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Issue Highlights

Note our new area code
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From the Editors

The technical staff at ECHO regularly receives questions concerning what resource-poor farmers can feed to their animals. In this issue we have added two extra pages in order to adequately cover the important topic of ruminant (e.g. cattle, goats) nutrition.

In "The Livestock Revolution," Dr. Don Cobb shares the result of weeks of reading and corresponding with scientists on the subject of using and supplementing what are normally considered low-quality feeds. You will be surprised and encouraged at what he has turned up.

But we start with an article on the basics of ruminant feed and digestion, including some of the concepts and words scientists use to discuss and evaluate feed quality. You can make better feeding recommendations if you have a basic understanding of how ruminants can survive on feeds that would be totally inadequate for us monogastric animals. This material will also help you understand scientific articles on feed quality.

The content of both of these articles is heavy—heavier than most *EDN* articles. You do not need to understand everything in the first article to understand the second, but Dr. Cobb assumes knowledge of the important parts in writing his article.

Basics of Ruminant Digestion

By Annie Shaw
ECHO Staff

Digestion occurs when complex materials found in feed are broken down into small fragments that can be absorbed into an animal's system and then used for growth, maintenance, reproduction and other functions. In ruminants (cows, sheep, goats, deer, etc.) digestion begins when food passes through the mouth, where it is chewed to break up the fibers. The food passes on to the **rumen** and **reticulum** – often considered one large organ called the **reticulo-rumen** – where **microbial digestion** (or fermentation) takes place. **M**icro-**o**rganisms (**MOs**) in the rumen and reticulum, such as bacteria and fungi, work to further break down the food. Specifically, they break down the carbohydrates in the diet and manufacture protein to meet the energy and nitrogen needs of the animal. The animal can regurgitate very fibrous material (the 'cud') from the rumen for more chewing. After leaving the reticulo-rumen, the partially digested food (digesta) enters the **omasum**, where water is absorbed. The rumen, reticulum and omasum constitute the **foregut**, which is the distinguishing feature of ruminants. The digesta then passes on to the **hindgut**, which includes the **abomasum**, or 'true' stomach, and the **intestines**. Here the digestive processes are the same as those that occur in other mammals – essentially the enzymatic (rather than microbial) breakdown of the digesta and absorption by the animal of the nutrients.

It is the distinctive processes that occur in the rumen that we are primarily concerned with in this article.

Energy Requirements in Ruminants

Energy can be defined as **the capacity of a body to do work**. Plants get their energy directly from sunlight, while animals must get a constant supply of energy through their food. They need this supply of energy to maintain their body functions: to move, to grow, to produce milk and to reproduce. Ruminants get their energy primarily from carbohydrates (sugar, starch and cellulose) and fats in the diet. The MOs in the rumen break down complex carbohydrates (e.g. cellulose – which cannot be digested by non-ruminants) into **v**olatile **f**atty **a**cids (**VFAs**), simpler molecules that can meet most of the energy needs of the animal (e.g. butyric and propionic acid). Other carbohydrates (e.g. sugars and starches) are also used for energy. Fats (found in oils) can also provide large amounts of energy when they are digested in the rumen. It might be tempting to include large amounts of fat in food rations to increase the animal's intake of energy. However, too much fat (more than about 5% of the diet) can decrease the ability of MOs to break down other parts of the diet.

If we give an animal a quantity of energy as food, we should be able to account for all of it in one form or another. What goes in must come out. Animals can lose energy in a number of ways: as excretions (e.g. feces, urine, sweat and methane), as mechanical work (e.g. pulling a cart) and as heat. Some energy can also be stored in the animal as fat. How do we ensure that an animal gets enough energy to supply its needs? We need to know how much energy the food can provide, and we need to know the energy requirements of the animal. These measurements have already been performed on a vast array of foods and animals in different stages of life. However, many of these measurements were performed on animals in temperate climates, where the cold climate can affect the energy requirements of animals. Care must be taken when using published tables of data, because the energy requirements of animals in the tropics are often lower than those of animals in temperate climates.

Units for Energy

In books and publications on animal nutrition, different units are used around the world to define quantities of energy. The preferred unit is the **joule** (**J**), which is defined precisely with respect to certain electrical measurements. Because the joule is a very small unit, it is more common in animal nutrition publications to see the **m**ega**j**oule (**MJ**, 1 000 000 J) or the **k**ilo**j**oule (**kJ**, 1 000 J). Another commonly seen unit, especially in older publications, is the **calorie**, which is equal to 4.184 joules. Most publications list energy contents of foods in terms of megajoules per kilogram of the dry matter in the food (**MJ/kg dry matter**).

Energy Definitions and Transformations

Gross **E**nergy (**GE**) is a very basic measurement of the energy content of food, determined by burning foods and measuring the heat produced. It is not often a very good indication of the nutritive value of a food, because foods have energy in different forms that may be more or less useful to an animal. For example, in terms of GE, wheat grain, dried grass and wheat straw have very similar amounts of energy (~18.5 MJ/kg dry matter). However, any farmer knows that an animal uses each of these three feeds very differently.

A more useful measure of energy is **D**igestible **E**nergy (**DE**). This takes into account the energy that is not digested, but rather lost in the feces (the largest single loss of energy from the diet). The DE of a food is more representative of its usefulness to an animal: less than 20% of the energy of a good quality food is lost through feces, while in a poor quality food, more than 60% can be lost this way. If we compare the DE of wheat grain, dried grass and wheat straw, we can see that the DE more accurately reflects their potential usefulness (~16 MJ/kg, ~12 MJ/kg and ~7 MJ/kg dry matter, respectively). However, supplementing feed can dramatically improve the efficiency of its use (see next article).

