ASSOCIATED EFFECTS AND INTERACTIONS AMONG FEED INGREDIENTS

by

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INTRODUCTION

Computer-assisted linear programming, and the majority of other methods, used to derive least cost diets for livestock depend on the assumption that nutrients from different feeds are used additively on the basis of their assigned nutritive value. This appears to be true for monogastric animals, partly because of their simple system of gastric digestion and partly because of the narrow range of feeds used in their diets.. It is also partly true for ruminants given concentrate feeds and temperate forages or legumes, supplemented with oilcakes and animal byproducts meals.

Additivity does not hold when starch-rich feeds are mixed with fibrous forages of relatively low potential degradability, and which we now know are imbalanced in nutrient availability. It also does not apply to sugar-rich feeds (which are imbalanced in nutrients) in combination with starchy or fibrous feeds.

Two major interactions take place in the rumen; when starch or sugar is a major component of the diet the digestibility of fibrous feeds is adversely affected and on sugar or fibre based diets the rumen ecosystem is characterized by a low propionate fermentation which places additional constraints on the utilization of energy. Interactions also occur between proteins and starches or other fermentable carbohydrates.

Interactions among feeds are of economic importance. They can rarely be identified by conventional analyses of feeds. This emphasizes the need to make greater use of animal-based feed evaluation systems (e.g. the nylon bag technique; wool growth assay for bypass protein and other animal response assays), when developing livestock feeding systems based on the feed resources available in developing countries.

Non-additivity may have negative consequences; as for example when the efficiency of utilization of a mixture of feeds is less than the sum of the individual components or/and feed intake is reduced. Or the effects may be positive as is the case when a supplement is used "catalytically" (i.e. meets the needs or balances the limiting nutrients) to increase the intake and efficiency of utilization of the basal diet.

The explanation of non-additivity may lie at the level of the rumen fermentation, through effects of a particular feed on the rumen ecosystem; or there may be interactions due to imbalances in the absorbed nutrients arising from digestion, in relation to the physiological needs of the animal.

INTERACTIONS IN THE RUMEN

Negative interactions

A well known example of decreased efficiency of feed utilization brought about at the level of the rumen is the depression in rate of fibre degradation caused by too high levels of "soluble" carbohydrates in the form of sugars or starch, Terry et al.,(1969), Mould *et al.*,(1983a) have identified two effects arising from adding starch-rich feeds to roughages. When the rumen pH fell below 6.0 the rate of cellulose digestion decreased (the "pH effect"). When the drop in pH was prevented, through adding a buffer (e.g. sodium bicarbonate), or by feeding roughages in the long form (to stimulate salivation) (Mould *et al.*, 1983b), the depression was less marked but nevertheless was still evident.

Similar depressions in digestibility of fibre are caused by sugar-rich feeds such as molasses. Herrera *et al.*, (1981) reported that when molasses accounted for more than 30% of a mixture of molasses and sisal pulp, the rate of disappearance of pulp from nylon bags in the rumen of cattle was markedly reduced. Similar results, using this technique, were reported by Encarnacion and Hughes-Jones (1981) for a wide range of feeds when these were incubated in the rumens of cattle fed diets with and without supplementary molasses.

This depressing effect of soluble sugars has been reported also in diets based on sugar cane (Figure 1). Rate of dry matter loss from hay in nylon bags was much slower when the bags were suspended in the rumens of cattle fed sugar cane as compared with the same animals fed pangola grass.

Positive interactions

The data in Figure 2 show the beneficial results from adding small amounts of green grass (African Star grass) to a basal diet of sisal pulp, urea and minerals fed to sheep. The degradation of pure cellulose (cotton wool) was increased from 40% to 80% during an incubation period of 48 hours, as a result of incorporating 25% grass in the diet. The increases in digestibility of the cellulose were reflected in parallel improvements in feed intake. In an attempt to elucidate the factors present in the grass, which might have been responsible for the stimulation in rumen activity, small amounts of soluble protein (casein), B-vitamins, minerals or washed fibre, were added to the basal sisal pulp diet. Each supplement induced slight improvements in cotton wool digestibility; but the effect was much less than when the grass was given (E. Gutierrez and Preston, T.R., unpublished data). Unfortunately, the effect of a supplement incorporating all the individual nutrients was not investigated.

