THE ROLE OF FEED SUPPLEMENTS IN IMPROVING INTAKE AND UTILISATION OF LOW QUALITY ROUGHAGE IN RUMINANTS

A thesis submitted for the degree of Doctor of Philosophy of the University of New England

By

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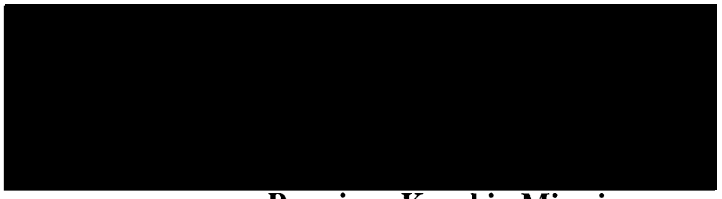
DECLARATION

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree.

I certify that to the best of my knowledge any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.



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LIST OF ABBREVIATIONS

AFRC	Agricultural and Food Research Council
ATP	Adenosine triphosphate
BWT or BW	Body weight
CP	Crude protein
CSM	Cottonseed meal
d	day
DAPA	2, 6-Diaminopimelic acid
DE & DEI	digestible energy & digestible energy intake
DM & DMD	dry matter & dry matter digestibility
DMI	Dry matter intake
GER	Glucose entry rate
h	hour
IVOMD	*in vitro* organic matter digestibility
LCFA	long chain fatty acids
MCP or MP	Microbial (crude) protein
ME	Metabolisable energy
ml & µl	milliliter (10^{-3}L) and microlitre (10^{-6}L)
mmol/L	millimol/litre
MN	Microbial nitrogen
N	nitrogen
NADPH	Nicotinamide adenine dinucleotide phosphate
NPN	Non-protein nitrogen
NRC	National Research Council
OM & OMD	Organic matter & organic matter digestibility
OMADR or OMTDR	organic matter apparently (or truly) digested in the rumen
P: E or P/E	Protein to energy ratio
PD	Purine derivatives
RFC	readily fermentable carbohydrates
SE or SEM	standard error or standard error of means
UDP	undegradable dietary protein
VFA	Volatile fatty acids

SUMMARY

The studies in this thesis were undertaken to investigate ways to improve the value of roughages and byproducts as feeds for ruminants through supplementation. Low quality basal roughages are high in fibre, low in N and other minerals; as a result their comminution rate in the rumen (and clearance rate) is generally low, leading to low intake. Moreover, their digestion in the gut often results in absorption of digestion products that are imbalanced in protein to energy (P/E), and also in glucogenic to acetogenic substrates. The imbalance in nutrients leads to inefficiency in the utilisation of the absorbed nutrients, often manifesting as high heat increment and generally low voluntary intake (MacRae and Lobley 1982; MacRae *et al.* 1987). This problem is further compounded by the high ambient temperature in the tropics where most of the ruminant livestock subsisting on crop residues are raised, which makes dissipation of heat very difficult (Preston and Leng 1987; Leng 1990). Animals in the tropical environments therefore respond to low digestibility feeds by reducing feed intake which leads to lower animal productivity (Preston and Leng 1987). This study investigated how strategic supplementation with rumen degradable nutrients and by-pass nutrients in animals fed low quality roughage basal diets may be used to stimulate an efficient rumen fermentation (and intestinal digestion). It was hypothesized that this is likely to result in the absorption of balanced nutrients (P/E and glucogenic/acetogenic ratio) from the gut, and therefore enhance efficiency in nutrient metabolism in the body tissues, resulting in improved animal productivity (Leng 1990).

The broad objective of the present study was to investigate the role of dietary N, protein and energy supplementation and ammoniation with urea in stimulating higher rumen fermentation, with a view of providing the small intestines with a better balance of protein and energy substrates (P: E), as well as of glucogenic to acetogenic substrates for digestion and absorption. It was hypothesized that when the body tissues are provided with balanced nutrients, this would lead to more efficient utilisation of those nutrients, lower heat production, and therefore higher animal productivity.