Metabolisable **E**nergy (**ME**) reflects other losses apart from feces. These include urine loss and methane produced in the rumen during carbohydrate digestion and lost through burping. These are unproductive uses of dietary energy.

There is a final energy loss to consider: **heat increment of feeding**. This is energy lost during digestion of food. If the animal eats more, it produces more heat. This is a problem in the tropics, because animals will reduce food intake (thus reducing useful production) in order to prevent overheating. The **N**et **E**nergy (**NE**) reflects this and is the fraction of energy input that is of direct benefit to the animal for maintenance and for actual production.

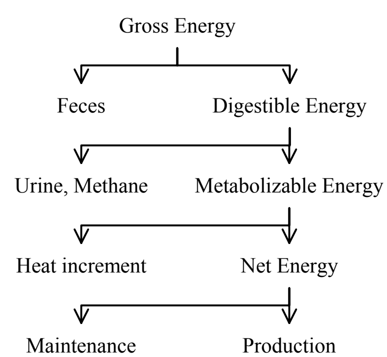


Figure 1: The overall pattern of energy use in animals. From Ruminant Digestion by John Chesworth.

Protein Requirements in Ruminants, Transformations, and Definitions

Proteins are essential in animal and plant cells. They form structural compounds, such as hair, skin and muscle, and they are regulators, or enzymes, in all internal functions. They are made up of chains of smaller compounds of **amino acids**, the building blocks of protein. About 16% of protein is **nitrogen**, and nitrogen is also important in other compounds in the body.

Non-ruminants must get almost all of their nitrogen from true protein in the diet, which tends to be the most expensive part of an animal feed. In ruminants, the MOs in the rumen need protein for their own growth and development, but they can manufacture their own amino acids and use these to manufacture protein, using simple, cheap, **n**on-**p**rotein sources of **n**itrogen (**NPN**). While the MOs are making protein for themselves, much of it passes on to the host animal, thus meeting many of the animal's protein needs. The MOs will degrade most protein in the diet to ammonia (NH_3) to use as their amino acid starting point, so there is little need to use expensive, high-quality protein in the ruminant's diet – it will get broken down in the rumen before the animal can use it. This means that when feeding ruminants, you can use very cheap, simple sources of nitrogen to meet most of their protein needs (for example urea, chicken manure or ammonia). The protein that can be and is broken down by the MOs in the rumen is called **R**umen **D**egradable **P**rotein (**RDP**).

Not all the protein in the diet will be degraded by the MOs in the rumen. Some of it reaches the stomach intact, where it can be used directly by the animal. This protein is called **U**n**d**egradable **P**rotein (**UDP**) or **bypass protein**. When an animal is growing rapidly or is lactating (both of which are times of high protein needs), the protein synthesized by the MOs may not be sufficient. The animal will need a source of bypass protein.

Figure 2 details the pathways that protein in a ruminant's diet can follow. So-called **Crude Protein** (**CP**) is not really a measure of protein, but rather a rough (or 'crude') estimate based upon measurements of amounts of nitrogen in the food (CP=nitrogen content x 6.25 because proteins are roughly 16% nitrogen. 16%=0.16, and 1/0.16 ~ 6.25). The CP can also include non-protein nitrogen, for example from DNA or coffee pulp.

Ruminants are able to recycle and reuse the nitrogen in urea. Instead of excreting it through the kidneys, as non-ruminants do, some urea passes through the blood stream to the salivary glands, then joins the food entering the rumen. This means that the urea can be used as a source of NPN for the MOs (though there are always some losses). Protein is also lost through the skin and hair, and it is always needed for growth and lactation.

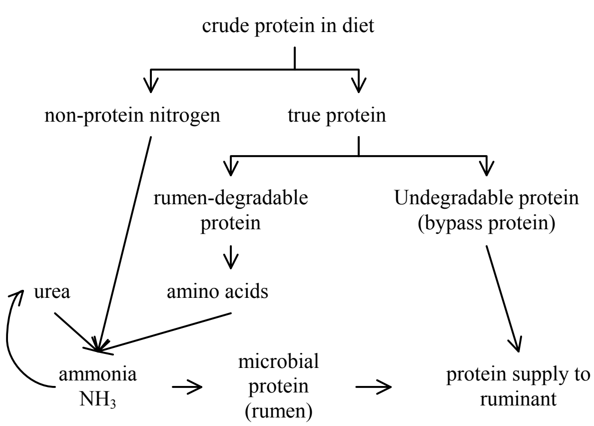


Figure 2: The paths by which crude protein in the diet arrives at the small intestine of the ruminant. From *Ruminant Digestion* *by John Chesworth.*

Systems for Planning Animal Diets

Several systems for planning animal diets, mainly for energy needs, have been developed independently by research organizations in many different, but mainly temperate, regions of the world.

Animals in the tropics live under very different conditions than those in temperate regions. Climate can have a large effect on an animal's feed intake, digestion, water intake, and other behaviors. Climate can also affect forage quality. Animals eat less when the temperature is high. The animal's body temperature rises (due to increased heat increment of feeding) when the ruminant eats poor quality forages and this results in lowered feed intake, decreased muscle activity and slower productive functions (lower growth, milk production and reproduction rates). Grazing time is reduced if animals are heat stressed in the middle of the day. They also require more water. As well, tropical forages mature more rapidly than temperate ones. They also have lower levels of protein, minerals and DE, and higher amounts of lignin that makes fiber less digestible.

The following article discusses some ways that forages can be supplemented to improve growth and milk production of ruminants on small tropical farms.

