

Chapter 3

Nutrition of non-ruminants

One of the major challenges to researchers in the tropics is to provide alternatives to the feeding and management systems for monogastric livestock, especially pigs, poultry and rabbits, introduced from temperate industrial countries. These introduced systems are not sustainable as they depend to a high degree on imported inputs. Typically they are large-scale, peri-urban, and vertically integrated with processing and marketing, promoting competition with, rather than participation of, the small-scale rural farmer. In many cases there are minimal provisions for waste treatment in these large-scale units and pollution of watercourses becomes a serious problem.

The development of alternative production systems, using locally available feed resources, must start with knowledge on the impact on nutritional requirements of using new feed resources, which are often rich in sugars, lipids and fibre, in contrast with the starch-rich feeds used in temperate countries. Respecting the innate capacity of animals to select a balanced diet from an array of ingredients, and to process feeds in their natural state, will help to maximize the participation of the farmer in the production process and reduce dependency on feed milling and mixing plants.

IMPLICATIONS OF USING NON-CEREAL FEED RESOURCES

This is not the place to give an extensive discourse on the nutrition of non-ruminant livestock. Text books and bulletins dealing with the species of animals in this category are available and should be consulted if the need is to understand some specific aspect of their digestive physiology or metabolism. Equally, it is not intended to refer to the series of recommendations on requirements for specific nutrients: amino acids, minerals and vitamins. This information is well documented in the bulletins published by ARC (1988) and NRC (1988).

What will be described are: (i) the nutritional consequences of using some of the non-cereal feed resources, mentioned earlier (Chapter 2) and discussed in detail in Chapter 4, as the basal energy supply of pigs and poultry; and (ii) the measures to be taken to obtain the most economical results when such feeds are used. This information is not available in the standard text books, nor in the bulletins of nutrition requirements where it is invariably assumed that cereal grain will be the principal source of energy.

There is another general point to be taken into account in any discussion about feeding standards and requirements. In almost all cases these have been worked out against a background of state-financed or environment-financed support for agricultural products, either directly in the form of guarantee payments or an export subsidy, or indirectly through externalizing the costs implicit in: (i) the damage to the environment, caused by soil and groundwater pollution from discharge of wastes; and (ii) the use of non-renewable fossil fuel-derived inputs. In almost all cases, the final effect is to encourage the maximization of biological performance. The consequence is that feeding systems tend to be predicated on what is needed to reach these levels of performance, rather than on the optimal use of the available feed resources.

The law of diminishing returns operates strongly at the extreme range of the production response curve thus the final increments in performance require high levels of inputs, especially protein. In contrast, in most tropical countries, livestock production is not subsidized and the point of optimum economic performance is found in the lower part of the response curve. Supplementary nutrients are used more efficiently in this case.

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

NON-CEREAL FEED RESOURCES FOR PIGS

The alternatives

The most promising alternatives to cereal grains for intensive feeding of pigs in the tropics are: sugar cane juice (Mena, 1983; Sarria *et al.*, 1990;

Speedy *et al.*, 1991), sugar cane molasses (High-test, "A" or "B" molasses) (Figuroa and Ly, 1990), juice from the sugar palm tree (FAO/TCP, 1994a), oil, whole fruit and by-products of the African oil palm (Devendra, 1992; Ocampo *et al.*, 1990a,b,c; Ocampo, 1992, 1994a, b), cassava roots (Buitrago, 1993) and by-products (Espinal, R. and Ospina, L., 1993, unpublished data) and organic waste from urban households, restaurants and canteens (Dominguez, 1990, 1991).

Other products and by-products from tree, root and tuber crops, are included in tropical pig diets but mostly on an *ad hoc* basis, and not as the basis of the feeding system.

