava root, when the thin peel was removed, was reduced by only 5 % and there was a 3% reduction in content of energy and farmers spent 256 % more time on peeling compared with no peeling.

Effect of processing methods and time of ensiling on DM, HCN content and pH

The data (Table 2) indicate that the effect of both processing methods (grinding or chipping) was to increase the dry matter content, with increased length of the ensiling period from 0 to 30 days and 60 days, although this difference disappeared at 180 days.

Table 2. Effect of processing methods and ensiling time of fresh cassava root on DM content and pH.

Whole cassava root

Days ensiled	Ground		Chipped	
	DM%	pH	DM%	pH
0*	36.2	6.2	34.7	6.3
30	40.8	4.0	37.0	4.0
60	41.8	3.9	38.3	3.8
90	43.0	3.7	41.3	3.7

120	43.0	3.7	42.0	3.7
150	41.8	3.7	41.7	3.7
180	41.0	3.7	41.0	3.7

***Samples were taken 2 hours after harvesting**

The increase of DM content in ground ensiled cassava root was higher than in chipped ensiled cassava root from 0 day to 30 days. Almost certainly the grinding (by machine) exposed a greater surface area to the air which facilitated loss of moisture. Chipping was by hand and thus the particles were larger and less likely to lose moisture. The ensiled material had some 10% more dry matter (after 150-180 days of ensiling) than the freshly processed root. A similar effect was reported by workers at CIAT (1978), who found that the dry matter content increased from 35 to 39% during the space of 25 weeks of ensiling.

The pH was reduced to about the same level (pH=4.0) for both processing methods after 30 days, and then decreased slightly to 3.7 at 90 days and remained at this value.

Effects of processing methods on cyanide content are shown in table 3. The HCN content was affected by the processing method and was lower at all stages of ensiling in the ground root than in the chipped root ($P<0.001$).

Table 3. Effect of processing methods and ensiling time of fresh cassava root on HCN composition.

Ensiling time, days	Total HCN		HCN % of initial concentration	
	Ground	Chipped	Ground	Chipped
0	109	111	100	100

30	76	88	70	80
60	64	71	59	64
90	61	68	56	61
120	59	66	54	59
150	58	61	53	55
180	56	60	51	54

HCN levels for both processing methods decreased very quickly up to 30 days and then continued to decrease more slowly up to 180 days. Ensiling ground cassava reduced HCN content to 70, 59 and 51 % of the initial value after ensiling periods of 30, 60 and 180 days respectively,while ensiling cassava chips reduced the HCN content to 80, 64 and 54% of the initial value, respectively. Similar findings were reported by CIAT (1981) and Gomez and Valdivieso (1988). These results shown that ensiling ground cassava procesing was slightly better in reducing HCN.

The reported levels of reduction of cyanide content are sufficient to make the ensiled cassava safe as a feed for pigs according to Gomez and Valdivieso (1988) who fed roots ensiled for 60 days with a residual cyanide content of 56ppm. Bolhuis (1954) proposed that the toxicity of cassava cultivars could be rated as follows:

(*) Innocuous: less than 50 ppm HCN in fresh peeled tuber.

(**) Moderately toxic: 50-100 ppm HCN in fresh peeled tuber

(***) Dangerously toxic: more than 100 ppm HCN in fresh peeled tuber.

However, Ikediobi *et al*.,. (1980) have reported that cassava containing 144 to 164 ppm HCN after processing can be used for livestock in Nigeria.

The HCN level of ground ensiled cassava root after 60 days ensiling (64 ppm HCN) apparantly caused no ill effect in the pig used in the experiments on farm and on station.

Organic acid content in whole ensiled cassava root

The effect of the ensiling time on organic acid levels in cassava root is shown in Table 4.

Table 4. Effect of ensiling time on organic acid content of whole cassava roots (% of DM)

Ensiling time, days	Acetic acid%	Lactic acid%	Butyric acid%
30	0.81	4.55	0.23
60	0.79	5.62	0.14
90	0.74	5.70	0.06

The content of acetic and butyric acids decreased with increased ensiling time, while that of lactic acid increased. The results are fairly similar to those reported by Serres and Tillon (1972) who recorded levels of acetic and butyric acids in ensiled cassava after three months of 0.3% and 0.09%, respectively.

Experiment 3.

