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Developing profitable strategies for increasing growth rates of cattle grazing tropical pastures

Foreword

The report was written to meet several goals. The first was to meet contractual commitments to the MRC whilst at the same time providing our major clients, the beef industry, with a relatively complete documentation of the research undertaken and the outcomes arising from their commitment of funding to the project work. In writing the report in this detailed manner, a further goal was for the project team to catalogue the information generated as the basis of further discussion, for further evaluation of the significance of the outcomes of the research, to identify needs for future research, and finally to provide a framework for future publication in scientific and extension articles.

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The project represented a highly successful and mutually beneficial collaboration between DPI and the UQ (principally Dr Dennis Poppi). The open and unqualified approach by both organisations towards achieving the objectives set down contributed greatly to the success of the project, and is a useful model for future collaborative research. The project team is grateful to all who contributed to this approach.

Overview

Project 'Target 300' was developed to address the needs of the northern beef industry to have strategies by which to profitably increase the growth rates of grazing cattle in the endowed zone of Queensland (mainly the Downs and Brigalow regions). A specific growth rate target of 300 kg/year was set; hence the name 'Target 300'. This zone, by virtue of its higher fertility soils and more favourable rainfall relative to areas north and west, has high potential to meet the needs for young, heavy carcases from grazing animals for premium markets. Possessing the capability to manipulate growth rates provides producers with increased flexibility in the choice of markets and increased ability to respond to changing market opportunities and seasonal conditions.

The project was a collaborative effort between the Department of Primary Industries (Queensland), University of Queensland and MRC, and included a major grazing trial at Brigalow Research Station Theodore, pen and metabolism studies in Brisbane, and a collation of information on production and feed plans from some high-producing beef enterprises which were already achieving the target growth rate (Case Studies). The major emphasis in the research was on supplementary feeding strategies, although the Case Studies indicated that, within the large diversity of feed plans employed, several other approaches were appropriate including use of improved pastures and forage crops.

The main industry outcome from the project was the development of a series of growth response curves relating the liveweight responses of young, growing cattle to increasing amounts of various supplement types. Cottonseed meal and grains (sorghum and barley balanced for urea and minerals) were the predominant supplements used, and they were fed over a range of intakes up to 2% of body weight (2 kg/ 100 kg bodyweight). Supplements were fed throughout the year in order to gauge the effect of pasture (and diet) quality on the response to feeding.

In general, growth rate increased linearly with increasing intake of supplement on forages of all qualities. However, the response to feeding was very low during the main wet season period, greater during the wet/dry season transition phase, and highest when forage quality was low. For instance, feeding barley at 1% of bodyweight (1 kg/ 100 kg bodyweight) produced an additional gain of 0.1 kg/day on high quality, and 0.55 kg/d on low quality, forage diets. On the low quality forages, cottonseed meal gave a substantially higher response than barley at low-medium intakes, but in all other situations barley and cottonseed meal were comparable at similar intakes. The liveweight response to sorghum feeding was about one-third less than for barley when both grains were fed dry-rolled. These responses were poorly predicted by the feeding standards and their associated models which appear inadequate for tropical grazing systems at present.

More intensive investigations in pen feeding studies indicated that feeding supplements to cattle on low quality forages substantially increased growth of micro-organisms in the rumen, which, by virtue of their major role as a source of protein to the animal, translated to increased protein supply. It was further shown that the efficiency of production of this microbial protein was very low on these tropical pastures, but was markedly increased with supplementation; that is, the amount of microbial protein produced per unit intake of digestible plant material. These studies also indicated that the greatest impediment to increasing growth rates of cattle, especially on higher quality pastures, was the substitution of supplement for pasture by the animal. Major increases in growth rate through supplementation on tropical pastures will require, therefore, strategies to reduce this substitution effect and to increase the efficiency of microbial protein production.

The availability of well-defined response curves to some major supplement types, aligned with pasture quality, has provided producers with tools by which they can more confidently predict growth responses and make more objective, economic decisions about supplementation strategies than was previously possible. Further research is needed to fully exploit the potential of these supplements by reducing the inefficiencies of feeding.

1. Executive summary

1.1 Background

The project addresses the needs of the northern beef industry to have strategies by which to increase the growth rates of grazing cattle in a profitable and resource-sustainable way. It was initiated in response to an industry request, through MRC, for research into ways of improving growth rates of grazing cattle in the endowed zone of Queensland (primarily the Downs and Brigalow regions), with a specific annual growth rate target of 300 kg; hence the colloquial project name - 'Target 300'. Although this region is highly productive, the target weight gain is not widely or regularly attained. The flow-on benefits for producers of achieving high growth rates include greater flexibility in the choice of markets, increased ability to respond quickly to changing markets or changing seasonal conditions, and most importantly, improved capacity to consistently meet stringent market specifications. By targeting the grass-fed market the project also endeavours to provide a viable, lower-risk, "clean-green" alternative to feedlotting, for providing product of optimum quality.

The project's general aim was to provide industry with strategies to increase growth rates through a combination of applied research, strategic research, compiling property case studies and technology transfer. This has been approached by addressing five specific objectives which are detailed below together with the major research findings and achievements arising from them. Much of the emphasis in this project was on supplementary feeding, not because it is the only or most appropriate option for producers to use in the pursuit of higher growth rates but because it provided the best way to quantify nutrient inputs and also provided practical strategies suitable for immediate industry adoption.

1.2 Research approach

The project was a collaborative study between DPI and the UQ and involved a sharing of staff and resources. It combined the various skills required to comprehensively pursue the objectives set, in particular ruminant nutrition, pasture agronomy and diet selection. The research included three main studies, viz. in order of increasing detail of investigation, a grazing study at the DPI's Brigalow Research Station (Theodore) set up primarily to measure the effects of supplements on growth rates under varying pasture conditions, a pen feeding study at the DPI's Rocklea Animal Husbandry Research Farm determining the effects of supplement on intake and growth rate of animals, and a metabolism study at the University of Queensland's (UQ) Mt Cotton Research Farm designed to provide information on the utilisation of nutrients, e.g., digestibility of feed sources and production of microbial protein.

The research approach was characterised by:

- Evaluation of a range of supplements representing the major types available, e.g., 'energy' supplements based on starch of low (sorghum) and high (barley) rumen degradability and on highly-fermentable soluble sugars (molasses), and protein meals containing protein of medium (cottonseed meal; CSM) and low (fishmeal) rumen degradability.

- Using seasonal conditions (wet and dry seasons) to generate a range in quality of the pasture and diet, against which responses to supplements were measured. Unfortunately, the lower end of the pasture quality scale was experienced for only short periods owing to unseasonal winter rainfall.

- Using the dose response approach incorporating several (5-6) levels of intake of each supplement to fully define the response curves.

- Feeding supplements to animals on a daily and individual basis and using common grazing of animals in order to overcome problems commonly encountered with paddock differences and uneven distribution of supplement through the mob.

1.3 Objectives, associated achievements and industry outcomes

The major findings and achievements are detailed below against the project objectives initially put forward. For discussion purposes, various objectives have been combined where there is a common approach or where outcomes are common to more than one objective.

Objective 1. Provide estimates of nutrient supply to cattle from these pastures throughout the year; &

Objective 2. Use these findings to identify the nutritional constraints to achieving high growth rates of cattle, e.g., 300 kg/year.

The grazing study at Brigalow Research Station was conducted on a buffel grass dominant pasture grown on soils characteristic of the brigalow zone. Presentation yield of the major plant species in the pasture and of their various components, i.e., green and dead, leaf and stem, and the chemical analyses of these and of the diet of grazing animals, estimated using oesophageally-fistulated (OF) steers, were determined every 6–8 weeks between October 1994 to October 1996 (15 sampling dates). The diet extrusa was also incubated in nylon bags in the rumens of fistulated steers to determine digestion characteristics. The major findings from the grazing study were as follows:

- Total pasture presentation yield usually exceeded 3 t/ha, indicating that pasture was not limiting in supply throughout the study.

- Buffel grass was the predominant species in the pasture, its proportion varying from 73–89%, but it varied more widely in its contribution to the diet (40–88%). Seca was only a minor component of the pasture (maximum 9% in February 1996) and usually of the diet except for a short period in the February/March period of each year when it represented as much as 29% of the diet.

- Yield of green grass leaf averaged 500 kg/ha overall but varied widely across seasons, as did its proportional contribution (2 to 30%; average 15%) to the total pasture yield. The proportion of green grass leaf in the pasture exceeded 20% only during the wet season periods, December 1994–February 1995 and November 1995–February 1996. Diet studies indicated that the proportion of green grass leaf selected was, on average, three-times greater than that represented in the pasture.

- Buffel grass green leaf, considered an appropriate indicator of the best quality plant material (excluding Seca leaf) available to the grazing animal, changed considerably in quality across seasons but crude protein (CP) content always exceeded 6.25% and usually 10% and *in vitro* organic matter digestibility (IVOMD) usually exceeded 60%. For other buffel grass plant components, CP content was at most samplings less than 6.25% and IVOMD less than 50%.

- The CP content and IVOMD of the selected diet exceeded the 6.25% and 60% thresholds respectively, except for short periods during the drier winter months and in March 1996

(CP only) when pasture conditions were also dry. Generally, quality of the diet, as indicated by these parameters, was less than that of buffel green leaf, except for short periods during the wet seasons.

- The CP content of the diet was, on all sampling dates across seasons and years, less than 210 g/kg digestible OM (DOM), the level above which it has been predicted there would be net loss of protein between ingestion and transfer to the intestines for absorption. This confirms what had previously been proposed for tropical grass pastures, in the absence of much reliable, detailed evidence relating to the diet of grazing animals.

- The grazing study provided, for the first time, estimates of the breakdown of the CP of tropical pastures into its two major components, viz. rumen degradable protein (RDP) and undegraded dietary protein (UDP), which provides key information on the supply of metabolisable protein (MP) to the animal. This was facilitated by a method acquired from the University of Nebraska, and was based on the rate of disappearance of neutral detergent insoluble protein (NDIP) from diet extrusa incubated in nylon bags in the rumen. The results indicated that:

  - the major component of dietary CP was RDP, which exceeded 75% of the total CP in all months;

  - estimated RDP concentration, expressed in relation to the estimated supply of DOM (g CP/kg DOM), followed a similar seasonal trend to CP concentration in the diet extrusa. This parameter exceeded 123 g CP/kg DOM, the level below which microbial protein synthesis is considered to be limited by protein supply to the rumen, during the main wet season period but not during the drier months of the year, indicating a requirement for soluble nitrogen in the diet in this latter period;

  - RDP supply (estimated) from the pasture was sufficient for growth at 0.8 kg/d (required for annual growth rate of 300 kg) only in December 1994 and May 1996 if total DM intake by steers was assumed to be 3% BW, but not at all if assumed to be 2% BW.

  - UDP supply was sufficient for growth at 0.8 kg/d at all times except from May to August 1996 assuming intake to be 3% BW, but was generally insufficient at an assumed intake of 2% BW.

- Plasma urea concentrations in grazing steers fluctuated markedly across seasons but, except during the main dry season period (July/August), were usually in excess of 4.2 mg urea-N/dL (1.5 mM), the point at which a response to non-protein N supplements would be expected.

Two pen feeding studies were carried out at Rocklea Animal Husbandry Research Farm in order to extend the range of supplement types investigated and to provide a more detailed examination of the growth responses. A basal ration of low quality (6.2% CP) Rhodes grass hay was fed *ad libitum* with various levels (0–2% BW) of different supplements in a response curve design. The main supplements included for which there are finalised results are barley, sorghum and CSM. The major findings were as follows:

- For all rations, increasing intake (DM) of supplement was associated with a depression in hay intake but an increase in total intake, demonstrating a clear substitution effect. Barley caused a greater depression in hay intake than sorghum or CSM, which were similar in their effects.

- When intakes were calculated on a digestible DM (DDM) basis, all three supplements had similar effects on hay and total DDM intake. Thus the differences in substitution recorded

with different supplements on a DM basis were not reproduced when related to the metabolisable energy (ME) supplied by the supplement. This finding provides an interesting insight into the underlying causes of substitution, and thus provides scope for possible manipulation and exploitation in the future.

- The differences in liveweight gain with the three supplements were primarily related to differences in DDM intake. However, there appeared to also be different relationships between liveweight gain and DDM intake for the different supplements, which were probably related to differences in microbial CP (MCP) supply and in the balance of MP/ME in the products available for absorption.

These pen studies were further complemented by detailed metabolism studies at Mt Cotton Research Farm, where the effects of the same supplements plus molasses on digestibility and on the production of microbial CP (MCP), were determined. The same basal diet was used. Main findings were as follows:

- The DM digestibility (DMD) of the hay was 51.8%, and the corresponding estimated DMDs for barley, sorghum and CSM were 75.0, 57.2 and 63.3, highlighting in particular the low digestibility of sorghum in this study.

- Production of MCP, as estimated from the excretion of purine derivatives in urine, increased linearly with increasing supplement intake. The rate of increase in production of MCP per unit intake of supplement (DM) was greatest with barley and CSM and least with sorghum; molasses was intermediate.

- There was a linear relationship between estimated MCP production and intake of digestible organic matter (DOM) across supplement types. The variability about this relationship (R^2=0.66) however, was probably related to differences in the extent to which the OM of different supplements was digested in the rumen (on a DOM basis).

- The project demonstrated the extremely low efficiencies of MCP production (62–92 g/kg DOM intake) on tropical rations such as the hay used in this experiment. With all supplements, efficiency increased with increasing intake of supplement, the greatest rate of increase occurring with CSM and molasses and the least with sorghum.

- Demonstration of these effects represents a significant advancement in the understanding of the production responses with these different supplement types.

- The estimated MCP production rates for this experiment deviated from those predicted from the feeding standards (AFRC 1992), especially at low production rates where the feeding standards overestimated actual MCP production rate.

- Use of the ratio of concentrations of purine derivatives to creatinine in urine has been proposed to indicate MCP production, in situations where total collections of urine are not feasible, e.g., in field studies. Creatinine excretion was considered to be a constant aligned with the bodyweight of the animal. There was a general relationship between the total excretion of purine derivatives and the ratio of concentrations of purine derivatives to creatinine, but creatinine excretion was shown to increase linearly (R^2=0.32) with intake of DOM, excluding its consideration as a constant value.

- Supplementation with CSM maintained rumen ammonia-N (NH_3-N) concentration in rumen fluid at a higher level than for the grain or molasses supplements, and was also associated with much higher concentrations of urea-N in blood plasma.

Objective 3. Collate and evaluate information on current property practices in the endowed zone, which regularly achieve cattle growth rates of 300 or more kg/year.

The Case Studies component of Target 300 arose out of a recognition that some producers in the endowed zone were already achieving the target growth rate (300 kg/year) by employing a variety of production systems and that other producers may benefit from a collation of the information derived from these various systems. A cross-section of 15 relevant producers representing a wide array of production systems (other than feedlotting) within the endowed zone were surveyed and information collated in relation to estimated growth rates of 20 groups of cattle and the feed year plans employed. The main findings were as follows:

- There were a diverse range of production systems employed, most incorporating some inclusion of improved pasture, with deployment of supplementation options very dependent on present product costs and market prices for cattle. Owing to drought conditions prevailing during the survey, few systems achieved the target growth rate but apparently did so in 'normal' years.

- The desire to maximise growth rates within the constraints of seasonal conditions and property resources was a common goal, often in the absence of any objective economic evaluation of the procedures undertaken.

- An extension of these Case Studies is warranted but with more attention given to collection of more detailed measurements of production, and with some form of evaluation of the outcomes. This would provide more reliable information upon which to develop management strategies for other producers.

Objective 4. Establish liveweight gain response curves to key nutrients provided as supplements to growing cattle grazing tropical pastures of the endowed zone in both the dry and wet seasons; &

Objective 5. Use research findings and producer knowledge to develop supplementation strategies (including level and type) and forage systems to increase growth rates of cattle in either the wet or dry seasons.

In the grazing study at Brigalow Research Station, liveweight gain responses were measured in young, growing cattle when supplements of CSM or grain mixes were fed during the wet and dry seasons between October 1994 and October 1996. Four drafts of steers were used. Separate curves were established according to whether the cattle were growing at a low, medium or high growth rate in the absence of supplement. Further refinement of the response curves is needed to relate them to attributes of pasture or diet quality. These response curves were best described by the following equations:

CSM:

High growth rate:	$LWR = 0.084 + 0.098\ Intk$	($R^2 = 0.05$; NS)
Medium growth rate:	$LWR = 0.147 + 0.361\ Intk$	($R^2 = 0.40$; $P<0.001$)
Low growth rate	$LWR = 1.187 - 1.11e^{-2.65\ Intk}$	($R^2 = 0.91$)

Barley:

High growth rate:	$LWR = 0.087 + 0.071\ Intk$	($R^2 = 0.10$)
Medium growth rate	$LWR = 0.311 + 0.122\ Intk$	($R^2 = 0.13$; $P<0.05$)
Low growth rate	$LWR = 0.086 + 0.549\ Intk$	($R^2 = 0.95$; $P<0.01$)

where LWR is the liveweight response (above control; kg/d) and Intk is daily supplement intake (% of BW). Linear relationships best fitted the data available, except for CSM fed with low quality diets. These response relationships can be applied to other supplements of similar type, i.e., the barley response curves should apply to other grains having starch of high degradability in the rumen. Some important points about these response curves are as follows:

- These response curves established were substantially different from those currently available and which were developed on a limited data-base, but were consistent with those derived from an exhaustive search and collation of the literature. They thus represent a significant contribution to the tools available for the use of producers.

- The relationships derived indicate the often low response to supplementation under grazing conditions, with generally poor conversion rates of supplement to additional liveweight gain. The exception was on low quality pastures.

- Supplementation provided a response during the wet season, but it was very small and obviously uneconomic. One of the challenges in the future will be to devise ways to improve animal performance during this period, or in the wet/dry transition period.

- Almost without exception there were major differences between the responses measured in the grazing experiment and those predicted using the feeding standards or their associated decision support models (GrazFeed, Cambeef and NRC 1996). This finding indicates a major gap in the knowledge or in its application to tropical pasture grazing situations.

Other industry recommendations arising from the results include:

- When fed as dry-rolled grains, the response to sorghum should be discounted by about 33% when compared with barley.