The Livestock Revolution

By Don Cobb, Ph.D.
ECHO Staff

High-tech, high input, industrialized livestock systems like those seen in developed countries are seldom appropriate for resource-poor farm families in developing countries. In countries experiencing intense population pressure, there is seldom enough land for pasture or for crops grown specifically for ruminants. In many instances they are fed the locally available agricultural by-products and scavenged mature forage, which are usually deficient in minerals, energy and protein. Animals in these situations are not primarily producers but rather serve many purposes: insurance, mobile capital, a source of fuel, traction, a fertilizer factory, and status symbols. Unsophisticated but scientifically based research has been carried out in developing countries, primarily on farms, over the past few decades seeking to optimize the production of such animals from local resources. **The purpose of this article is to show that with strategic supplementation, using locally available resources (straw, maize stover, poor quality grass, etc.), small-scale farmers in the tropics can have productive ruminants that emit less methane (believed to contribute to global warming) and that produce milk and meat more efficiently.**

When poor families in developing countries have access to a little more money they spend a good part of it on animal products to supplement their meager staple diet. The combined figures for all developing countries show that per capita consumption of beef, mutton, goat, pork, poultry, eggs and milk rose by an average of almost 50 percent per person between 1973 and 1996. This is still about a quarter of the per capita consumption of the developed countries. Recent figures indicate that the trend continues.

Urbanization, population growth and income growth have all been factors in the increasing demand for animal products. Such changes in diets of billions of people could significantly improve the lives of many rural poor **if** NGO's, governments and industry prepare for this continuing revolution with long-range policies and investments that will satisfy consumer demand, improve nutrition, direct income growth opportunities to those who need them most, and alleviate environmental and public health stress (Delgado et al. 1999).

We live in a world where 800 million people suffer from at least some degree of hunger and almost 50 percent of the grains produced in the world are fed to livestock. About 85 percent of the grain-fed animals are in developed countries. Grain production in developed countries is highly subsidized. With globalization more of the excess is finding its way into intensive feeding systems in developing countries with predictable consequences: the rising demand for protein is being supplied by imported inputs and systems, and havoc ensues in the market for locally produced protein and feed resources (Sansoucy, *Livestock*, 1995).

As the demand for animal products grows, the number of animals will also grow—unless we can make the existing animals more efficient. This has happened with dairy animals in developed countries. More milk (and less methane) is produced by fewer cows in these intensive, high-tech, high input, industrialized livestock systems. Increased production and profits are the bottom line. Extensive, sophisticated research in ruminant nutrition has sought to maximize animal production using high quality energy-dense protein-rich rations—often grain-based. Complex computer models are used to fine-tune the nutrient balances for maximum digestion and absorption of the diet.

There are alternative ways to make animals more efficient. The ideas presented here are not new and they are not my own—though I have worked with ruminants in previous assignments overseas and have had first-hand experience with a number of the approaches that are highlighted. Ruminant nutrition, like human nutrition, is very complex. Many factors other than feed are involved, including climate, genetic potential, parasites, availability of water, and disease (see Figure 3 on page 8). Despite the fact that every situation will be different, some guidelines have been developed that can be applied in almost every situation. As words of encouragement I would like to quote from a paper by Dr. R.A. Leng (*Evaluation of tropical feed resources for ruminant livestock*, 1995):

"If the feed evaluation systems, as applied in temperate countries. . . were applied literally in developing countries most of the present ruminant feeds of the developing world would be rejected as being too low in digestible nutrient densities to be useful. . . .The standards of developed countries for feed quality based on any energy measurements for ruminants are clearly misleading when they are applied to poor quality forage or non-conventional feedstuffs . . . .In at least two major developments in Asia involving millions of animals in each, high growth rates of cattle . . . and high milk production in cows . . . have been achieved on feeds that are rejected in developed countries as being of too poor quality to be used, yet these systems have production outputs that come close to those of many developed country systems based on high quality pastures."

With knowledge gained in the past thirty years (take note especially of the work of **T.R. Preston and R.A. Leng,** ***Matching Ruminant Production Systems with Available Resources in the Tropics and Subtropics,*** **1987**) it has been shown that large increases in productivity and efficiency can be brought about by small changes in the balance of nutrients in the feed base. These increases include not only faster weight gain and better milk production, but also cows begin calving at an earlier age, give birth more reliably and at more frequent intervals, and give milk over a longer time. Better nutrition is the key to all of these.

For many years there has been a misconception in the scientific literature concerning ruminants fed on tropical forages. It was believed that low productivity was the result of low energy density (i.e., low digestibility) of the feed. There is now abundant evidence that low productivity in ruminants on these forages results from inefficient utilization of the feed because of deficiencies of critical nutrients in the diet. In temperate regions nutritionists correctly believe that the basic nutritional needs of rumen organisms and the need for sufficient protein will be met in the basal diet. However, in feeding systems based on agricultural residues and mature tropical forage, this is not the case.

We have long been aware that tropical forages and crop residues are low in digestibility. Now there is ample evidence to suggest that with proper supplementation, ruminants fed these forages and crop wastes can be much more productive. **The animals need a source of fermentable nitrogen and minerals (especially sulfur and phosphorus) for rumen organisms; a source of protein that is not readily degraded in the rumen and thus moves rapidly to the lower tract to improve the animal's amino acid supply and the protein/energy ratio; and, if possible, some way to reduce the number of protozoa in the rumen since protozoa compete with bacteria for nutrients.**

According to Leng (*Evaluation*, 1995) correcting the rumen deficiencies will increase digestibility and increase the protein to energy ratio in nutrients from microbial digestion in the rumen. This in turn will decrease overall heat load from heat of fermentation and metabolic heat and allow an increased feed intake that will vary according to the environment of the animal and its ability to lose heat.

