The Livestock Revolution

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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 microbial protein (rumen) ammonia NH3 protein supply to ruminant 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 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.

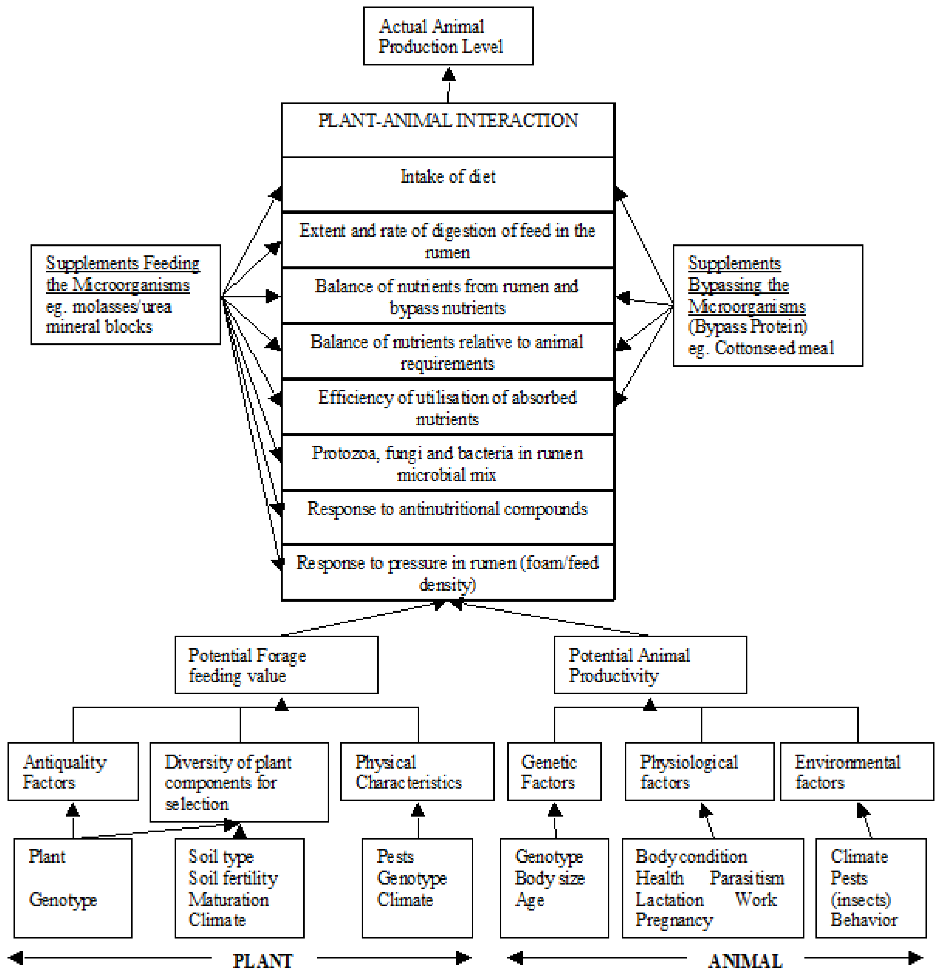
Urbanization, population growth and income growth have all been factors in the increasing demand for animal products. Such changes in diets of billions of people could significantly improve the lives of many rural poor if NGO's, governments and industry prepare for this continuing revolution with longrange 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). 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.”



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

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.

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

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.

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 tanninprotein 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 inTonga 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.

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