- Barley-based supplements can be substituted for CSM under the following conditions:
  - at all levels of feeding on medium to high quality pasture (ADG >0.4 kg/d);
  - at high levels of intake (>1.5% BW) on pasture of all qualities;

  but not:
  - at lower levels of intake on poor quality pasture supporting low growth rates. Under these pasture conditions, a mixture of protein meal and grain is recommended with the proportion of protein meal declining from 100% at low intakes to zero at high intakes of supplement, based on a need to ensure adequate protein for optimum utilisation of both the supplement and the pasture consumed, and on maintaining low cost of feeding.

- The protein inclusion in grain-based supplements should be not less than the equivalent of 20 g urea/kg grain, and where small amounts of supplement are fed in association with dry pastures, should be considerably higher to provide the necessary protein for utilisation of both the supplement and the pasture. A safe method of feeding higher concentrations of urea in grain is required, or the above alternative of replacing urea with protein meals could be employed.

1.4 Technology transfer

Three main avenues of technology transfer are envisaged, or have been initiated:

1. Incorporation of the response curves into decision support systems such as BeefLink and Feedman. The growth response curves developed within the Target 300 project represent key decision tools in the framework of these whole property models, which in turn represent a valuable means of disseminating the information most widely and effectively.

2. The use of traditional methods of direct information dissemination on a need or demand basis will continue to be employed.

3. An extension of the Case Studies aspect of the project is proposed as a method of information sharing within the producer group achieving high-production goals, and thence to other producers. This should include collection of more long-term, objective information about feed year plans and production achievements.

1.5 Recommendations on further R&D

The project results highlighted three broad issues requiring further research attention, the solutions to which would represent major advancements in knowledge and in the capacity to increase the production of ruminants grazing tropical pastures, viz.:

1. **The substitution effect associated with supplementary feeding.** Substitution has a major impact on the efficiency of use of supplements and thus on the cost-effectiveness of this practice, effectively precluding the economic use of supplements on higher quality pastures. The demonstration in this project and elsewhere that different supplements cause differing extents of substitution raises the possibility that this phenomenon can be manipulated if the underlying principles are understood.

2. **The low efficiency of microbial protein production in cattle on tropical pastures.** Efficiencies of MCP production in this project were well below those proposed in the feeding standards, and this also provides ample scope for improvement with consequences for increased growth rate. It is hypothesised that soluble carbohydrates and amino acids provide the key for changing efficiency and that supplements are one way of increasing supply of this nutrient. The availability now of methods by which microbial protein production can be studied in intact animals will enable more strategies to be examined quickly.

3. **The low efficiency of use of absorbed protein for growth.** This problem also affects the economic efficiency of nutritional strategies and has been recognised and investigated widely. Factors involved probably include the interaction of protein/energy and possibly energy substrate type. The research team consider this topic of lowest priority of the three proposed.

Other aspects requiring further research include:

- **Establish growth response curves to protein sources having high lipid content**, e.g., copra meal, palm kernel expeller meal and whole cottonseed. This type of supplement was not represented in any of the studies carried out but is important owing to the restricted number of protein meals available commercially, their sometimes lower cost and due to the discontinued availability of meat meal for ruminant feeding.

- **Evaluate molasses as an alternative 'energy' source to grains.** Some information is already available in relation to this supplement, but only limited information on its use for promoting liveweight gain and little describing the response relationships. In view of the

cost advantage molasses has over grains in northern Australia, this work needs to be expanded.

- **Extend the response curves to cover the finishing animal.** The research to date has mainly targeted the young, growing animal but the nutritional requirements will be different for older, finishing animals which are depositing relatively more fat and less protein than their younger counterpart. Further work is required to define the differences in the response relationships between the two groups, as feeding strategies are often targeted at cattle during the last six months prior to slaughter. More attention should also be given to changes in carcase composition arising from these treatments.

- **Develop tools for assessing the nutritional status of cattle under practical grazing conditions.** For producers to reliably use the growth response curves, it is necessary for them to know the current nutritional status of their animals so that the appropriate strategy can be applied. The lack of a reliable tool by which to do this, for instance using some parameter of the pasture but preferably of the animal (e.g., blood or faeces), restricts objectivity in determining appropriate management strategies. Identification of appropriate tools is a priority.

- **Quantify protein supply from tropical legume-based pastures.** Although one of the main reasons given for including legumes in tropical pastures is to improve the protein nutrition of grazing animals, relatively little is known about the contribution legumes make to the supply of RDP and UDP to the animal at different times of the year. This is so even for the stylos which are widely used by industry in northern Australia. Information of this nature could alert workers of the possibilities for different management strategies, and highlight the need for other nutritional inputs, perhaps through supplements, at key times of the year.

- **Evaluate the feeding standards under a wide variety of feeding systems in the tropics.** The poor agreement between actual growth rates/responses and those predicted from the feeding tables in the current project indicates a need to (a) further test the feeding standards under grazing conditions, and (b) provide key information which can contribute to improving the application of these standards to tropical situations. In the interests of optimising research spending in the future, and of increasing extrapolation of results from research to industry, it is proposed that some common features be included in future research experiments, especially those involving supplementary feeding. A suggested template for project design is as follows:

  - inclusion of an up-to-date review of the literature;
  - good description of experimental animals, including previous history and performance;
  - description of pasture in terms of major species and the proportion of legume;
  - collection of key information to run models linked to feeding tables (e.g., GrazFeed), including pasture yield and height, the proportion of green and dead material, and the digestibility and CP content of these components, at regular intervals;
  - regular weighing of animals, including during the post-experimental phase to quantify compensatory growth effects;
  - where supplements are fed, incorporation of two or more intake levels (response curve);
  - evaluation of results in relation to existing response curves.

- **Evaluate longer term strategies for increasing productivity.** Research in the current project has, by design, been aimed at providing short-term strategies for increasing growth rates. However, under commercial grazing situations, these short-term strategies need to be incorporated into 'whole of life' plans. This raises the other question of timing

of application of treatments. Complementary research is needed to define the important principles in terms of producing the most appropriate growth curve for cattle, from the point of view of economic efficiency and meeting market specifications, for the major markets available.

1.6 Conclusions

The project results represent a significant advancement in the knowledge of ruminant nutrition, especially as it relates to grazing cattle in the tropics. It has also, however, identified that there are significant gaps in the knowledge as is best demonstrated by the failure of the feeding standards to predict the growth rates and responses recorded in the project. This highlights the need for further research in the area, which is contrary to the recent groundswell of opinion that a collation of existing information will fill the gaps. The project team strongly urges the re-evaluation of the current imbalance in support for sustainable grazing research almost to the exclusion of production research, on the basis that sustainable grazing research will do little to increase productivity, without which the pressures on producers to remain profitable will increase. An alternative goal should be that of increased production or efficiency of production, through the various avenues of improved nutrition such as supplementation and plants of higher nutritional value, in compliance with best practice sustainable grazing principles. Such an approach will meet the dual criteria of improved financial status of producers and long-term sustainable use of grasslands.

2. General introduction

The project was set up to address the needs of the northern beef industry to have strategies by which to increase the growth rates of grazing cattle in a profitable and resource-sustainable way. It was initiated in response to an industry request, through MRC, for research into ways of improving growth rates of grazing cattle in the endowed zone of Queensland (primarily the Downs and Brigalow regions), with a specific annual growth rate target of 300 kg; hence the colloquial project name - 'Target 300'. Although this region is highly productive, the target weight gain is not widely or regularly attained. The flow-on benefits for producers include greater flexibility in the choice of markets, increased ability to respond quickly to changing markets or changing seasonal conditions, and most importantly, improved capacity to consistently meet stringent market specifications. By targeting the grass-fed market the project also endeavours to provide a viable, lower-risk, "clean-green" alternative to feedlotting, for providing product of optimum quality.

This general objective of increasing growth rates is seemingly at odds with the current preoccupation with sustainable grazing, and the major shift in resources towards that area of research. This shift in direction has arisen in response to the realisation that pastures will continue to be the major feedbase for ruminant production and that its sustainable use poses the major problem facing the grazing industry as it seeks to maintain a resource for its own use and at the same time counter criticism from the wider community about the environmental impact of its practices. Much of the current emphasis into sustainable grazing practices revolves around monitoring experiments with few interventionist strategies available other than stocking rate and fire. These treatments alone will not provide the necessary stimulus to growth rates to achieve the market objectives outlined above, particularly as they relate to those markets requiring young, heavy carcases of high quality. For this to happen animals need to move to a higher plane of nutrition than is achievable on unimproved pasture without nutritional input, for instance that provided by introduction of new plants into pastures, total replacement of smaller areas of specialist pastures or supplementary feeding strategies. Only in a climate of improved economic well-being will the necessary financial incentives be available for producers to adopt sustainable grazing practices. Thus whilst this project is about increasing growth rates, it acknowledges the important part this plays in the long-term sustainable grazing approach. It appears that the importance of this balance between increased production and sustainable use of resources is often lost.

The project's general aim was to provide industry with strategies to increase growth rates through a combination of applied research, strategic research, compiling property case studies and technology transfer. This has been approached by addressing five specific objectives which are detailed below. Much of the emphasis in this project was on supplementary feeding, not because it is the only or most appropriate option for producers to use in the pursuit of higher growth rates but because it provided the best way to quantify nutrient inputs and also provided practical, directly applicable strategies for producers. Many other options are available, as were detailed in the Case Studies component of the project in which strategies of 'elite' producers regularly achieving growth rates of 300 kg/year were documented. Most of these refer to the replacement of the existing pasture with an improved species, or augmentation of the existing pasture base for instance with a legume.

2.1 Project objectives

The objectives of the project were to, by June 1996:

1. Establish liveweight gain response curves to key nutrients provided as supplements to growing cattle grazing tropical pastures of the endowed zone in both the dry and wet seasons.

2. Provide estimates of nutrient supply to cattle from these pastures throughout the year.

3. Use these findings to identify the nutritional constraints to achieving high growth rates of cattle, e.g., 300 kg/year.

4. Collate and evaluate information on current property practices in the endowed zone, which regularly achieve cattle growth rates of 300 or more kg/year.

5. Use research findings and producer knowledge to develop supplementation strategies (including level and type) and forage systems to increase growth rates of cattle in either the wet or dry seasons.

The emphasis on supplementary feeding in this project is in keeping with the large concentration of research resources in this field of cattle nutrition in the northern tropics over the past three decades. The need to do more research is this area has been questioned of late, and rightly so. It has been argued that all the answers are currently available in the literature or in unpublished trial reports. However, efforts to find clear extension material detailing the most appropriate type of supplement, or level of feeding, to achieve a given liveweight response in cattle growing under differing circumstances, are usually unsuccessful. This has arisen partly because there has been insufficient attention given to collecting information on the grazing conditions existing during the research, thereby reducing the confidence with which results can be extrapolated from one region to another. Furthermore, few of the experiments carried out have used a response curve approach encompassing a range of intakes of supplement; most 'gamble' on one or two usually low levels of feeding which restricts options of higher feeding levels for specific short-term applications.

The experiments in the current project have endeavoured to confront these issues by using appropriate research methodology, which included:

- Evaluation of a range of supplements representing the major types available, e.g., 'energy' supplements based on starch of low (sorghum) and high (barley) rumen degradability and on highly-fermentable soluble sugars (molasses), and protein meals containing protein of medium (cottonseed meal; CSM) and low (fishmeal) rumen degradability. These supplement types represent the extremes of what is available and what can be readily provided by producers to their animals.

- Using seasonal conditions to generate a range in quality of the pasture and diet, i.e., by feeding the supplements at pasture throughout the wet and dry seasons, and thereby providing results which can be widely extrapolated across regions. The other advantage of this approach was to provide valuable practical information on the responses by cattle to feeding during the wet season, a period which is generally avoided in terms of interventionist strategies but which cannot be ignored if high growth rates are to be achieved.

- Using the dose response approach incorporating several (5-6) levels of intake of each supplement to fully define the response curves.

- Feeding supplements to animals on a daily and individual basis in the paddock, and using common grazing of animals in order to overcome problems otherwise likely to be

encountered with paddock differences and uneven distribution of supplement through the mob.

- Intensive measurement of the effects of supplements on the utilisation of nutrients by animals in order to better understand the principles applying.

Our knowledge of the nutritional requirements of animals and the nutritional value of pasture and supplements is encapsulated in the feeding standards (e.g., SCA 1990). Thus application of these should enable prediction of animal performance from a particular pasture and the response to supplements. If reasonably accurate predictions of responses to supplement can be made the need for further research in this area would be greatly reduced. However, to date many of the experiments carried out in this field have provided inadequate description of the pasture in particular for the feeding standards to be tested. In setting up the current project, one of the goals was to provide the necessary information upon which to test the adequacy of the feeding standards for the tropics.

The following chapters describe the research carried out in grazing, pen feeding and metabolism studies, and the major findings and conclusions associated with them. A brief description of the case studies compiled to document strategies used by commercial cattle producers to achieve high growth rates is also provided. Based on the combination of these results, several recommendations are made for use by the grazing industry.

3. Grazing study - Brigalow Research Station

3.1 Introduction

This section describes a major grazing experiment set out to establish growth response curves to different supplement types, namely protein meals and 'energy sources' containing starch with high (barley) and low (sorghum) degradability in the rumen, over a range in diet quality as provided by the changing quality of the pasture across seasons. The aim was to relate these response curves to key parameters describing pasture and diet quality. The industry need for this research, and the general methodology used, have been detailed in the General Introduction, and will not be repeated here. However, it is clear that despite all the research carried out in this field in the past, the industry still does not have response curves upon which it can rely and which have application across pasture communities and regional boundaries. This has occurred principally because of the lack of appropriate description of the pasture or diet, and the failure to use appropriate methodologies to produce response curves covering a range of intakes of the supplement. The present experiment aimed to correct these deficiencies.

3.2 Research methodology

3.2.1 Experimental site/facilities

The experiment was conducted on an area of predominantly loamy duplex and sandy duplex soils with small areas of gilgaied cracking clay complexes. The original vegetation was predominantly brigalow/belah, brigalow/dawson gum communities with a small area of open forest and with an understorey predominantly wilga and sandalwood. Initially the trial area incorporated six paddocks of combined area 73 ha, but one paddock (4.2 ha) was excluded from October 1995 onwards on the basis of being botanically atypical. Buffel grass (Cenchrus ciliaris cv. Biloela) was the predominant pasture species, with minor contributions from Rhodes grass (Chloris gayana), Blue grasses (Dichanthium spp.), Eragrostis spp., Eriochloa sp. and others. Seca (Stylosanthes scabra cv. Seca) had been oversown into the paddocks in 1984 but it represented only a small proportion of the total dry matter (DM) on offer for most of the experimental period (see later).

3.2.2 Experimental animals

Four drafts of steers were used over four seasons, the 1994/95 wet, 1995 dry, 1995/96 wet and 1996 dry seasons. From this point on, the dry season will refer to the winter/spring period until the commencement of first storms, although this nomenclature does not accurately represent the type of seasons encountered. A description of the experimental animals is given in Table 3.1. Steers were allocated to treatment groups by stratified randomisation on the basis of fasted (24 h without food or water) liveweight. Steers used in the 1994/95 wet season were continued on for the 1995 dry season, and remained in the same treatment groups for both feeding periods. This was necessary because weaner steers purchased for the second draft of the experiment arrived in low body condition, after being recently weaned, and consequently consumed inadequate amounts of the supplement.

3.2.3 Experimental procedures

Table 3.1. Cattle used for the various drafts of the experiment and duration of the feeding periods

Season	Feeding duration	Experimental animals[A]		
		Breed / class	Age (mths)	Initial Lwt (kg)
1994/95 wet	161 d[B] 12/10/94 - 10/04/95	Brahman X weaner steers	8-10	169.4 (1.11) [C]
1995 dry	76 d 31/07/95 - 30/10/95	Brahman X yearling steers	16-20	383.9 (3.46)
1995/96 wet	168 d 18/10/95 - 22/04/96	Brahman X weaner steers	8-10	159.5 (1.15)
1996 dry	71 d 22/07/96 - 1/10/96	Belmont Red X Hereford weaner steers	15-18	187.3 (0.33)

[A] There were 36 steers for the first three drafts and 42 steers for the 1996 dry season draft.
[B] Represents period over which growth rates were calculated, which excluded first three weeks equilibration phase during which intakes were steadily increased to treatment levels.
[C] Standard error of mean in brackets.

The 36 steers were used in a dose response design incorporating two supplement types each at five levels of intake replicated three times (three steers per level), and with six controls (unsupplemented). Supplements were cottonseed meal (**CSM**) and a sorghum-based ration (hereafter sorghum) for the 1994/95 wet and 1995 dry seasons, and CSM and a barley-based ration (hereafter barley) for the 1995/96 wet and 1996 dry seasons. For the 1994/95 wet season, the sorghum supplement comprised 94.6% (air-dry basis) cracked sorghum grain (coarsely rolled in a roller mill), 1.16% urea, 0.24% sulphate of ammonia, 2.0% bentonite, 1.0% limestone (Ag Lime) and 1.0% molasses. The urea concentration was increased for the 1995 dry season owing to concerns about the adequacy of rumen degradable nitrogen for total carbohydrate utilisation, and the final supplement composition was 93.9% grain sorghum, 1.74% urea, 0.36% sulphate of ammonia, 2.0% bentonite, 1.0% limestone and 1.0% molasses. This ration formulation was also used for the final two drafts of the experiment, except that rolled barley grain was substituted for sorghum. For the final draft, molasses was added to both the CSM and barley at the rate of 2 and 3.5 kg/45 kg mix respectively to stimulate intake of the supplements. Intake levels were 0.3, 0.6, 0.9, 1.2 and 1.5% of bodyweight (**BW**) for the CSM and 0.4, 0.8, 1.2, 1.6 and 2.0% BW for the grain-based rations.

In general, the steers grazed the trial paddocks on a 1-2 d rotation as a single group. The exception was the final draft in which 36 of the steers, including six controls (pen controls), grazed as a single group whilst another six steers (the paddock controls) grazed as a

separate group which was also rotated through the trial paddocks. All steers, including the unsupplemented controls, for the first three drafts, and the main group of 36 steers for the final draft, were mustered daily at about 0700 h and fed their respective supplements in individual stalls situated centrally in the experimental area; the six paddock controls for this final draft remained at pasture during this time. The additional control group for the 1996 dry season was included in order to quantify any effect on animal performance through daily confinement of the steers. The steers remained in the stalls for about 3-5 h before being returned to pasture, but if after this time a considerable amount of supplement remained uneaten, all 36 steers were again mustered in the afternoon and confined to the stalls for another period of approximately 2-3 h.