PROTEIN SUPPLEMENTATION OF TROPICAL ENERGY-RICH FEED RESOURCES

With the exception of the organic waste of urban origin, all the feed resources mentioned above are characterized by very low levels of protein in the dry matter ranging from 1% in sugar cane juice and molasses to 5% in whole African palm fruit. One consequence of this low level of protein in the basal diet is that almost all the requirements for amino acids have to be supplied in a supplement. While this could be considered to be a disadvantage, in fact the contrary may be the case because:

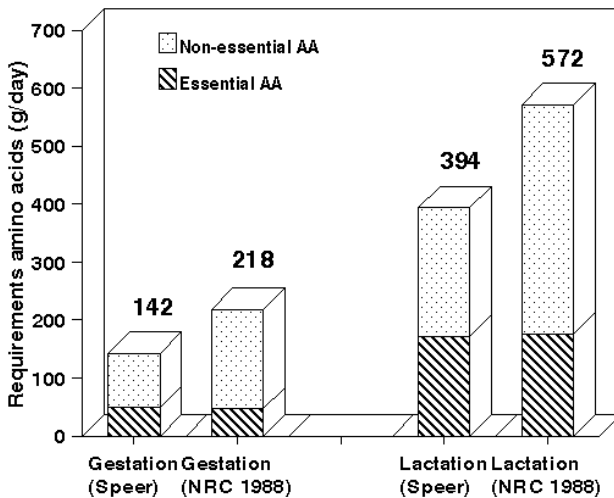
- It is much easier, and may be cheaper, to find a supplement already balanced with respect to the essential amino acids (lysine, methionine, etc.) than to make a supplement that will compensate for the imbalanced amino acid profile present in cereal grains.
- The total amount of protein to be offered is less because when it is derived almost wholly from supplements, rather than partially from cereal grains, it is better balanced in the essential amino acids.

These possibilities can be visualized more easily in the comparisons presented in Figure 3.1 which show that the essential amino acid requirements of sows can be contained in 30-35% less total protein, than what is recommended by NRC (1988) which is inflated by the presence of excessive amounts of the non-essential amino acids present in cereal grains.

The final point is the relationship between the amount (and therefore cost) of the supplement and the level of animal performance. This is

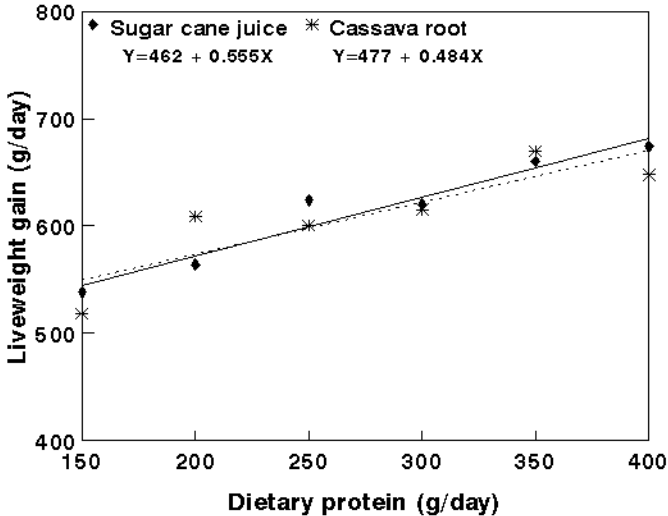
especially important in most tropical countries where the ratio - price of protein : price of energy - is much wider than is the case in temperate (cereal growing) countries. Thus the point on the response curve (to protein) where profit per fattening pig is optimized will not necessarily coincide with the point where biological performance is maximized.

Figure 3.1. Protein requirements for pregnant and lactating pigs (Essential Amino acids and total protein) (Source: Speer, 1990).



An example taken from Vietnam clearly illustrates this point (Figure 3.2). The regression equations show that for every 100 g/day increase in supply of protein (approximately 200 g/day of soya bean meal), liveweight gain was increased by 55.5 g/day on sugar cane juice and by 48.4 g/day on cassava root meal. Putting the value of liveweight at US\$1.00/kg and the cost of soya bean at US\$400/tonne (the approximate prices in Vietnam in 1993) then a liveweight gain of 55.5 g/day, worth US\$0.055, requires 200 g soya bean meal which costs US\$0.080. Clearly there is no economic advantage in giving more than the minimum amount of soya bean meal (300 g/day = 150 g protein) which will support a liveweight gain of 542 g/day (on cane juice). This is well below the optimum biological response of 684 g/day liveweight gain obtained with 800 g/day of soya bean meal.