Effect of Different Levels of A Molasses Replacing Cassava Root Meal Or Ensiled Cassava Root on the Performance of Growing- finishing Pigs

Hypotheses

An on-farm survey (Nguyen Thi Loc *et al.*, 1997) in two villages in the hilly areas in Central Vietnam indicated that

the cheapest feed resources with potential for pig feeding were fresh cassava roots and A molasses. The hypotheses to be tested in the following experiment were: 1. Ensiling would be a convenient way of processing cassava root and that the feeding value for pigs would be similar to that of cassava root processed by sun-drying. 2. There would be advantages from incorporating low levels of A molasses in the basal diets of dried and ensiled cassava root

Materials and Methods

Choice of families

The families were selected in cooperation with the local Womens Union, and the criteria taken into consideration for selecting the families for the on farm trials were

- **Farmers willingness to participate in research trials**
- **Importance of pig production as a source of income in the household**
- **Experience with pig rearing**
- **Availability of a closed pig pen with cement floor of adequate size**
- **Cassava and vegetables were planted on the farm**
- **Number of family members supported by farm**

Experimental design

The experiment was carried out from May to November, 1995. Pigs were purchased by groups of farmers with the assistance of the researcher and Women's Union of the villages.

Seventy two crossbred (Mong Cai x Large White) pigs of 18 kg initial weight were randomly assigned to 12 treatments with 3 replicates per treatment and 18 farms (10 in Xuan Loc and 8 in Binh Dien). Each farm had 4 pigs fed the same A molasses level, but 2 pigs per pen (1 castrate and 1 gilt) were fed cassava root meal and 2 pigs were fed ensiled cassava root. The design comprised 2 factors :

- **Level of molasses (0, 5, 10, 15, 20, 25% of diet DM)**
- **Ensiled whole cassava root (ECR) versus cassava root meal (CRM)**

Diets and feeding

An adaptation period of 25 days was used to change to the experimental feed. Experimental diets were given for 5 months.

Diet composition and amounts of dry matter supplied per pig per day are given in Table 5 and 6. Feed samples were taken for analysis of dry matter (DM), crude protein (CP), ether extract (EE), ,crude fibre (CF) and ash at the laboratory of the Animal Nutrition Department of the Hue Agricultural and Forestry University using AOAC procedures (AOAC 1985).

Table 5. Dry matter (DM) intakes of the dietary ingredients, kg/day

Live weight,kg	10-30	30-50	50-70	70-90
Intake (kgDM/day)				
Cassava+-A Molasses	0.35-0.82	0.82-1.21	1.2-1.71	1.71-2.04
Fishmeal+Groundnut	0.42	0.42	0.42	0.42

Sweetpotato leaves	0.06	0.06	0.12	0.12
Total diet	0.83-1.30	1.30-1.75	1.75-2.25	2.25-2.58

***Two hundred g crude protein (CP) supplement obtained from 384 g of a 39 % CP of groundnut cake (GC)and 120 g of a 42 % protein fish meal fortified with salt per day per pig, this being kept constant throughout the experiment**

Table 6. Chemical composition of the experimental diets (% fresh basis)

	*CRM	ECR	AM	FM	GC	SL
DM	87	42	75	87	83	12
N*6.25	2.9	0.95	1.75	42	39	2.4
EE	2.2	0.42	-	9	10.2	0.6
CF	3.84	1.05	-	-	4.3	2.6
Ash	2.52	0.85	4.5	30	4.6	1.4
ME MJ/kg	12.5	4.7	6.9	11.6	14.1	1.3

***CRM, cassava root meal ECR,ensiled cassava root AM, A molasses FM, fish meal GC, groundnut cake SL, sweet potato leaf.**

Details of the methods of processing the cassava root are given in Experiment 2. The A molasses was purchased from an artisan factory in Binh Dien village. On the basis of the results of Ospina *et al*., (1995), the ad libitum

feeding of the cassava root was complemented by 200 g protein/day derived from a mixture of 75% groundnut cake and 25% fish meal. The required weekly amounts of molasses (according to treatment) and cassava root were weighed and put into plastic bags to facilitate the work of the farmers. The farmers mixed these two ingredients immediately prior to feeding three times per day, estimating the quantities needed at each feed according to indicated guidelines provided by the researchers which were revised weekly. The protein supplement was also weighed in weekly amounts and given in two feeds per day. The daily amount remained constant (384 g groundnut cake: 120 g fish meal) throughout the experiment.

Measurements and statistical analysis

The pigs were weighed in the early morning every 30 days using a 100 kg capacity portable scale with an accuracy of 0.5 kg. Records of feed consumption were kept by the farmers and checked twice weekly during visits to the farms.

All data collected were analysed by analysis of variance using the General Linear Model (GLM) procedure of Minitab statistical software.

Results and Discussion

The pigs on all dietary treatments readily consumed the diets with no palatibility problems or digestive upsets, except for a few cases of diarrhoea. Cassava diets have often been found to be of low palatability due to the powdery nature of the root flour (Balagopalan *et al*., 1988).

