NEW ANIMAL FEEDING SYSTEMS BASED ON THE INTENSIVE USE OF TROPICAL BY-PRODUCTS

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Summary

The development of efficient feeding systems based on tropical agro-industrial products and crop wastes can play an important role in the improvement of animal production practices, resulting in an increase in high quality protein production for human nutrition. Research within the context of developing feeding systems is based on the establishment of bio-mathematical relationships between inputs and outputs. This procedure will also result in rapid accumulation of knowledge on the feed value of feedstuffs and in the reduction of time and cost in a research program.

As illustrated by research on the utilization of sugar cane by-products (molasses and bagasse) and crop residues (cane tops), input-input and input-output functions will serve to choose specific levels of each input to obtain bio-economic optimization and the synthesis of a feeding system. Sugar cane-derived feedstuffs are very low in protein, and their extensive use

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requires the addition of high levels of urea, which reduces the total weight output. However, net returns on feed lot operations can be as high as 25 percent. Moreover, the inclusion of starch, so as to provide 25 percent of the total ME, will cause a 30 percent improvement of weight gain.

Feeding systems based on the efficient use of cull bananas and sweet potato crop residues are also being developed producing net returns of 54 to 63 percent on the total investment, under present conditions in Costa Rica.

Key Words: Cattle Feeding Systems, Tropical By-products

Introduction

The humid tropics posess a wide spectrum of grasses, legumes and agro-industrial by-products and wastes. Also there exist a number of tropical crops of high efficiency in the conversion of solar energy to food energy. These resources could be used in the design of adequate feeding systems (Nestel, 1973). However, little has been done in the past to understand the special balance of factors which control animal production in the tropics. As cattle are mostly grass fed, their production tends to reflect the cyclical variation in both quality and quantity of grasses resulting in low animal protein production levels. According to FAO (1973), tropical countries produce only 1/3 of the total beef despite the fact that 2/3 of the total cattle population is contained in this area. Agricultural by-products can play a useful role in the improvement of production systems either through their use as pasture-supplements or as basal components of feeding systems.

The objective of this paper is to present a research procedure for the development of feeding systems with a simultaneous assessment of feed value, through the establishment of input-output biological relationships and economic appraisals. The procedure is illustrated with reseach conducted on the utilization of sugar cane by-products and residues, although some information on other tropical feeds is included in the latter part of the paper.

Sugar Cane By-products: Basic Biological Information

Sugar cane by-products comprise all materials arising during the industrial sugar manufacturing process: molasses (IFN Nº 4-04-696), bagasse (IFN Nº 2-09-909) and sugar mill scum (26% DM, 10% crude protein), while the residues include the sugar cane tops (IFN Nº 2-13-568) left in the field as a normal harvesting practice.

Feeding systems based on molasses on sugar cane roughages are necessarily different from other known feeding schemes, due to the liquid nature imposed by molasses and the very low crude protein content in these materials. A first step in the systematic development of technology for their utilization must then include the establishment of input-output mathematical relationships.

<u>The inputs: molasses, fiber and protein intake.</u> It has been found that the ruminant is capable of consuming up to 3.2 kg of molasses (78% DM, 79º Brix)/100 kg body weight/day, without detrimental effects to the animal (Ochoa, 1973). Molasses may constitute between 60 and 80 percent of the total dry matter intake (Ochoa, 1973; Elias <u>et al.</u>, 1969) and consumption depends largely on the level of crude protein in the diet and the level and type of roughage provided (Ochoa, 1973; M.E. Ruiz and F. Flores, unpublished data; Elias <u>et al.</u>, 1969). Other factors, including a positive effect of true protein concentration and a downward quadratic effect of Brix level (Preston, 1975), have also been found to influence molasses intake.

\- figure 1 -

In figure 1 it can be observed that as the level of protein increases above 350 g/100 kg body weight, the consumption of molasses increases rapidly. Similarly, molasses consumption increases with increments in the level of a relatively undigestible fiber (such as bagasse) above 600 g DM/100 kg body weight (figure 2). However, when the source of fiber is succulent and provides energy and protein (e.g., cane tops, green grass), then its effect on molasses intake is one of substitution at levels of fiber above 300 g DM/100 kg body weight (figure 2).