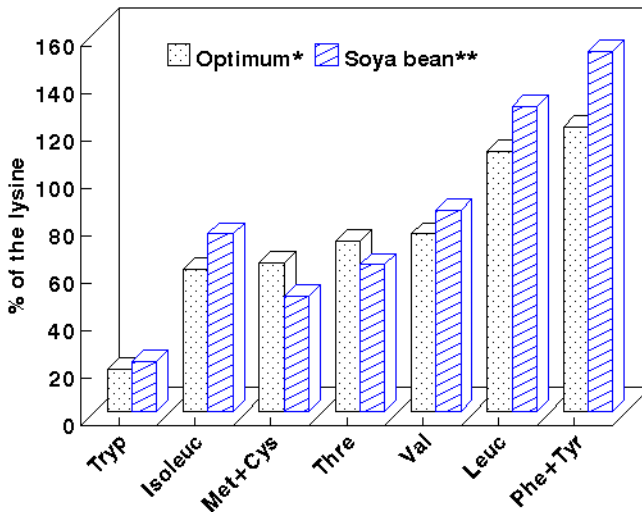
Figure 3.2. Effect of dietary protein supply on growth rate of pigs fed basal diets of sugar cane juice or cassava root meal (Source: Phuc *et al.*, 1994; Ospina *et al.*, 1994).



The calculation is a little more complex as faster growth means less time for reaching slaughter weight, and the higher protein level was associated with slightly leaner carcasses, which leads to lower interest and labour costs and increased returns respectively. But even if these factors are taken into account, it will be seen that the fastest growth rate (biologically optimum supply of dietary protein) is not necessarily the most profitable one.

It is almost certainly more important to aim for the biologically optimum ratio of: (i) the essential amino acids relative to one another (eg: as a percentage of the lysine); and (ii) the total essential amino acids relative to the non-essential ones. Wang and Fuller (1989) in an elegant series of experiments using purified diets have provided estimates of both these criteria for growing pigs. In Figure 3.3 the estimated requirements are expressed as a percentage of the lysine. The minimum proportion of essential to non-essential amino acids they estimated to be at least 45:55. Speer (1990) gave estimates of 35:65 and 44:56 for gestating and lactating pigs respectively.

Figure 3.3: Amino acids in soya bean meal: comparison with the ideal protein (Source: * Wang and Fuller, 1989; **Tropical Feeds, 1994).



The recommended strategy when balancing tropical energy-rich feeds (such as juice from sugar cane and sugar palm, molasses, cassava root meal, cassava starch processing by-products, palm oil, oil-pressed fibre and oil palm fruit), is to prepare a protein supplement which has a balance of amino acids that resembles as closely as possible that proposed by Wang and Fuller (1989) (Table 3.1). Where a variety of protein sources are on offer, a "least cost" computer program can be used to achieve such a balance. An example of this approach was given by Speedy *et al.* (1991) for preparing a protein supplement to balance sugar cane juice for pig fattening in Swaziland.

For the next step one should ideally be able to refer to regression equations relating productive function to protein (balanced according to Wang and Fuller, 1989) for the particular energy-rich "tropical" feed being used. An example of this approach is given in the work reported by Bui Huy Nhu Phuc *et al.* (1994) and Ospina *et al.* (1994), referred to above (Figure 3.2). Response curves relating growth and carcass traits with supply of a balanced protein (soya bean meal), were determined for basal diets of sugar cane juice and cassava root meal, respectively. From

such data it is possible to calculate the marginal advantage (or disadvantage) of a particular level of protein input in terms of the expected increase in productivity that will result, compared with using a lower level of protein.