Cattle in the tropics may require less feed for maintenance, as they do not have to combat cold stress. If they have proper supplementation they can process the nutrients that would otherwise have been oxidized for maintenance of body temperature and can be more efficient than animals using the same feed in a cold climate. To be of advantage, the energy thus spared must be supplemented with protein to ensure a good protein to energy (P/E) ratio, because the amino acid requirements are higher for cattle in the tropics.

With information supplied in the previous article we have a better understanding of the need for appropriate supplementation. When nutrients are in good balance, digestion in the rumen produces protein (P), temporarily tied up in the cells of microbes that will soon themselves be broken down in the digestive tract, and energy (E) in the form of volatile fatty acids. These are the major components used by the animal to carry on the processes necessary for life. The amount of protein and energy is determined by how well the needs of the rumen organisms have been met. Even when the nitrogen and mineral needs of the rumen organisms have been met, the efficiency of digestion (P/E ratio) can still be improved by feeding some form of protein that is not degraded in the rumen (called "bypass protein") and by reducing the protozoa population in the rumen.

Meeting the Needs of Rumen Organisms

The needs of the rumen organisms (and the need for bypass protein) can be met in many different ways. They can be supplied by good quality pasture or a complete mixed feed, as is done in developed countries. When poor pasture or agricultural residues are all you have to feed your animals, strategic supplementation is needed. One way to supply fermentable nitrogen and minerals for the rumen organisms is with molasses and urea (non-protein nitrogen). This combination works well and the technology of making and using molasses/urea mineral blocks (MUMB) is well known. These are good because, where it is practical to use them, the animal can regulate its own mineral intake by licking the blocks as it senses the need to do so.

R. Sansoucy (1995) supplies some helpful information on this topic in an article titled "New developments in the manufacture and utilization of multinutrient blocks." The article suggests using a cold mixing process so you do not need sophisticated equipment. If cement is expensive and you have good local clay, this may be used as a binding agent. In areas near sugar factories, scums (filter muds) may be used to replace molasses. In places where molasses is expensive or unavailable alternatives have been studied. Adding phosphorus to the blocks may help improve herd reproduction if a bypass protein is also being fed. (Without the added protein, the added phosphorus may not have the desired effect. I observed this in Kenya where our animals cycled well with added phosphorus and yet farmers not giving bypass protein seemed to have cycling problems even when they added phosphorus). Formulas from several sources are presented in Table 1 to show different ways to achieve the same end. Also see the article "How to Make Your Own Salt Licks and Urea Blocks" in *EDN* 65-2.

Table 1: Several different recipes for supplementary mineral blocks.

Ingredients (percentage by weight)	**Block A**[1]	**Block B**[2]	**Block C**[3]	**Block D**[3]	**Block E**[3]
Molasses	35	50			
Urea	15	10	10	10	10
Salt	5	5	10	10	5
Bone Meal/Min. Mix	2				
Cement	13	10	15	5	10
Clay				15	
Bran/Cottonseed Meal		25	65	60	17.5
Fine Wheat/Rice Polishings	30				
Coconut Meal					17.5
Filter Mud (Sugar Factory)					40
Additional Water (% of total weight of above)			60	30-50	

[1] Kinsey 1993.
[2] Sansoucy et al. 1995
[3] Sansoucy, *New Developments*, 1995

Kinsey, in his *Integrated Smallholder Dairy Farming Manual* (published by Heifer Project International), suggests mixing the molasses and urea first, then adding the minerals, salt and cement and mixing uniformly. Finally, he says, add the bran, cottonseed meal or other ingredients and pour into wooden or plastic frames. The blocks should be allowed to dry for two to three days before they are used. The urea supplies the fermentable nitrogen, and the molasses supplies a good mix of concentrated minerals plus B vitamins and a small amount of fermentable energy. You will need to experiment with the mixture to get the best results, as ingredients vary. The blocks should be neither too hard nor too soft. Concentrated palm oil sludge also offers a useful source of minerals for rumen microbes. Both palm oil sludge and molasses are quite palatable (taste good) to cattle and are useful in supplements to hide less palatable nutrient sources like urea. Urea is toxic to monogastric animals. Even for ruminants it needs to be introduced slowly and intake must be controlled.

Table 1 gives suggestions for supplementation in places where MUMB are not practical. In addition, work in different parts of the world indicates that the needs of the rumen organisms can be met with legumes and fodder trees (Peters et al. 2001). Farmers know that legume forages, other edible tree leaves, and seed pods can be fed to animals, but sometimes they do not understand their vital role in balancing the nutrient needs of ruminants fed on agricultural residues or poor quality pasture.

In high rainfall areas of Colombia, the forage peanut (*Arachis pintoi*) has worked well in pastures with *Brachiaria* grass species. In South China, the use of the legume *Stylosanthes gianensis* (Australian selected cultivar Graham and CIAT 184) has spread rapidly among poor farmers who grow it as a rotation crop or as an intercrop in fruit orchards. In Central America and West Africa, velvet bean (*Mucuna pruriens*) is being used mainly to improve soil fertility but it is not fully exploited as forage for livestock. In semi-arid Northeastern Brazil, nitrogen-fixing trees like *Prosopis juliflora* have been used with adapted grasses to establish a system that is quite productive. The pods are collected and processed for cattle that graze on the grass under the trees. *P. juliflora* is an invasive species where rainfall is higher, so it should be used with care.