- figure 2 -

Observations by Ochoa (1973) and M.E. Ruiz and F. Flores (unpublished data) indicate, furthermore, that regardless of the source of fiber, bloat incidence occurs when the level of fiber/100 kg body weight is equal to or less than 232 g DM, in the case of bagasse, and 171 g DM, in the case of green roughage.

Obviously, if molasses is the basic component in a ration, any input possitively affecting its consumption will show a similar, although enhanced, effect on the total dry matter consumption.

Input-output (weight gain) relationships. There is abundant literature pointing to the fact that weight and energy intake increase as the energy concentration in the ration is increased, up to a certain point after which the animal tends to maintain its energy intake constant therefore reducing dry matter intake. For example, according to Panamanian work by M.H. Ruiloba and M.E. Ruiz (unpublished data), when molasses is used as supplement to rice straw (IRN Nº 1-03-925) an exponential response in weight gain is elicited, reaching a value equal to 95 percent of the asymptotic maximum when the level of molasses is about 1.5 kg DM/100 kg body weight/day. When the roughage is sugar cane tops a nearly maximum response in weight gain is obtained at a molasses level of 1.8 kg DM/100 kg body weight/day (Armendariz, 1976).

In contrast, with high levels of molasses (above 2 kg DM/100 kg body weight), variations in molasses intake caused by changing the fiber or protein consumption will not cause significant changes in weight gain. For instance, despite the large changes in molasses intake caused by changes in levels of fiber (as illustrated in figure 2), no definite trends were observed in daily weight gain as a function of the level of fiber. Also, Armendariz (1976) has found that weight gain depends on molasses intake up to a certain level, beyond which additional increases in molasses consumption will not significantly alter animal response. This is expressed by the function $Y = 1.24 - .67e^{-.37X}$ ($R^2 = .97$) where Y = daily weight gain in kg/animal, and X = daily molasses consumption in kg DM/animal.

It is well known that weight gain is highly sensitive to the amount of protein consumed. However, due to the unique characteristics of tropical by-products it is necessary to produce local mathematical relationships between protein input and animal production output. Figure 3 shows a typical response curve obtained in Costa Rica by M.L. Ruiz and F. Flores (unpublished data), where the supplementary protein source was sardine fish meal (IFN No. 5-02-015) and only an average of 105 g of crude protein/100 kg body weight/day were provided by molasses and green grass. The animals used in this experiment had an initial body weight of 300 kg and were of various breeds and crosses. It may be calculated from the regresion equation that when the total crude protein intake is 300 g/100 kg body weight, the expected animal gain is 772 g/day. This closely agrees with data from Panama (M. E. Ruiloba and M. E. Ruiz, unpublished data), which predicts a gain of 802 g/day on rations high in molasses and using sardine fish meal. In the latter case, the average basal crude protein consumption was approximately 150 g/100 kg body weight/day, due to higher crude protein content in the molasses and roughage as compared to the Costa Rican materials.

- figure 3 -

<u>Biological efficiency</u>. Having established and quantified the interrelationships between molasses intake, protein intake, level of roughage and animal production, a subsequent step may be the examination of how efficiently the inputs are utilized. Lacking sophisticated laboratory facilities, a practical procedure is to measure the actual total dry matter, calculated energy and total crude protein intakes and relate these with the output parameter. From the data of Ochoa (1973), the following information is produced (figure 4). First, increases in total protein intake beyond 263 g/100 kg body weight/day result in linear decreases in the efficiency with which the protein is utilized

for weight gains. Presumably, at some point below the 263 g of crude protein, the efficiency will reach an optimum value and then decrease with further reductions in protein intake. This is evident in figure 3, where a wider range of protein intake was investigated, as compared to Ochoa's work.

- figure 4 -

With regard to the energetic efficiency (figure 4), it is apparent that the minimum amount of metabolizable energy required per kg of gain is 20.4 Mcal. This value is maintained until the level of protein exceeds an approximate value of 400 g/100 kg body weight. From this point, conversion of energy to weight gain rapidly deteriorates. Total feed conversion to weight gain follows the same trend as depicted by the function Y_2 in figure 4, since there were small variations in energy concentration in all treatments used by Ochoa (1973).

Clearly, equations Y_1 (figure 4) and Σ (figure 3) indicate that protein intake should be restricted to about 280 g/100 kg body weight for growing-fattening young bulls. This would imply that some of the growth rate potential of these animals must be sacrified if maximum biological efficiency in the utilisation of protein and energy is to be obtained. However, from the economic point of view, the point at which optimum <u>net</u> return is obtained may not coincide with the optimum biological efficiency or with the maximum biological output.