In **Exp 1** thirty (30) Border Leicester x Merino cross wether lambs weighing 25±2.5 kg (SD) and blocked on a live weight basis were allocated to 5 dietary treatments, each treatment with six (6) animals. The lambs were offered *ad lib* a basal roughage diet consisting of oaten chaff hay (11.8 gN/kgDM or 7.4% CP) unsupplemented (**T1**) (control), or supplemented with urea as a source

rumen degradable nitrogen (**T2**), protein (CSM) (**T3**), urea + ME (wheat bran & molasses) (**T4**), or protein and ME (**T5**). Therefore, with the exception of the control (**T1**), the other four dietary treatments received iso-N supplements supplying each animal with about 7 gN/d. The trial was conducted over a period of 4 weeks, consisting of a 7-d backgrounding period for all the animals during which they were given the basal roughage, followed by a 14-d adaptation period, and finally a 5 d measurement period for the determination of voluntary intake. Supplementation with urea or protein, with or without energy, improved N intake from 9.2 g/d in the unsupplemented basal diet (**T1**) to 16-18 g/d in the supplemented dietary treatments (**T2-T5**). The basal DM intake was not increased ($P>0.05$) by urea or protein supplementation, with or without energy, while the total dietary intake was increased ($P<0.05$) by protein or protein and energy. Although total intakes increased in response to or protein and energy supplements, the basal DM intake was depressed to levels lower than that of sheep on the control diet but this was not statistically significant ($P>0.05$). Supplementation with protein or protein and energy resulted in a higher total DM intake but the intake of the basal roughage did not change significantly. In addition, it was concluded that N did not limit voluntary intake, and that other factors associated with the roughage, such as high concentration of cell wall constituents (CWC) may have constrained its intake in these animals.

In Exp 2, sucrose was administered as a means of enhancing rumen microbial fermentation or generating a more suitable balance of digestion products or both. The aim was to increase the metabolism of acetate in the body tissues, and improve voluntary intake. A urea-treated mixture of wheaten chaff and barley straw (3:1 DM) and containing 22.2 gN/kgDM (13.9% CP) was used as the basal diet in this study. Four Border Leicester x Merino cross wethers weighing 45±4.38 kg (SD) and fitted with permanent rumen fistulas and abomasal cannulae were allocated to four dietary treatments in a 4 x 4 Latin square design. A scheduled set of determinations was made in each of the 4 periods lasting about 4 weeks. The four dietary treatments included: the unsupplemented basal diet as the control ($\mathbf{E_0}$), the basal diet supplemented with sucrose (112.5 g/d) administered entirely intraruminally ($\mathbf{E_R}$), abomasally ($\mathbf{E_A}$), or via both routes (50:50) ($\mathbf{E_{RA}}$). The basal roughage diet was fed at 09.00 h and made available *ad lib*, while the sucrose supplement was given in two equal doses at 09.00 and 16.00 h. Feed intake, rumen fermentation and fluid kinetic parameters, and body tissue clearance of intravenously loaded acetate were monitored and determined.

Feed intake (dietary and basal) was higher in animals on the control diet ($P<0.05$) when sucrose was administered entirely through the rumen ($\mathbf{E_R}$) or abomasum ($\mathbf{E_A}$). However, there was no difference ($P>0.05$) in intake between animals on the control dietand those supplemented with sucrose via both the intraruminal and abomasal routes ($\mathbf{E_{RA}}$). The apparent digestibility of DM or OM was higher in intraruminally ($\mathbf{E_R}$) or abomasally ($\mathbf{E_A}$) supplemented animals than in the control ($\mathbf{E_0}$) or those supplemented through intraruminally and intra-abomasally ($\mathbf{E_{RA}}$). Even though the rumen pH was reduced significantly ($P<0.001$) in those animals that were supplemented with sucrose entirely intraruminally ($\mathbf{E_R}$), the *in sacco* degradation of barley straw in the rumen was not adversely affected, as evidenced by the lack of significant difference ($P>0.05$) between the four dietary treatments in major degradation characteristics. Intraruminal administration of sucrose boosted the supply fermentable substrates in the rumen and produced a higher total concentration of VFA in the rumen. The total VFA concentration in sheep receiving the sucrose supplement abomasally ($\mathbf{E_A}$) was, however, low indicating that factors than total fermentable substrates in the rumen may also have influenced VFA concentration. The pattern of fermentation in the rumen was also changed by intraruminal supplementation of sucrose i.e. there was a higher propionate: acetate ratio (0.46 & 0.43), compared to the control ($\mathbf{E_0}$) or abomasally ($\mathbf{E_A}$) supplemented animals (0.30 & 0.28). This subsequently increased the glucogenic potential of the absorbed VFA in animals on dietary treatments $\mathbf{E_R}$ and $\mathbf{E_{RA}}$ than those on control diet or abomasally supplemented.