Table 3.1. Balance of essential amino acids in "ideal;" protein and that from soya bean meal (SBM), *Azolla* and *Trichanthera gigantea* (Tg) (Source: Wang and Fuller, 1989; Buckingham, 1978; Rosales, M., Personal communication)

Amino acid	Proportion in the protein (as % of lysine)			
	"Ideal"	SBM	<i>Azolla</i>	Tg
Tryptophane	18	21	31	NA
Isoleucine	60	75	60	97
Meth+Cystine	63	49	63	81
Threonine	72	62	72	100
Valine	75	85	103	134
Leucine	110	129	138	172
Phenylalanine +Tyrosine	120	152	149	217

The other point concerns the need or otherwise to increase protein supply with increase in live weight. The experience in Colombia and Vietnam with sugar cane juice, "B" molasses, cassava root by-product and oil palm derivatives, as the basal diet, is that it is simpler for the farmer to give a fixed quantity of protein daily and that there is no economic advantage in having varying levels according to liveweight. The allowances presently used are set out in Table 3.2.

Table 3.2: Allowances of "ideal" protein for pigs in different phases of the production cycle (Source: Wang and Fuller, 1989)

Category protein	Liveweight (kg)	"Ideal" allowance (g/day)
Growing-finishing	20-90	200
Gestation	>90	150
Lactation	>90	350

These quantities are based on the assumption that the essential amino

acids will supply at least 45% of the total amino acids and that the essential amino acids will be balanced according to the recommendations of Wang and Fuller (1989) (Table 3.1).

The fact that the regression coefficients linking protein supply with liveweight gain were almost the same for cassava root meal and sugar cane juice (Figure 3.1) indicates that probably other low-protein, low-fibre energy feeds will respond in a similar manner. Support for this hypothesis is found in the results with oil-press fibre (30% oil; zero protein) fed as the basal diet to fattening pigs (Ocampo *et al.*, 1990b). In an experiment with levels of from 500 to 1,000 g/day of a fortified soya bean supplement (soya bean meal with added minerals and vitamins) (200 to 400 g/day protein), there was no biological advantage from giving more than 200 protein g/day throughout the growing-fattening (20-90 kg) period.

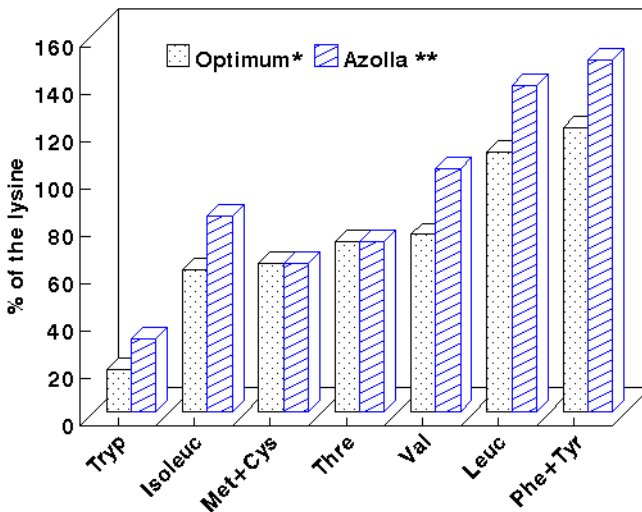
It is interesting, in the light of the above recommendations, to refer to an experiment carried out over 30 years ago (1957/58) in Louisiana State University by Thrasher *et al.* (1958). These researchers offered growing- fattening pigs (from 24 to 90 kg) mixed diets with either 0, 20, 30, 40 or 50% raw sugar (replacing maize meal), balanced with soya bean meal, meat meal and alfalfa meal to provide 16 declining to 14% protein; a 6th group of pigs had free access to raw sugar, maize meal and a protein supplement (36% protein from soya bean, meat meal and alfalfa meal). Growth and feed conversion on all treatments were similar (785 to 872 g/day; 3.1 to 3.4 conversion, air dry feed basis) but the pigs on the free choice system only consumed 258 g protein/day, of which 95 g came from the maize and only 163 g from the protein supplement. These same pigs consumed 45% of their diet as sugar. The pigs on the mixed feeds consuming this same level of sugar (average of 4th and 5th groups) consumed 400 g protein daily yet they performed no better than the free choice group which consumed 36% less protein.

