A CHALLENGING ROLE FOR ORGANIC RABBIT PRODUCTION TOWARDS POVERTY ALLEVIATION IN SOUTH EAST ASIA

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ABSTRACT

This paper addresses the challenging role of organic rabbit production applied towards poverty alleviation. The objective of the paper is to provide information on organic rabbit production with applications to food security and income generation. Rabbits are easily incorporated into integrated farming systems as they convert plant materials, which often are of low nutritive value, to high quality meat, as well as providing faeces whereby nutrients are returned to the soil. Fresh faeces from rabbits can be the raw material for biodigesters used to produce gas and effluent for applying to crops, and for use by earthworms for production of casings are a source of organic fertilizer. In general, the linkage between livestock and crops improves the sustainability of the farming system. The potential of locally feed resources has been used successfully for growing rabbits as an alternate feed supply in terms of cost effectiveness and sustainability. These feed resources can be cultivated in the farmers' plots to provide diets with high contents of digestible energy and protein without the need for cash resources to buy off-farm supplemental feeds. Feed sources from forages, vegetables and aquatic plants (e.g., Cassava, Mulberry, Leucaena, Gliricidia, Sweet Potato vines, Water Spinach, and Stylo) can be used in diets to replace or in combination with a protein source from conventional feed ingredients (soybean and fish meals). Therefore, poor families with limited resources could benefit through increased income and increased consumption of rabbit meat to meet the families' nutritional needs. Farmers can also re-invest their capital to expand their rabbit operation as a means to abandon poverty, but an emphasis on market accessibility and creating a high consumer demand for rabbit meat must also be developed.

Key words: Food security, Integrated farming systems, Local feed resources, Poverty, Rabbit.

INTRODUCTION

Countries in South East Asia, such as Cambodia, Laos, Myanmar, and Vietnam, are the poorest in the region and most of these populations depend mainly on agriculture for their food, income, and mere subsistence. In all four countries, growing inequalities exist between rural and urban populations (Ngo Van Man and Luu Trong Hieu, 2005). CelAgrid and ILRI (2007, unpublished data) reported in Cambodia that the average monthly income of urban households was US$ 723 while in rural households was only US$ 210. This income gap might reflect consumption patterns of local people between both areas, especially in the demand for meat from fish and livestock. Taucher (2000) indicated that the gross national product (GNP) in Cambodia is about US$ 300 per person per year, similar to that of Vietnam and Laos, which is considerably lower when compared to Thailand, Indonesia, and Malaysia, which are better off by 3.5 to over 9 times.

Livestock play a significant role in improving living conditions of the poor. The purpose of livestock keeping of small-scale farmers in the Southern region is for the draught power, food, cash income, and organic fertilizer from faeces. Perry *et al.* (2003) reported on the animal species kept by smallholders and their contributions to the families' assets (Table 1). Poor households rarely kept only one species, due to the risk of the diseases, and so raise several livestock species based on market value.

Table 1: Livestock species kept by the poor and their contribution to household assets (Perry *et al.*, 2003)

Species	Financial	Social	Physical	Natural	Human
Cattle/buffaloes	Sales for milk, meat, hides, animals, draught power services, transport and savings	Networking mechanisms and social status indicators	Draught power for crop cultivation and transport	Faeces for maintenance of soil fertility	Household consumption for milk and meat
Goats/Sheep	Sales for milk, meat, hides, animals and savings	Networking mechanisms and social status indicators	-	Faeces for maintenance of soil fertility	Household consumption for milk and meat
Pigs	Sales of meat, animals and savings	Networking mechanisms and social status indicators	-	Faeces for maintenance of soil fertility	Household consumption for meat
Poultry	Sales of eggs, meat and fowl	Networking mechanisms	-	Faeces for maintenance of soil fertility	Household consumption for meat and eggs

According to CelAgrid (2007, unpublished data), the reported numbers of livestock kept per household in Takeo, Kandal and Pursat provinces of Cambodia, in terms of the average number of cattle, pigs, and chickens, were 3.15, 2.91 and 16.0 heads, respectively. In Thailand, 120 million village chickens are distributed over a small number on rural farms (Chantalakhana and Skunmun, 2002). Recent outbreaks of Avian Influenza in birds have occurred in several countries in the world, such as in Italy, Spain, and Hong Kong. In 1997, outbreaks also reached several Asian countries including Cambodia. Human deaths from the disease have been reported in Indonesia, Vietnam, Thailand, and Cambodia (CelAgrid and AED 2007; unpublished data).

Rabbit production is a new development in the region, which plays an important role in view of the economic risks by the spread of Asian bird flu (Otte *et al.*, 2007). According to the FAO (2001), backyard rabbit keeping provides additional income and supplies additional protein for poor rural and urban households with low investment and labor inputs. Rabbits have small body size, short generation interval, high reproductive potential, rapid growth rate, genetic diversity, and the ability to utilize forages and by-products as major diet components that make the animal appropriate for small livestock keeping in developing countries (Cheeke, 1986). As quoted from Rastogi (2000) the advantages of small-scale rabbit production are shown below:

- Small size and quiet nature of rabbits makes it easy to raise them in cities, suburbs and village communities;
- Large litter size and short generation interval allows for economic returns in the short term (12-15 fryers/doe/year);
- Rabbits are 2.5 and 4 times more efficient in extracting protein from forages than sheep and beef cattle;
- Rabbits can easily subsist on waste materials from the vegetable garden, family kitchen and institutional canteens/cafeterias;
- Low investment is required for establishing a small rabbitry with 3-5 breeding does;
- Meat of rabbits is an excellent, alternative source of healthy food being low in fat, salt and cholesterol.

The aim of the paper is to describe the potential of organic rabbit production in improving income and food security of smallholder families by utilizing feed resources in countries of South East Asia.

RABBIT-BASED FARMING SYSTEM

Integrated farming systems play an important role for small-scale farm families in rural areas in terms of sustainability ("environmentally-friendly"), while minimizing economic risks (Lukefahr and Preston, 1999). According to Pok Samkol *et al.* (2007), livestock convert plant materials that are low in nutritive value into high quality products, such as meat and milk, and return nutrients to the soil in the form of faeces. This synergistic interaction between livestock and crops can improve the sustainability of the farming system and improve soil fertility. According to Lukefahr (2007), using solar energy and ensuring that there is an efficient flow of nutrients in components of the farm ecosystem, there is reduced dependence on off-farm inputs (e.g., commercial feed, fertilizer, and wire) with lower capital investment and hired labor requirements.

Livestock faeces, including rabbits' wastes and human excreta, have been used as materials for biodigesters to improve soil fertility. The soil organic matter content may be an important source of energy for organisms that oxidize methane (Keller *et al.*, 1990). In many situations, the effluent from biodigesters has become the most important product for improving soil fertility (UTA, 2001). The advantage of the biodigesters is that it can become a major source of fuel for cooking, providing organic fertilizer for crop/tree/water plants and fish ponds, and organic fertilizer (Preston and Rodríguez, 2002) and as fuel for engines (Ho Thi Lan Huong, 2002). The appropriate use of biodigesters can also give rise to a number of related socio-economic benefits through improvements to the quality of life for rural women and children (e.g., reduction of labor in fuel wood collection and in cleaning the kitchen, cooking pots and utensils). The fertilizer value of faeces aids to improve the environment by reducing methane emissions and preventing deforestation. When applying graded levels of effluent from biodigesters loaded with pig or cattle faeces at 0 to 140 kg N/ha, the response of biomass yields of Water Spinach, an excellent forage for livestock, was linear from 6.66 to 23.6 tons/ha (R^2= 0.97) (Kean Sophea and Preston, 2002). Also, the growth rate of the fish applied with effluent fertilizer was higher than with U-DAP or fresh faeces from cattle and pigs (Table 2) (Pich Sophin and Preston, 2002).

Table 2: Daily weight gains of fish species according to the fertilizer treatments (Pich Sophin and Preston, 2002)

	Effluent	Faeces	U-DAP	SE
Tilapia	0.499	0.348	0.358	0.045
Silver carp	1.326	0.716	1.049	0.114
Bighead carp	0.572	0.207	0.276	0.078
Silver barb	0.682	0.551	0.651	0.133
Mrigal	0.946	0.831	0.996	0.004

Using the gas produced from biodigesters as fuel for engines can be appreciated as the price of the oil is at peak levels (Leng and Preston, 2005). According to Ho Thi Lan Huong (2002), 1 m^3 of gas can replace 0.85 liters of gasoline by adding a gas-air mixer to the original carburetors, and then the gas can be used to replace petrol to power the engine.

The role of the earthworms in improving soil fertility has long been appreciated by farmers, but until the last two decades there has been no major attempt to cultivate them as a component in an organic recycling system. The potential value of earthworms as a source of high quality protein to supplement poultry diets is now being recognized, but their major role is in the recycling of animal excreta for production of high quality organic fertilizer in the form of worm casings (worm compost). The biomass yield response to fertilization with worm compost was higher than urea (Figure 1) (Tran Hoang Chat *et al.*, 2005a).