Steers were weighed once weekly, and heights at the hip were determined monthly. The amount of supplement fed was adjusted weekly for each steer based on this liveweight determination. Each days supplement allocation was added to that left unconsumed from the previous day, except that on the day the steers were weighed the residues were collected, weighed and sampled, and discarded. Dry matter (**DM**) determinations were made on the supplement fed out and on any weekly residues.

Pasture presentation yield and species composition were determined every 6-8 weeks using the Botanal procedure. At the same time, representative samples of the major pasture species (buffel grass, Rhodes grass, blue grass (*Dichanthium* spp.), Seca and other grasses) were cut and stored in a cold room. These samples were subsequently dissected and sorted into green leaf, green stem, dead leaf and dead stem, and the components were oven-dried at 65^{o}C, weighed and milled (1mm screen) awaiting chemical analysis. Pasture composition for these components was estimated on the basis of these measurements.

The diet was sampled over the same period using oesophageal-fistulated steers, aged about 5 years and weighing approximately 700 kg, which grazed an adjoining area of similar pasture type between sampling events. Duplicate sequential samples were collected from each of two or three steers for each of the six (or later five) paddocks. These extrusa samples were handled in two ways. A representative portion of each extrusa sample collected was retained, whilst further sample was bulked across animals within duplicates and within paddocks (two bulk samples per paddock per sampling). Between these major sampling dates, interim extrusa samples were collected every 2-3 weeks from one of the six paddocks (C paddock), considered representative of the whole trial area, using the procedures described above except that only one sample was obtained at each time and this was bulked across animals. All samples were initially stored frozen (-18 ^{o}C). The individual animal samples were thawed and botanical composition in the extrusa was estimated using the point-hit method for samples collected between October 1994 and October 1996. Bulk samples were subsequently freeze dried, sub-sampled and ground at either 1 mm for chemical analysis or at 3 mm for later *in sacco* digestibility studies.

Samples of urine, faeces, blood and rumen fluid were also collected from the experimental animals at times coinciding with the pasture and diet sampling events (hereafter the sampling period). Faecal samples were collected from each of the control steers during each sampling period, and from all steers on 10 occasions between December 1994 and July 1996. Two samples were taken from each steer, within a week, at each sampling time. Samples were stored frozen initially and later dried in a forced draught oven at 65^{o}C and ground through a 1 mm screen. For the control group, the duplicate samples were bulked across animals (one sample per sampling period), whilst the duplicate samples for supplemented steers were bulked but kept separate for each animal.

A single blood sample was taken from the tail vein of each control steer in each sampling period, and from all steers on several occasions during the course of the experiment. Samples were usually taken soon after mustering in the morning and prior to supplements

being offered. These samples were centrifuged and the resulting plasma was frozen awaiting analysis.

Rumen fluid was taken from the control steers on one occasion in each sampling period, and from all steers on 6/12/94 and 29/8/95 (3 h after feeding). Samples were taken *per os* using a stomach tube and vacuum pump, strained through two layers of muslin, and separate sub-samples kept for determination of ammonia-nitrogen (**NH_3-N**; all times) concentration, for volatile fatty acid (**VFA**; one occasion) concentration and composition, and for protozoa enumeration (all times). For these determinations, the rumen fluid was mixed with equal volume of 0.2N HCl and frozen, collected into tubes containing mercuric chloride and frozen, or mixed with formal saline (0.9% NaCl and 4.0% formaldehyde (w/w) in water), respectively.

On four occasions during the experiment (February, March, September and October 1995) coinciding with the pasture sampling periods, two urine samples were taken from each animal within about one week,. The samples were collected whilst the steers were confined to the stalls during the feeding period by positioning a harness containing a sponge, covered with a cloth to filter out dirt, beneath the animal's pizzle. The urine was squeezed from the sponge through a cloth filter to remove any dirt, and 5 mL was diluted to 50 mL with ammonium phosphate buffer, acidified with concentrated HCl to further reduce pH to 3.0 or less, and frozen awaiting analysis for concentrations of creatinine and purine derivatives.

3.2.4 LABORATORY ANALYSES

Representative samples of the supplements were analysed for organic matter (**OM**), nitrogen (**N**), ether extract (**EE**), crude fibre (**CF**; grains only) and neutral detergent fibre (**NDF**; CSM only). Estimates of metabolisable energy (**ME**) content were made on the basis of these proximate analyses.

For sampling dates between October 1994 and February 1996, the green leaf, dead leaf, green stem and dead stem components of the major plant species represented in the pasture were analysed for OM, N, and *in vitro* OM digestibility (**IVOMD**). From March 1996 onwards, these analyses were conducted only for the four components of the buffel grass and for the green leaf of the remainder.

Bulked extrusa samples collected from all paddocks at the major sampling times, and from C paddock at interim samplings, were analysed for OM, N and IVOMD. C paddock samples were also analysed for NDF, acid detergent fibre (**ADF**), neutral detergent insoluble N (**NDIN**) and acid detergent insoluble N (**ADIN**). The degradation properties of the extrusa samples were determined using an *in situ* (nylon bag) technique.

In situ technique. A composite of the extrusa sample for each sampling period was prepared by mixing equal weights of dried extrusa (3 mm screen) from each paddock, representing samples previous pooled across animals. Approximately 5 g of this bulk sample was placed into polyester bags (24 cm x 10 cm; 45 μm pore size) that were then closed at the top using a rubber band. Each extrusa sample was incubated in duplicate in each of three steers, with a maximum of two sampling periods represented per run. Friesian steers weighing approximately 900 kg and fitted with permanent large-diameter (10 cm i.d.) rumen cannulae (Bar -Diamond, Inc.) were used. The steers were housed in individual pens and offered, daily, 15 kg of a mixed basal diet comprising chaffed Rhodes grass (*Chloris gayana*) and lucerne (*Medicago sativa*) hay (2:1; 18.8 g N/kg DM), together with 2 kg of CSM; a trace mineral supplement was available at all times. The ration was designed to maintain adequate rumen NH_3-N concentration throughout the day, and provide a slightly above-maintenance plane of nutrition. One-third of the hay, and half the CSM, was fed in the morning with the remainder fed in the late afternoon. Analysis of the rumen fluid confirmed that NH_3-N concentration exceeded 120 mg/L just prior to the morning and

afternoon feeds. The bags were soaked in water for 10 min prior to incubation, attached to a length of chain (1.7 kg) using cable ties (15 cm) and submerged in the rumen. Incubation times of 3, 6, 9, 13, 16, 24, 48, 72 and 96 h were used, with the bags introduced in reverse time order and removed all at a common time in order to standardise the washing procedures. Upon removal, the bags were submerged in cold water, hand-rinsed to remove external particulate matter and then washed in a domestic clothes washing machine using a 12 min initial wash followed by a 5 min rinse and then a 3 min spin dry cycle. A further six bags per sampling time received this washing treatment alone (0 h sample). The bags were subsequently dried in a forced-draught oven for 36 h at 55^{o}C, desiccated and weighed. To monitor any between-run variability, a standard feed sample of Rhodes grass hay (3 mm screen; 4.3 g N and 885 g OM/kg DM) was always included and handled in the same way as the extrusa except that incubation times of 0, 6, 24 and 96 h were used. Residues were pooled across duplicates and steers (six bags) to obtain one residue per incubation time/sampling date, and analysed for OM and N (all incubation times), and NDF, ADF, NDIN and ADIN (0, 6, 9, 13, 16, 24 and 96 h).

The data for both OM and crude protein (**CP**; N x 6.25) disappearance generated from these incubations were fitted to the exponential equation:

$$p = a + b(1 - e^{-ct})$$

according to McDonald (1981), where p was defined as OM or CP disappearance in time t, a was the immediately soluble component which represents the y-intercept, b the potentially fermentable, but not immediately soluble component, and c was the proportional rate of fermentation of b (h^{-1}). The degradation constant, a, b and c, were fitted and the potential degradability B was estimated using these constants and the initial washing value A, ie., $B = a + b - A$. Furthermore, the effective degradability (ED) of OM and CP, was determined using the equation:

$$ED = a + (bc/(c + k))e^{-(c + k)t}$$

where k is the fractional rate of passage of the particulate matter in the rumen. For extrusa samples, a presumed value for k of 2% h^{-1} was used. Effective degradability estimates degradability of food in the rumen, as opposed to digestibility in the total tract, with rumen degradability usually of the order of 80% of total tract digestibility. Digestibility estimated by *in vitro* process (**IVOMD**) is an estimate of the latter.

The degradabilities of supplements (CSM, and barley and sorghum grains) in the rumen were also estimated using this *in situ* method in the same way as for the extrusa samples with minor modifications. The CSM was placed in the bags 'as fed' whereas the two grain sources were ground to pass through a 3 mm screen. Incubation times for the grains were the same as above, but incubation only continued for 72 h with CSM.

Interim extrusa samples collected from C paddock were handled in the manner described above but were incubated in the rumen for 24 h only. Residues were bulked across duplicates and animals and were analysed for OM, N and NDIN.

Current feeding standards express protein requirements in terms of metabolisable protein, which represents the true protein absorbed in the intestines and accounts for the protein supplied as microbial protein and that dietary protein escaping rumen fermentation, ie., undegraded dietary protein (**UDP**). The protein degraded in the rumen and therefore available for microbial utilisation is referred to as rumen degraded protein (**RDP**); hence total CP intake is the sum of RDP and UDP. Estimations of the composition of the CP in the diet, in terms of RDP and UDP content, were made using a methodology provided by the University of Nebraska group (Prof. Klopfenstein) and modified for use in our own situation.

This method is based on the assumption that neutral detergent insoluble protein (**NDIP**; ie., NDIN x 6.25) represents the potentially rumen-undegradable fraction of the CP.

Escape protein content or UDP was determined in extrusa samples pooled across paddocks, and from interim samples collected from C paddock alone, using the procedures of Mass *et al.* (1996). Analysis for NDIN was done for pooled residues at 6, 9, 13, 16, and 24 h, and the rate of disappearance of NDIN (k_d) was calculated as the slope of the regression line for the natural log of NDIN remaining (% of initial sample) versus time of incubation (h). Using an assumed passage rate (k_p) of 0.02 h^{-1}, UDP content of the extrusa was calculated using the formula:

$$UDP = (k_p / (k_p + k_d)) * \text{potential NDIN pool} * 6.25$$

The potential NDIN pool was estimated as grams of NDIN/gram of sample in the extrusa. No correction was made for the ADIN content of the extrusa sample or of residues at the various incubation times. The RDP content was assumed to be the difference between the total CP available and UDP; ie., RDP = CP - UDP.

3.3 Results

3.3.1 SEASONAL CONDITIONS

Total annual rainfall recordings for 1994/95 and 1995/96 were similar to the long-term average (see Table 3.2), but above-average rainfall in April/May of both years ensured high soil moisture reserves throughout the winter/spring period.

Table 3.2. Rainfall recordings (mm) on experimental area and long-term mean for the station (Stn avge)

Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
1994/95	0	0	16	43	39	156	133	13	42	64	84	10	600
1995/96	0	5	116	57	113	67	220	47	6	43	86	9	769
1996/97	21	0	55	76									
Stn avge.	36	31	34	64	75	109	97	95	48	43	49	27	708

3.3.2 PASTURE PRESENTATION YIELD AND DIET SELECTION

3.3.2.1 Species and plant parts

Pasture presentation yield (total) was slightly in excess of 2 t/ha at the commencement of the study in October 1994 and, except for short periods at the end of winter in both years, was subsequently maintained at a level in excess of 3 t/ha throughout (see Figure 3.1). Yields of green grass leaf and stem (all species) are also shown in this figure. The yield of green grass leaf in the pasture varied widely between seasons from a low of 45 kg/ha in October 1994 to a high of 1043 kg/ha in November 1995; the average yield was 500 kg/ha. Its proportion of the total yield also varied over a wide range (2 to 30%; average 15%), with the maximum and minimum values occurring in the same months as outlined above. Only during the December 1994 to February 1995 and November 1995 to February 1996 periods

did the proportion exceed 20%. By comparison, the yield of green grass stem ranged from 739 kg/ha in October 1994 to 2123 kg/ha in February 1996, and its proportion of the total presentation yield varied over a narrower range (30 to 52%; average 45%) than for the leaf fraction.

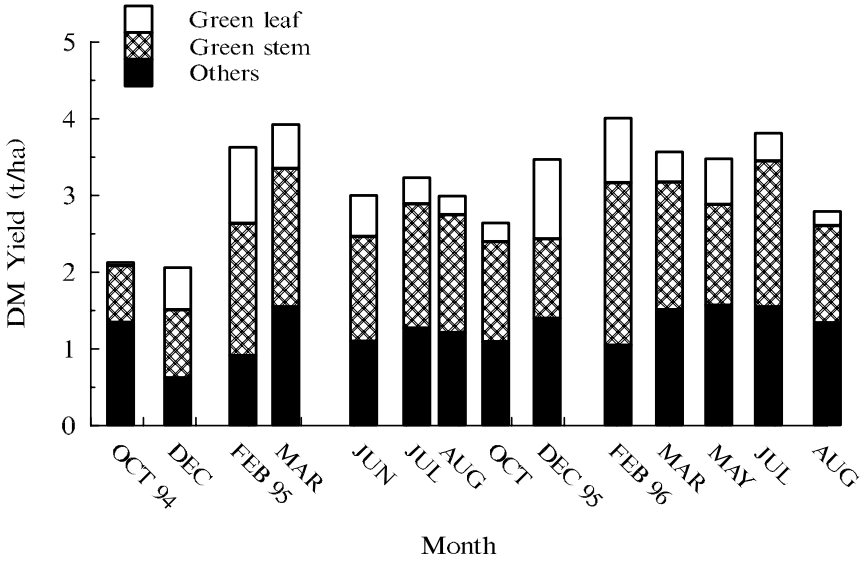

Figure 3.1. Presentation yield of total pasture and of various components, i.e., green grass leaf and stem. The 'Others' component refers to dead grass leaf and stem, forbs, stylo etc.

Changes in the proportions of the major grass species (buffel) and legume (Seca) in the pasture on offer, and in the diet, are shown in Figure 3.2. Buffel grass was the predominant plant species in the pasture, its contribution varying between 73 and 89% of the total DM on offer over the course of the experiment. However, the proportion of buffel grass in the diet varied over a much wider range, with a minimum value of 40% in November 1995 and a maximum of 88% in May 1996. Seca generally comprised a minor component of the pasture on offer (maximum of 9% in February 1996), but at times represented a much larger component of the diet, reaching a peak in the February-March period each year with values as high as 29% of the diet. Rhodes grass comprised one-third of the diet selected in the period July to October 1995, despite only representing 5% on average of the DM on offer. The data indicated that, on the basis of pasture and diet composition, the animals obviously selected for the 'other grass' component but against *Dicanthium* spp. for most of the year.

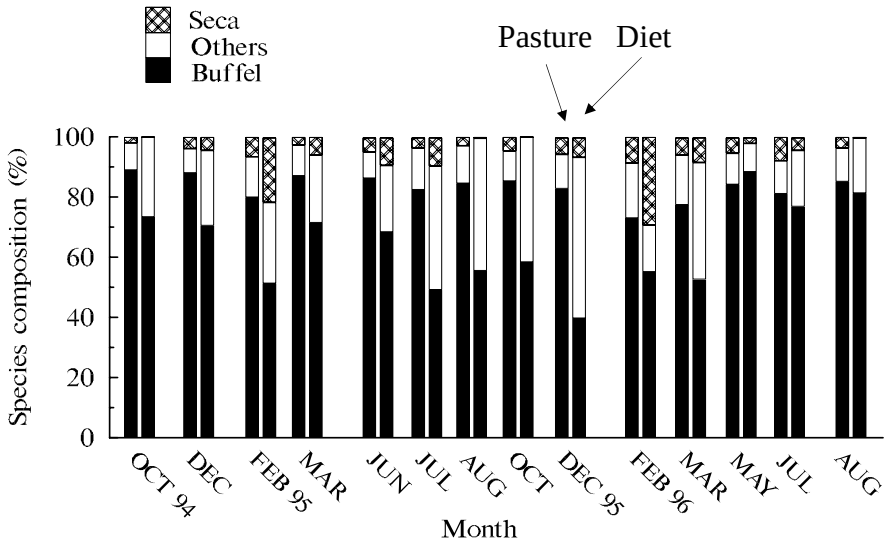

Figure 3.2. Proportion of buffel grass, Seca and other species in the pasture (left) and the diet (right).

In general, selection of green grass (combined leaf and stem) in the diet was proportional to that on offer in the pasture. Exceptions occurred in the wet periods around November 1995 and May 1996, when composition of green grass in the diet was, on average, 34% greater than that in the pasture, and in the drier months of February and March 1996 when green grass content in the diet was 34% lower than in the pasture. Considering the leaf fractions of this green grass component separately indicates that the animals always selected a much higher proportion of green grass leaf in the diet (three-fold difference on average) than was available in the pasture. This was especially evident in the drier months of the year.

3.3.2.2 Chemical composition

The chemical composition of the green leaf component of the major plant species, and of various components of the buffel grass, at the various sampling dates are shown in Table 3.3. Within species, the CP content and digestibility of the green leaf component varied widely over the trial period, in line with changing seasonal, especially rainfall, conditions. Nevertheless, the CP content of buffel green leaf always exceeded 6.25% (1% N) and usually 10%, and its IVOMD exceeded 60% at all except two sampling dates (February and November 1995). Between grass species, there were sometimes quite large differences in the CP content of the green leaf component, with Rhodes grass tending to be lowest and the 'other grass' the highest in this attribute; buffel grass was intermediate. Seca leaf was usually considerably higher in CP content than the grasses, ranging from 13.1 to 22.5%. Rhodes grass leaf also tended to have the lowest IVOMD, whilst buffel leaf was usually highest. For most sampling dates, Seca leaf was lower in IVOMD than buffel green leaf. The low quality of the other components of the buffel grass, viz., green stem and dead leaf and stem, is highlighted by the fact that only in rare instances did CP content exceed 6.25%, and IVOMD was usually well below 50%.