In Kenya, 6 kg of fresh *Calliandra* tree leaves replaces 2 kg of dairy meal in rations based on Bana grass (improved *Pennisetum purpureum*—Napier grass) in the highlands. In coastal areas the research center recommends 8 kg of legumes per day (*Clitoria, Siratro, Dolichos* and *Mucuna*) with 60 to 70 kg of Napier grass to get more than 10 liters of milk daily. In Thailand, cassava hay (*Manihot esculenta*) has been tested as a supplement to help productive ruminants get through the dry season. The leaves appear to have a tannin-protein complex that allows some of the protein to bypass the rumen. In Colombia, steam-treated bagasse has been used successfully with MUMB and *Gliricidia sepium* (1 or 1.5 percent of body weight—usually fed slightly wilted) to fatten cattle. In cases where the base feed is more nutritious than bagasse, *Gliricidia sepium* has given growth rates slightly above the response to MUMB. In Nicaragua, when moringa leaves constituted 40-50 percent of the feed, the milk yields and daily weight gains of cattle increased by 30 percent over the standard forage diet. (See *EDN* 68. Too much protein can be a problem, but this is seldom a danger with animals that are fed mainly crop residues because, as noted, ruminants in the tropics have higher protein requirements.)

More than thirty years ago, while working with the Ministry of Agriculture in Tonga as a Peace Corps Volunteer, I observed a very successful ruminant feeding trial funded with Australian aid. Grass pastures were interplanted with *Leucaena* (fodder trees) in rows 4 m apart. Santa Gertrudis (beef) crosses were rotationally grazed on these pastures. The growth rates were outstanding, as I recall. To check my memory I contacted Dr. R.A. Leng to ask him about the system. He says that Australia currently has about 200,000 ha of *Leucaena*/grass pastures for grazing in the southeastern part of Queensland. The farmers have gained a lot of experience with the system over the years, and growth rates of young cattle can approach 1 kg/day (Personal communication).

Psyllids (insects that can defoliate *Leucaena* trees) arrived in Tonga and killed the *Leucaena* and brought an end to the experiment there, but when psyllids reached Australia they began working with psyllid-resistant *Leucaena* and also introduced biological controls. Incidentally, Australian researchers were also the pioneers in transferring bacteria from ruminants in countries where *Leucaena* had long been a feed to ruminants in areas where *Leucaena* had been introduced. Before that, consumption of *Leucaena* leaves had to be limited because of the presence of an unusual amino acid called mimosine that is harmful to animals. The new bacteria were able to destroy the mimosine. Australia is a developed country, but much of the work with forages there has taken place in tropical and subtropical regions.

Bypass Protein

Supplementation with a protein source that is easily degraded in the rumen can lead to a lower yield of microbial cells and a higher production of volatile fatty acids, because degradable protein is converted less efficiently than fermentable carbohydrate. However, if the protein source is degraded in the rumen at a rate that allows some to remain in the digesta to be transported to the lower tract, then the ratio of P/E is improved. In "Requirements for Protein Meals for Ruminant Meat Production in Developing Countries," a paper presented at an FAO conference in Thailand in 2002, Leng says that the ratio of protein (amino acids) to energy in the nutrients absorbed may be altered by supplementing with a meal high in protein that has: 1) a structure relatively resistant to microbial attack, or 2) been protected from microbial action by chemical or physical treatments, or 3) when chewed, has come in contact with materials that protect it from microbial action. (This often occurs when secondary plant compounds such as tannins are in high concentrations.)

Good supplements include vegetable protein meals processed with formaldehyde or xylose; meals that have been through a process of heat treatment in solvent or pressure extraction (e.g. cottonseed meal, cottonseed cake and copra meal); meals that are associated with relatively low levels of secondary plant compounds that bind proteins (e.g. some leaf protein in tree foliages, some vegetable protein meals); and meals that have a high degree of sulfur amino acids with considerable cross linkage in the amino acid chains (e.g. gluten meal and dried distillers' waste from grains). When available, cottonseed meal is one of the best supplements, due to the fact that it seems to be protected by both heat treatment and secondary plant compounds.

When bypass meals are unavailable or too costly, it appears that some tree forages can supply at least part of the needed bypass protein. While the primary role of *Leucaena* leaf seems to be to provide nitrogen and minerals for the rumen organisms, the daily weight gains associated with its use seem to indicate that some of the protein is escaping the rumen undegraded. The best results from *Leucaena* and other fodder tree leaves seem to come when it makes up about 30 percent of the ration. Feeding below this level is still helpful but above 30 percent usually gives no added benefit.

Preston (2002) suggests that cassava stems and leaves (*Manihot esculenta*) (which may also contain some protected amino acids) are an excellent protein source for ruminants. He says that cassava can be managed as a perennial forage crop with repeated harvests of the forage at 50 to 70 day intervals, with the yield increasing over successive harvests as repeated cutting stimulates new growing points. He says that 3 to 4 tonnes of protein/ha/yr are possible if it is planted with N-fixing legumes such as *Flemingia macrophylla* or *Desmanthus virgatum* or if it is fertilized with heavy dressings of livestock manure or biodigester effluent.

[Ed: Perhaps supplementing with varieties of sorghum that are high in tannin (grown because the tannin confers resistance to birds) would combine with protein in the rumen and thus increase bypass protein.]

The Question of Protozoa in the Rumen

Leng (2002) has noted that one way of partially reducing the initial high requirement for bypass protein in cattle on forage diets is to increase the net flow of protein-rich bacterial cells to the lower tract by removing the protozoa that feed upon rumen bacteria. There appears to be consensus that protozoa in the rumen reduce total protein flow to the intestines and therefore lower the availability of protein in the feed. Recently Nguyen Thi Hong Hhan et al. (2001) in Vietnam showed that when young cattle fed on rice straw with grass were made to drink a single vegetable oil drench at the beginning of the fattening period (5 ml vegetable oil/kg live weight), the number of protozoa in the rumen were greatly reduced and growth rates were improved. The effect of this one-time treatment was the equivalent of feeding 0.5 kg of rice polishing (15 percent crude protein) throughout the growing period.