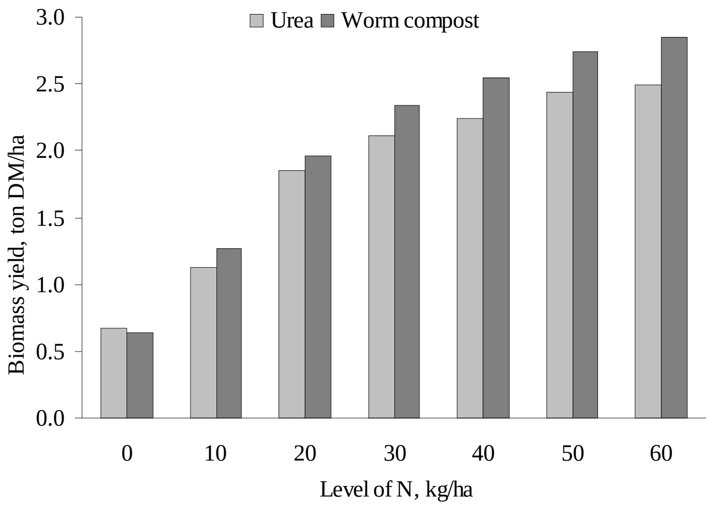

Figure 1: Biomass yield of Water Spinach fertilized either urea or worm compost (Tran Hoang Chat *et al.*, 2005a)

Earthworms can be cultivated on the faeces from virtually all species of livestock. However, they have the comparative advantage over other forms of recycling when the faeces are from pigs, goats, cattle or rabbits (UTA, 2001). The faeces from rabbits make excellent compost, which is rich in organic matter, and nutrients that can produce remarkable results for the home garden and flowers. On the other hand, California earthworms grown in rabbit faeces produce a superb and fairly odorless organic material that resembles peat moss. As demonstrated by Nguyen Quang Suc *et al.* (2000), rabbit faeces is rich in nutrients that provide growth rates of California earthworms higher than faeces from buffaloes or cattle but lower than faeces from goats (Table 3). The value of the worm casts as a source of nutrients for growth of maize was twice that of the raw faeces and, within animal species, the faeces and worm casts derived from goats and rabbits were superior to that from buffaloes and cattle (Nguyen Quang Suc *et al.*, 2000).

Table 3: Consumption of faeces and production of earthworms and conversion of faeces to worms (Nguyen Quang Suc *et al.*, 2000)

	Goats	Rabbits	Buffaloes	Cattle	SE
Faeces, kg DM	85.0	108	77.6	72.3	3.00
Earthworms, kg fresh	5.61	5.38	3.65	2.93	0.25
Conversion rates, kg DM/kg fresh	14.7	18.2	21.6	28.3	0.60

In general, growth rates of rabbits range from 10 to 20 g/day in the tropical regions compared to temperate countries where growth performance typically is between 35 to 40 g/day. The differences may be largely due to heat stress and quality of the diets. High ambient temperatures can cause infertility in breeding rabbits, bucks being more sensitive than does (Lukefahr and Cheeke, 1991). The establishment of the house for rabbits can be made from local materials, such as small poles or sticks and bamboo. However, the house should be well designed to prevent losses from predators. Lukefahr and Cheeke (1991) stated that proper hygiene and management of cages could prevent the spread of certain epidemic diseases. Studies in Vietnam by Nguyen Quang Suc *et al.* (1996) compared traditional cages to an underground system consisting of a shelter using stones, bricks, clay or concrete, which can be covered by earth. The measurements were made at 7:00 am, 12:00 pm and 7:00 pm, and the temperatures did not change for houses constructed underground, which ranged from 25 to 27°C, while the temperature for above-ground cages ranged from 28-30.5°C. The results indicated that there was a significant difference in growth rate of rabbits accommodated underground than rabbits confined in traditional cages which were 21.3 g/day compared with 17.7 g/day of feeding the same diets.

In addition, it is recommended to also use local feed resources which farmers can produce in plots to provide diets that have high contents of digestible energy and protein. However, Lukefahr and Cheeke (1991) reported that many tropical feeds contain toxins, such as mimosine in Leucaena and HCN in Cassava. There are practical ways to minimize toxicity problems (mentioned in a later section). Due to such anti-nutritional factors, in general, the feeds that contain toxins should only be partially used by mixing with other ingredients.

Khieu Borin (2005) reported that in South East Asia, farmers keep animals as part of their traditional culture. Limited resources, such as small land holdings and shortage of capital, prevent farmers from fully developing integrated farming systems. Devendra and Chantalakhana (2002) confirmed that the average farm size in Indonesia is only 0.4 ha. Baseline surveys conducted in the Phnom Kravagn district of Pursat, Cambodia, revealed that families had a mean farm size of 0.26 ha, a paddy field of 1.15 ha, and chamka of 0.47 ha (CelAgrid, 2006). Lukefahr (2007) recommended that all farming activities or components should be complementary, using animal faecess for compost to add to forage and garden plots, fish ponds, and earthworm bins, while forages are mostly fed to rabbits and other livestock.

Chantalakhana and Skunmun (2002) pointed out that crop/livestock interactions evolved through various process stages: (i) the pre-intensification phase of crop/livestock development, (ii) intensification phase of the integration crop/livestock system, (iii) income diversification phase, and (iv) specialized/commercial production phase. These phases depict the nature of this evolution involving crop/livestock systems in Asia and could reflect some directed changes of Asian livestock production systems in the future (Table 4). At present, the majority of livestock production systems in Asia fall under phase (ii), while some systems are moving to phase (iii). Cambodia, Laos, Myanmar and Bangladesh are still in phase (i), while Japan has moved to phase (iv).

Table 4: The evolution of crop/livestock systems in Asia (from Chantalakhana and Skunmun, 2002)

	Phase			
	(i)	(ii)	(iii)	(iv)
Region	Pre-intensification	Intensification	Income diversification	Specialization
East Asia:				
Japan				x
Korea			x	x
Taiwan				x
China		x	x	
Southeast Asia:				
Indonesia		x		
Philippines		x	x	
Thailand		x	x	
Malaysia				x
Vietnam		x	x	
Cambodia	x	x		
Laos	x	x		
Myanmar	x	x		
South Asia:				
India		x	x	
Pakistan			x	
Sri Lanka		x	x	
Nepal	x			
Bangladesh	x			

FEED RESOURCES FOR RABBITS

Feed preferences and feeding systems of rabbits

Rabbits are very selective in their feeding behaviour and in the wild will select specific plant parts. They generally select leaves rather than stems, young plant materials rather than old and green rather than dry materials, resulting in a diet that is higher in protein and digestible energy and lower in fiber than the total plant material available. They are much more sensitive to slight changes in the feed than other livestock. Sometimes they will refuse to accept a new diet and will starve rather than accept the new feed for several days (McNitt *et al.*, 2000).

According to Chiv Phiny (2007), many different forage crops, including water plants and agricultural products and by-products, can be used for animal feeding in tropical regions. For example, Water Spinach, Mulberry and Cassava leaves, and Sweet Potato vines, are rich in protein and can be grown by farmers, and these match with sources of energy available in villages, such as sugar cane juice, sugar palm juice, and cassava root. The leaves of most water plants are more digestible than the leaves of trees and shrubs, but the high water content limits high levels of inclusion in diets, while forage crops often have low palatability and high fiber contents that can negatively influence feed intake and therefore reduce the availability of nutrients to monogastric animals (Cheeke *et al.*, 1980). In backyard rabbit rearing systems, as is now widely practiced in many parts of Africa, the feeding of green herbage is advantageous, since greens are available year-round in the coastal regions and low plains of the continent. In some cases, palatable greens are fed *ad-libitum* which can reduce the amount of concentrate pelleted feeds by 50% with no adverse effects on performance of rabbits (Cheeke *et al.*, 1987).

Lukefahr (1992) presented information on suitable feed sources and basic primary dietary requirements and concluded that feeds for rabbits could be obtained from a variety of sources. These include: wild, indigenous plant stands, cultivated forage plots, farm crop residues, farm surplus foods, agricultural by-products, kitchen wastes, and market sources. However, wild plants may be poor in palatability and some forages may only be seasonally available. Pound *et al.* (1984) reported that the more appropriate approach for smallholder farmers is to grow trees, shrubs and water plants that produce much higher unit area yields of protein in the form of leaf biomass rather than cultivating traditional protein crops, such as soybeans, groundnuts or sunflowers, as components of their farming systems. Strategies to efficiently utilize these unconventional feeds are more likely to succeed when the production system is matched with the available resources (Preston and Leng, 1987).

According to Honthong Phimmasan (2005), the palatability of forages is important in rabbit production, particularly in situations when the forages are expected to provide a major part of the daily nutrient intake. Raharjo and Cheeke (1985) reported that tropical legumes were preferred over grasses and agricultural by-products, with the exception of Gliricidia (*Gliricidia sepium*), a legume which proved to be unpalatable. Leucaena (*Leucaena leucocephala*) is a very palatable to rabbits, even though it contains the toxin, mimosine. Erythrina (*Erythrina lithosperma*), another legume, was well accepted. Sweet Potato vines were palatable to rabbits, while banana and papaya leaves were poorly accepted. Most of the grasses (e.g., Setaria, Brachiaria, and Elephant grass) were less palatable than legumes (Raharjo, 1987). Tree leaves with potential for feeding include the Mulberry (*Morus spp*.), which has been used in India, Brazil and Costa Rica as a forage and black Locust (*Robinia pseudoacacia*), grown extensively in China for rabbit feed. Ramie is utilized in Brazil, where it is considered a highly palatable and nutritious green feed for rabbits (Raharjo, 1987).

Water Spinach *(Ipomea aquatic)*

Water Spinach can be planted either in the soil or water and has been used traditionally in South East Asia as a vegetable for consumption by people and animals. Preston (2006) reported that it appears to be devoid of non-nutritional elements. It has a short growth period and is resistant to many common insect pests. Among aquatic weeds, Water Spinach has great potential for use as a forage for livestock and it is also effective in waste water treatment systems. Average annual fresh weight production of

90, 70 and 100 tons/ha have been reported in Hong Kong, Fiji and the Netherlands, respectively, and the dry weight production during an eight-month period exceeded 20 tons/ha when cultivated in a culture solution (Jain *et al.*, 1987).

Water Spinach contains approx. 29% crude protein (CP) in DM and it may be suitable as a protein source more so than alfalfa (19.6% CP) (Shurson *et al.*, 2002). Moreover, Water Spinach has a lower fiber content than alfalfa leaves (Bruemmer and Roe, 1979).
Pok Samkol *et al.* (2006) fed Water Spinach as the sole diet to crossbred (Local x New Zealand) rabbits, which can support satisfactory growth rates from 14 to 20 g/day. When fed different levels of the Water Spinach plant, rabbits consumed more leaves than stems, resulting in increased protein intake (Figure 2 and 3).