Figure 3.3 illustrates, for buffel grass, changes in the CP content and IVOMD of the total plant (green and dead, leaf and stem) and the total green (green leaf and green stem) material, relative to the green leaf alone. The composition of the total green and total plant material was estimated based on the proportions of their various components, and the chemical composition of those components. The markedly higher quality of the green leaf compared to the other groupings, throughout the sampling period, is clearly demonstrated.

In general, there were only small differences in either CP content or IVOMD between the total green and total plant material.

Changes in the chemical composition of the extrusa collected from oesophageal-fistulated steers are documented for the total experimental period in Table 3.4. The OM contents of the extrusa were similar to those of the corresponding buffel green leaf (see Table 3.3), indicating minimal levels of saliva in the samples analysed. A comparison of the CP content and digestibility (IVOMD) of the extrusa with that of the buffel green leaf is presented in Figure 3.4. Crude protein content of the extrusa varied over a narrower range than for the green leaf, and was usually lower than for the leaf, although not in the December 1994 to February 1995 period or in November 1995, when it was marginally higher. Extrusa CP content exceeded 6.25% for most of the experimental period, the main exceptions being in the short, dry periods of the 1995 and 1996 winters but also in October 1994 and March 1996 when conditions were dry. Similarly, the IVOMD of the green leaf fraction was higher than for extrusa, except in the December-February period of both years. Extrusa digestibility exceeded 60% during the growing seasons but was slightly below this level (55-60%) in the drier part of the year from July to October 1995 and in August 1996.

Seasonal changes in the OM digestibility of extrusa, as determined using the nylon bag technique, viz. the potential degradability (PD) and effective degradability (ED), paralleled the changes in IVOMD (see Figure 3.5). In turn, these estimates of digestibility of the diet followed the reverse trend to changes in the NDF and ADF content, with the higher contents of fibre corresponding to lower digestibility, and *vice versa* (Figure 3.5). The dietary content of ADF and that of NDF followed a similar pattern of change, but with ADF tending to vary over a slightly narrower range (36.0 to 44.1%) than NDF (56.5 to 70.3%).

Crude protein content was expressed in relation to digestible OM (**DOM**) content, ie., g CP/kg DOM, in Table 3.4. Values followed the same seasonal trend as for CP with highest values occurring in December 1994 and May 1996.

Table 3.3. Chemical composition of major pasture species and their components (summary)

	Oct '94	Dec '94	Feb '95	Mar '95	Jun '95	Jul '95	Aug '95	Oct '95	Nov '95	Feb '96	Mar '96	May '96	Jul '96	Aug '96	Oct '96
CP (% DM)															
Gn leaf-Rhodes	9.4	10.0	8.3	9.4	9.4	8.1	8.8	10.6	6.3	7.1	6.0	11.2	8.9	10.1	
blue grs		11.5	9.2	12.7	14.4	10.6	10.6	11.3	8.8	6.1	6.6	12.9	10.8	8.8	
othr grs	9.4	15.8	13.5	12.2	16.3	11.9	15.0	11.3	12.5	10.7	6.2	15.8	16.4	14.6	
Seca	15.6	14.7	16.4	17.7	22.5	18.1	20.6	19.4	19.4	16.2	13.1	20.5	19.3	19.3	
buffel	**19.4**	**11.1**	**6.9**	**12.2**	**15.6**	**8.8**	**11.3**	**13.1**	**8.1**	**16.5**	**6.6**	**13.8**	**11.3**	**12.6**	
Dd leaf- buffel	3.8	3.9	2.8	3.5	3.8	3.1	2.5	3.8	5.0	6.8	2.4	1.9	2.3	2.6	
Gn stem- buffel	5.0	4.0	2.5	3.2	3.1	3.1	2.5	3.1	4.4	7.4	2.8	2.5	2.6	2.0	
Dd stem- buffel	2.5	2.1	1.9	2.2	2.5	1.9	1.9	2.5	3.1	4.4	2.6	1.7	1.8	1.4	
Total gn buffel	**5.8**[A]	**6.6**	**4.2**	**5.4**	**6.6**	**4.0**	**3.7**	**4.5**	**6.3**	**9.9**	**3.5**	**7.5**	**3.8**	**3.2**	
Total buffel	**4.1**[A]	**5.6**	**3.8**	**4.4**	**5.5**	**3.5**	**3.1**	**4.0**	**5.2**	**9.3**	**3.1**	**4.2**	**3.3**	**2.7**	
IVOMD (%)															
Gn leaf-Rhodes	48.7	66.3	55.2	54.8	50.1	54.7	48.3	58.1	52.6	51.8	45.1	59.0	57.7	62.6	
blue grs		66.0	62.8	65.3				62.0	61.4	59.6	59.2	69.0	63.2	61.5	
othr grs		69.9	57.2	54.2	55.2	59.9	59.2	54.7	55.2	52.6	47.0	69.2	64.7	62.7	
Seca	60.0	65.1	61.6	61.6	66.3	61.5	61.1	63.1	63.9	65.1	57.7	72.7	58.1	61.8	
buffel	**62.7**	**67.4**	**57.6**	**64.6**	**73.3**	**65.5**	**64.1**	**64.6**	**57.6**	**63.3**	**61.4**	**76.3**	**71.0**	**72.2**	
Dd leaf- buffel	51.8	43.3	42.3	43.1	33.7	39.5	39.7	25.1	35.3	46.5	49.5	[B]	43.0	44.7	
Gn stem- buffel	23.4	43.8	37.2	32.0	39.6	34.6	29.0	26.2	40.2	40.9	34.0	27.0	28.2	28.4	
Dd stem- buffel	17.1	23.0	25.4	22.4	18.7	23.2	17.2	14.1	10.9	29.7	20.8	17.2	15.3	15.5	
Total gn buffel	**25.5**	**52.5**	**45.1**	**40.0**	**48.9**	**39.6**	**33.7**	**31.6**	**49.2**	**47.1**	**39.0**	**48.7**	**34.5**	**33.5**	
Total buffel	**27.9**	**46.7**	**42.8**	**36.7**	**41.7**	**37.3**	**31.4**	**26.8**	**36.2**	**46.2**	**40.0**	**[B]**	**33.8**	**30.8**	
OM (% DM)															
Gn leaf- **buffel**	**92.4**	**88.9**	**87.7**	**88.1**	**87.7**	**87.2**	**86.8**	**88.0**	**87.6**	**88.3**	**90.6**	**89.1**	**85.7**	**87.3**	

[A] Estimated using the proportions of the various components of the buffel plant, ie., green leaf & stem, dead leaf & stem and their known chemical compositions

[B] To be re-analysed.

Gn - green; Dd - dead; grs - grass. A description of the major pasture species is given in the text (Materials and methods section)

Table 3.4 Chemical composition of oesophageal-fistulae extrusa samples (mean of all paddocks)

	Oct '94	Dec `94	Feb '95	Mar '95	Jun '95	Jul '95	Aug '95	Oct '95	Nov '95	Feb '96	Mar '96	May '96	Jul '96	Aug '96	Oct '96
OM (% DM)	88.4	86.7	87.6	87.4	87.5	86.9	88.5	88.0	86.1	86.9	86.5	86.5	86.5	87.9	
ADF (% DM)	44.1	36.0	39.9	39.1	39.9	39.0	42.1	41.1	40.5	41.2	40.4	36.6	36.9	41.7	
NDF (% DM)	66.7	58.5	61.5	64.0	63.1	65.2	70.3	69.5	61.1	59.6	59.8	56.5	60.8	63.0	
SCHO (%DM)															
PD of OM (%)	70.2	77.6	71.0	70.9	68.2	66.1	59.2	67.7	77.8	66.7	68.5	78.0	69.9	63.7	
ED of OM (%)	54.4	62.9	59.6	57.0	55.3	52.4	43.8	54.1	62.8	53.1	52.9	63.0	54.8	47.5	
IVOMD (%)	61.1	71.4	64.0	63.0	60.9	58.9	56.6	56.6	70.3	62.8	60.5	70.8	64.1	55.9	
CP (% DM)	5.0	11.9	8.8	8.4	8.3	5.8	4.9	7.2	9.3	8.4	4.7	11.3	6.0	4.6	
(g/kg DOM)	93	192	157	153	156	113	98	145	154	154	90	185	108	94	
UDP (% DM)	0.83	1.22	1.13	1.16	1.13	1.39	0.92	0.93	1.11	1.13	0.84	0.47	0.73	0.79	
(% CP)	16.5	10.2	12.8	13.8	13.7	24.0	18.7	13.0	11.9	13.5	17.9	4.2	12.1	16.7	
RDP (% DM)	4.20	10.75	7.66	7.24	7.16	4.41	3.98	6.25	8.18	7.27	3.86	10.81	5.30	3.86	
(% CP)	83.5	89.8	87.2	86.2	86.3	76.0	81.3	87.0	88.1	86.5	82.1	95.8	87.9	83.3	
(g/kg DOM)	78	174	137	131	134	86	79	125	135	133	74	177	96	79	
ADIP (% DM)	0.38	0.74	0.55	0.40	0.56	0.61	0.04	0.66	0.16	0.98	0.14	0.05	0.07	0.01	
(% CP)	7.6	6.2	4.5	4.7	6.7	10.5	0.8	9.2	1.7	11.7	3.0	0.4	1.2	0.2	
NDIP (% DM)	1.78	5.15	3.34	3.66	3.35	2.91	1.94	3.06	3.93	3.44	1.87	2.73	2.27	1.65	
(% CP)	35.4	43.1	38.0	43.6	40.4	50.1	39.7	42.6	42.3	40.9	39.9	24.2	37.6	35.6	

SCHO - soluble carbohydrate
PD of OM - potential degradability of organic matter (ie., A + B)
ED of OM - effective degradability of organic matter, assuming rumen outflow rate (kp) of 0.02
UDP - undegraded dietary protein (estimated from NDIP disappearance; assuming passage rate through rumen (kp) of 0.02)
RDP - rumen degradable protein (100 - UDP); g/kg DOM = g/100 kg DM x 100/OM% x 100/IVOMD
ADIP - acid detergent insoluble protein (assumed to be lignified protein)
NDIP - neutral detergent insoluble protein (assumed to be fibre-bound and lignified protein)

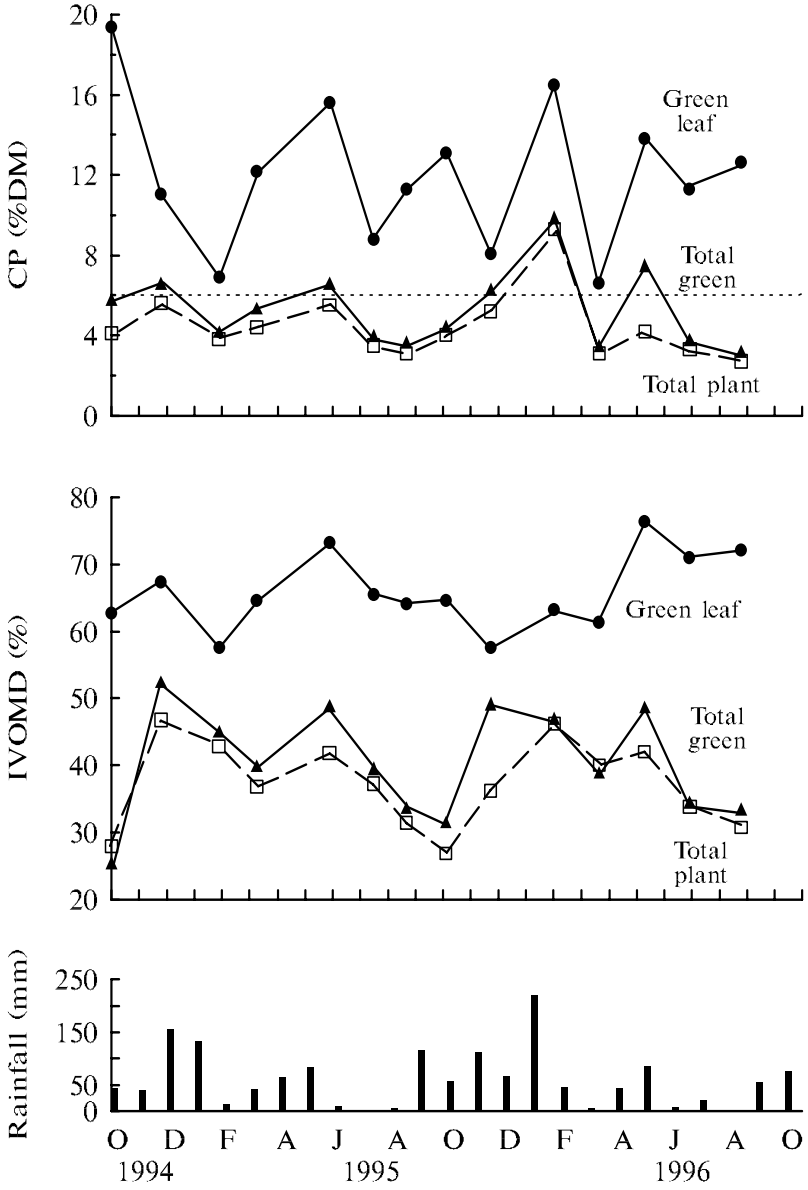

Figure 3.3. Changes across seasons in the in vitro *organic matter digestibility (IVOMD) and crude protein (CP) content of green grass leaf (●), total green material (leaf + stem; ♦) and total plant material (□) for buffel grass, and the monthly rainfall recordings on the trial site.*

The concentrations of acid detergent insoluble protein (**ADIP**) and NDIP for the various diet extrusa samples are shown in Table 3.4. Concentrations of ADIP were always low, being <1% on a DM and <12% on a CP basis, and there was no clear pattern of change over seasons. NDIP content was considerably higher at all sampling times and although never exceeding 5% of DM, it represented up to 50% of the CP in the diet. The trend was for NDIP to represent a relatively constant proportion of the CP on offer, with the result that its concentration on a DM basis followed the same seasonal pattern of change as total CP content (see above). The major exception was in May 1996, corresponding with the heavy unseasonal Autumn rain, when NDIP reached its lowest concentration (24.2% of CP).

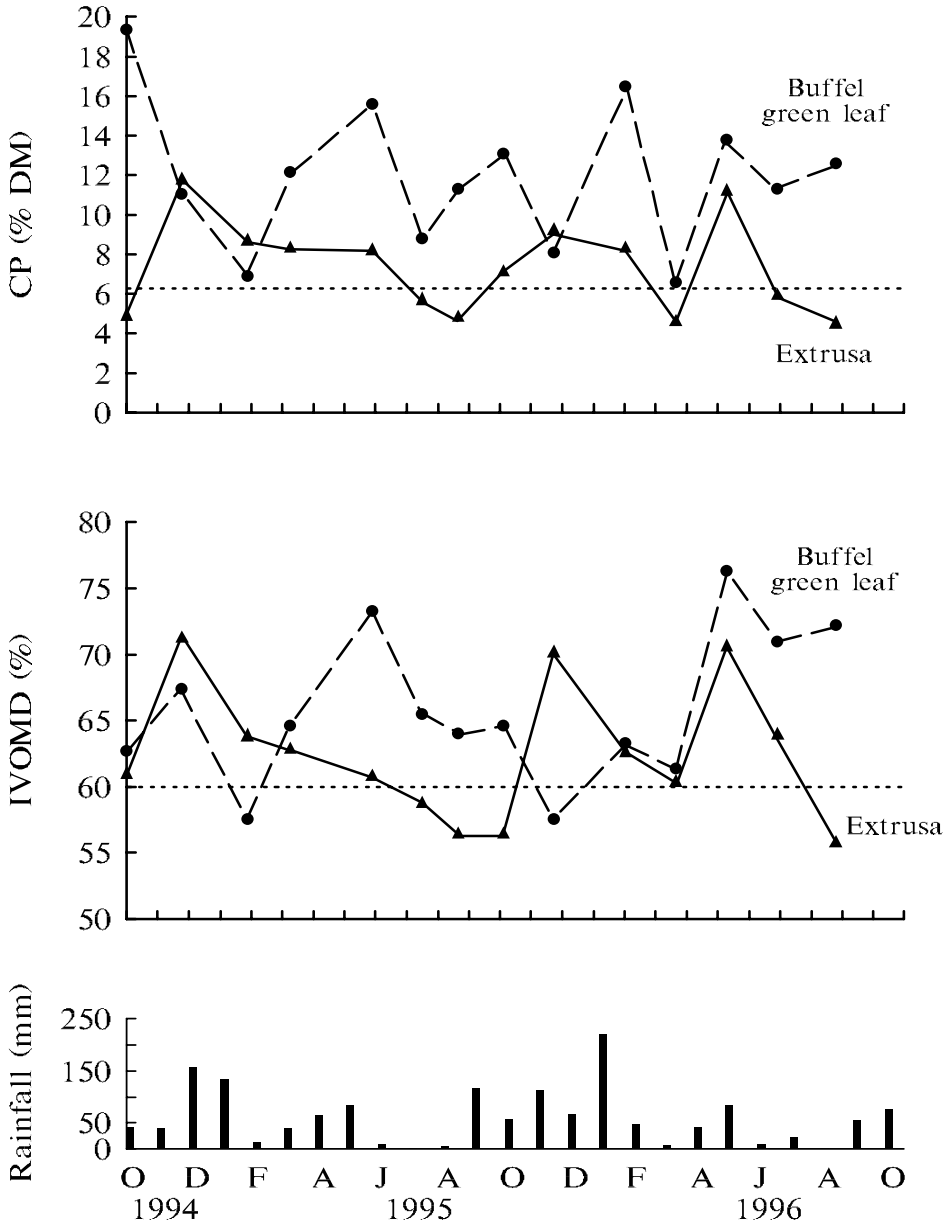

Figure 3.4. Changes across seasons in the in vitro *organic matter digestibility (IVOMD) and crude protein (CP) content of buffel grass green leaf and of the diet, collected as extrusa from oesophageal-fistulated steers, and the monthly rainfall recordings on the trial site.* The dotted lines indicate 6.25% CP and 60% IVOMD.

3.3.2.3 Protein degradability of extrusa samples

The estimated contents of UDP and RDP in the extrusa samples, expressed both on a DM and CP basis, are documented in Table 3.4, and the patterns of change over seasons are shown in Figure 3.6.