Juul-Nielsen (1981) added small amounts of a readily fermentable sugar beet pulp to an in vitro incubation using rumen fluid inocula. Inclusion of the pulp led to significant increases in the rate of digestion of barley straw. This positive interaction was subsequently confirmed by Silva and Orskov (1985) who used the rumen nylon bag technique to study additions of 15% sugar beet pulp to a barley straw diet fed to sheep.

Increasing the rate of cell wall digestion is of major importance as a means of improving animal productivity on roughage-based diets. However, when molasses contributes more than 60% of the diet, fibre digestibility is less important as this contributes an insignificant fraction of the digestible energy. In this case the major constraint appears to be the low glucogenic characteristics of the rumen fermentation, due to low concentrations of propionic acid in the total VFA (Marty and Preston 1970).

Supplementation of a high molasses diet with poultry litter increased rumen propionate in the total VFA (Fernandez and Hughes-Jones 1981; Marrufo 1984) with associated beneficial effects on liveweight gain and feed conversion rate in the fattening cattle (Meyreles and Preston 1982; Herrera 1984). The interaction between the poultry litter and the molasses was greater when the forage source was low in nitrogen and had a low potential degradability of the dry matter (cane tops) as compared with a forage relatively rich in protein and highly digestible (leucaena) (Meyreles et al., 1982). Marrufo (1984) also noted that poultry litter increased rumen propionate more when elephant grass (similar chemical characteristics to cane tops) was the roughage source in a molasses-based diet than when leucaena was fed.

Interactions due to the balance among absorbed nutrients

The most widely known example of an increase in nutritive value of feed caused by changes in the balance of end products fermentative digestion is the case when an ionophore such as monensin is included in the diet (see Chalupa 1980) This inhibits methanogenesis and increases production of propionic acid in the total VFA. The feed is used more efficiently for tissue synthesis when propionate availability is high. This is in addition to the specific effect of propionate in diets requiring fermentative digestion (see below).

Marked interactions have been reported between a basal diet of sugar cane and the type of supplementary carbohydrate (see Table 1). Cattle fed sugar cane pith (derinded cane stalk), supplemented with urea and protein, grew faster and utilized their feed more efficiently when a supplement of maize grain was given (1% of bodyweight). In contrast, animals given the same amount of supplementary energy in the form of molasses had poorer feed efficiency. Thus depending on the composition of the supplementary carbohydrate, the interaction can be positive (as with starch in molasses or forage based diet) or negative (as with sugars in molasses).

The explanation for these differences appears to be the increase in the proportion of glucogenic precursors in the absorbed end products of digestion when maize grain is fed (maize starch is relatively resistant to microbial attack and can escape partially to the intestine where it is hydrolysed directly to glucose) and the decrease in glucogenic status when molasses is fed (there is no escape of carbohydrate to the intestines; and the rumen fermentation is less glucogenic due to decrease in propionate production relative to total VFA) (see earlier comments).

The data in Figure 3 illustrate the same interaction. In this case the variation in glucogenic status of the diet was achieved by infusing acetic acid into the rumen of cattle given hay (low glucogenic capacity) or mixed hay and concentrate (high glucogenic capacity). The proportion of the energy of the infused acetic acid stored in tissue was greater in cattle fed the diet with the higher glucogenic capacity. There are many other examples demonstrating this same point (e.g. see Preston and Leng 1986).