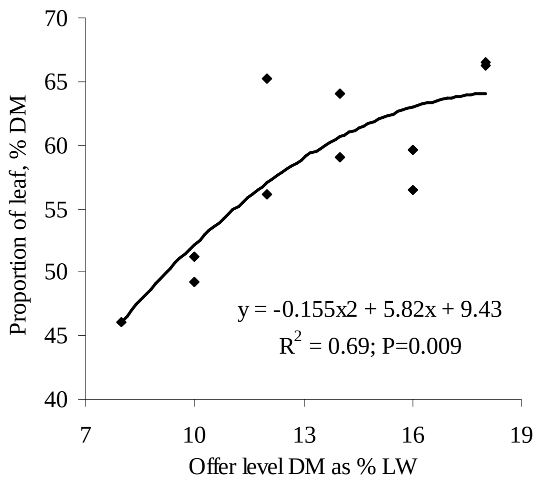

Figure 2: Proportion of Water Spinach leaves (%) in DM consumed, according to offer level (Pok Samkol *et al.*, 2006)

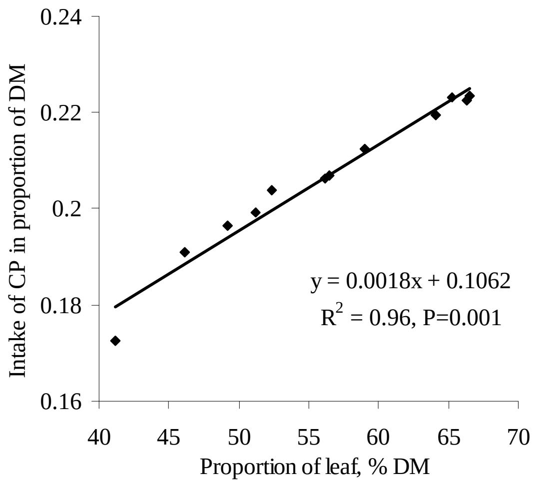

Figure 3: Relationship between proportion of leaves of Water Spinach consumed and proportion of CP in diet DM (Pok Samkol *et al.*, 2006)

When weight gains were plotted against the proportion of CP, the relation was negative (Figure 4). However, the relationship between the proportions of the DM consumed as crude fiber (CF) and weight gains was positive (Figure 5) (Pok Samkol *et al.*, 2006).

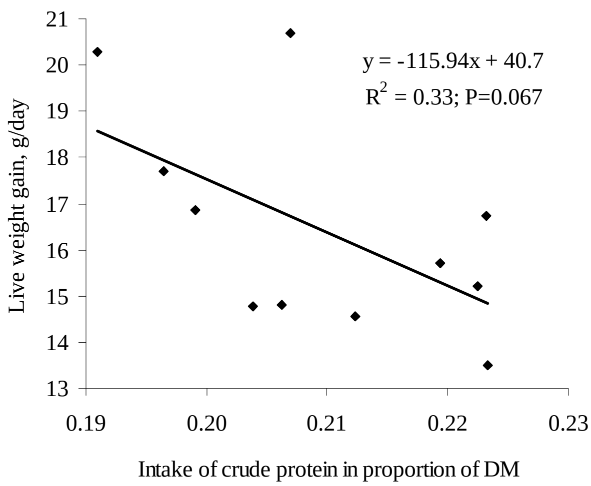

Figure 4: Relationship between proportions of DM of Water Spinach consumed as crude protein and daily weight gains (Pok Samkol *et al.*, 2006)

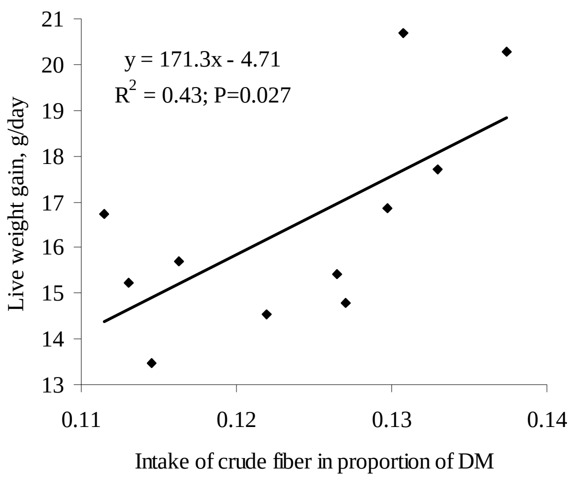

Figure 5: Relationship between proportions of DM of Water Spinach consumed as crude fiber and daily weight gains (Pok Samkol *et al.*, 2006)

Supplementation of fiber in the feed from Water Spinach added to diets based on Stylo *(Stylosanthes guiensis),* Para grass *(Panicum maximum),* or rice bran, fed to crossbred (Local x New Zealand) rabbits, supported growth rates in the range from 18 to 23 g/day (Khuc Thi Hue and Preston, 2006). According to Tran Hoang Chat *et al.* (2005b), an experiment conducted on the replacement of Guinea grass with Water Spinach to complement use of concentrates showed a general increase CP intake. When Water Spinach was used to replace Guinea grass, there was an improvement of body weight gains of growing rabbits and milk yield and litter size of does (Tables 5 and 6). They concluded that fresh Water Spinach foliage was 25% superior to Guinea grass in supporting growth and lactation performance of rabbits when offered *ad-libitum* (contributing about 50% of the diet DM) as a supplement to fixed amounts of concentrates (fed 3% of LW) and a molasses block (2% of LW).

Table 5: Effect of replacement of Guinea grass with Water Spinach on intake, live weight gains and feed conversion of growing rabbits (Tran Hoang Chat *et al.*, 2005b)

	Water Spinach replacing guinea grass (% DM basis)					
	0	20	40	60	80	100
Feed intake, g/day DM:						
Guinea grass	54.0	37.8	26.9	19.9	12.8	0.00
Water Spinach	0.00	17.2	29.9	38.4	44.5	50.5
Concentrate	39.4	39.4	39.1	39.8	40.6	40.5
Mineral block	29.9	28.6	31.1	26.4	25.8	29.8
Total DM	123.5	123.2	127.1	124.5	123.7	120.8
Total crude protein	16.0	17.6	19.1	20.8	20.8	21.0
Growth performance:						
Initial live weight, g	1390	1443	1413	1403	1473	1420
Final live weight, g	2462	2571	2557	2587	2705	2740
Weight gain, g/day	25.5	26.9	27.2	29.2	29.3	31.4
DM feed conversion	4.79	4.66	4.64	4.28	4.26	3.87

Table 6: Effect of replacement of Guinea grass with Water Spinach on feed intake, weight change, milk yield of the doe mother and growth of the litter (Tran Hoang Chat *et al.*, 2005b)

	Water Spinach replacing guinea grass (% DM basis)					
	0	20	40	60	80	100
Feed intake, g/day DM:						
Guinea grass	65.1	49.1	33.0	21.0	18.1	0.00
Water Spinach	0.00	17.9	36.0	49.0	66.4	81.2
Concentrate	73.0	72.6	71.0	70.0	71.7	70.8
Mineral block	56.2	56.7	57.0	56.0	51.7	49.6
Total DM	194	196	197	196	208	201
Total crude protein	25.7	28.0	30.0	32.0	34.5	34.6
Performance of does:						
Initial live weight, g	3400	3570	3400	3430	3500	3470
Final live weight, g	3660	3900	3730	3900	3967	3760
Weight change, g	267	333	333	566	466	300
Milk yield, g	83.2	86.0	90.2	94.4	97.8	101
Survival rate, %	95.2	95.8	96.3	95.2	96.3	96.3
Weight of litter:						
At birth, g	403	399	420	402	436	435
At 21 days, g	1883	1930	2125	1903	2177	2230
At 30 days, g	3267	3900	3933	4567	5133	5300
Weight gains (0-20days), g/day	15.9	18.5	18.7	19.8	19.5	21.1

Sweet Potato vines (*Ipomea batatas* L)

Sweet Potatoes can be cultivated for tuber or forage production depending on the purpose and season. It is considered as a small farmer's crop that grows well under many farming conditions. It can also be grown in poor soils with little fertilizer. Sweet Potatoes are relatively east to plant for the purpose of harvesting vine cuttings rather than seeds. In addition, the crop is highly tolerant of weeds, allowing farmers to devote more time to other crops (CGIAR, 2004-2005). It is an important crop in many areas of the world, and is cultivated in over 100 countries. It has been ranked among the five most important food crops in tropical regions where a high population of the world's poorest people live (Woolfe, 1992). About 80% of the Sweet Potato crop in the world is grown in Asia, under 15 % in Africa, and about 6% in the rest of the world (Horton, 1988). With the advantages of Sweet Potato cultivation and its high nutritive value, the Sweet Potato has been developed as an alternative crop to supply food for human and feed for livestock.

Sweet Potatoes can be planted once and cut for vines as animal feed for a whole year with daily harvesting (Le Van An *et al.*, 2003). Le Van An (2004) concluded that the best options for the proportion of the stems and leaves would be the cutting interval of 20 days and a defoliation of 50% of the total branches. Defoliation reduces tuber production. There appears to be considerable differences, depending on variety, in the content of CP and CF in DM of Sweet Potato vines. CP contains approx. 26.2% DM, Neutral Detergent Fiber (NDF) 31.0% DM, and Acid Detergent Fiber (ADF) 22.7% DM (Doan Thi Gang *et al.*, 2006).

Doan Thi Gang *et al.* (2006) fed Sweet Potato vines as the sole diet to growing rabbits; the daily weight gains were similar to that from feeding Water Spinach (Table 7). Allowing rabbits access to Guinea grass with Water Spinach, or Sweet Potato vines, or the combination of the two, depressed nutrient digestibility (Figure 6). They concluded that when rabbits were fed a basal diet of concentrates (15% soybean meal, 25% cassava root meal, 20% rice bran, 5% minerals and 35% molasses) and highly digestible foliages (Water Spinach and/or Sweet Potato vines and access to Guinea grass) there were beneficial effects on growth rate, even though there was a decrease in digestibility of the overall diet.