Growth performance

Overall treatment effects are shown in Table 7.

Table 7. Effect of location, cassava processing and A molasses levels on live weight gain of pigs , feed conversion ratio and feed costs

	Live weight gain (g/day)	FCR kg DM/kg LW	Feed costs VND/kg gain
Villages			
Xuan Loc	433	4.12	8520
Binh Dien	436	4.09	8440
SE/P	3.50/0.621	0.04/0.578	70/0.450
Processing			
Ensiling	429	4.16	7550
Drying	440	4.05	9420
SE/P	3.50/0.027	0.03/0.022	64/0.001
A molasses levels			
0	417	4.27	8910
5	423	4.22	8720
10	435	4.09	8520
15	442	4.03	8330
20	458	3.90	8000

25	432	4.13	8400
SE/P	6.30/0.001	0.60/0.001	110/0.001

The major parameters of biological performance in finishing pigs (rate of gain and feed conversion) were significantly better for dried cassava root meal than for the ensiled root, although the absolute differences were relatively small (2.5 and 2.6%, respectively, for gain and feed conversion).

Live weight gains of pigs fed ensiled cassava roots were lower than of pigs fed cassava root meal for A molasses levels from 0 to 15%.

Live weight gains of pigs fed ensiled cassava roots were similar to those of pigs fed cassava root meal for A molasses levels from 15 to 25%.

The response to A molasses appeared to be curvilinear with optimum performance in terms of growth and feed conversion being observed for levels of between 15 and 20% of A molasses for both methods of processing the cassava root.

These results agree with those of Vinas and Cisneros (1990) who found that mean daily gains of pigs were significantly greater for a group given 15-20 % molasses than for the controls.

In addition, the taste and consistency of the ration can be maintained by the addition of molasses (Gomez, 1979). The average growth rates of the experimental pigs were quite satisfactory considering the genotype (exotic*local) and the restricted protein level (200 g/day).

Average daily gains of pigs in Binh Dien village (436g/day) did not differ (P=0.62) from those on farms in Xuan Loc (433 g/day) and there were no interactions between village and the dietary treatments (P>0.70).

This is evidence for the reliability of data from on-farm experiments of the kind described in this study.

Economic Comparisons of the Dietary Treatments

In contrast to the results for growth and conversion, feed costs per unit liveweight gain were much lower (20%) for ensiled cassava root than for the sun-dried meal (Table 7) and followed a similar pattern as growth performance for the effect of molasses level, with the lowest feed costs corresponding to molasses levels of 15 to 20%.

Experiment 4.

Sugar Cane Juice for Pigs

A trial with cane juice was conducted in Binh Dien village, Huong tra district, Hue province involving 40 pigs (crossbred between Mong cai and Cornwall) and 20 farmers. The pig ration (DM base) consist of sugarcane juice 68%, fish meal 16%, vegetable 16% and salt. Data was collected from pigs raised by 7 families.

In the morning the pigs were fed the full ration of protein supplements (fish meal and groundnut cake) and half the sugar cane juice ration and some sweet potato leaves

The second feed at 17.00h, the pigs were fed the remainder of SCJ and some sweet potato leaves .Water was available ad-libitum.

The results are showed in Table 8.

Table 8. Daily gain of pigs fed sugar cane juice

Groups	No of pigs	Initial LW	Final LW	Gain g/day
I (low				

init. LW)	8	18.3�1.97	56.5�3.7	318.5�19
II (high init. LW)	8	43.5�3.44	104.1�5.96	505.3�45.7

The results were satisfactory (a mean daily live weigh gain of 318 g/d and 503 g/d) so it is feasible to use sugar cane juice to replace cereals and their by-products in the diet of pigs.

The data show that the weight gain of pig fed sugar cane juice was good. It is possible to replace entirely concentrates with sugarcane juice in pig rations. The ADG was affected by farmer management.

Conclusions

- **The typical diet fed to fattening pigs is based on the following ingredients in order of importance: cooked rice, rice bran, cassava meal, fresh cassava root and sweet potato leaves. Calculation of the probable nutrient supply showed that protein was the main limiting nutrient with the amount supplied being less than 100 g per pig per day in most cases.**

- **Limited supplementation of the traditional diet with the equivalent of 100 g protein/pig/day increased live weight gain by 83% and improved economic benefits to the farmers.**

- **Ensiling ground cassava roots appeared to be as effective as sun-drying in reducing cyanide levels to non-toxic proportions. Ensiling increases the palatability of the roots for pigs. The technique is simple, cheap and suited to the conditions of farmers in Central Vietnam.**

- **Inclusion of low levels of "A" molasses appears to improve slightly the utilization of cassava root meal and ensiled cassava root. Feeding cassava meal or ensiled cassava root with 15 or 20% replaced** by "A" molasses and maintaining the protein allowance at a level of 200 g/pig/day throughout the growing-finishing period gave reasonably high growth rates and good economic returns (20% lower feed costs per unit gain).