The nutritional value of diets with less than the optimum balance of protein to energy (e.g. most of the dietary nitrogen in the form of urea) can be improved by eliminating protozoa from the rumen (Tables 2 and 3) on low protein, starch or sugar-rich diets. This is because the (microbial) protein synthesis rate is high and propionate levels are also high. On fibrous diets the benefits appear to be due to increased colonization of fibre by fungi and bacteria permitting a more rapid digestion of the cell wall. (Table 3) as well as to a narrower protein:energy ratio in the products of digestion (protozoa are preferentially retained in the rumen which reduces the amount of microbial protein passing to the duodenum; Leng, 1984).

Improvements in nutritive value of low-protein, high-urea molasses-based diets fed to defaunated cattle appear to be due mainly to the protein sparing effect (Ffoulkes et al., 1984).

Conclusions

Interactions and associated effects among feeds are ofen viewed negatively because predictability of animal performance from ration composition tables is less accurate.

The more important issue, from the point of view of developing countries, is that the manipulation of interactions - correcting the negative ones and exploiting the positive ones - offers a means of increasing the efficiency of utilization of the "imbalanced" dry season pastures, crop residues and agroindustrial byproducts wich are the major feed resources in those countries.

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Figure 1: The rumen digestion (from dacron bags) of hay by cattle given chopped sugar cane or pangolas hay (Orskov, E.R. and Hovell, B. 1978)

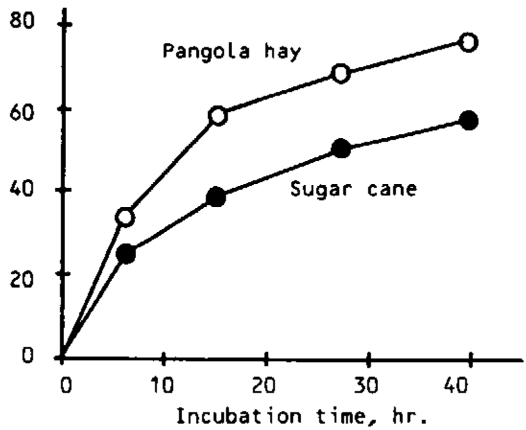

Figure 2: Supplementing a diet of sisal pulp (included urea and minerals) for sheep with freshly harvested African Star grass improved the rumen ecosystem as evidenced by the 50% increase in the rate of cellulose digestion (in nylon bags in the rumen). This in turn led to an 80% increase in feed intake (Guttierrez and Elliott, 1984)