Table 7: Feed intake and growth rate of rabbits fed a molasses block and either Sweet Potato vines, Water Spinach or a mixture of the two foliages, and access or no access to Guinea grass (Doan Thi Gang *et al.*, 2006)

	WS	WSGG	SP	SPGG	WSSP	WSSPGG	SE
Feed intake, g DM/day:							
Water Spinach	48.0	36.1	0.00	0.00	33.0	24.3	0.38
Sweet Potato	0.00	0.00	44.3	26.8	23.6	15.7	0.4
Guinea grass	0.00	40.2	0.00	43.9	0.00	33.6	0.68
Molasses block	74.3	73.5	67.2	76.3	68.1	73.8	1.18
Total DM	122	149	112	148	125	147	1.68
Crude Protein	20.5	21.8	23.9	24.8	25.4	25.3	0.26
Growth performance:							
Initial live weight, g	980	940	925	970	930	950	0.04
Final live weight, g	2700	2890	2530	2900	2760	3060	0.06
Weight gain, g/day	21.9	26.4	21.1	26.7	23.1	27.2	1.11
DM feed conversion	10.7	8.23	7.68	7.26	6.21	7.03	0.52

WS: Water Spinach, **WSGG:** Water Spinach and guinea grass, **SP:** Sweet Potato vines, **SPGG**: Sweet Potato vines and Guinea grass, **WSSP**: Water Spinach and Sweet Potato vines, **WSSPGG:** Water Spinach, Sweet Potatoes vines and Guinea grass.

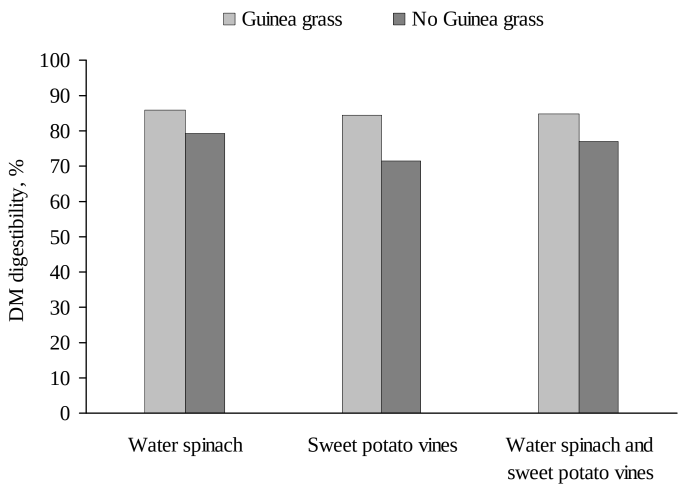

Figure 6: Effect of Guinea grass on digestibility in rabbits fed a molasses block and either Sweet Potato vines, Water Spinach or a mixture of the two foliages (Doan Thi Gang *et al.*, 2006)

Mulberry (*Morus alba*)

Mulberry has been planted as substrate for growth of the larvae of the silkworm. It is a perennial tree, capable of being periodically cut in a plantation style, resulting in high biomass yields, which in turn can be improved when the plant is irrigated with effluent from biodigesters. It is also grown as a shade tree on wastelands and along roadsides, and as a border of fields and around farmers' houses (Sánchez, 2000).

Mulberry grows very well in most soils and produces a high biomass yield with proper management. Proper planting density and fertilization and irrigation rates are important strategies to increase yield. In East China, it is recommended to cultivate 10,500 to 15,000 seedlings/ha to harvest 26.25 tons/ha/year of leaves. However, in South China, the average annual leaf production can even reach 37.5 to 52.5 tons/ha/year by increasing planting density to 90,000 to 120,000/ha (Yongkang, 2000). In the tropics, Mulberry grows best with a sunlight range of 9 to 13 hours a day (Datta, 2000). Biomass yields were increased when applying fertilizer from livestock wastes in the form of compost or from biodigesters (Rodriguez and Preston, 1996). The yield of Mulberry can reach nearly 35 to 45 tons of fresh leaf/ha/year with CP of 20 to 23% DM and minerals of 12 to 18% in DM. The cell wall constituents have NDF content of 45.6%, cell contents 54.4%, ADF 35.0%, hemicellulose 10 to 40%, cellulose 21.8%, lignin 10%, and silica 2.7% (Lohan, 1980).

Lara y Lara *et al.* (1998) fed rabbits *ad-libitum* mulberry leaves, replacing 85% of a conventional concentrate diet. Although live weight gains were reduced slightly from 22 to 18 g/day, the feed cost was decreased by 50%. The potential of Mulberry leaves for rabbits was confirmed in a preliminary report from Colombia (Preston, 2006; unpublished data) in which rabbits fed only Mulberry leaves had average live weight gains of 20 g/day. Singh *et al.* (1984) studied the effect of replacing Mulberry leaves *ad-libitum* to concentrate diets when fed to Angora rabbits on production of wool. The results indicated that average intake of Mulberry leaves was 10.4 g/day/kg $LW^{0.75}$, while the total DM intake was 29.5 g/day/kg $LW^{0.75}$. The digestibility coefficients for DM, CP, CF and NFE were 69, 66, 72 and 78%, respectively. They concluded that Mulberry leaves can be used to supplement the diets of Angora rabbits for wool production. Mulberry leaves may be supplemented up to a level of 40% in DM in rabbit diets. Mulberry leaves fed to rabbits as a replacement of concentrates was studied by Bamikole *et al.* (2005) in Nigeria (Table 8). Live weight gains were depressed when the level of Mulberry leaves was higher than 50%. However, there was an improvement in the DM feed conversion ratio when increasing the level of Mulberry leaf diet. Nutrient digestibility of DM, CP and CF were high in all diets. They concluded that Mulberry leaves when fed up to 50% of the total diet had a high nutritive value for feeding rabbits with comparable DM intake, digestibility and weight gains to an all-concentrate ration. In overall, satisfactory growth rates were achieved at lower costs.

Table 8: Effect of Mulberry leaves replacing concentrate fed to rabbits on intake, growth performance, and nutrient digestibility (Bamikole *et al.*, 2005)

	Level of mulberry leaves replaced concentrate (%)					SE
	0	25	50	75	100	
Feed intake:						
Dry matter, g/day	38.0	38.5	38.4	37.4	36.5	0.34
Crude protein, g/day	7.22	7.73	8.10	8.27	8.47	0.07
Crude fiber, g/day	4.56	7.16	9.64	11.8	14.0	0.10
Growth performance:						
Weight gain, g/day	5.72	5.14	4.72	3.43	2.27	0.40
DM feed conversion	0.15	0.13	0.12	0.09	0.06	0.01
Digestibility:						
Dry matter, %	82.3	75.7	75.7	77.0	79.7	2.39
Crude protein, %	84.0	77.7	76.3	80.3	83.7	2.17
Crude fiber, %	81.7	86.7	79.7	83.7	88.7	2.19

Cassava foliage (*Manihot esculenta* Crantz)

Cassava is one of the world highest calorie producers for human food and is generally grown without fertilization on soils with poor fertility and where other crops would fail (Howeler and Cadavid, 1990). It is possible to obtain from cassava leaves more than 6 tons CP/ha/year with proper agronomic practices directed towards foliage harvesting (AFRIS, 2004).

Cassava leaves have been used to replace soybean in conventional diets for pigs in Vietnam (Bui Ngu Phuc, 2000) and for goat and cattle in Cambodia (Seng Sokerya and Rodríguez, 2001; Seng Mom *et al.*, 2001). Omole (1977) observed that Cassava leaves are a good source of protein, fiber, minerals and vitamins. It contains approx. 25.8 to 27.3% CP, 7.6 to 10.5% fat, 5.7 to 8.8% ash, 4.8 to 7.9% CF, and 50.1 to 51.9% NFE, on the DM basis. The lysine content is considerably high (6.33 to 7.20% of CP), but methionine, and probably tryptophan, are deficient (Rogers and Milner, 1963). Cassava leaves may be useful in rabbit nutrition as it compares favorably with alfalfa meal, which of course is a very popular feed for rabbits and is the largest single component of commercial rabbit feeds in the United States (Cheeke, 1987). It also compares favorably with *Aspilia africana*, which is often used as a major forage feed for rabbits in Africa. However, there are limitations of the utilization of cassava leaves and roots as animal feeding due to the content of anti-nutritional factors, such as HCN and tannins (Awoyinka *et al.*, 1995).

Techniques for reducing the level of anti-nutritional factors in Cassava have been developed through ensiling, sun-drying, boiling, and fermentation. However, the ensiling of Cassava, either with sugar palm or rice bran, has been used as the best methods because drying requires sunlight and boiling requires fuel wood (CelAgrid 2007; unpublished data). The HCN content of fresh Cassava leaves was 508 mg/kg DM (Chhay Ty and Preston, 2005) and this was reduced to 70.7 mg/kg DM when ensiling within 21 days with 5% of sugar palm syrup (1:1 of sugar and water) (Du Thanh Hang, 1998).

Khieu Borin (2005) reported that for several decades now Cassava has been given considerable attention by a number of research institutes in developing countries, in particular at the International Centre for Tropical Agriculture (CIAT). However, research has mainly been concentrated on tuber production, and less attention on evaluating Cassava for forage production. In the last few years, with financial support from SIDA/SAREC to the MEKARN (Mekong Basin Agricultural Research Network) programme, researchers in South East Asia have focused their efforts on Cassava with respect to forage production and its utilization as an animal feed.

Pok Samkol *et al.* (2007; unpublished data) reported that rabbits fed fresh Cassava foliage in combination with Water Spinach had daily weight gains of 11 g/day, while Water Spinach fed as a sole diet resulted in weight gains of 14 g/day. However, the intake of Cassava was only 23% of the total DM intake. Akinfala *et al.* (2003) reported that growth rates ranged from only 11.2 to 12.4 g/day when whole Cassava plant meal was included up to 45% of the diet. They concluded that whole Cassava plant meal can be used to replace maize in diets for weaned rabbits without any adverse effects on performance or on apparent nutrient digestibility.