Economic considerations. Especially in tropical regions, proteinaceous feeds are scarce and expensive. In previous sections it was noted that high-quality, but very expensive, fish meal was used to produce protein response curves. Other sources of protein such as meat and bone meal (IRN No. 5-00-387) and cottonseed meal (IRN No. 5-01-623) have also been used in some of the experiments reviewed. The objective was to obtain maximum growth rates at each protein level. From the practical standpoint, true protein supplements should not be used to a large extent since the ruminant is able to utilize inexpensive urea or other non-protein nitrogenous sources to partially satisfy its protein requirements. The feed lot performance of young bulls with increasing levels of urea (as a substitute for meat and bone meal) has been reported by Villegas and Ruiz (1976) using rations high in molasses and holding the total crude protein intake constant at 360 g/100 kg body weight/day. The result is shown in figure 5, which clearly indicates a linear decrease in weight gain as the proportion of urea increases. However, molasses intake remained constant, despite a reduction in the energy intake resulting from decreases in the level of meat and bone meal. The overall effect on energetic efficiancy was a constancy in the amount of ME (21.3 Mcal) required per kg of weight gain. Since crude protein was constant, the protein efficiency decreased linearly as the urea substitution level increased. The most important result was a linear increase in the profitability of the fattening operation as the level of urea increased. At the time the experiment was conducted (1973), the use of urea at the 60 percent substitution level implied a 5-fold increase in net income compared to the 0 percent urea level.

- figure 5 -

These results have been confirmed by work by Clavo (1974), who used substitution levels up to 72 percent.

Recent results (Herrera and Ruiz, 1976) have shown that further improvements in biological and economic efficiencies may be obtained by introducing into the high-urea, high-molasses feeding system a starch-rich ingredient to provide 25 percent of the total metabolisable energy (figure 6). In this study, total crude protein and energy intake were maintained constant at 350 g and 6 Mcal ME/100 kg body weight/day, respectively. Urea was used to substitute 60 percent of the supplementary protein. Green bananas (IRN No. 4-11-004) were used as the source of starch. Briefly, the reasons for the beneficial effect of starch on weight gain may be a more efficient utilisation of urea for microbial protein synthesis, a protein-sparing effect of starch as a source of glucose for the ruminant itself and a more efficient use of energy derived from starch. The discussion of these aspects is, however, beyond the scope of this paper.

The response to starch, as illustrated in figure 6, necessarily has a positive influence on the economy of a feeding system, as long as the cost of the starch-ME does not exceed 130 percent of the cost of sugar-ME.

– figure 6 –

Synthesis of a feeding system. The final consideration in developing a feeding system from the technological point of view, is the economic analysis. This analysis will provide the value of the variable(s) at which the optimum net return is obtained. Upper and lower limits may be assigned from the economic analysis curves. Having detected the value of the input(s) that will result in the highest economic benefit, then this value is used in every mathematical function that will provide additional information, not only on the amounts of other nutrients needed and the efficiency with which they are utilized, but also on the expected growth rate. A simplified example is illustrated in figure 7, resulting from the work of Armendariz (1976) where the objective was to replace the amount of molasses by a cheaper energy source: sugar cane tops. The definitions and mathematical relationships implied in figure 7 are shown in table 1.

– table 1 –

From the net income function $Y_1 = K_1Y_1 - K_0 - (K_2Y_2 + K_3Y_3 + K_4Y_4 + K_5Y_5)$, the first derivative shows that the optimum level of molasses is given by the equation

$$X = \frac{K_1(.75) - K_2(3.62) + K_3(5.32)}{2\,[K_1(.26) + K_3(2.48)]}$$

Under present Costa Rican economic indices the optimum X-value is 1.016 kg DM/100 kg live weight/day. Substituting this value in the Y- functions (table 1) the final result is obtained as shown in table 2.

- table 2 -

Research Outlook on the Utilization of Other Crop Residues and Wastes

Procedures similar to those previously described are being followed in other research conducted at CATIE concerning the use of commercial cull bananas (IRN Nº 4-11-004), aerial part of sweet potatoes (IRN Nº 2-11-554), non commercial sweet potato roots (IRN Nº 4-11-555), chicken litter as a nitrogen source (IRN Nº 5-13-518), coffee pulp (IRN Nº 2-11-471), cacao pod shells (IRN Nº 1-01-053) and other potential feeds including crops grown for the direct feeding of cattle.