It was hypothesized that intestinal digestion of sucrose would enhance the availability of glucogenic substrates for the body tissues even further, because intestinal digestion of carbohydrates delivers 10-30% more energy than the absorbed products of fermentation of the same quantity of carbohydrate in the rumen (Leng 1982c; Harmon and McLeod 2001). However, this hypothesis was not strongly supported by the acetate clearance results which did not differ ($P>0.05$) between the control and the supplemented animals. The mean values of the abomasally supplemented animals did, however, point to their having a higher acetate clearance rate than the animals in the other three dietary treatments. There was also no difference ($P>0.05$) in the rumen liquid kinetics parameters between the dietary treatments.

There was no difference ($P>0.05$) between dietary treatments in microbial protein outflow from the rumen (predicted by means of urinary allantoin excretion) whether this was expressed as microbial N production per day or per kg OMADR. The lack of response in microbial protein

supply to intraruminal sucrose supplementation (given that synthesis was sub-optimal) showed that factors other than fermentable energy or ammonia were limiting microbial growth efficiency. These factors may have included rumen turnover rates, and microbial growth efficiency of different groups of microbes whose proportion in the rumen ecosystem may have been influenced by the supplement. It is noteworthy that numbers of protozoa were quite high in the rumen of the intraruminally supplemented animals, and given that protozoa are known to engulf bacteria and therefore increasing intraruminal recycling of microbial N, it is conceivable that their presence in the rumen in high numbers could impair microbial protein flow to the small intestine. While N intake was generally high, most of it was readily degraded in the rumen resulting in high N digestibility values, and which is a common finding with basal diets high in NPN (Ferrell *et al.* 1999). The extensive hindgut fermentation in the abomasally supplemented animals was attributed to escape of sugars from the small intestines due to low sucrase (invertase) enzyme activity in the small intestines of ruminants (Walker 1959b; Siddons 1968; Ørskov *et al.* 1972). As a consequence, the faecal N excretion was rather high, thus depressing N digestibility in the sucrose supplemented animals.

It is concluded from this study that any strategy to stimulate higher productivity in animals subsisting on low quantity basal roughage, especially those in the tropics, would have to start with simple and inexpensive physical and/or chemical treatment such as treatment with urea, to increase the proportion of potentially digestible OM. This roughage treatment could be complemented by the provision of rumen degradable nutrients such as N and S to overcome deficiencies and thereby stimulate higher microbial growth in the rumen, and additional protein to the small intestines. The chemical treatment is likely to improve OM digestibility and therefore make more VFA energy available from the roughage. Provided availability and cost are not prohibitive, and ruminal ammonia is adequate, readily digestible carbohydrates such as sucrose may be utilised as an energy-rich supplement to further boost the fermentable OM availability in the rumen and to further increase VFA energy absorption. However, the potential benefits of such supplementation to the animal at the tissue metabolism level may be moderated by a variety of other changes in the rumen fermentation and post-absorptive metabolism triggered by the presence of the sugar in the rumen (e.g. increase in number of protozoa). Furthermore, while there may be some benefits of by-passing rumen fermentation of sucrose in favour of intestinal digestion that leads to increase in glucose supply to the body tissues, these may be undermined by the limitations associated with post-ruminal sucrose digestion.