Leucaena (*Leucaena leucocephala*)

Leucaena is a legume tree that originated in Mexico where its fodder value was first recognized by the Spanish conquistadors who carried Leucaena seeds on their galleons to the Philippines to feed their stock, where it is called Ipil Ipil in Pilipino. In the Philippines, Leucaena has been cultivated in alley cropping schemes to reduce soil erosion. It produces a high biomass yield of relatively high nutritive value for animal production (FIRA, 1980). The yield of Leucaena can range from 3 to 30 tons DM/ha/year and the CP in the leaf is about 22%. The level of protein depends, in part, on the quality of contents of soil, potassium and phosphorus.

Cultivation of Leucaena improves the soil fertility and aids in the control of soil erosion. It has been used as vegetables for humans and as foliage for animals. Therefore, the major land-use system is subsistence farming. Mixed cropping is very popular with main crops such as coffee, tea, bananas, maize, wheat, potatoes, and beans. However, Leucaena has also been cropped in backyards as "living fences" around houses (NAS, 1977). During seed propagation, the bed should be of sandy soil mixing with animal manures and rotten leaves or rice husks if possible. During transplanting, animal manures or rotten leaves should be used as a basal fertilizer. After planting, farmers can frequently fertilize with animal manure or effluent from the biodigesters.

Leucaena contains the anti-nutritional factor, mimosine, which causes loss of hair and poor growth and reproductive performance. It is recommended that Leucaena should not be used as the sole diet for rabbits. However, there is a method to reduce mimosine, which is to soak it in the water and drying.
Leucaena and Arachis in the form of foliage meal were used in an experiment at the level of 30 to 40% as a complement to concentrates of 70 and 60% of the basal diet (consisting of soybean meal 20, maize meal 30, wheat bran 40, sugar cane molasses 8, $CaCO_3$ 0.4, $CaPO_4H.2H_2O$ 0.8, vitamins and minerals 0.5, and NaCl 0.3%) (Nieves *et al.*, 2004). Feed intake and feeding time were increased when feeding Leucaena compared to Arichis (Table 9). It was concluded that diets containing 30 to 40% Leucaena meal were also more palatable than diets containing the same levels of Arachis meal.

Table 9: Feed behavior and intake of growing rabbits fed foliage meals in the diet (Nieves *et al.*, 2004)

	Leucaena (% inclusion)		Arachis (% inclusion)		MSE
	30	40	30	40	
Times eating, mins	5.79	7.35	2.6	3.12	1.82
Feed intake, g/day	73.9	73.2	58.1	63.2	2.80

Ruiz-Feria *et al.* (1998) conducted a rabbit experiment involving the partial replacement of concentrate with Leucaena leaves (10, 20, and 30%). When using Leucaena at the 10% level, rabbits grew faster than at the levels of 20 and 30%. They discussed that the reduction of growth rate may have resulted from the effects of mimosine contained in Leucaena. The recommendation was made of the feeding level of Leucaena in the range of the 0 to 30%, and should depend on economics in terms of realized feed cost savings in relation to growth response. Onwudike (1995) reported that Leucaena fed to rabbits produced reddish-brown urine and loss of hair. Kidneys of Leucaena-fed rabbits showed serious degenerative changes in the tubules. The livers of the Leucaena-fed rabbits showed a dense chronic inflammatory reaction in the portal tracts. It was recommended that Leucaena should not supply more than 50% of the green feed given to rabbits. Martínez *et al.* (2005) compared the hay from Leucaena and Mulberry that substituted diets consisting of barley grain, soybean meal, animal fat, and minerals. The results indicated that intake from the Leucaena-based feed was significantly higher than Mulberry at 144 g/day compared to 102 g/day, while daily weight gains were 46 g/day for Leucaena and 34 g/day for Mulberry. However, digestibility of CF was higher in Mulberry than in the

Leucaena diet, and there was no significant different between the two diets in terms of DM and CP digestibility.

Gliricidia (*Gliricidia sepium*)

Gliricidia is a legume tree that has been used for many years in Colombia and in other countries as living fences around houses. It is a tropical species that grows at altitudes from 0 to 1,500 m above sea level. It can be grown in acidic soils of low to medium fertility. It is also planted in plots involving intercropping with other crops such as Cassava and Maize.High biomass yields of Gliricidia occur when fertilizer is applied. Farmers can apply animal manures as the basal fertilizer during plot preparation. Animal manures or effluent from biodigesters are very important to apply to plots once Gliricidia is first harvested. The chemical composition of Gliricidia is 24.3% CP, 2.12% EE, 16.0% CF, 9.50% ash, and 37.9% NFE, on the DM basis (Onwudike, 1995).
However, there are many anti-nutritional compounds in Gliricidia, and the most significant one is tannins. According to Phimphachanhvongsod (2001), Gliricidia was found to contain 40.7 g/kg DM of condensed tannins that many animals cannot tolerate when consuming large quantities. The tannins bind to proteins and decrease the nutritive value of the plant.

Onwudike (1995) studied two different foliage supplemental diets from fresh Giricidia and Leucaena added *ad-libitum* to a pelleted feed made from yellow maize, groundnut cake, fish meal, brewer's dried grain, dicalcium phosphate, oyster shell, palm oil, salt, and a premix. Results indicated that there was a significant difference in growth rates of the rabbits when fed Gliricidia compared to Leucaena versus the feeding of pellets alone (Table 10). However, there was less feed consumed for Gliricidia than for Leucaena, which might have been due to Gliricidia being less palatable than Leucaena. Feed conversion of the rabbits was improved 3.07 when fed Gliricidia compared to 3.91 with a Leucaena diet. The study concluded that Gliricidia is suitable as a green feed for rabbits and its use helps to ensure an increase in growth rate and improved efficiency compared to concentrated pelleted feeds. This will help to reduce the cost of rabbit production in developing countries of the world where the costs of animal proteins and concentrate feeds are high.

Table 10: Growth performance of rabbits fed Gliciridia and Leucaena as a substitute to pelleted feed (Onwudike, 1995)

	Control	Gliricidia	Leucaena	MSE
Feed intake:				
Pelleted intake, g/day	58.7	65.1	52.7	2.66
Foliage intake, g/day	-	5.86	7.17	0.143
Total intake, g/day	58.7	70.96	59.87	0.705
% of foliage intake	-	8.26	11.9	-
Growth performance:				
Initial live weight, g	552	554	559	-
Final live weight, g	1582	1741	1314	19.2
Weight gains, g/day	18.4	21.2	13.8	0.342

Stylo (*Stylosanthes guianensis*)

Stylo is a short-lived (2 to 3 years), perennial legume that grows into a short shrub with some woody stems. It is adapted to a wide range of soils and climates; however, it is one of the few herbaceous legumes that grow well on infertile, acid soils. It is usually grown as a cover crop, which is cut every 2 to 3 months. It does not tolerate close cutting to the ground since there are few buds on the lower stem for re-growth. Cuts must be made higher than 25 cm to ensure good re-growth (Horne and Stür, 1999). Stylo has the chemical composition of 19.7% DM, 19.9% CP, 13.3% CF, 9.38% ash, 1.34% EE, and 56.0% NFE (Omole *et al.*, 2007). The percentage of DM digestibility of young plant material ranged from 60 to 70%; however, when the age of the plant increased the digestibility was reduced by 40% due to lignification (Mannetje and Lones, 1992). Kryothong (2003) studied the effects of cutting height and time on DM yield of Stylo. The results indicated that when increasing the cutting height from 20 to 30 cm that there was a reduction of DM yield from 4.7 to 4.3 tons/ha.

A recent study by Hongthong Phimmasan *et al.* (2004) investigated the *ad-libitum* feeding of Stylo with graded levels of broken rice as the energy supply. Results indicated that when rabbits were offered high levels of broken rice that they consumed less quantities of Stylo. However, total intakes of DM and CP of rabbits fed graded levels of the broken rice were not different. Also, there was no significant difference in growth rate between experimental and control groups (the latter being rabbits fed only Stylo), which ranged from only 5.61 to 6.67 g/day. Rabbits fed different forages from Stylo, Lablab and Sunflower leaves as sole diets were studied by Omole *et al.* (2007). Rabbits fed Stylo had higher feed intake than either Lablab or Sunflowers, and had more rapid daily weight gains (Table 11). Also, there were no reported deaths observed from the feeding of these forages.

Table 11: Growth performance and health of rabbits fed different source of foliages (Omole *et al.*, 2007)

	Stylo	Lablab purpureus	Sunflowers	MSE
Initial weight, g	516	515	519	-
Final weight, g	1232	1119	1124	15.3
Live weight gain, g/day	7.95	6.71	6.72	0.16
Feed intake, g/day	39.2	35.6	35.8	0.35
Feed conversion ratio	4.93	5.31	5.32	0.21
Survival rate, %	100	100	100	-

RABBITS FOR FOOD SECURITY AND INCOME

Many of the developing regions of the world are now facing a double burden of a growing population and malnutrition (Weingartner, 2005). According to the World Health Organization (WHO), the estimated number of cases of diabetes in developing countries is likely to increase more than two-fold in the next 30 years from 115 million in 2000 to 284 million in 2030 (WHO, 2003). In most developing countries in Asia, and even in food surplus countries such as Thailand, malnutrition still exists (Valyasevi and Winichagoon, 1992), especially in rural areas. It was indicated that most animals and animal products produced on rural farms are usually sold for cash by farmers and therefore flowed out of the communities. It is suggested that malnutrition has remained a basic cause of poor health for rural people. Children, pregnant and post-partum mothers, and sick children and adults can get infected more easily due to their low resistance to infected diseases, which often causes their absence from school or work. Malnutrition results in ignorance and poverty among rural people (Chantalakana and Skunmun, 2002).

Animal products have contributed from 3 to 45% of total food calories for humans in the Asia-Pacific region in 1999 with the lowest (3.0%) in Bangladesh and highest in Mongolia (45%), while Australia, Japan and New Zealand also consume high quantities of animal products, accounting for 20 to 33% of food calories from animal products. Livestock products, such as meat, milk and eggs, are not only foods used to overcome hunger but are critical to develop healthy minds and bodies. Without the availability of animals that largely use agricultural by-products, and forages and vegetative plants, there would certainly be less total food production (Anonymous, 2001). One clear advantage of rabbits is their ability to directly consume forage and convert proteins into animal protein (Lukefahr, 1992), which is appropriate in traditional agriculture systems in Asia that largely maintain mixed crop and livestock farming systems where the economic viability of animal products is realized by the small-holder farmers (Devendra and Chantalakhana, 2002).