It is unlikely that, on all occasions, it will be possible to prepare an "ideal" protein supplement with the perfect complement of amino acids. For all practical purposes, the protein of soya bean is sufficiently close to the ideal protein (see Figure 3.3) as to be the supplement of choice where it is available or can be grown.

In fact, on small farms in remote areas, the availability of protein sources may well be restricted to what can be grown on the farm or at

best complemented with some by-product produced in the nearby village. In these situations it is important to have some idea of the amino acid balance of feeds that can be grown locally. This topic will be discussed more fully in Chapter 4. It is enough at this stage to point to the examples in Figures 3.4 and 3.5 of two foliar sources of protein which can be grown in the tropics: the water fern *Azolla* spp. and the multi-purpose tree *Trichan-thera gigantea*. *Azolla* is readily consumed by pigs, especially during pregnancy. The data in Figure 3.4 indicate that the protein in *Azolla* (about 23% in the dry matter) has an excellent balance of amino acids, better even than soya bean. In this case the limitation to its use will be voluntary intake and the digestibility of the protein.

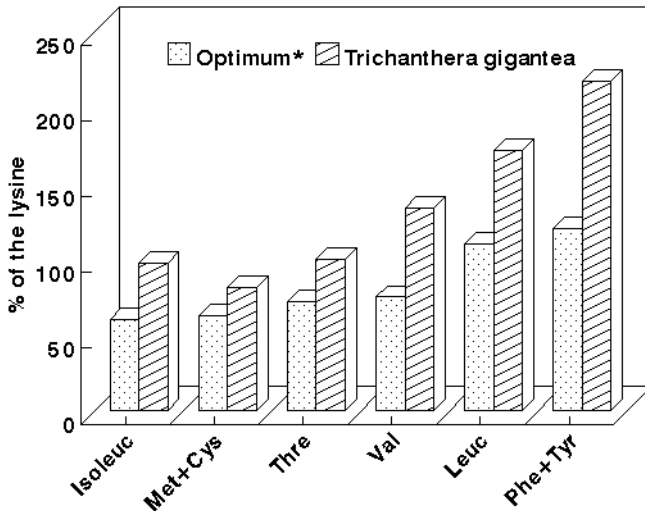
Figure 3.4. Amino acids in *Azolla*; comparison with the ideal protein (Source: * Wang and Fuller, 1989; **Buckingham, 1978).



The same is true, although to a lesser extent, with *Trichanthera gigantea*. The protein in the leaves has a good amino acid balance and according to some early work there are few secondary plant compounds (Rosales, M. 1994, unpublished data). Pigs eat it well, especially during

pregnancy. However, even when eaten in amounts that theoretically supply all the protein needs (about 3 kg/day), pregnant pigs rapidly lost body condition when given only *Trichanthera* as a supplement to sugar cane juice (Sarria, P., personal communication). Up to 30% replacement of the soya bean protein by *Trichanthera* appears to be feasible, but either low digestibility or presence of secondary plant compounds appeared to limit its use at higher levels. This aspect will be discussed in Chapters 4 and 8.

Figure 3.5. The essential amino acids in *Trichanthera gigantea* as percentage of lysine, compared with the ideal protein of Wang and Fuller (1989) (Source: Rosales, M., personal communication).



ENERGY ALLOWANCES

The energy allowances for pigs in the classical tables of feeding standards are expressed in terms of metabolizable energy. At this stage of development of the use of non-cereal tropical feed resources, this is an unnecessary sophistication. The production cycle of the pig can be divided into four stages: gestation, lactation, pre-weaning growth and fattening. It is not very precise to put replacement females in the same

category as fattening, but for all practical purposes the former are not separated until they reach 90 kg. In all categories with the exception of gestation, the general rule will be to feed the basal diet *ad libitum* and to restrict the protein to approximately 65% of the recommendations in NRC (1988). It is emphasized again that the NRC figures for total protein are inflated by the non-essential amino acids present in cereal grain diets on which NRC (and all temperate country) standards are based. When low-protein tropical feed resources are used, the ratio of essential to non-essential amino acids can be set at close to the optimum (45:55) because:

- the total amount of amino acids in the basal diet is low therefore most of the amino acids comes from the protein supplement which is usually well balanced, and
- the protein that is present in tropical energy-rich feeds tends to have a better amino acid balance than the protein in cereal grains.