Summary

Ruminant animals are found on millions of small farms in developing countries. If they were more efficient they could make a substantial contribution toward meeting the growing demand for meat and dairy products. Small-scale farmers cannot have their forages analyzed to determine the feeding value. We know that mature tropical forage is deficient in protein and minerals and has low digestibility. We also know that non-protein nitrogen, legumes and some tree leaves can supply the needed fermentable nitrogen. Molasses/urea mineral blocks and other local sources of minerals can supply a “complete” mineral mix including sulfur and phosphorus. Protected protein sources like cottonseed cake, and, it seems, some high protein forages, can supply bypass protein. A simple vegetable oil drench can reduce the number of protozoa in the rumen, thus allowing more bacteria and protein to pass from the rumen to improve the P/E ratio. Imported or locally grown grains do not have to be used to make the millions of ruminant animals in developing countries more productive. Rather, strategic supplementation is needed. Solutions are available for the problems of poor forages and unproductive animals, but implementing the solutions requires knowledge, planning and work.

Strategic supplementation of ruminants may have begun about the time these animals were first domesticated, when a herder broke off branches his animals could not reach or drove them to better grazing. Then, as today, the soils, animals and climate (especially the rainfall patterns) were critical factors in ruminant husbandry. It is still the case that in some situations local breeds and indigenous plants will give the best performance even if the production is not so high. The important point to remember is that almost every situation can be improved. Local or adapted legumes can provide nitrogen and ground cover for the soil plus extra fodder for the animals. Tropical crops that are efficient biomass producers (sugarcane, palms, elephant grass, bananas) can be integrated into ruminant systems. Trees, nitrogen fixing and others, can provide shade, fodder and improved microclimates. With improved conditions local animals can be crossed with more productive animals. Results will vary from a local goat giving an extra cup of milk each day to an exotic cow in a hot part of India giving more than 6,000 kg of milk per lactation on a diet of straw, grass, molasses, urea and a by-pass protein. Milk production and growth are usually what we emphasize, but even more important may be the fact that we make maximum use of local resources and remove some of the stress from the animals and the farmers.

References

Delgado, C., M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois. 1999. Livestock to 2020: The Next Food Revolution. *Food, Agriculture, and the Environment Discussion Paper 28*. International Food Policy Research Institute. Washington DC. Download from: www.ifpri.org.

Kinsey, E. 1993. *Integrated Smallholder Dairy Farming Manual*. Heifer Project International. Little Rock, AR, USA.

Leng, R.A. 1995. Appropriate Technologies for Field Investigations in Ruminant Livestock Nutrition in Developing Countries. *Agricultural Sciences for Biodiversity and Sustainability in Developing Countries – Proceedings of a Workshop*. www.husdyr.kvl.dk/htm/php/tune95/6Leng.htm

Leng, R.A. 1995. Evaluation of tropical feed resources for ruminant livestock. *FAO Electronic Conference on Tropical Feed and Feeding Systems*. www.fao.org/livestock/agap/frg/econf95/html/evalu.htm

Leng, R.A. 2002. Requirements for Protein Meals for Ruminant Meat Production in Developing Countries. Presented at FAO conference in Thailand.

Nguyen Thi Hong Nhan, Van Hon Nguyen, N.T.Ngu, T.R. Preston and R.A. Leng. 2001. Practical application of defaunation of cattle on farms in Vietnam: Response of young cattle fed rice straw and grass to a single drench of ground nut oil. *Asian-Australian Journal of Animal Science* 14(4) 485.

Peters, M. *et al*. 2001. The Role of Forages in Reducing Poverty and Degradation of Natural Resources in Tropical Production Systems. *Agricultural Research and Extension Network (AgREN) Network Paper No. 117*. Overseas Development Institute. Download from: www.odi.org.uk/agren/publist.html

Preston, T.R. 2002. Towards local resources-based integrated crop livestock systems. *LEISA* 18(1).