Rosegrant *et al.* (1995) projected the demand per capita of animal products in Asia as shown in Table 12. In East Asia (including Japan), between 1990 and 2020, the rates of increase for demand were more than double for beef, pork, and poultry meat and were approximately double for eggs. The projection based on the population growth in Asia that would reach to 4,689 million people in 2020, which will account for almost 58.2% of the total population in the world (Nygaard, 1994). Despite trends that the population is becoming more and more urbanized with time, the actual number of people in rural areas of LDC's is still increasing, and they depend directly or indirectly on agriculture for their survival. According to Chantalakhana and Skunmun (2002), much of the world's children born today can expect to live longer and be better educated than their parents, and there is no doubt that much of the improvement will come from the increase of consuming more animal food products (e.g., meat, milk and eggs).

Table 12: Projected per capita demand for livestock products in Asia (kg/year) (Rosegrant *et al.*, 1995)

Livestock products	South Asia			Southeast Asia			East Asia (including Japan)		
	1990	2010	2020	1990	2010	2020	1990	2010	2020
Beef	1.2	1.4	1.5	2.5	4.5	6.0	1.3	2.3	3.1
Pork	0.3	0.4	0.4	5.5	8.6	10.5	18.8	30.6	38.2
Sheep meat	1.0	1.1	1.2	0.3	0.5	0.7	1.0	1.0	1.2
Poultry meat	0.5	0.6	0.7	4.2	6.9	8.5	3.0	5.2	6.5
Eggs	1.3	1.6	1.8	3.3	5.5	7.0	6.8	10.9	13.6
Milk	63.4	84.9	95.3	3.2	3.8	3.5	7.7	9.3	10.2

The forecast for ruminant and non-ruminant meat production and the demand per person in 2010 for selected Asian countries were presented by Vercoe *et al.* (1997) (Table 13).

Table 13: Forecast of ruminant and non-ruminant production and demand (kg per capita) in the year 2010 in Asia (Vercoe *et al.*, 1997)

Countries	Ruminant meat demand	Ruminant meat production	Non-ruminant meat demand	Non-ruminant meat production
Bangladesh	3.0-3.4	1.7	1.0-1.2	0.8
Cambodia	5.2-5.9	3.3	14.2-16.3	9.1
China	5.8-7.4	8.5	54.5-71.3	49.8
India	5.1-6.2	3.8	1.5-1.9	26.2
Indonesia	4.6-6.0	2.5	12.3-16.7	26.2
Laos	4.8-5.4	3.0	12.4-14.2	7.8
Malaysia	6.3-7.9	0.6	73.7-93.9	139.6
Pakistan	16.9-20.3	14.6	19.8-24.5	9.8
Philippines	4.4-4.9	2.7	27.8-31.7	29.8
Sri Lanka	2.7-3.3	1.2	3.4-4.3	3.8
Thailand	10.1-14.8	6.3	35.5-53.5	42.3
Vietnam	10.1-14.8	3.0	21.5-25.2	18.9

It is projected that there will be a deficit of ruminant meat production in every country, and a deficit of non-ruminant meat production in most countries. According to Devendra (2001) the demands for animal products will be more than double in the next two decades which is the meat and eggs from non-ruminant animals in industrial systems will continue to be the main source of animal proteins, and it is unlikely that these systems will meet all of the projected demands. However, the consumption of ruminant meat and milk is increasing in most of Asia, and 95% of ruminants are found in the mixed farming systems. Mixed farming systems will continue to be the main avenue for intensification of food production, with some specialization in crop or animal activities. This is clear evidence that countries in Asia need more animal products to be produced either through the expansion of production or an increase in productivity.

Lebas and Colin (1992) calculated that the world production of rabbit meat is of the order of 1.5 million tons. This would mean a per capita annual consumption of roughly 280 g of rabbit meat; however, most inhabitants in many countries do not consume rabbit meat as compared to the consumption of 2.5-3 kg/year in France and 4-4.5 kg/year per capita in Italy. Europe is indeed the centre of world rabbit production. The major world producers far surpass all other countries, which include Italy, the Commonwealth of Independent States countries (particularly Russia and the Ukraine), France, China and Spain. Europe, collectively accounts for 75% of total world production. China ranks second, which specifically involves the central Chinese provinces, such as Sichuan and Szechuan. Less major production areas are found in some regions of Africa, Central America, and

Southeast Asia, particularly Indonesia. Colin and Lebas (1996) indicated that countries such as Indonesia, the Philippines, Thailand, and Vietnam account for 87% of the region's total doe population, and Brunei has the largest number of breeding does per 1,000 inhabitants. Vietnam led other countries in the total value of rabbit meat produced per 1,000 USD of the country's total gross national product. Rabbits are not reared in significant numbers in most countries of the Near East.

According to Lukefahr and Cheeke (1991), whose report involved a survey of literature reports from lesser developed countries and provided a summary of production parameters, stated that a breeding doe could produce 20 marketable offspring from 4 litters/year and ten does could yield 200 fryers annually. This first set of figures assumes a forage-based diet and using supplements produced from the farm. The inclusion of purchased concentrated feeds could increase doe production to 6 litters per year. Depending on the family size and its age and body weight composition, 2 to 5 fryers could be consumed weekly, and the rest sold for income. As a guide, a live fryer weighing an average of 2.5 kg with a 60% carcass yield should produce about 1.0 kg of edible meat of which there should be approx. 200 g of protein. As estimated by Lukefahr (2007) a small farm family that raises 10 breeding does and consumes only 2 fryers a week, would yield 86 fryers at a final weight of 2.5 kg, which could generate additional income of US$ 262 with the market price of US$ 1.22/kg. This production level could contribute a 19.8% increase in the average income of farmers in Indonesia, while in Cambodia, Laos, and Vietnam this same figure could represent an increase of approx. 87.3% of income for the family (CelAgrid and ILRI, 2007; unpublished data; Taucher, 2000). In general backyard rabbit farming with the size of 4 to 5 breeding does can produce meat with low investment and operating costs. It takes little time or money to either down-scale or expand the size of the operation. Moreover, the labor input can be shared among the family members. These features associate the rabbit enterprise with minimum economic risk (Lukefahr, 1992). Lukefahr (2007) emphasized that opportunities for expansion should carefully consider the market demand. Also, farmers should certainly avoid flooding the market with rabbits. In addition, rabbit meat should be competitive with other meats by setting the price lower than that of broiler chickens.

CONCLUSIONS

- This paper has presented the topic of the role of organic rabbit production for improving the income and food security of poor families in the case of risk aversion from crop failures and natural disasters, and also for farmers who can re-invest funds to expand their enterprises to eventually alleviate poverty.
- Development of locally grown feeds has a high priority and it is important that the alternative feed resources can be cultivated on local farms to directly benefit poorer farmers who do not have cash resources to purchase supplements from outside the farm.
- Forages such as Cassava, Mulberry, Leucaena, Gliricidia, and vegetables such as Sweet Potato vines, together with water plants such as Water Spinach, and Stylo can be used successfully in diets for rabbits to replace or in combination with a protein source from conventional feed ingredients, including soybean and fish meals.

REFERENCES

AFRIS 2004. Animal Feed Resources Information Systems. *Updated from B. Gohl (1981) Tropical Feeds. Food and Agriculture Organization. http://www.fao.org./ag/AGa/agap/FRG/AFRIS/DATA/535.htm.*

Akinfala E.O., Matanmi O., Aderibigbe A.O. 2003. Preliminary studies on the response of weaned rabbits to whole Cassava plant meal basal diets in the humid tropics. *Livestock Research for Rural Development. 15(4). http://www.cipav.org.co/lrrd/lrrd15/4/akin154.htm.*

Anonymous 2001. Selected indicators for food and agriculture development in Asia-Pacific region, 1990-2000. *RAP Publication:2000/17. FAO Regional Office, Bangkok, Thailand, pp 206.*

Awoyinka A.F., Abegunde V.O., Adewusi S.R. 1995. Nutrient content of young Cassava leaves and assessment of their acceptance as a green vegetable in Nigeria. *Plant Foods for Human Nutrition (Dordrecht, Netherlands), 47, 21-28.*

Bamikole M.A., Ikhatua M.I., Ikhatua U.J., Ezenwa I.V. 2005. Nutritive value of Mulberry (*Morus Spp.*) leaves in the growing rabbits in Nigeria. *Pakistan Journal of Nutrition 4(4), 231-236.*

Bruemmer J.H., Roe B. 1979. Protein extraction from Water Spinach (*Ipomoea aquatica*). *In Proc. Fla Stat. Hortic. Soc., 92, 140-143.*

Bui Ngu Phuc, Ogle B., Lindberg J.E. 2000. Effect of replacing Soybean protein with Cassva leaf protein in Cassava root meal based diets for growing pigs on digestibilty and N retention. *Animal Feed Science and Technology, 83, 223-235.*

Centre for Livestock and Agriculture Development (CelAgrid) 2006. Situation of Food Security and Income Generation Activities of Villagers in Pteas Rong, Samroung and Pro Ngil Communes. *Report of Baseline Survey of Eight Selected Villages in Three Communes in Phnom Kravanh district, Pursat Province. Project funded by FSIF-CIDA and HPI.*

CGIAR 2004-2005. Research and impact: Areas of the research, Sweet Potatoes. *http://www.cgiar.org/impact/research/sweetpotato.html.*

Chantalakhana C., Skunmun P. 2002. Sustainable smallholder animal systems in the tropics. *Kasetsart University Press, Bangkok, Thailand, 23-129.*

Cheeke P.R. 1986. Potentials of rabbit production in tropical and subtropical agricultural systems. *J. Anim. Sci., 63, 1581-1586.*

Cheeke P.R. 1987. Rabbit Feeding and Nutrition. *Academic Press, Orlando, FL, USA.*

Cheeke P.R., Telek L., Carlsson R. 1980. Nutritional evaluation of leaf protein concentrates prepared from selected tropical plants. *Nutr. Rep. Int., 22(5), 717-895.*

Chhay Ty, Preston T.R. 2005. Effect of Water Spinach and fresh Cassava leaves on intake, digestibility and N retention in growing pigs. *Livestock Research for Rural Development, 17(23). http://www.cipav.org.co/lrrd/lrrd17/2/chha17023.htm.*

Chiv Phiny 2007. Water Spinach and Mulberry leaves (*Morus alba*) as protein source for pigs fed diets with different sources of energy. *Msc. Thesis of Mekarn-SLU, Upsalla-Sweden. http://www.mekarn.org/MSC2005-07/thesis07/phinlr.htm.*

Colin M., Lebas F. 1996. Rabbit meat production in the world. A proposal for every country. *In Proc. 6th World Rabbit Congress, 1996 July, Toulouse, France, Vol. 3, 323-330.*

Datta R.K. 2000. Mulberry for Animal Production: Mulberry cultivation and utilization in India. *In: Sánchez M.D. (Ed.). FAO Animal Production and Health Paper 147, Rome, Italy, 52-53.*

Devendra C. 2001. Crop-animal systems in Asia: future perspectives. *Agricultural System, 71 (1-2), 179-181*.