In gestation the feed allowance will be determined by the energy density of the basal feed. The aim should be to use feeds (or supplements) with low nutritional density so the animal can have free access to at least one component of the diet. In this way, the "hunger syndrome" (abnormal behaviour of sows rationed to small amounts of low volume-high energy density feeds) is avoided. The result is a "contented" sow and the support, rather than the opposition, of animal welfare activists.

MINERALS AND VITAMINS

In this case the indicator of sustainability is "minimum" dependence on outside inputs, especially those sold by feed mills and other intermediaries. Careful selection of the supplement can help to eliminate part of the need for both minerals and vitamins. For example if some palatable and digestible green foliage can be given free choice the pigs will obtain from it most of the vitamins (except for D which is abundantly provided through the medium of sunlight) and trace minerals they need. The major minerals provided by the commonly used protein supplements are shown in Table 3.3. When a mixture of soya bean meal and fish meal (75:25) is used as the protein source it will provide much of the needed calcium, phosphorus and sodium. Sources of calcium (lime) and sodium (salt) are available in most farm households and rural

villages. In some cases the phosphorus can be supplied as phosphate fertilizer. Useful data on vitamin and mineral content of tropical feed resources can be found in Tropical Feeds (1994).

Table 3.3: Amounts of major minerals supplied by the protein supplement as soya bean meal alone, or in combination with fish meal, *Azolla* or *Trichanthera gigantea*.

Protein source	DM	P (g/d)	Ca (g/d)	K (g/d)	(g/d)
Soya bean meal		450	1.3	1.3	6.7
50:50 SBM: fish meal		425	7.3	13	5
<i>Azolla:</i>					
30% fattening		200	1.4	3.4	3.6
100% pregnancy		500	3.5	8.5	9.0
<i>Trichanthera gigantea</i>					
30% in pregnancy		200	0.8	4.8	7.6
Requirements (g/d)*					
Fattening		9-12	11-16	2-3	
Pregnancy		11	14	4	

* From NRC (1988)

NON-CEREAL GRAIN FEED RESOURCES FOR POULTRY

As with pigs, it must be made clear at the outset, that the purpose of this section is to assist those researchers who believe that poultry and water fowl production should be carried out in a sustainable way respecting the indicators set out in Chapter 1. Feeding systems based on cereal grain will not therefore be discussed. In any event, there is a wealth of information on such systems in the classical text books and bulletins in developed countries.

There appear have been no attempts to re-examine the nutrient needs of poultry in the light of alternative non-cereal grain feeding. One promising development, instigated in the University of New England, Australia (Cumming, R., personal communication), is based on the premise that, given the opportunity to select (in the case of Cumming's

work, between grain and protein supplement), poultry are able to balance their diet according to productive need and environmental stress (high temperature). Cumming and his colleagues have reported economies in feed and no loss of production with this free-choice management system.

The disadvantage of this approach, in the context of tropical feed resources, is that protein-rich feeds in such regions are generally much more expensive than energy-rich feeds. Thus it is almost never profitable to feed protein at a level which will maximize animal performance. For this reason protein almost always will be rationed to secure the most profitable response.

There has so far been no commercial development of poultry feeding systems which use non-cereal tropical feed resources. Work with ducks is the most advanced in this regard (see Chapter 4). But the principles are the same. If tropical feed resources of low protein content are used then the protein supply, balanced according to the "ideal" protein (see above), can probably be reduced to two-thirds of the recommended allowances (NRC, 1988) which, as for pigs, were worked out against the background of cereal grain diets. A factor which may have to be taken into account, especially with ducks, is the need for sulphur-containing amino acids for feather growth. The testing of this hypothesis is recommended as a high priority research area.

The other principles set out for pig feeding on tropical feed resources, with regard to energy, minerals and vitamins, apply equally well to poultry including water fowl.