The data indicate that the major component of the dietary CP was RDP, which exceeded 75% of the total CP in all months and attained values approaching 11% of DM at two sampling times. The trend was for RDP content (DM basis) to change in parallel with total CP content, whilst UDP content remained relatively constant across seasons (Figure 3.6), except for a high point in July 1995 and a low one in May 1996. Consequently, when

expressed as a proportion of total CP, UDP described the reverse pattern to total CP across seasons whilst RDP was a relatively constant, high proportion of CP (Table 3.4). The highest RDP level (95.8% CP), and by corollary the lowest UDP level, occurred in May 1996.

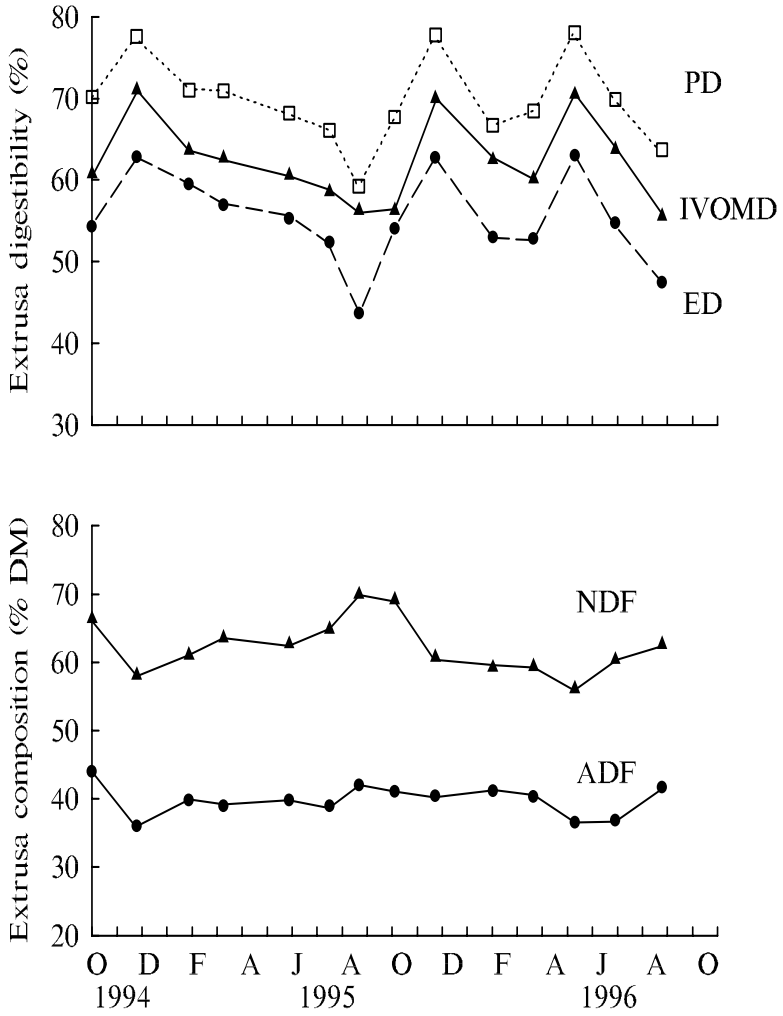

Figure 3.5. Changes across seasons in the ADF and NDF content, and in the IVOMD, potential digestibility (PD) and effective degradability (ED; kp of 0.02 /h assumed) of extrusa collected from oesophageal-fistulated animals on the trial area.

Figure 3.6 also illustrates changes in the concentration of RDP when expressed in relation to the estimated supply of digestible OM (DOM), which was in turn calculated from the IVOMD values. The pattern of change was similar to that described for RDP expressed as a proportion of DM. The constant value describing the point below which microbial protein synthesis is considered to be limited by protein supply in the rumen (123 g CP/kg DOM; Klopfenstein, 1996) is also shown. RDP content was below this threshold during the dry months and was only marginally above it during much of the remainder of the experimental period, with the exceptions of December 1994 and May 1996.

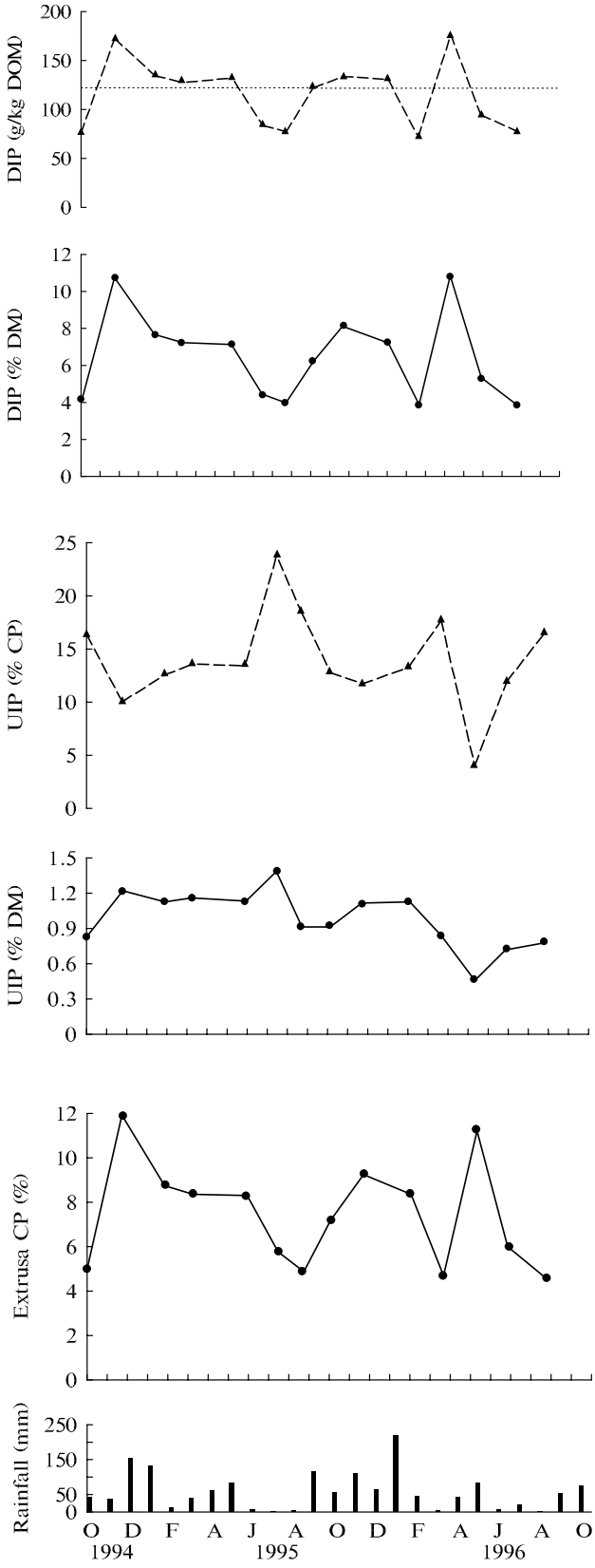

Figure 3.6. Changes in the content of crude protein (CP) and of undegraded dietary (UDP) and rumen degraded (RDP) protein in extrusa samples taken across seasons, and the rainfall recordings on the trial area. The dotted line indicates a concentration of 123 g CP/kg digestible organic matter (DOM), the concentration below which microbial protein synthesis is limited by protein supply in the rumen.

Estimates were made (using the model, Cambeef) of the amounts of RDP and UDP an 18 month old, 250 kg Brahman crossbred steer would have consumed from the pasture at the various sampling dates (see Figure 3.7). These estimates were based on the CP content and IVOMD of the diet, and estimates of the proportion of that CP which was RDP, as outlined above. In the absence of actual feed DM intake data, separate estimates were made to cover the likely extremes of DM intakes, ie., for DM intakes of 2% and 3% of bodyweight (BW). Intakes probably approach the lower value during the dry period of the year whilst animals consuming new, young growth at the beginning of the wet season would be expected to consume 3% of BW. Also shown in the figure are the theoretical requirements for RDP and UDP for this 'standard' animal in order to grow at either 0.5 or 0.8 kg/d.

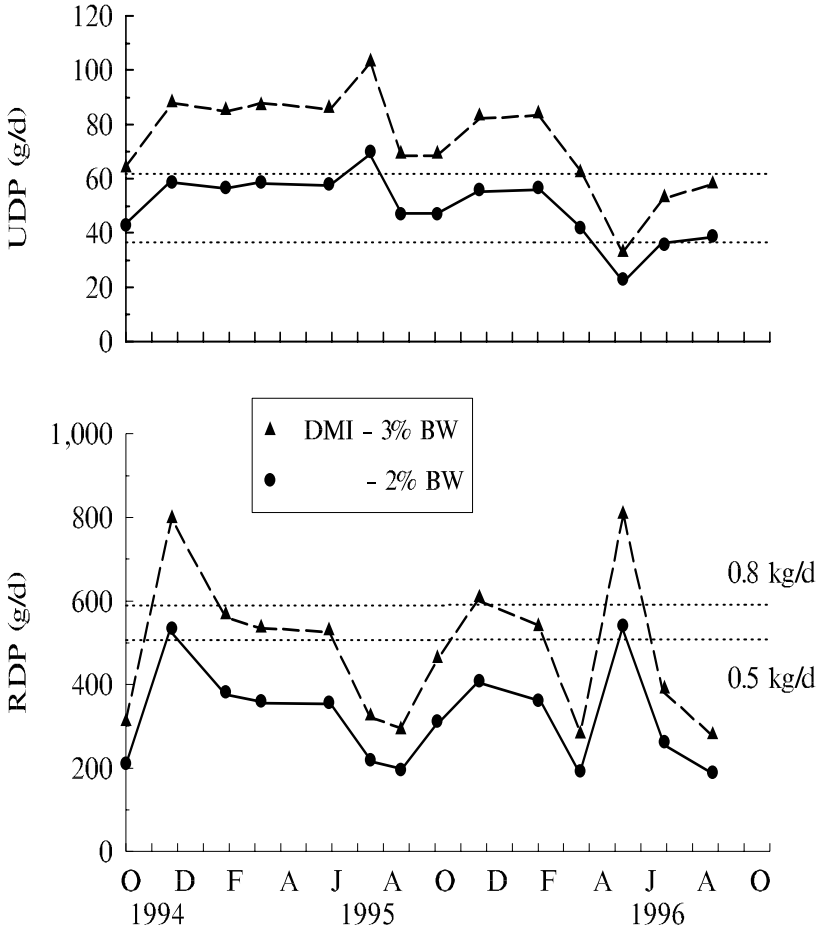

Figure 3.7. Changes in the supply of RDP and UDP from the diet, estimated using Cambeef, for an 18 month-old, 250 kg Brahman crossbred steer consuming pasture at 3% (triangles) or 2% (circles) of BW, in relation to the estimated requirements for growth at 0.5 or 0.8 kg/d (dotted horizontal lines).

With DM intake set at 2% of BW, RDP intake was always below requirements for growth at 0.8 kg/d and, except in December 1994 and May 1996, was also insufficient for a growth rate of 0.5 kg/d. At the higher rate of DM intake, RDP intake exceeded requirements for growth at 0.8 kg/d only at the two samplings previously mentioned, but was adequate for growth at 0.5 kg/d except during the dry months of the year. By contrast, at both levels of DM intake UDP requirements were met for growth at 0.5 kg/d in all months except May 1996. Intake of UDP was sufficient to achieve the higher growth rate only when DM intake was 3% of BW, and even then not between May and August 1996.

3.3.2.4 Growth rate of unsupplemented steers

Growth rates of unsupplemented control steers from the various drafts of cattle have been plotted for each 28 d period, irrespective of changes in seasonal conditions, in Figure 3.8. In general, growth rates reflect seasonal (rainfall) conditions, with rates in excess of 1.2 kg/d for short periods during the 1995 and 1996 wet seasons, and rates equivalent to maintenance or below for short periods during the dry periods. The extreme nature of the seasons is reflected in the rapid decline in growth rate in the March to May 1996 period.

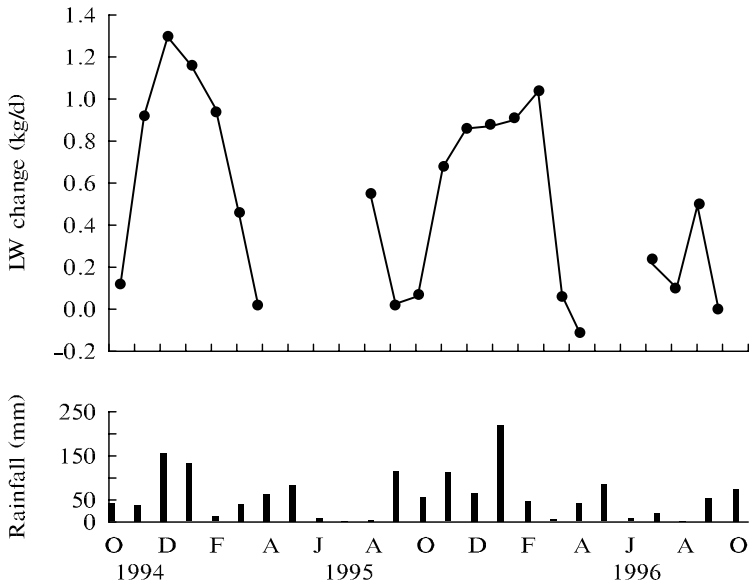

Figure 3.8. Monthly changes in growth rate of unsupplemented steers, and the rainfall recordings, over the experimental period.

The relationships between growth rate and various parameters describing pasture and diet availability and quality have been examined. For this exercise, the growth rates had to be aligned in some way to the sampling dates used throughout the experiment. The monthly growth rates calculated and presented in Figure 3.8 did not satisfy this requirement. Hence growth rates were instead arbitrarily assigned to sampling dates by including liveweight changes encompassing the period before and after the sampling time, with cognisance of rainfall events and their likely influence on the quality of the diet at the particular sampling date. This growth rate refers to periods ranging in duration from 21 to 84 d, with the longer periods usually occurring during the growing season.

In this experiment, animal production measured as average daily gain (**ADG**) was not correlated with yield (DM) of total pasture, of green pasture or of stylo but was correlated with yield of green grass leaf (kg DM/ha) and the proportion of green grass leaf in the total pasture (% of total DM presentation yield). These relationships are shown below:

1. ADG = 0.013 + 0.0009 GGLY, (R^2 = 0.62);
   where ADG is average daily gain (kg/d) and GGLY is green grass leaf yield (kg/ha).

2. ADG = 0.080 + 0.0359 GGLP, (R^2 = 0.78);
   where GGLP is green grass leaf in pasture (% of total DM).

The correlation between ADG and green grass leaf proportion was only marginally improved when the CP content and IVOMD of the buffel green leaf fraction were included in the multiple regression, as indicated below:

3. ADG = -0.287 + 0.3749 GGLP + 0.1522 $BGLCP^2$ + 0.000014 $BGLD^3$; (R^2 = 0.81);
where BGLCP and BGLD are buffel green leaf CP (% DM) and IVOMD (%) respectively.

When diet green grass leaf proportion (% of total diet) was correlated with pasture green grass leaf proportion, 61% of the variation was accounted for. However, when diet green grass leaf proportion was regressed against ADG, the relationship was poor with only 35% of the variation accounted for when all the data was considered, as is shown below:

4. ADG = -0.191 + 0.0136 GGLD, (R^2 = 0.35);
where GGLD is green grass leaf in diet (% DM)

The relationships between daily growth rate and the CP content or digestibility of the diet (extrusa) are also shown below:

5. ADG = -0.422 + 0.1240 ECP, (R^2 = 0.59);
where ECP is extrusa CP (% DM)

6. ADG = -2.573 + 0.0488 EOMD, (R^2 = 0.43);
where EOMD is extrusa IVOMD (%).

Plots showing the relationships between ADG and the proportion of green grass leaf in the pasture and in the diet are illustrated in Figure 3.9.

3.3.2.5 Supplement intake and liveweight response to supplementation

1994-95 wet season

Cumulative liveweight changes for the unsupplemented steers, and for steers from the high-intake groups of the CSM (1.5% BW) and sorghum (2.0% BW) treatments, for the 26 weeks of the 1994/95 wet season are illustrated in Figure 3.10. All groups showed rapid growth during the period November to February, but growth rates declined during the last six weeks (March-April). The supplemented groups grew slightly faster than the controls over the total period, but the main response occurred during this final 6 week period. Consequently, the responses to supplementation will be considered separately for weeks 4-20, and weeks 21-26 (see Figure 3.11); weeks 1-3 represent the equilibration period when supplement intakes were being increased to treatment levels, and are not included in the analysis.

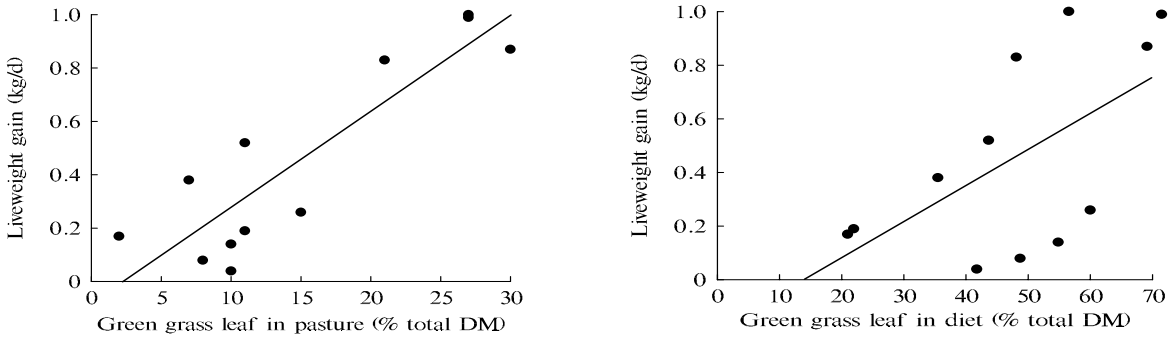

Figure 3.9. Relationships between average daily gain of steers at various times over the

experimental period and the proportion of green grass leaf in the pasture (left) or in the diet (right). Points represent the various sampling dates.