Devendra C., Chantalakhana C. 2002. Animals, poor people and food insecurity: opportunities for improved livelihoods through efficient natural resource management. *Outlook on Agriculture (London), 31(3), 161-175.*

Doan Thi Gang, Khuc Thi Hue, Dinh Van Binh, Nguyen Thi Mui 2006. Effect of Guinea grass on feed intake, digestibility and growth performance of rabbits fed a molasses block and either Water Spinach (*Ipomoea aquatica*) or Sweet Potato (*Ipomoea batatas L*) vines. *In: Workshop-seminar "Forages for Pigs and Rabbits", MEKARN-CelAgrid, 2006 August, Phnom Penh, Cambodia, 191-203. http://www.mekarn.org/proprf/gang.htm.*

Du Thanh Hang 1998. Ensiled Cassava leaves and Duckweed as protein sources for fattening pigs on farms in Central Vietnam. *Livestock Research for Rural Development, 10(3). http://www.fao.org/ag/AGA/agap/frg/FEEDback/lrrd/lrrd10/3/hang2.htm.*

FAO 2001. FAO recognizes the increasingly important role of rabbit breeding: Global rabbit production exceeds 1 million tons. *Press released 01/57, FAO, Rome, Italy. http://www.fao.org/waicent/ois/press_ne/presseng/2001/pren0157.htm.*

FIRA 1980. Leucaena, leguminosa tropical mexicana. Uso y potencial. *Banco de México. México D.F. pp 90.*

Ho Thi Lan Huong 2002. Utilization of biogas technology for generating electricity and storing oranges. *In: Proc. International Workshop Research and Development on Use of Biodigesters in SE Asia region, 2002 March, Ho Chi Minh, Vietnam, 70-74. http://www.mekarn.org/procbiod/huong.htm.*

Hongthong Phimmasan 2005. Evaluation of tropical forages as feeds for growing rabbits. *Msc. Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.*

Hongthong Phimmmasan, Siton Kongvongxay, Chhay Ty, Preston T.R. 2004. Water Spinach (*Ipomoea aquatica*) and Stylo 184 (*Stylosanthes guianensis CIAT 184*) as basal diets for growing rabbits. *Livestock Research for Rural Development, 16 (34). http://www.cipav.org.co/lrrd/lrrd16/5/hong16034.htm.*

Horne P. M., Stür W.W. 1999. Developing forage technologies with smallholder farmers-how to select the best varieties to offer farmers in Southeast Asia. *ACIAR Monograph No. 62, 68-69.*

Horton D.E. 1988. World patterns and trends in Sweet Potato production. *Tropical Agriculture, 65(3), 268-270.*

Howeler R.H., Cadavid L.F. 1990. Short and long term fertility trials in Colombia to determine the nutrient requirements of Cassava. *Fertilizer Research, 26, 1-18.*

Jain S.K., Gujral G.S., Vasudevan P. 1987. Potential utilization of Water Spinach (*Ipomoea aquatica*). *J. Scient. Ind. Res., 46, 77-78.*

Khieu Borin 2005. Cassava foliage for monogastric animals. *Doctoral diss. Dept. of Animal Nutrition and Management, SLU. Acta Universitatis agriculturae Sueciae, vol. 2005, pp 82. http://diss-epsilon.slu.se/archive/00000903/.*

Khuc Thi Hue, Preston T.R. 2006. Effect of different sources of supplementary fiber on growth of rabbits fed a basal diet of fresh Water Spinach (*Ipomoea aquatica*). *Livestock Research for Rural Development. 18 (58). http://www.cipav.org.co/lrrd/lrrd18/4/hue18058.htm.*

Kean Sophea, Preston T.R. 2002. Comparison of biodigester effluent and urea as fertilizer for Water Spinach vegetable. *In Proc. International Workshop Research and Development on Use of Biodigesters in SE Asia region, 2002 March, Ho Chi Minh, Vietnam, 42-55. http://www.cipav.org.co/lrrd/lrrd13/6/kean136.htm.*

Keller M., Mitre M.E., Stallard R.F. 1990. Consumption of atmospheric methane in soils of central Panama; effects of agricultural development. *Global Biogeochemical Cycles, 4, 21-27.*

Kryothong K. 2003. Cassava-legume intercropping: A potential feed production system for small-holder dairy farming. *MSc. Thesis, Dep. of Animal Nutrition and Management, Uppsala, Sweden, 3-27.*

Lara y Lara P.E., Sanginés G.R., Dzib M.R. 1998. Utilización de hojas de morera (*Morus alba*) en la producción de carne de conejo. *In Proc. IX Congreso Nacional de Investigación y Desarrollo Tecnológico Agropecuario, 1998 November, ITA#2, Conkal, Yucatán, Mexico, 257.*

Lebas F., Colin M. 1992. World rabbit production and research: situation in 1992. *In Proc. 5th World Rabbit Congress, 1992 July, Corvallis, USA, Vol. A, 29-54.*

Leng R. A., Preston T.R. 2005. Implications for livestock production of the decline in world oil reserves. *In: Workshop-seminar on Making better use of local feed resources (Preston R., Ogle B., Eds.), MEKARN-CTU, 2005 May, Cantho, Vietnam, 15-31. http://www.mekarn.org/proctu/leng.htm.*

Le Van An 2004. Sweet Potato leaves for growing pigs: Biomass yield, digestion and nutritive value. *Doctoral diss. ISSN 1401-6249, ISBN 91-576-6750-0. Swedish University of Agricultural Sciences, Uppsala, Sweden.*

Le Van An, Lindberg B.E.F., Lindberg J.E. 2003. Effect of harvesting interval and defoliation on yield and chemical composition of leaves, stems and tubers of Sweet Potato (*Ipomoea batatas L (Lam.*)) plant parts. *Field Crops Res., 82, 49-58.*

Lohan O.P. 1980. Cell wall constituents and in vitro DM digestibility of some fodder trees in Himachal Pradesh. *Forage Res., 6, 21-27.*

Lukefahr S.D. 1992. A Trainer's Manual for Meat Rabbit Project Development. The Rabbit Project Manual. *A Heifer Project International Publication, Little Rock, AR, USA, 36-39.*

Lukefahr S.D. 2007. Strategies for the development of small- and medium-scale rabbit farming in South-East Asia. *Livestock Research for Rural Development, 19 (138). http://www.cipav.org.co/lrrd/lrrd19/9/luke19138.htm.*

Lukefahr S.D., Cheeke P.R. 1991. Rabbit project development strategies in subsistence farming systems. *World Animal Review, 6, 60-70. http://www.fao.org/docrep/U5700T/u5700T0d.htm.*

Lukefahr S.D., Preston T.R. 1999. Human development through livestock projects: alternative global approaches for the new millennium. *World Animal Review, 93, 24-35. http://www.fao.org/docrep/x3770t/x3770t04.htm.*

Mannetje L., Lones R.M. 1992. Plant Resources of South-East Asia. *No 4, Forage, Bogor, Indonesia. pp 300.*

Martínez M., Motta W., Cervera C., Pla M. 2005. Feeding Mulberry leaves to fattening rabbits: effects on growth, carcass characteristics and meat quality. *Animal Sci., 80, 275-281.*

McNitt J.I., Patton N.M., Lukefahr S.D., Cheeke P.R. 2000. Rabbit Production. *8th edition. Interstate Printers and Publishers, Inc., Danville, IL, USA.*

NAS 1977. Leucaena: Promising forage and tree crop for the tropics. *NAS, Washington D.C., USA.*

Ngo Van Man, Luu Trong Hieu 2005. Research Cooperation for Livestock-Based Sustainable Agriculture in the Lower Mekong Basin. *In: Workshop-seminar on Making better use of local feed resources (Preston R., Ogle B., Eds.), MEKARN-CTU, 2005 May, Cantho, Vietnam, 7-14. http://www.mekarn.org/proctu/man1.htm.*

Nguyen Quang Suc, Dinh Van Binh, Le Thi Thu Ha, Preston T.R. 1996. Effect of housing system (cage versus underground shelter) on performance of rabbits on farms. *Livestock Research for Rural Development, 8 (4). http://www.fao.org/ag/AGA/AGAP/FRG/FEEDback/lrrd/lrrd8/4/suc84.htm.*

Nguyen Quang Suc, Le Thi Thu Ha, Dinh Van Binh 2000. Manure from rabbits, goats, cattle and buffaloes as substrate for earthworms. *In: Workshop-seminar "Making better use of local feed resources", SAREC-UAF, 2000 January, Ho Chi Minh, Vietnam, 95-98. http://www.mekarn.org/sarpro/sucew.htm.*

Nieves D., Silva Basilia, Terán O., González C., Ly J. 2004. A note on the chemical composition and feeding characteristics of diets containing *Leucaena leucocephala* and *Arachis pintoi* for growing rabbits. *Livestock Research for Rural Development, 16 (99). http://www.cipav.org.co/lrrd/lrrd16/12/niev16099.htm.*