- The technical of feeding sugar cane juice with 200 grams CP supplement derived from fish meal and ground cake in farm households in two villages were good.

References

Association of Official Analytical Chemists (AOAC), 1985. Official methods of analysis. 12th ed. Washington, DC.

Balagopalan, C., Padmaja, G., Nanda, S.K. and Moorthy, S.N. 1988. Cassava in food, feed and industry. CRC Press, Florida, USA. 205pp.

CIAT (Centro Internacional de Agricultura Tropical), 1978. Informe anual, programa de Yuca. 1978. Cali, Colombia.

CIAT, 1981., Informe anual, programa de Yuca. 1981. Cali, Colombia.

Dolberg F., 1993 Transfer of sustainable technologies in Vietnam. Development of sustainable livestock technologies for ecologically fragile zones in the tropics. Swedish International Development Agency (SIDA) Stockholm Sweden. Internal Report

Easley.J.F, J.T. McCall, G.K. Davis and R.L. Shirley., 1970. Nutrition laboratory of department of Animal Science University of Florida,1970

Gomez, G., 1977. Lifecycle swine feeding systems with cassava. In: Nestel, B.; Graham, M. (Eds.) World Animal Review .

Gomez, G., Valdivieso, M., De la Cuesta, D. And Salcedo, T.S. 1984. Effect of variety and plant age on the cyanide content of whole root cassava chips and its reduction by sundrying.Animal feed Science and technology 11: 57-65

Gomez, G., 1979. Cassava as swine feed. World Animal Review 29: 13-20.

Ikediobi, C.O.; Onyila, G.O.C.; Eluwah, C.E., 1980. A rapid and in expensive enzymatic assay for total cyanide in cassava and cassava products, Agric. Biol. Chem. 44 (12): 2803-2809.

Lepper *et al*., 1982. Methods how to determine volatile fatty acids in silage. Handbook for feed analyses. Moscow Kolos. Ministery of Agriculture, Soviet Union-Cooporation Chemistry Agriculture.

Nguyen Van Thuong, 1992. The hand book of nutrient composition of animal feed in Vietnam. Agricultural Publishing House, Hanoi, 1992. 237-238 pp

Nguyen sinh Cuc, 1995. Agriculture of Vietnam 1945-1995.Stat. Publishing House, Hanoi, 1995. 225-231 pp.

Nguyen Kim Duong and Le Duc Ngoan, 1993. A molasses in diets for pigs, broilers and ducks. Proceeding of the Regional Workshop: Increasing Livestock Production by Making Better Use of local Feed Resources. Hanoi/Ho Chi Minh City. Vietnam. Nov. 25-29, 1991. FAO-SAREC. FAO Regional Office for Asia and the Pacific (RAPA) publications. Bangkok, Thailand. 80 pp.

Nguyen Thi Loc, Ogle, R.B. and Preston, T.R. 1997. Village pig production in central Vietnam: results of a participatory rural appraisal survey and on-farm feeding trials with protein supplementation of traditional diets. Livestock Research for Rural Develoment. In Press.

Ospina Liliana, Preston, T.R and Ogle, R. B., 1995. Effect of protein supply in cassava root meal based diets on the performance of growing - finishing pigs. Livestock Research for Rural Develoment. Volume 7, number 2, October 1995, pp 30-39. Serres. H.y

Ostergarrd V., 1994. Livestock systems research-appropriate methods of the future. Integrated livestock / crop production systems in the small scale and communal farming sector. Symposia at the Department of Animal Science, University of Zimbabwe, January 26- 28, 1994

Serres. H.y Tillon.J.P., 1972. L ensilage des racines de manioc. Rev. Elev. Med. Vet. Pays Trop. 25 (3): 455-456.

Tewe, O.O. and Iyayi, E.A. 1989. Cyanogenic glucosides. In Toxicants of plant origin, Vol II. Glycosides. Ed. Cheeke, P.R. CRS Press. pp. 43-60.

Vinas, RC; Cisneros, JC., 1990. Feeding growing pigs with sugarcane molasses to replace maize as an energy source. Revista- Argentina-de-Production-Animal.1990, 10:3, 193- 199