For weeks 4-20, supplement intakes for the CSM groups approached those intended at all levels of feeding (0.3-1.5% BW). Actual intakes of CSM (as fed) equated to (group average) 0.69, 1.40, 2.12, 2.71 and 3.44 kg/d respectively as intake on a BW basis was increased from 0.3 to 1.5%. High CSM intakes were also achieved during weeks 21-26, and the corresponding actual intakes were 0.91, 1.86, 2.90, 3.66 and 4.65 kg/d. The desired sorghum intakes were also achieved at the lower levels of feeding, but intakes were slightly less than intended for the 1.2 to 2.0% BW groups for both periods (see Figure 3.11).. Actual intakes of the sorghum mix were 0.85, 1.67, 2.61, 3.20 and 3.98 for weeks 4-20 and 1.17, 2.26, 3.62, 4.36 and 5.41 for weeks 21-26, respectively, as proportional intake increased from 0.3 to 2.0% BW.

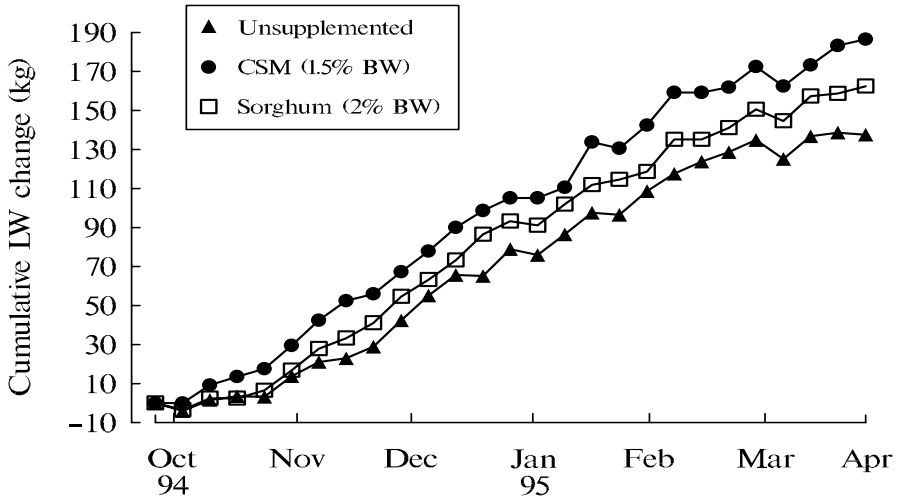

Figure 3.10. Liveweight changes of weaner steers grazing predominantly buffel grass pastures and either not supplemented or supplemented with cottonseed meal (CSM) at 1.5% BW or with sorghum at 2% BW during the 1994/95 wet season. Points represent the mean for six steers for the control group and for three steers for the supplemented groups.

The linear relationships between supplement intake (INTK; % BW) and liveweight gain (LWG; kg/d) are plotted in Figure 3.11 for the different supplements over the two periods described above. For weeks 4-20, when unsupplemented steers gained weight at the rate of 1.01 kg/d, the relationships were:

CSM: LWG = 1.019 + 0.163 INTK, (R^2 = 0..34)
Sorghum: LWG = 1.042 + 0.050 INTK, (R^2 = 0.08);

indicating a weak relationship between the two parameters for the grain supplement and a slightly better correlation for CSM treatments. The slope of the line for the CSM treatment indicated a trend for a small increase in liveweight gain with increasing intake of supplement, improving growth rate over the range of supplementation from about 1.0 kg/d to 1.2 or 1.25 kg/d. Note that these relationships above are derived by including individual data for each unsupplemented steer in the control group, whereas for simplicity of presentation, the

relationships plotted in Figure 3.11 are derived using a single mean value for the six control steers. There was only marginal difference in the relationships derived in the two different ways.

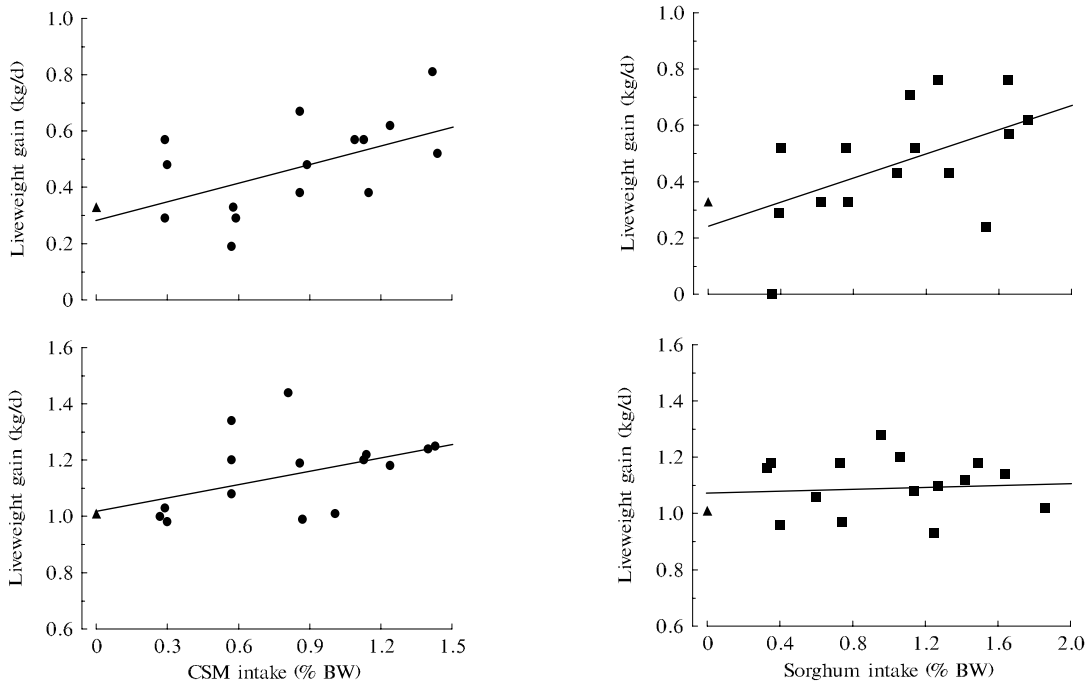

Figure 3.11. Effect of intake of supplements of cottonseed meal (CSM; ●) or sorghum (■) on the growth rate of weaner steers grazing predominantly buffel grass pastures during weeks 4-20 (bottom figure) and weeks 21-26 (top) of the 1994/95 wet season. Points represent individual animals except for the control group for which the point (♦) represents the mean for the six animals.

During weeks 21-26, growth rate for the control group declined to 0.33 kg/d and responses to supplementation were more evident, particularly with the sorghum supplement. The corresponding linear relationships during this period were as follows:

CSM: LWG = 0.311 + 0.203 INTK, (R^2 = 0.38)
Sorghum: LWG = 0.293 + 0.180 INTK, (R^2 = 0.34).

The slopes of the lines were similar for the two supplements, indicating a similar response relationship. The slope of the line for the CSM treatment was only marginally greater than for the equivalent treatments during weeks 4-20.

1995 dry season

The cumulative liveweight change of the unsupplemented steers, and of the steers from the high-intake groups of the CSM (1.5% BW) and sorghum (2.0% BW) treatments, for the 14 weeks of the 1995 dry season are illustrated in Figure 3.12. After the first four weeks, unsupplemented steers only maintained liveweight whilst the supplemented groups continued to gain weight throughout the feeding period. The liveweight responses to supplements of CSM or sorghum for weeks 4-14, excluding the first three week equilibration period, are illustrated in Figure 3.13.

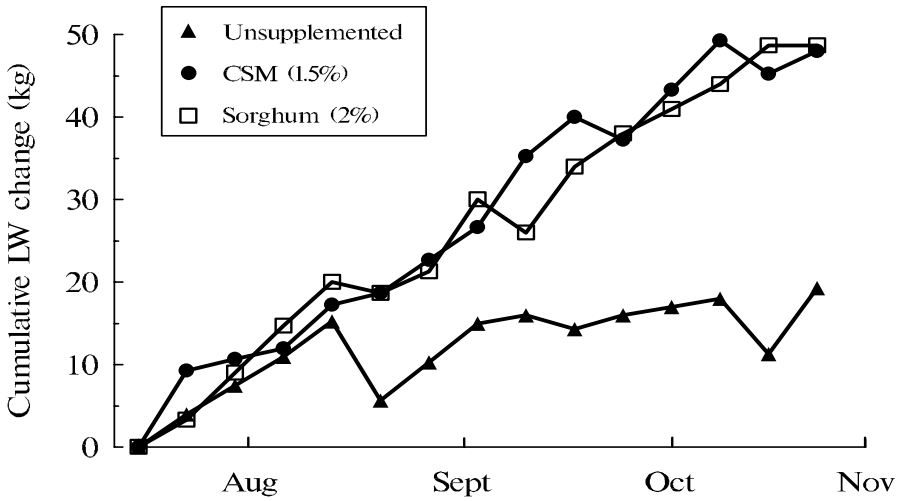

Figure 3.12. Liveweight changes of yearling steers grazing predominantly buffel grass pastures and either not supplemented or supplemented with cottonseed meal (CSM) at 1.5% BW or with sorghum at 2% BW during the 1995 dry season.

Over this period, the desired level of supplement intake was achieved or the intake was within 10% of the intended level for both supplements except at the highest level of sorghum feeding, when the mean intake for the group was 1.62% BW instead of the intended intake of 2% BW. Actual intakes of supplement were 1.22, 2.51, 3.94, 4.88 and 5.88 kg/d for CSM, and 1.60, 3.16, 4.99, 5.66 and 6.75 kg/d for sorghum as intakes on a BW basis increased from the lowest to highest level of feeding.

The linear functions describing the relationships between supplement intake (% BW) and liveweight gain for weeks 4-14 are as follows:

CSM: LWG = 0.148 + 0.304 INTK, (R^2 = 0.58)
Sorghum: LWG = 0.117 + 0.223 INTK, (R^2 = 0.72).

With both supplements the trend was for increased growth rate with increasing supplement intake, with growth rates peaking at about 0.6 kg/d at the highest level of feeding.

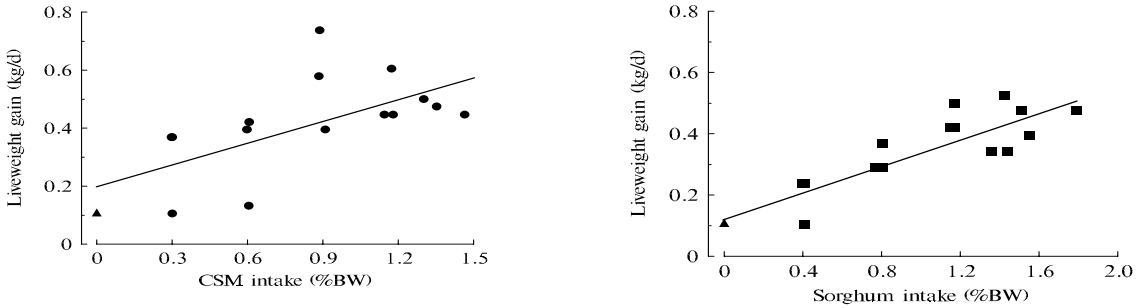

Figure 3.13. Effect of intake of supplements of cottonseed meal (CSM; ●) or sorghum (■) on the growth rate of weaner steers grazing predominantly buffel grass pastures during weeks 4-14 of the 1995 dry season. Points represent individual animals except for the control group for which the point (♦) represents the mean for the six animals.

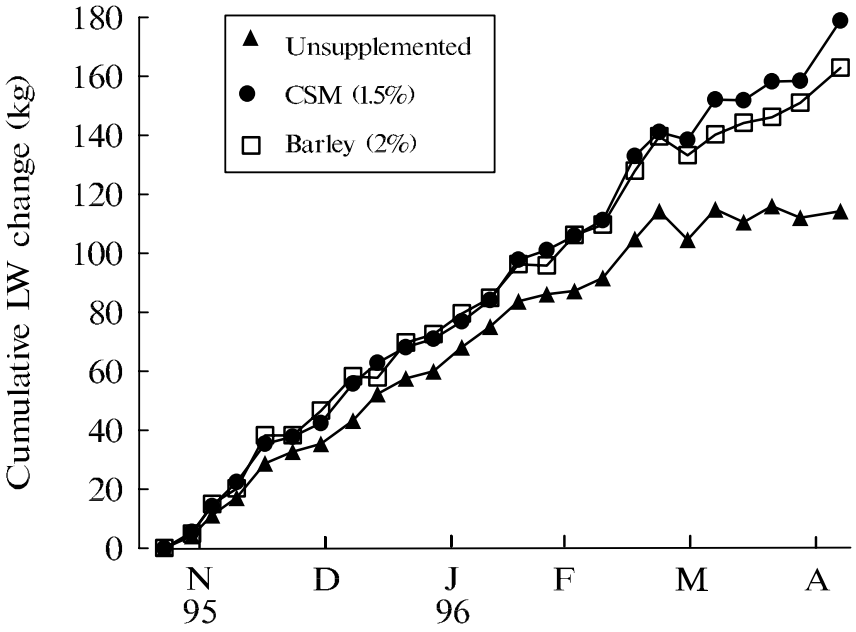

Figure 3.14. Liveweight changes of weaner steers grazing predominantly buffel grass pastures and either not supplemented or supplemented with cottonseed meal (CSM) at 1.5% BW or with barley at 2% BW during the 1995/96 wet season. Points represent the mean for six steers for the control group and for three steers for the supplemented groups.

1995/96 wet season

Figure 3.14 shows the cumulative liveweight changes for control group and for the 1.5% BW CSM and 2.0% BW barley groups, over the 27 weeks of the 1995/96 wet season. All groups gained weight rapidly between November 1995 and February 1996, but from late February until the end of April the control group only maintained weight whilst the supplemented groups continued to gain weight but at a slightly lower rate than in the early wet season. In keeping with these seasonal changes in growth rate, liveweight responses to supplementation are shown separately in Figure 3.15 for the initial period to the beginning of February (weeks 4-16) and for the latter period of the wet season (weeks 17-27).

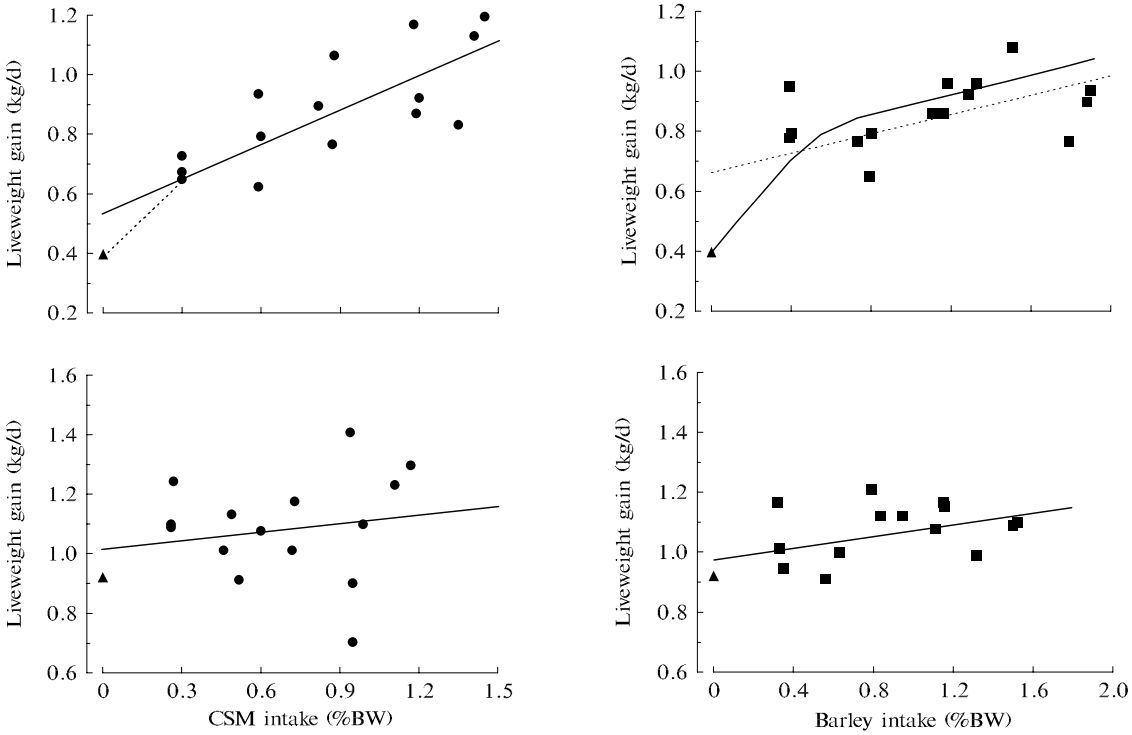

Figure 3.15. Effect of intake of supplements of cottonseed meal (CSM; ●) or barley (■) on the growth rate of weaner steers grazing predominantly buffel grass pastures during weeks 4-16 (bottom) and weeks 17-27 (top) of the 1995/96 wet season. Points represent individual animals except for the control group for which the point (♦) represents the mean for the six animals.

Supplement intakes were generally less than intended for both supplement types during the first period (weeks 4-16), with the major discrepancies occurring with higher intake treatments (see Figure 3.15). Actual intakes for this period were 0.60, 1.06, 1.53, 2.13 and 2.36 kg/d for CSM and 0.73, 1.32, 1.89, 2.55 and 3.22 kg/d for barley treatments. Intakes were closer to intended levels across all treatments in the second period (weeks 17-27), and the corresponding actual intakes were 0.92, 1.75, 2.63, 3.70 and 4.33 kg/d for CSM and 1.18, 2.24, 3.52, 4.31 and 5.65 kg/d for the barley treatments.

The linear functions describing the relationships between supplement intake and liveweight gain for the initial period, November to February, are shown in Figure 3.15 and are as follows:

CSM: LWG = 0.960 + 0.167 INTK, (R^2 = 0.15)
Barley: LWG = 0.947 + 0.129 INTK, (R^2 = 0.31),

indicating that for both supplements there was a positive relationship between the two parameters, albeit a poor relationship for CSM in particular. The small magnitude of the slope of the line in both cases suggested only a marginal increase in growth rate, from a base level of 0.92 kg/d for the controls, over the full range of supplementation. Similar relationships are plotted for the February to April period when the growth rate for unsupplemented steers had declined to 0.4 kg/d (Figure 3.15). These linear relationships are as follows:

CSM: LWG = 0.455 + 0.466 INTK, (R^2 = 0..77)
Barley: LWG = 0.510 + 0.279 INTK, (R^2 = 0..59).