Nygaard D.F. 1994. World population projections, 2020. *International Food Policy Research Institute 2020 Brief 5, 1994 October. http://ageconsearch.umn.edu/bitstream/123456789/19640/1/br5.pdf.*

Omole T.A. 1977. Cassava as animal feed: Cassava in the nutrition of layers. *In Proc. Cassava as Animal Feed Workshop (Nestle B. Graham M., Eds.), University of Guelph, 1977 April, Ottawa, Canada, IDRC-095e, 51-55.*

Omole A.J., Adejuyigbe A., Ajayi F.T., Fapohunda J.B. 2007. Nutritive value of *Stylosanthes guianensis* and *Lablab purpureus* as sole feed for growing rabbits. *African Journal of Biotechnology, 6(18), 2171-2173.*

Onwudike O.C. 1995. Use of the legume tree crops *Gliricidia sepium* and *Leucaena leucocephala* as green feeds for growing rabbits. *Animal Feed Science and Technology, 51(1-2), 153-163.*

Otte J., Pfeiffer D., Tiensin T., Price L., Silbergeld E. 2007. HPAI risk, bio-security and small-holder adversity. *In Proc. World's Poultry Science Association-Asian Pacific Working Federation Group on Small-Scale Family Poultry Farming Symposium, 2007 March, Bangkok, Thailand, 1-8.*

Perry B.D., Randolph T.F., McDermott J.J., Sones K.R., Thornton P.K. 2003. Investing in animal health research to poverty alleviation. 4. The association of livestock species with the poor. *International Livestock Research Institute, Nairobi, Kenya, pp 43.*

Phimphachanhvongsod V. 2001. The potential of *Gliricidia sepium* as a feed for goats in smallholder farming systems in Laos. *MSc. Thesis in Tropical Livestock Systems. SLU, Dept. of Animal Nutrition and Management, Uppsala, Sweden.*

Pich Sophin, Preston T.R. 2002. Effect of processing pig manure in a biodigester as fertilizer input for ponds growing fish in polyculture. *In Proc. International Workshop Research and Development on Use of Biodigesters in SE Asia region, 2002 March, Ho Chi Minh, Vietnam, 27-41. http://www.mekarn.org/procbiod/pich.htm.*

Pok Samkol, Khieu Borin, Sen Sovann 2007. Pig System in SE Asia-Cambodia Case. *In: PPT presentation regional workshop on pig system in Asia and the Pacific: How Can the R & D Enhance the Benefit to the Poor? 2006 November, Bangkok, Thailand. http://www.aphca.org/workshop/pigWS_nov2006/files_pdf/CambodiaPigSys_Nov06.pdf.*

Pok Samkol, Preston T.R., Ly J. 2006. Effect of increasing offer level of Water Spinach (*Ipomoea aquatica*) on intake, growth and digestibility coefficients of rabbits. *Livestock Research for Rural Development, 18 (22). http://www.cipav.org.co/lrrd/lrrd18/02/samk18022.htm.*

Pound B., Done F., Peralta C. 1984. Effect of cutting frequency on seed and forage yield of *Canavalia ensiformis (L) D C* (Jack bean). *Tropical Animal Production, 7, 272-276.*

Preston T.R. 2006. Forages as protein sources for pigs in the tropics. *In: Workshop-seminar "Forages for Pigs and Rabbits", MEKARN-CelAgrid, 2006 August, Phnom Penh, Cambodia. http://www.mekarn.org/proprf/preston.htm.*

Preston T.R., Leng R.A. 1987. Matching ruminant production systems with available resources in the tropics and subtropics. *PENAMBUL Books Ltd., Armidale NSW, Australia.*

Preston T.R., Rodríguez L. 2002. Low-cost biodigesters as the epicenter of ecological farming systems. *In Proc. International Workshop Research and Development on Use of Biodigesters in SE Asia region, 2002 March, Ho Chi Minh, Vietnam, 5-11. http://www.mekarn.org/procbiod/prest.htm.*

Raharjo Y.C. 1987. Evaluation of tropical forages and by-product feeds for rabbit production. *Ph.D. Thesis, Oregon State University, USA, pp 251.*

Raharjo Y.C., Cheeke P.R. 1985. Palatability of tropical tree legume forage to rabbits. *Nitrogen Fixing Tree Research Reports, 3, 31-32.*

Rastogi R.K. 2000. Periurban small livestock production for food and community development. *Department of Food Production, Faculty of Agriculture and Natural Sciences, UWI, St. Augustine, Trinidad. HTML prepared using 1st Page 2000, revised September 29th, 2000. htp://www.uwichill.edu.bb/bnccde/sk&n/conference/papers/RKRastogi.html.*

Rodriguez L., Preston T.R. 1996. Use of effluent from low cost plastic biodigester as fertilizer for Duckweed ponds. *Livestock Research for Rural Development, 8(2). http://www.cipav.org.co/lrrd/lrrd8/2/lylian2.htm.*

Rogers D.J., Milner M. 1963. Amino acid profile of manioc leaf protein in relation to nutritive value. *Economic Botany, 17, 211-216.*

Rosegrant M.W., Agcaoili M., Perez N. 1995. Rice and global food economy: projection and policy implications of future food balance. *In Final Workshop on Projection and Policy Implications of the Medium and Long Term Rice Supply and Demand, 1995 April, Beijing, China, 7.*

Ruiz-Feria C. A., Lukefahr S.D., Felker P. 1998. Evaluation of *Leucaena leucocephala* and cactus (*Opuntia sp*.) as forages for growing rabbits. *Livestock Research for Rural Development, 10 (2). http://www.cipav.org.co/lrrd/lrrd10/2/cont102.htm.*

Sánchez M.D. 2000. Mulberry: an exceptional forage available almost worldwide! *FAO Electronic Conference on "Mulberry for Animal Production". World Animal Review 2000, 93(1), FAO, Rome. http://www.fao.org/ag/aGa/AGAP/FRG/Mulberry/Papers/PDF/Mulbwar2.pdf.*

Seng Mom, Preston T.R., Leng R.A., Meulen U. ter. 2001. Response of young cattle fed rice straw to supplementation with Cassava foliage and a single drench of cooking oil. *Livestock Research for Rural Development, (13)4. http://www.cipav.org.co/lrrd/lrrd13/4/seng134.htm.*

Seng Sokerya, Rodríguez L. 2001. Foliage from Cassava, *Flemingia macrophylla* and bananas compared with grasses as forage sources for goats: effects on growth rate and intestinal nematodes. *Livestock Research for Rural Development (13)2. http://www.cipav.org.co/lrrd/lrrd13/2/sok2132.htm.*

Shurson J., Whitney M., Johnston L., Koehler B., Hadad R., Koehler D. 2002. Designing Feeding Programs for Natural and Organic Pork Production: Challenges in feeding organically raised pigs. *University of Minesota Extension Service Bulletin 07736-BU. http://www.extension.umn.edu/distribution/livestocksystems/components/7736c03.html.*

Singh B., Goel G.C., Negi S.S. 1984. Effect of supplementing Mulberry (*Morus alba*) leaves *ad-libitum* to concentrate diets of Angora rabbits on wool production. *J. Applied Rabbit Research, 7(4), 156-160.*

Taucher T. 2000. Strategic development options for cattle and buffalo production and marketing in Cambodia. *Mission report of Consultant Large Ruminant Specialist. Agriculture Productivity Improvement Program (APIP) in Animal Health and Production Component, IFAD Loan 423 –KH, Phnom Penh, Cambodia.*

Tran Hoang Chat, Ngo Tien Dung, Dinh Van Binh, Preston T.R. 2005a. Effect on yield and composition of Water Spinach (*Ipomoea aquatica*), and on soil fertility, of fertilization with worm compost or urea. *In: Workshop-seminar "Making better use of local feed resources (Preston T.R., Brian Ogle, Eds.), MEKARN-CTU, 2005 May, Cantho, Vietnam, 289-295. http://www.mekarn.org/proctu/chat47.htm.*

Tran Hoang Chat, Ngo Tien Dung, Dinh Van Binh, Preston T.R. 2005b. Water Spinach *(Ipomoea aquatica)* as a forage source for rabbits; effect of fertilization with worm casts or urea on yield and composition; using it as replacement for Guinea grass in diets of growing and lactating rabbits. *In: Workshop-seminar "Making better use of local feed resources (Preston T.R., Brian Ogle, Eds.), MEKARN-CTU, 2005 May, Cantho, Vietnam, 296-303. http://www.mekarn.org/ctu05/chat.htm.*

University of Tropical Agriculture (UTA) 2001. Creating opportunities for research and learning in integrated farming systems for sustainable use of local resources in the tropics. *Report April 1996 to December 2000, UTA, Phnom Penh, Cambodia, 18-19.*

Valyasevi A., Winichangoon P. 1992. Contribution of animals to meet the human nutritional needs in rural Asia. *In Proc. 6th AAAP Animal Science Congress, 1992 November, Kasetsart University, Bangkok, Thailand, Vol. I, 41-56.*

Vercoe J.E., Coffey S., Farrell D.J., Rutherford A., Winter W.H. 1997. ILRI in Asia: An assessment of priority for Asian livestock research and development. *ILRI (International Livestock Research Institute), Nairobi, Kenya. pp 62.*

Weingartner L. 2005. The food and nutrition security situation at the beginning of the new millennium. *Achieving Food and Nutrition Security (Action to meet the global challenge) (Klennert K. Ed.). Feldafing, Munich, Germany, pp 33.*

World Health Organisation (WHO) 2003. Diabetes cases could double in developing countries in next 30 years - But the increase could be slowed through prevention. *http://www.who.int/mediacentre/news/releases/2003/pr86/en/print.html.*

Woolfe J.A. 1992. Sweet Potato: An Untapped Food Resource. *Cambridge University Press, Cambridge, UK.*

Yongkang H. 2000. Mulberry for Animal Production: Mulberry cultivation and utilization in China. *FAO Animal Production and Health Paper 147 (Sánchez M.D., Ed.), Rome, Italy, 15-24.*