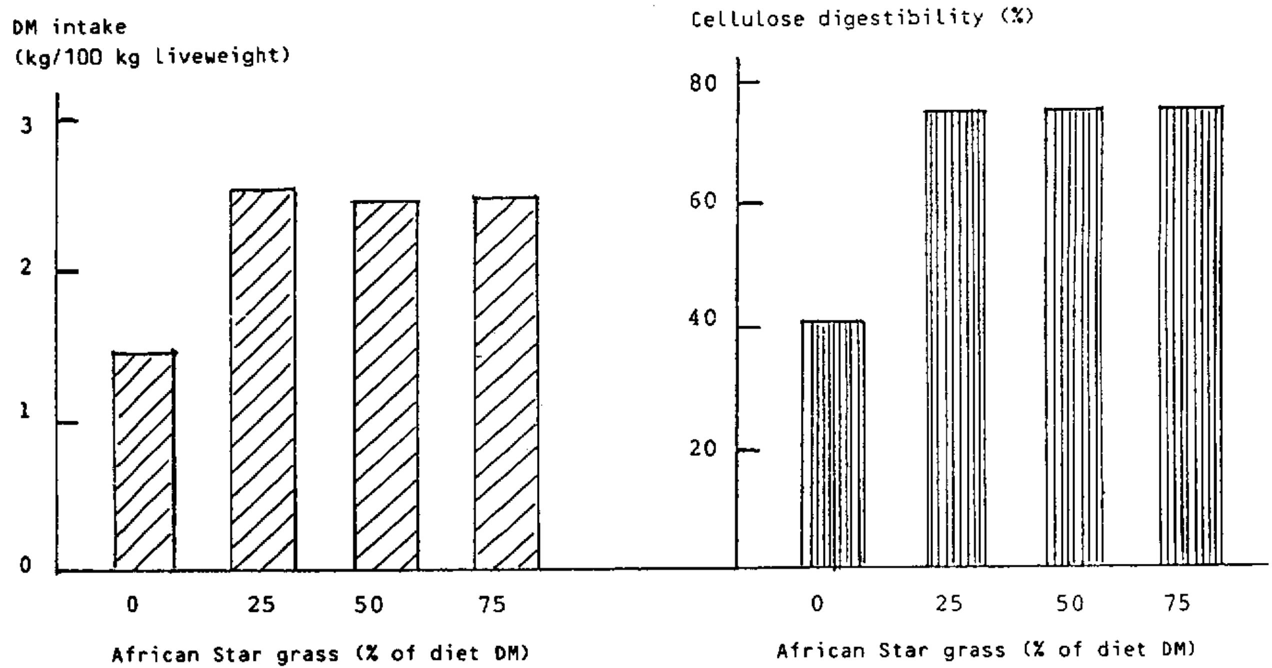

Figure 3: Effect of the basal diet on the efficiency of utilization of acetic acid infused into the rumen of cattle. The highest retention of energy was on the diet rich in glucose precursors (adapted from Tyrell et al., 1979).

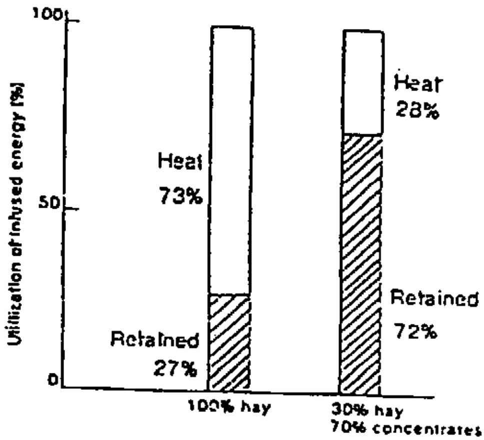

Table 1: Effect on performance of fattening steers of adding (1% of liveweight) maize grain or molasses to a basal diet of sugar cane pith (derinded cane stalk) supplemented with urea and rape seed meal (from Pigden 1972)

	Control	Improvement over control (%)	
		Molasses	Maize grain
Liveweight gain (kg|d)			
Trial 1	0.99	9	27
Trial 2	0.95	13	21
Trial 3	1.02	3	32
Conversion rate (kg DM|kg gain)			
Trial 1	9.1	-16	8
Trial 2	10.1	0	11
Trial 3	9.9	-15	15

<u>Table 2</u>: In three out of four experiments, defaunated sheep (-P) grew faster than defaunated (+P) sheep. The response was highest on the molasses-based diet (after Demeyer et al., 1982)

Diet	Study period (days)	Liveweight change (g/d)		Benefit from defaunation (%)
		+P	-P	
Sugar beet pulp/urea/minerals	91	181	213	17
Alkali treated straw/molasses	56	102	140	37
Alkali treated straw/molasses/ tapioca	35	239	192	-17
Molasses/protein	49	135	208	54

Table 3: Effects of defaunation on dry matter loss from nylon bags in the rumen of sheep[1]

Host diet	Wheat straw[1]	Ammoniated wheat straw[2]		Wheat straw[1]	
Material in bag	Wheat straw	Wheat straw	Cotton wool	Wheat straw	Cotton wool
		(DM loss %)			
6 hr:					
+ protozoa	21				
- protozoa	24				
24 hr:					
+ protozoa	38				
- protozoa	42				
4 hr:					
+ protozoa		15	4	5	12
- protozoa		20	6	6	12
48 hr:					
+ protozoa		50	63	32	74
- protozoa		55	72	37	88

[1] Soltanto (1985)

[2] Leng (1984)