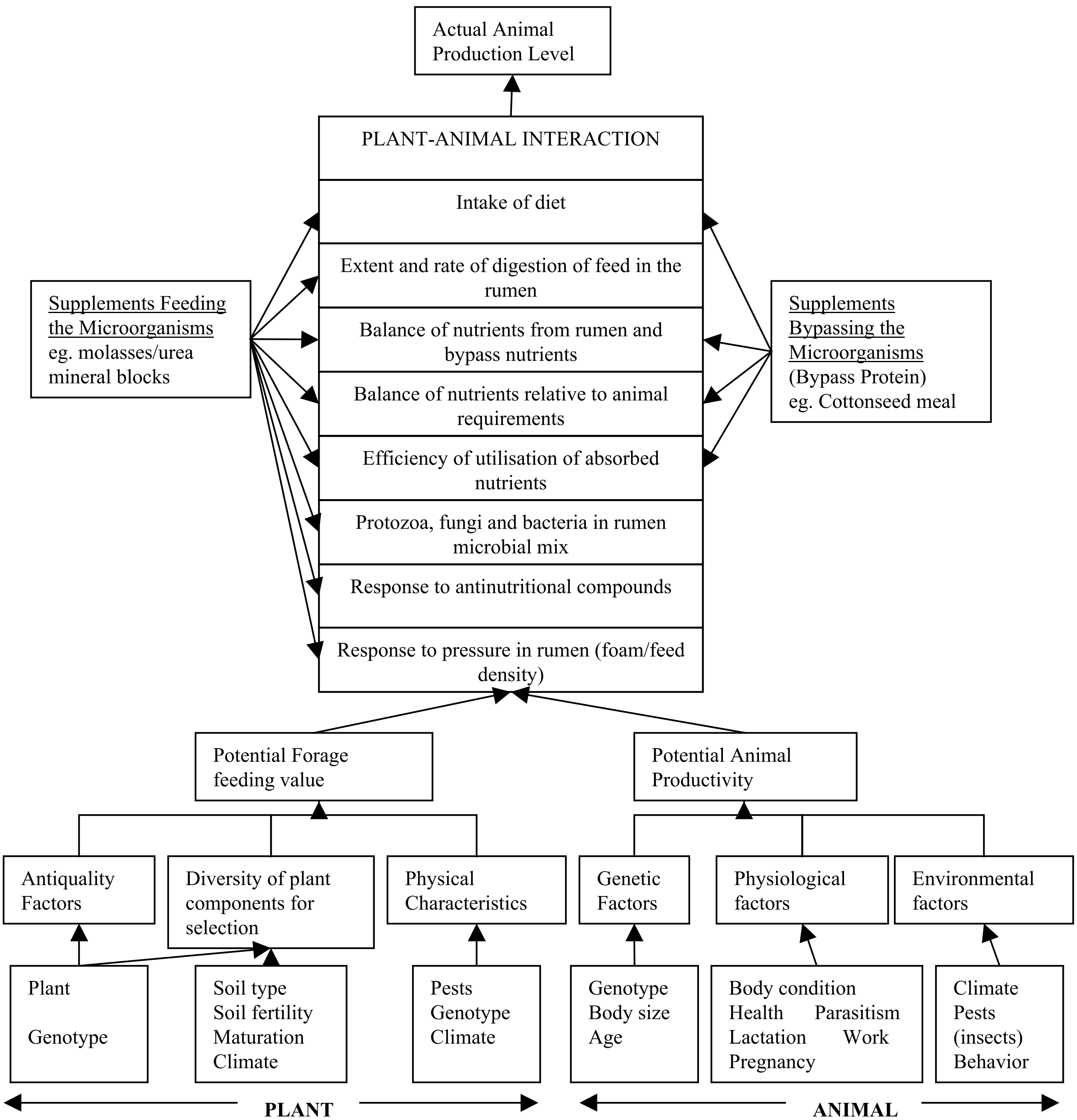
Preston, T.R. and R.A. Leng. 1987. *Matching Ruminant Production Systems with Available Resources in the Tropics and Subtropics*. Penambul Books, Armidale.

Sansoucy, R. 1995. Livestock—a driving force for food security & sustainable development. *World Animal Review* No. 84/85. Download from: www.fao.org/livestock/agap/war/war84.htm

Sansoucy, R. 1995. New Developments in the manufacture and utilization of multinutrient blocks—Short communications. *World Animal Review* 82(1) www.fao.org/livestock/agap/war/warall/V4440b/v4440b0s.htm

Sansoucy, R., D. Aarts, and R.A. Leng. 1995. Molasses/Urea Blocks. *FAO Electronic Conference on Tropical Feed and Feeding Systems.* www.fao.org/waicent/FaoInfo/Agricult/AGA/AGAP/FRG/ECONF95/HTML/MUB.HTM

Figure 3: Plant/animal factors that interact to determine the feeding value of a forage. Reprinted with permission from R.A. Leng (Appropriate Technologies, 1995).



2003-2004 Anderson International Scholarships

Overseas Ministries Study Center (OMSC)
New Haven, Connecticut

The Gerald and Joanne Anderson International Scholarships for 2003-2004 are designated for international Christian workers (citizens of nations other than the U.S.), especially those engaged in cross-cultural ministries.

Scholarships are granted on a competitive basis. Requirements include: 1) a minimum of four years' experience in Christian ministry; 2) endorsement by one's mission agency or church; 3) residence at OMSC for eight to ten months; 4) enrollment in OMSC's Certificate in Mission Studies program, requiring participation in at least 22 weekly seminars (on topics relating to cross-cultural missions); and 5) a commitment to return to one's place of ministry.

Furnished accommodations and a modest living stipend are provided. Families with children are welcome. Successful applicants are responsible for their own travel costs and medical insurance. The application deadline is January 1, 2003, but applications should be submitted as far in advance as possible. To obtain an application and further information, contact Jonathan J. Bonk, Executive Director; Overseas Ministries Study Center; 490 Prospect Street; New Haven, Connecticut 06511; Phone: (203) 624-6672; Fax: (203) 865-2857; e-mail: study@OMSC.org; web site: www.OMSC.org

Can You Help Us?

Do You Have Research Needs?

Some of the letters we receive from our network contain intriguing references to practices that we've never heard of before. Take, for example, this letter from Brazil:

> "A practice that is becoming more widely used in Brazil is the feeding of the aerial part of the cassava [tapioca] plant to cattle. It must be chopped and left for a day before feeding, to lower the toxicity. Not only does it contain around 12% crude protein, but it controls ticks, probably due to the small amount of prussic acid remaining even after drying for a day. Although this practice is encouraged by Brazilian researchers, I still wonder if it might not adversely affect the beneficial micro-organisms in the rumen of cattle as well as the ticks."

For years we have gathered research ideas like this one and published them in a technical note that we send to scientists looking for ideas. In an effort to get more of these ideas investigated, the Center for Christian Studies (based at Gordon College) and ECHO have recently entered into a partnership. Scientists have been invited to submit research proposals and we are actively seeking funding to cover the costs of research. If this effort succeeds, useful information arising from these projects will be published in future issues of *EDN*.