NUTRITION OF NON-RUMINANT HERBIVORES

The species which are raised commercially in a number of tropical countries are rabbits and guinea pigs. Unfortunately, as in the case of poultry, the intensive "modern" feeding systems are invariably based on conventional, mostly "non-tropical" feed resources and no serious attempt has been made to re-assess their nutritive requirements when alternative "tropical" feeds are used. Advances are now being made in the design of feeding systems for rabbits, using tropical feeds (see Chapter 4), but as yet there are no reports of possible savings in protein requirements, for example that might be achieved by replacing cereal grain with low-protein sugar or oil-rich energy feeds. Theoretically, savings

should be possible as the same arguments concerning digestive processes apply to non-ruminant herbivores as to pigs. There is an urgent need to make such studies in the newly developed feeding systems being used for rabbits, and to begin comparable research with guinea pigs.

The most recent version of the recommendations of the ARC on nutrient requirements of rabbits and guinea pigs was published in 1977 (ARC, 1977). Since this date, much research has been done on the digestive physiology and metabolism in these species, although it has not been interpreted in terms of recommendations on nutrient requirements. It must also be made clear, however, that almost always this research was done using conventional "temperate" feed resources (e.g., maize, soya bean meal and alfalfa), which are neither available nor sustainable in the way they are produced in temperate countries (e.g., dependence on fossil-fuel derived inputs and excessive use of water for irrigation). On such feeding systems the objectives of maximizing biological efficiency led progressively to a reduced capacity to utilize herbaceous plants. Emphasis was put on optimizing availability of glucose and amino acids, which was favoured by the use of diets with high levels of starch (from cereal grains) and preformed protein (from dietary protein). The role of microbial synthesis in the caecum and the utilization of this source of amino acids by coprophagy was largely ignored (Cardozo, A., 1993, personal communication).

For these reasons, researchers in tropical countries are encouraged to take advantage of the opportunities offered in the area of nutrition of "small non-ruminant herbivores" in the tropics, and to participate in the development of feed resources and feeding systems which take account of sustainability criteria. The appearance of a new computerized journal dealing specifically with small non-ruminant herbivores reflects the increasing interest being given to these species (RLPHNR, 1993).

The nutritional requirements of small non-ruminant herbivores are determined by the relative activities of:

- digestion and absorption in the duodenum, and
- digestion by fermentation and absorption in the caecum.
- In the case of the rabbit, the guinea pig and probably the picture (*Dasyprocta* spp.), must be added coprophagy as a physiological recycling mechanism.

The last two processes are ruled out in the case of the snails at least until more is known about the physiology of digestion in these species.

The fact that the small non-ruminant herbivores must satisfy their nutritional requirements by pathways (i) and (ii) has important implications, for example:

- Energy metabolism is based on the utilization of glucose, VFA and lipids.

Therefore, tropical feed resources must be selected according to their capacity to supply: digestible fibre (the source of VFA), sugars and starch (sources of glucose) and pre-formed lipids.

In the tropics, satisfying the energy needs of small non-ruminant herbivores in a sustainable manner probably requires that major emphasis is given to maximizing intake rather than digestibility. The reasons for this are as follows:

- From the physiological standpoint, these animal species have a high capacity to tolerate bulky feeds.
- Optimizing the concentration of fibre in the diet is a way of ensuring that intake is maximized, provided that there is an appropriate balance between the digestible and indigestible fractions. This because these fractions perform separate functions: "fibre" as a source of VFA and "fibre" as a mechanism to stimulate rate of passage. Rate of passage is a fundamental feature of the strategy, because of its close relationship with intake and coprophagy, in the case of the rabbit and guinea pig.
- The role of lipids is important because of the enormous potential in tropical regions of sources of plants that produce these nutrients in the fruit (e.g., the African oil palm). Many trees found in the tropics produce nuts and seeds which are rich in lipids. A tree attracting attention in Venezuela (Cardozo, A., personal communication) produces oil which can be "tapped" from the trunk in a similar way to that used to obtain latex from the rubber tree.