Despite the high correlation coefficients, the plotted data indicate a curvilinear relationship, particularly for barley where the greatest increase in growth rate occurs with the first increment of supplement. Supplementation increased growth rates to approximately 1.0 kg/d with the higher levels of intake during this period.

1996 dry season

The cumulative liveweight changes for the control group and representative groups (1.2% BW groups) from the CSM and barley treatments, over the 10 weeks of the 1996 dry season, are shown in Figure 3.16. Throughout the feeding period, supplemented steers grew faster than the control steers which gained at 0.23 kg/d. The liveweight responses to supplement intake are shown in Figure 3.17.

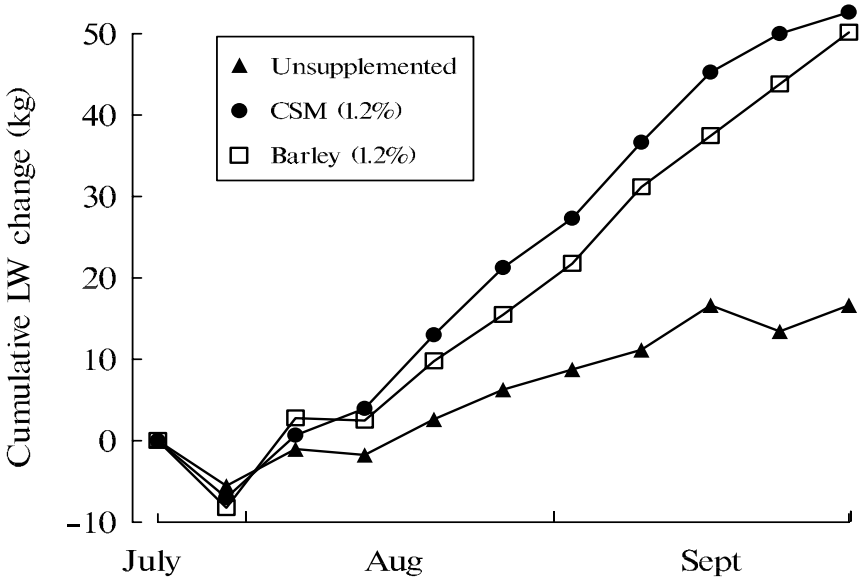

Figure 3.16. Liveweight changes of yearling steers grazing predominantly buffel grass pastures and either not supplemented or supplemented with cottonseed meal (CSM) at 1.2% BW or with barley at 1.2% BW during the 1996 dry season. Points represent the mean for six steers for the control group and for three steers for the supplemented groups.

The desired intake of supplement was achieved for all except the 1.5% BW group of the CSM treatment, and for all except the two highest intake groups of the barley treatment. The highest intake barley group only consumed supplement at 1.2% BW overall. Actual intakes were 0.57, 1.17, 1.71, 2.11 and 2.87 kg/d for the five CSM groups and 0.73, 1.71, 2.17, 2.58 and 2.41 kg/d for the five barley groups.

The linear relationships between supplement intake and liveweight gain for the two supplement types are as follows:

CSM: LWG = 0.273 + 0.453 INTK, (R^2 = 0.83)
Barley: LWG = 0.288 + 0.361 INTK, (R^2 = 0.62)

However, the data in Figure 3.17 suggests a curvilinear relationship between the two parameters for both supplement types, and a suggested response curve is drawn. Growth rates appear to plateau out at about 0.8 kg/d for the CSM treatments, and slightly lower for the barley groups.

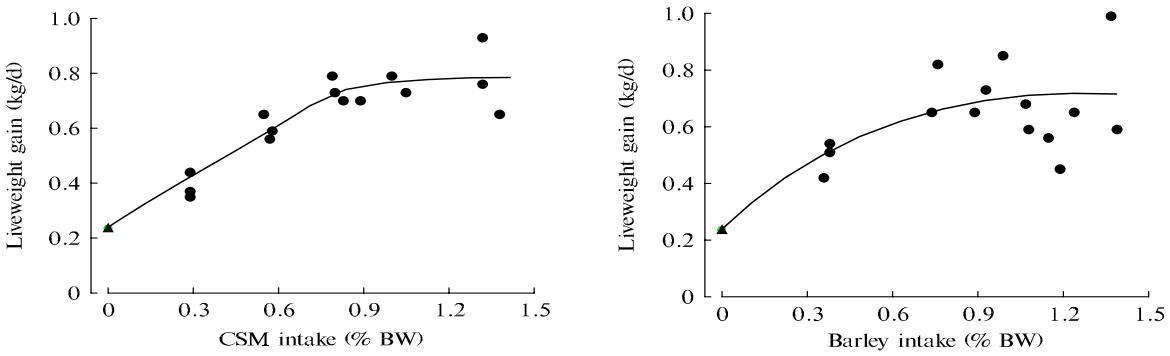

Figure 3.17. Effect of intake of supplements of cottonseed meal (CSM; ●) or barley (■) on the growth rate of weaner steers grazing predominantly buffel grass pastures during the 1996 dry season. Points represent individual animals except for the control group for which the point (♦) represents the mean for the six animals.

3.3.2.6 Rumen ammonia and plasma urea concentrations

Changes over time in the concentration of urea-N in the blood plasma of unsupplemented steers grazing the experimental area are illustrated in Figure 3.18. Values tended to follow seasonal patterns in pasture growth, with peak concentrations in December 1995 and May 1996 and lowest concentrations in the dry periods of July 1995, March/April and July/August 1996, but the concentration rarely fell below 4.2 mg/dL, the point at which other studies in north Queensland indicated a response to soluble N supplements would occur. The mean concentration of plasma urea-N was only 12% greater when measured 3.5 h after feeding compared with values obtained in the early morning, soon after mustering and before feeding.

The effects of supplement treatment on plasma urea-N concentration are illustrated in Figure 3.19. Feeding CSM was associated with a linear increase in urea-N concentration in the plasma whilst with sorghum or barley supplementation there was a slight increase at the lowest level of supplementation but no further increase with subsequent increments of supplement. A similar trend was evident for the concentrations of NH_3-N in rumen fluid (see Figure 3.19).

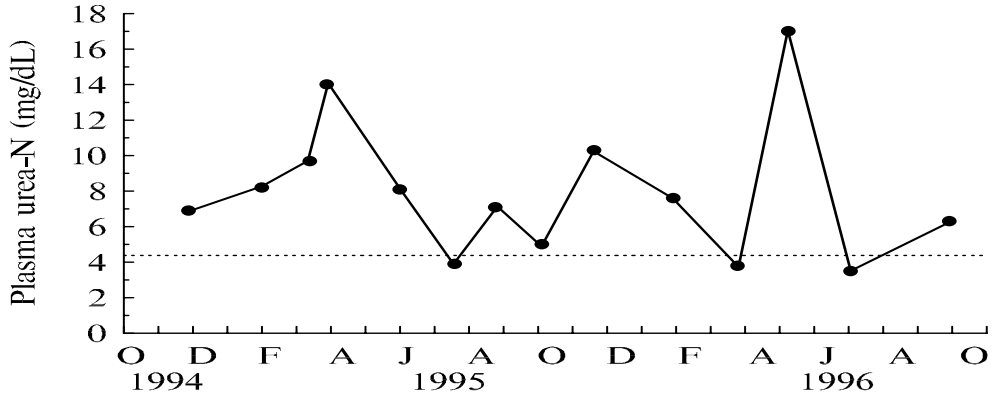

Figure 3.18. *Changes across seasons in the concentration of urea-N in the plasma of unsupplemented steers grazing the experimental area.* Points represent the mean for six steers. The dotted line denotes a concentration of 4.2 mg/dL.

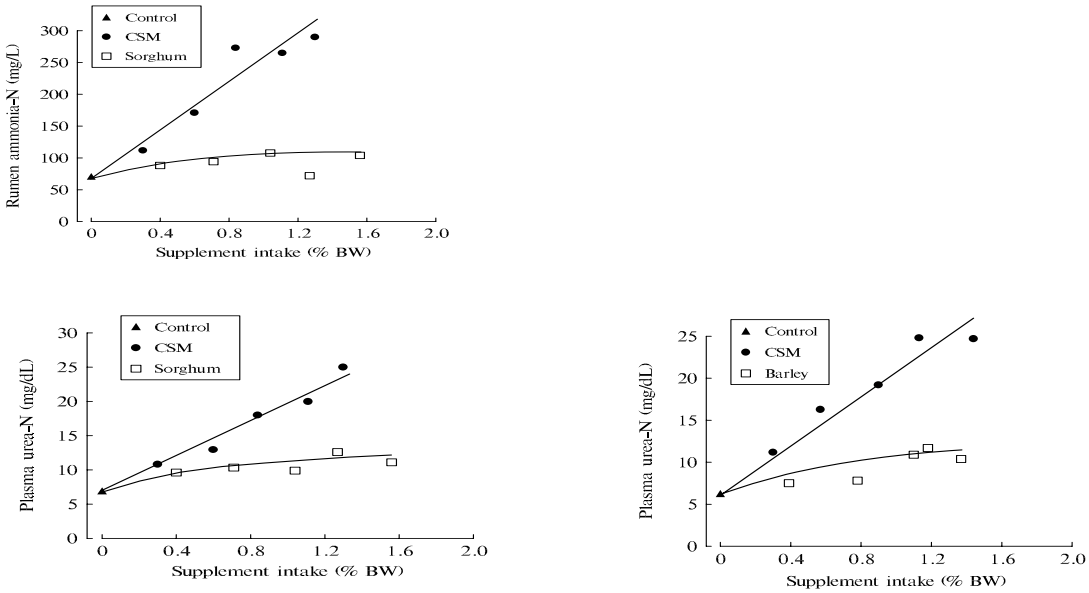

Figure 3.19. Effect of intake of supplements of cottonseed meal (all graphs), sorghum (bottom left; December 1994) or barley (bottom right; September 1996) on the concentrations of urea-N in plasma, and of CSM or sorghum on the concentration of ammonia-nitrogen (NH_3-N) in rumen fluid of steers grazing the experimental area (top left; December 1994). Points are the mean for three steers except for the control which is the mean for six steers.

3.3.2.7 Protozoa population density in rumen fluid

The changes in the population density of protozoa in rumen fluid of unsupplemented control steers from the commencement of the trial until April 1996 are shown in Figure 3.20. Generally, the population density was highest when pasture conditions were at their best during the wet season, and declined during the drier months. The composition (Genera; percentage of total) of the population was, on average, 65% small *Entodinium*, 10.3% *Dasytricha*, 7.8% *Eudiplodinium*, 7.3% *Ostracodinium*, 3.5 % *Isotricha*, with the remaining 6.1% comprising *Epidinium*, *Diplodinium*, *Metadinium* and *Elytroplastron*.

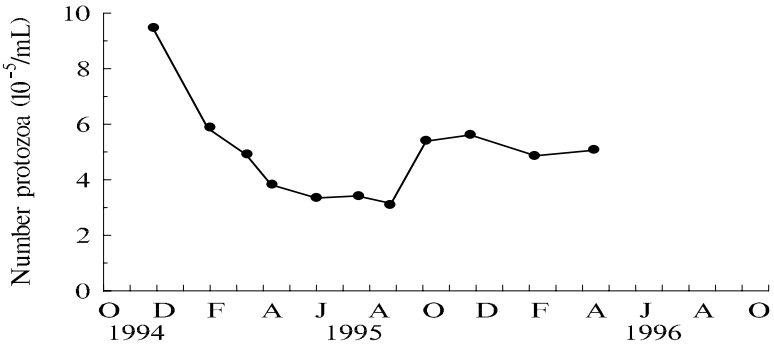

Figure 3.20. Changes across seasons in the population density of protozoa in the rumen fluid of unsupplemented steers grazing the experiment. Points represent the mean for six steers.

When populations were compared at the two sampling times at which all animals were sampled, ie., December 1994 and August 1995, the mean numbers for the controls and the average across all feeding levels for the CSM treatments were similar (6.3 and 6.4 x 10^5/mL); there was little effect of feeding level on numbers within the CSM treatment. However, mean numbers across the sorghum treatments were higher (10.6 x 10^5/mL) and there was little

difference between feeding levels except at the highest intake when numbers declined (7.7 x 10^5/mL). Feeding CSM had little effect on the species composition but the proportion of small *Entodinium* was higher on average (80% of total) for the sorghum treatments.

3.3.2.8 Concentration of purine derivatives in urine

Table 3.5 documents the ratio of allantoin:creatinine in spot urine samples taken at various times during the experiment in relation to supplementation treatments. The results indicate no consistent trend in terms of supplement type or level on this parameter.

3.4 Discussion

Pasture was not limiting in quantity at any time during the grazing study, so that animal performance at any time should be related mainly to attributes of pasture quality. By contrast, the amount and proportion of green grass leaf available to the grazing animals varied widely and at times was in short supply, especially during the late winter and spring months prior to the main pasture growth periods in the early wet season. The growth rate of grazing animals has often been related to the availability of green leaf in the pasture on offer (see later).

Table 3.5. Ratios of allantoin to creatinine in spot samples of urine taken from experimental animals on various sampling dates

Treatment	Allantoin : creatinine ratio			
	February 1995	March 1995	September 1995	October 1995
Control	1.6	1.3	1.7	1.7
CSM				
0.3% BW	1.6	1.5	1.7	1.7
0.6%	1.6	1.6	2.1	1.7
0.9%	1.3	1.6	1.4	1.6
1.2%	1.6	1.8	1.5	1.9
1.5%	2.0	1.6	1.6	1.8
Grain				
0.4%	1.6	1.7	2.0	1.7
0.8%	1.4	1.5	1.3	1.6
1.2%	1.4	1.5	1.4	1.8
1.6%	1.8	1.8	1.9	1.8
2.0%	1.7	1.6	1.7	1.6

3.4.1 Seasonal changes in pasture quality and diet selection

Pasture quality, as indicated by CP content and IVOMD of 'plucked samples' of buffel grass, the predominant plant in the pasture, varied over a wide range across seasons. Buffel green leaf collected in October 1994 was unexpectedly high in quality considering the dry conditions prevailing, but this is probably because this fraction was in very low supply (45 kg/ha) and mainly meristematic material of high quality was collected. The green leaf component was, predictably, of much higher quality than the total green (leaf plus stem) or total plant material, and always exceeded 6.25% CP and usually exceeded 60% IVOMD. By contrast, samples of the total green or total plant material were usually below these thresholds.

It was significant and somewhat unexpected that there was little difference in quality between total green and total plant material (see Figure 3.3). Several factors contributed to this

finding, the major ones being the generally high proportion of green stem and low proportion of green leaf in the total plant material, especially during the dry season, and the low quality of this green stem in relation to other components such as the green leaf and even the dead leaf. In most instances, green stem was considerably lower in quality attributes than dead leaf. Except in the very dry months, dead material comprised only one-third or less of the total DM on offer.

The significance of these comparisons in quality of the various plant component groupings lies in the use of such quality attributes in models for predicting grazing animal performance. Obviously, it is important to understand the significance of the differences in quality between the various plant components in development of these models, and to clearly specify which component of the pasture is to be used in the growth rate predictions. This is especially important for tropical pastures where the differences between green and dead, and leaf and stem material are greater than for temperate pastures. Failure to acknowledge this fact may have contributed to the sometimes poor predictive capacity of feeding standards, derived using predominantly temperate data sets, in tropical pasture situations.

As has been abundantly demonstrated in the past, composition of the pasture on offer was not a reliable indicator of the composition or quality of the diet selected by the grazing animal in the present study. For instance, the proportion of green grass leaf in the diet was three times greater, on average, than that in the pasture on offer with the major difference occurring in the drier months. As further example, despite being only a minor component of the pasture DM on offer, Seca represented a major contributor to the diet in the mid- to late wet season months. Diet samplings in early February of both 1995 and 1996 yielded the highest values for Seca content in the diet (up to 29%). This seasonal trend in stylo selection is consistent with that from comparable stylo studies, eg., “Galloway Plains”. Nevertheless, buffel grass represented the major component of the pasture and the diet throughout the experiment.

This capacity of the experimental animals to select for green leaf or specific higher quality plants meant that the diet was usually of higher quality than the total pasture on offer. In most months, however, the CP content and digestibility of the green buffel leaf was higher than that of the corresponding extrusa samples (see Figure 3.4), indicative of the fact that some of the lower quality components of the plant such as stem and dead leaf also contributed significantly to the diet, as would be expected especially when green leaf was limiting in availability. The two exceptions to this general rule occurred in the periods corresponding to the December 1994 to February 1995 samplings, and the November 1995 sampling, when extrusa quality was slightly greater than that for the green buffel leaf component. As green leaf is the highest quality component of the buffel plant, this suggests that for a short period of the early wet season the cattle were consuming a considerable amount of plant material other than buffel grass. Diet selection studies (see Figure 3.2) indicated that this higher quality plant material could have been Seca leaf at the February samplings although forbs were also a small but significant component of the diet at all three sampling times (data included as part of ‘other species’ component). Chemical analysis of the plant material indicated little difference in quality between Seca leaf and buffel leaf in February 1996, thereby implicating other species at this time.

It is significant that, even with the capacity to select a diet of higher quality plant material, the experimental animals consumed a diet of CP content lower than 6.25% and IVOMD less than 60% during the drier months of the year. Intake is usually considered to be restricted by a deficiency of N for efficient rumen function when protein content in the diet is below this threshold level. This is reflected in the low growth rates of steers during these periods (see Figure 3.7).

When CP content was expressed in relation to DOM content, values were always less than 210 g CP/kg DOM which is the level above which Poppi and McLennan (1995) predicted that

there would be incomplete net transfer of ingested nitrogen to the intestines, through degradation of protein to NH_3 in the rumen and eventual excretion of some of this NH_3 as urea in urine. This was the case even when there was a flush of new pasture growth following rain, such as in the early wet season and in May 1996, and agrees with the predictions of Poppi and McLennan (1995) that tropical grasses are unlikely to exceed this critical CP value. They further proposed that tropical legumes may exceed this critical level in view of their much higher protein content, but not digestibility, relative to tropical grasses and surmised that production benefits may accordingly result from provision of a soluble form of energy in the rumen to stimulate increased microbial incorporation of the available N. This remains to be demonstrated under practical grazing conditions.