As this process moves forward, we will need new ideas. Do you have questions that you think could be answered with a research project? If so, please write to let us know about them. Give us the most detailed description of your problem as you can. As we gather more ideas they can be sent to scientists and serve as the bases for future research. Please address information to Dr. Edward Berkelaar, Director of Research at ECHO.

Correction

In *EDN* Issue 71, page 9 ("Echoes from our Network"), we wrote about farmers in Japan using Aigamo ducks in rice fields. We were originally told that 15 to 30 ducks are used per "10a," which we interpreted as 10 acres. However, we have been informed that in Japan, the single letter "a" stands for 1/100th of a hectare. Thus 10a really translates to 1/10th of a hectare (or 0.25 acres). We apologize for the confusion!

BOOKS, WEB SITES & OTHER RESOURCES

New ECHO Technical Note: *Acid Soils of the Tropics*

By Dr. Robert D. Harter
Published by ECHO, 2002
Reviewed by Edward Berkelaar

Over one-half of tropical soils are considered acidic (pH less than 5.5). In humid climates, soil acidification is a natural process. Soil acidity significantly affects plant growth, especially if the soil pH is below 4.5. ECHO has published a new Technical Note (TN), *Acid Soils of the Tropics*, covering various topics related to acidic soils.

For example, if your soils are acidic, what can be done to raise the pH? The common solution, where it is available, is to add crushed limestone ($CaCO_3$). Lime (CaO) or slaked lime ($Ca(OH)_2$) can also be used; these compounds are more expensive, but more effective. Crushed seashells or coral sands are also acceptable; oyster shells were added to soils in Roman times to improve crop yields. The practice of shifting cultivation, where the forest is cut and burned, results in higher soil pH because the ash from the burned vegetation contains calcium and magnesium, which decrease soil acidity.

The extensive use of wood ash from off-site is not recommended. Wood typically has a high ratio of potassium to calcium, and its addition in high amounts may throw these nutrients off balance. Bones are another good source of calcium; they can be boiled (to soften them), crushed, and added to soil.

Dr. Harter, author of this TN, is a professor emeritus (soil science) at the University of New Hampshire.

The complete TN can be downloaded from our website (http://www.echonet.org/tropicalag/technote.html) or you can write to us and request a copy.

FROM ECHO'S SEEDBANK

New Silage Maize with More Biomass and Higher Fiber Levels

By Grace C. Ju, Ph.D.
ECHO Seedbank Manager

A new maize (*Zea mays* L.) cultivar, Tex-Cuban silage maize, has been released by the Florida Agricultural Experiment Station. This open-pollinated (non-hybrid) silage corn has higher yields and contains more fiber than other silage varieties. The Cuban varieties used in the breeding program are well adapted to the tropics. Tex-Cuban out-yielded standard varieties at six of the seven test sites. It has a higher lignin content (which makes it somewhat less digestible) and lower starch content (i.e. higher protein) than commercial hybrids.

Tex-Cuban silage maize has potential for use as a cut-and-carry crop in the tropics. Penned animals can get a good source of carbohydrates, protein and fiber from this maize. It is a quality feed.

Those working in agricultural development in developing countries may request one sample packet of Tex-Cuban from ECHO free of charge. All others may purchase seed from ECHO. The overseas price is $3.50/packet (includes shipping), the domestic price (i.e. within North America) is $2.50/packet plus $1.00 shipping.

**Please Note: Our seedbank has bulk quantities of the following seeds for sale while supplies last: *Mucuna pruriens* ('tropical' Velvet bean); *Abelmoschus esculentus* ('African okra'); *Helianthus annuus* ('Peredovik' Sunflower); *Psophocarpus tetragonolobus* ('Chimbu' Winged bean); *Moringa oleifera; Moringa stenopetala.* Contact us for prices and to let us know the amount of seed that you wish to purchase.

UPCOMING EVENTS

IFDC International Training Program on Integrated Soil Fertility Management in the Tropics

Lomé, Togo
October 7-12, 2002

For information, contact the Director; Training and Workshop Coordination Department; IFDC; P.O. Box 2040; Muscle Shoals, Alabama 35662; (U.S.A.); Telephone: +1 (256) 381-6600; Telefax: +1 (256) 381-7408; E-mail: hrd@IFDC.org; Web Site: www.ifdc.org. Program Fee: US $1,050. Late Fee (after September 7, 2002): $1,200. Note that registration can be done online at www.ifdc.org.

ECHO's Ninth Annual Agricultural Missions Conference

ECHO, Fort Myers, FL, USA
November 12-14, 2002

Vision Conference: Community Health Evangelism (CHE), a Holistic Ministry

Following ECHO's Ninth Annual Agricultural Missions Conference
ECHO, Fort Myers, FL, USA
November 15-17, 2002

Medical Ambassadors International (MAI) has developed and tested a program called Community Health Evangelism (CHE) for people who want their organizations to establish a community-based development program that integrates evangelism and discipleship. The training program is based on MAI's experience with over 188 training teams in 55 countries of the world.

At the Vision Conference, organization leaders will be introduced to CHE concepts and given a vision and guidelines for implementing CHE. They can then decide whether or not to implement a CHE training program (three one-week seminars spread over one year) in a specific location.

The number of participants is limited to 30, so register early. The Vision conference will begin at 1:00 pm on Friday, November 15 (right after the ECHO conference), and will be completed by dinnertime on Sunday the 17th. It is an 18-hour program.

The cost of this Vision Conference is $75 (includes lunch during days of conference). Additional expenses include the cost of hotel rooms, breakfasts and dinners. Contact ECHO for registration information.

One participant from a previous Vision conference said about the program, "The training in understanding what goes into starting and establishing a program has been very useful. It has given me confidence to begin such a program."