Feeding green bananas to cattle has to be carried out under controlled conditions since cattle demonstrate a strong appetite for this material. Banana intakes up to 4.6 k DM/100 kg body weight/day have been reported (Isidor and Ruiz, 1976). A summary of results obtained by these investigators is presented in figure 8.

- figure 8 -

It may be noted that function Y_1 in figure 8 contains in parenthesis the biological relationship between weight gain in kg/animal/day, and protein intake in kg/100 kg body weight. Since cull green bananas are thrown away, at the present time the only cost involved in their use is due to their transportation and distribution. Therefore, the principal variable cost in this experiment was caused by the protein supplement. It may also be noted that the maximum net income represents a net return of 63 percent on the total investment.

The sweet potato is another widely cultivated crop in Tropical America. One ha of sweet potatoes can normally yield 13 MT of foliage and 15 MT of roots/crop. Two crops per year can be obtained. The foliage is normally left in the field while about 12 percent of the root harvested cannot be marketed due to small size, unripeness or damages in the root. Backer (1976) has found that when young cattle (184 kg initial weight and one-year of age) are fed aerial sweet potato parts, the consumption of foliage was 2.45 kg DM/100 kg body weight which provided 300 g crude protein and 5.05 ME Mcal/100 kg body weight/day, the weight gain was 656 g/animal/day. As the foliage was supplemented with the roots plus urea (to maintainequal protein intake) the weight gain increased to a maximum of 825 g/animal/day. The implications are that if a small farmer obtains one crop of sweet potatoes in one ha, he can utilize 13 MT of foliage (16.8% DM) and 1.8 MT of non-marketable roots (30.1% DM). To this basal ration he can add one percent urea (on dry basis) and vitamins and minerals, to provide enough feedstuff for 5.5 animals, during 100 days, which could gain 710 g/head/day. The economics of this design would be a net return of 48 percent considering all fixed and variable costs, including the purchasing of the animals.

Concluding remarks

In the light of the information presented, it appears that highly productive cattle feeding systems can be developed in the humid tropics based on local resources, through research leading to the formulation of biologically and economically efficient feeding systems. Although other factors must be taken into account before recommending a system, the highest priority must be given to the socio-economic impact on the rural people of Tropical America. The development of feeding systems, from the technological point of view, is only one factor. Proper credit, education, marketing and consideration of the total farm-production system will finally dictate how much the producer can benefit from this type of information.

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TABLE 1 Functions and definitions referring to figure 7

Dependent variables	Independent variable X = Molasses intake, kg DM/ 100 kg body weight/day
Y_1 = Weight gain, kg/head/day	$Y_1 = .58 + .75X - .26X^2$
Y_2 = Molasses intake, kg DM/head/day	$Y_2 = -.034 + 3.62X$
Y_3 = Cane tops intake, kg DM/head/day	$Y_3 = 7.95 - 5.82X + 2.48X^2$
Y_4 = Meat and bone meal intake, kg DM/head/day	$Y_4 = .647$
Y_5 = Urea intake, kg/head/day	$Y_5 = .215$
K_0 = Fixed costs $/head/day	$K_0 = .06$
K_1 = Price of beef on the hoof, $/kg/day	$K_1 = .61$
K_2 = Cost of molasses, $/kg DM	$K_2 = .044$
K_3 = Cost of cane tops, $/kg DM	$K_3 = .025$
K_4 = Cost of meat and bone meal, $/kg DM	$K_4 = .22$
K_5 = Cost of urea, $/kg	$K_5 = .22$

TABLE 2 Optimum feeding system for fattening steers[a/] using sugar cane tops molasses and high levels of urea

Ingredients	Amount (100% DM),kg/animal/day
Molasses	3.280
Cane tops	4.830
Meat and bone meal	.647
Urea	.215
Common salt	.029
Vitamins and minerals	According to NRC recommendations

Expected weight gain: 1.041 kg/animal/day

Expected feed conversion: 8.65 kg DM/kg weight gain

Expected net return: 25.5% (based on economic indices presented in table 1)

a/ Initial weight: 300 kg. Final weight: 420 kg. Approximate age: 2 years.