Despite the marked seasonal trends associated with CP content and digestibility, ADF content of the extrusa changed over a relatively small range whilst the changes in NDF were slightly greater and tended to mirror image changes in IVOMD (see Figure 3.5). Digestibility of the extrusa was determined by *in vitro* analysis, but also using the *in sacco* technique. A comparison of the various data sets indicated parallel trends for the two analytical methods, with the effective degradability (ED) of OM 12% on average lower than IVOMD. This would account for the fact that IVOMD is designed to estimate total tract digestibility whereas ED represents digestibility in the reticulo-rumen alone which usually accounts for about 80% of total tract digestibility.

3.4.2 METABOLISABLE PROTEIN SUPPLY

Current feeding standards express protein requirements in terms of metabolisable protein, which represents the true protein absorbed in the intestines and accounts for the protein supplied as microbial protein and that dietary protein escaping rumen fermentation, ie., undegraded dietary protein (UDP). The protein degraded in the rumen and therefore available for microbial utilisation is referred to as rumen degraded protein (RDP), and total CP intake is the sum of RDP and UDP. Estimations of the composition of the CP in the diet, in terms of RDP and UDP content, were made using a methodology provided by the University of Nebraska group (Prof. Klopfenstein) and modified for use in our own situation. This method is based on the assumption that NDIN represents the potential ruminally-undegradable fraction of the CP. Prior to initiation of this project, there was no objective information on the status of tropical pastures in northern Australia in relation to the supply of metabolisable protein. This project has provided data for consideration and discussion.

It is usually assumed that RDP is not limiting for animal growth during the wet season when green leaf is available in abundant supply. High DM presentation yields during the wet seasons in the present study ensured adequate opportunity for diet selection and usually high content of green leaf in the diet. However, data presented in Figure 3.7 suggests that RDP supply was slightly limiting for most of the wet season for steers to achieve even moderate growth rates of 0.8 kg/d when DM intake was assumed to be 3% of BW. On the other hand, when RDP supply was considered in relation to energy supply in the rumen, values determined during most of the wet season periods approximated the theoretical requirement of 130 g/kg DOM to ensure adequate N availability for microbial growth, as proposed by the feeding standards (SCA 1990; NRC 1996; see Figure 3.6). An excess of RDP only eventuated in the early part of the 1994/95 wet season and in May 1996, when heavy rain following dry conditions promoted rapid and abundant growth of new lush pasture.

These estimates of RDP supply should be considered as optimistic on two counts. Firstly, they are calculated with the assumption that DM intake is maintained at 3% of BW throughout the wet season when it is doubtful that this level of intake would be maintained. In fact, the SCA (1990) feeding tables estimate a range of 2.1 to 2.7% of BW for animals of this breed and size for the 1994/95 wet season based on the range of diet digestibilities encountered over this period. Secondly, RDP supply was estimated assuming a rumen

passage rate (kp) of 0.02 when a higher rate may be expected for some part of the wet season, thereby reducing the proportion of RDP and increasing UDP.

Irrespective of DM intake, RDP supply was limiting for growth at even 0.5 kg/d during the 1995 and 1996 dry seasons, and in March/April 1996 when conditions were dry. This is supported by the low values for RDP in relation to DOM intake, ie., less than 100 g/kg DOM for most of the period. Under these conditions, growth responses to a supplement providing degradable N would be expected, and further increments may be achieved by increasing supply of readily fermentable energy in conjunction with the N supply. Actual responses to supplements are discussed later.

In contrast to RDP, UDP supply was apparently adequate or in excess during the wet season for a growth rate of 0.8 kg/d, except in May 1996, if a DM intake exceeding 2% of BW is assumed. Furthermore, even at the lower range of DM intake, there was apparently sufficient UDP for growth to occur at 0.5 kg/d throughout the year, including the dry season. These findings have implications for RDP supply during the wet and dry seasons in that, whilst a shortage of RDP may limit microbial growth, this may in part be compensated for by increased passage of UDP.

3.4.3 GROWTH RATE OF UNSUPPLEMENTED STEERS

The growth rates of cattle in this experiment, averaged on a monthly basis, follow the expected seasonal pattern. Very high growth rates were recorded during the early part of the wet season in response to the flush of new green growth and the high availability of green leaf in the pasture, and these declined to maintenance during the drier months. The changes in growth rate generally reflected changes in pasture and diet quality, as indicated by the relationships derived earlier (see Section 3.2.3.4). The growth rates used in that exercise were those arbitrarily considered to be most closely aligned with the sampling date, on the basis of proximity of date and rainfall records.

These linear correlation equations derived reflect the importance of the green grass component of the pasture in determining growth rate of the grazing animal. ADG was most closely related to the proportion of green grass leaf in the pasture, but was surprisingly poorly related to the proportion of this component appearing in the diet. The plot of ADG against the proportion of green grass leaf in the diet (see Figure 3.9) suggests two separate relationships, with four sampling points well displaced to the right of the main data set, ie., low growth rates despite relatively high content of green grass leaf in the diet. These points represent samplings carried out in March, August and October 1995 and in July 1996. The same sampling points are also displaced to the right in the plot of ADG against green grass leaf in the pasture (Figure 3.9), although not to the same extent. Similarly, when ADG is plotted against either extrusa CP content or IVOMD, the same sampling dates are outliers. Whilst most are from the drier part of the year, other sampling dates from similar dry periods with low growth rates are included in the main data set and there are no obvious differences to suggest why the two groups of sampling dates are divergent. From the results provided above it appears that the problem probably lies in the estimation of growth rate during the relevant period. This is not unexpected owing to the imprecise nature of liveweight as an indicator of tissue growth, and the inaccuracies involved in ascribing pasture and diet quality parameters from a single sampling date to liveweight changes occurring over varying periods of time with changing seasonal and pasture conditions applying. Nevertheless, it is also possible that these data belong to a wet season set and a dry season set. If they are treated in this way and regressed against liveweight gain then the green leaf content of the diet accounts for 88-90% of the variation in liveweight gain. A more precise relationship would result from more frequent sampling of the pasture and diet. Nevertheless, the general principle, namely a relationship between green grass leaf content in the pasture and thence diet and ADG, still applies and is consistent with previous findings.

Based on these relationships derived, growth rate would have reached 0.8 kg/d when green grass leaf yield was 875 kg/ha, when the proportion of green grass leaf in the pasture was 20% and in the diet was 73%, and when extrusa CP was 9.9% and IVOMD was 69%. On the other hand, for animals to merely maintain liveweight required the proportion of green grass leaf in the diet to be 14% of DM, and the CP content and digestibility to be 3.4% and 52.7% respectively. The value for CP content for maintenance seems low when it is usually considered that intake is depressed when CP content falls below about 6%.

3.4.3 RESPONSES TO SUPPLEMENTATION

The highly variable growth rates by individual animals with access to a common pasture was evident from data pertaining to the unsupplemented control steers (not shown in figures). It is also evident from the figures presented that the responses to supplement by individual animals were also highly variable. This variability affects the precision of the relationships derived but is consistent with that obviously experienced under practical feeding situations on commercial properties. Much greater variability would be expected employing 'usual' research techniques which involve group feeding of animals grazing separate paddocks, although it would not have been possible to identify or quantify this variability. Having individual data on experimental animals allows smaller group numbers and more treatment levels and thus provides a powerful methodology for establishing meaningful response surfaces. The present research methodology, whilst very labour intensive, was well justified and is highly recommended.

3.4.3.1 Wet season responses

The liveweight responses described below refer to changes in unfasted liveweight, and take no account of possible changes in carcase composition and dressing percentage. In some cases this will result in underestimation of the response as other workers have shown that, during grain feeding, carcase gains are about 65-75% of liveweight gains (B. Gulbransen, pers. comm.). Reduction in gut-fill early in the feeding program, for instance from 12 to 8% of total liveweight with high-grain diets, will contribute to this observation. This effect was reduced by estimating responses to supplementation from week 4 of the feeding program.

Cottonseed meal. The LW responses to CSM fed during the main part of the two wet seasons encountered were small, being of the order of 0.16 kg/d additional liveweight gain for an increase in intake of CSM equivalent to 1% of BW. Whilst at this response level it is obvious that feeding is unlikely to be economic, it is interesting from a nutritional point of view that growth rates can be increased to a level approaching 1.2 kg/d over an extended period (84-112 d) when the baseline growth rate is around 1 kg/d. The challenge is to achieve a similar or greater response with lower inputs by manipulating aspects of growth in some way. It is not possible from a grazing study such as this to categorically define the reason for this response when pasture conditions were at their best. However, Figure 3.10 showing cumulative liveweight changes indicates that the responses started early in the feeding period when RDP availability was high, but continued on at a low rate of response throughout the wet season until pasture continues dried off and higher responses occurred. It is possible that the animals responded to additional UDP from the supplement in the early phase and then to RDP as the pasture content of this nutrient declined.

In the latter part of both wet seasons the responses to CSM increased although for the 1994/95 wet season the response level was only 0.2 kg/d for each additional 1% BW of supplement fed despite the growth rate of the controls being only 0.33 kg/d. The corresponding response rate was 0.47 kg/d during the latter phase of the 1995/96 wet season, with the unsupplemented group growing at 0.46 kg/d. These increased responses coincided with declining supply of RDP from the pasture and supply of this nutrient from the CSM may have contributed to increased supply of microbial protein, in addition to the UDP supplied directly from the CSM, for intestinal absorption.

Grain. The responses to sorghum (1994/95) and barley (1995/96) were generally less than those to CSM during the main wet season period (0.05-0.13 kg/d for an intake of grain equivalent to 1% BW). As mentioned earlier, changes in gut fill (and thus dressing percentage) may have masked higher responses in terms of carcass growth but the responses were nevertheless small and unlikely to be economically tenable. CSM may have had the same effect on gut fill at equivalent intakes; this is yet to be determined.

In the latter phase of the wet season, the response to grain feeding increased but was still only an additional 0.18 to 0.28 kg/d for each additional unit (1% BW) intake of grain. In the second year, although a linear relationship has been plotted between barley intake and liveweight gain, the response surface appears to be curvilinear with a marked growth response to even small intakes of the barley mix. Once again, this response coincided with a declining supply of RDP and the sharp increase in growth rate may have been in response to additional soluble N in the supplement (as urea/S) or a combination of this and increased availability of readily fermentable starch which promoted increased synthesis of microbial protein.

General. The generally low response to both supplement types during the wet season, despite quite high intakes, suggests a high degree of substitution of supplement for pasture. This is consistent with the bulk of evidence from the literature and with results from the pen studies from the present project. In general, substitution rate increases as the quality of the basal diet increases. This principle has mainly applied to "energy" supplements such as grains in the past as the protein meal supplements have not usually been fed at high levels of intake. In the present experiments, there appears to be little difference between the two types of supplement in this regard (see results of pen studies). The fact that the feed supplements tend to be acting as substitutes for, rather than supplements to, the pasture is a major impediment to increasing growth rates during this period of the year.

Whilst with existing knowledge and on crude economic analysis it is difficult to envisage supplementation during the main wet season period being viable, increasing growth rates of cattle in this latter part of the wet season can be very important for commercial graziers as it may represent the difference between achieving high-value market specifications or having to accept other lower priced markets or carry cattle over for an additional season. This changes the whole nature of the economics of feeding and producers or their advisers are best positioned to evaluate these implications. Nevertheless, the challenge is there to improve the efficiency of nutrient supply in order to improve the economics of strategies employed.

3.4.3.2 Dry season responses

The term 'dry season' is somewhat of a misnomer in this project as late, heavy rain in May in both years, early storms in October and periodic falls of rain between these months ensured availability of some green grass pick and positive growth rates by unsupplemented cattle in most months. Thus the response periods were unfortunately short in duration.

Cottonseed meal. Responses to feeding CSM during the dry season ranged from 0.30 to 0.45 kg/d for each 1% BW increment in supplement intake. Although linear relationships between intake and LW gain have been applied, in both dry seasons there is a suggestion of curvilinearity in the response curve. During the 1995 dry season, the greatest incremental response appeared to occur with the first level of supplement intake, if one outlier point is ignored. Similarly, during the 1996 dry season, there appeared to be a linear response to feeding to the 0.9% BW level of supplementation, whereupon a threshold was reached at a growth rate of about 0.8 kg/d. This curvilinear nature of the response surfaces is consistent with others derived from pen feeding studies, including those from the present project. At this time of year, RDP supply from the pasture was limiting both in absolute terms (g/d; see Figure 3.7) and in relation to supply of energy in the rumen. That is, RDP concentration in the pasture was well below the level of 130 g/kg DOM necessary to maximise efficiency of

microbial protein synthesis (see Figure 3.6). Thus the response to CSM at lower levels of intake may have been partly due to increased supply of RDP, with additional response at higher intakes to UDP supplied from the supplement.

Grain. Sorghum feeding during the 1995 dry season produced a linear growth response to supplement intake with an additional 0.22 kg/d growth for each 1% BW increment of sorghum intake. However, in the case of barley feeding during the 1996 dry season, there was little apparent advantage gained by feeding in excess of about 0.8% of BW although the results were quite variable at higher intakes. Responses probably reflected increased supply of both fermentable energy in the rumen, in the case of barley, and RDP as urea, with a stimulus in microbial protein synthesis. Sorghum starch is less degraded in the rumen than barley, and it is possible that microbial protein synthesis was limited by low energy availability for this process.

3.4.4 RUMEN AND BLOOD METABOLITE CONCENTRATIONS

The linear increase in concentrations of both NH_3-N in rumen fluid and urea-N in plasma reflected the significant incremental effect of this supplement on N availability to the animal. Plasma urea-N concentrations were apparently relatively stable over the day, as indicated by the relatively small decrease between feeding and mustering on the following day, approximately 20 h later.

By contrast, increasing intake of the grain supplements only marginally increased rumen NH_3-N and plasma urea-N concentrations despite the inclusion of urea at about 2% of the total DM in the case of barley. This finding indicates that the soluble N was being quantitatively and rapidly utilised in the rumen, presumably by the rumen microbes in the process of microbial proteosynthesis. Although the inclusion rate of urea was calculated from the feeding standards based on theoretical requirements for utilisation of available OM, it appears that higher concentrations are required to ensure optimum utilisation of the energy substrates available. Part of the problem in estimating requirements stems from thinking of requirements in terms of "percentage" inclusion rather than an absolute amount. Thus at high intakes of grain there is probably sufficient urea available for utilisation of both the starch and pasture when a set low percentage urea is included in the supplement (eg., 2%), but when low levels of grain are fed and most of the diet comes from the pasture, the small amount of urea included will not allow optimal utilisation of both energy sources. That is, a percentage inclusion for optimising supplement use may not meet the RDN requirements for the diet as a whole when the basal diet is low in RDN, and RDN requirements need to be considered for the total diet. The same principles will apply to other "energy" supplements, eg., molasses-based mixes. One of the solutions to this dilemma may be the feeding of mixed energy - protein meal supplements to provide sufficient RDP over a sustained period.

3.4.5 PROTOZOA POPULATION DENSITY IN RUMEN FLUID

We are unaware of any published information on the changes in protozoal populations in the rumen of cattle grazing tropical pastures yet this group of microorganisms can have profound effects on the N economy of the grazing animal, and thus on animal production. The population numbers changed in accordance with pasture quality, with higher numbers during the periods when pasture quality was highest and nutrients, in particular soluble nutrients, were most abundant. Feeding CSM seemed to have little effect on protozoal numbers or the population composition. Demonstration that grain feeding increased protozoal numbers at lower rates of intake is consistent with other findings reported in the literature, as is the finding that increasing grain intake beyond a threshold will result in a reduction in numbers. The initial increase in numbers is related to increased supply of nutrients, particularly starch, whilst the decrease at higher intakes is usually attributed to reduced pH in the rumen. Complete defaunation can occur if very high grain intakes are achieved. Part of the reason for the increased numbers of protozoa, however, may be the change in population composition, with higher numbers of small *Entodinium* in grain-fed animals. In this process,

although total numbers are increasing, the protozoal biomass may not increase since the small *Entodinium* are replacing larger species with greater volume and greater capacity to engulf bacteria.

3.4.6 PURINE DERIVATIVES IN URINE

In the present study, collection of spot samples of urine and determination of the ratio of allantoin:creatinine did not indicate any treatment differences in the excretion of purine derivatives and hence presumably of microbial protein synthesis. This result may have arisen because most samples were, unintentionally, collected when pasture quality was not very low so that treatment differences were masked by quite high production levels in the absence of supplementation. However, based on information from our pen studies (see later) and other recent research, it is more likely that the methodology is flawed due to the fact that creatinine, assumed to be a constant of liveweight, varies in its output with digestible energy intake. Thus for the methodology to work under grazing situations, it will be necessary to quantify output of purine derivatives (or urine output) in some way. As a result of the findings of this experiment, research at the University of Queensland is currently being directed to providing this methodology.

3.5 Conclusions

A series of response curves were derived across the various seasons during which the experiment was conducted. These response curves have been combined in Chapter 8 to provide generic response curves aligned with the growth rate of the unsupplemented steers, in lieu of some other indicator of pasture or diet quality at this stage. Thus separate response curves are provided according to whether the control steers were growing at a low, medium or high rate irrespective of the seasonal conditions etc. Further alignment of the animal growth responses to pasture/diet quality will probably require a modelling approach in the future.

4. Pen feeding study - Rocklea Animal Husbandry Research Farm

4.1 Introduction

This pen feeding study, and the following metabolism study (Chapter 5), were undertaken to complement the major grazing study at Brigalow Research Station (see Chapter 3). The primary objectives were to screen a wider range of supplement types than could be achieved in the grazing studies over the short term, and to do this under controlled conditions which would allow collection of important information relating to the effects of the different supplement types on intake and utilisation by cattle. This part of the research program was particularly aimed at gaining a better understanding of the effects of the different supplement types of intake, and in particular the role substitution was playing in determining ultimate nutrient intake and animal performance. Such information is difficult or impossible to obtain from grazing studies.

Several different supplement types were screened in these experiments, and the characteristics of these and the philosophy behind using them are discussed in more detail in the General Introduction (Chapter 2). The main supplements discussed here will be barley, sorghum and CSM; molasses and fishmeal were also fed but molasses intakes were well below the desired levels and laboratory analyses are still required before intake of fishmeal, which was fed as a mixed supplement, can be determined.

4.2 Research methodology

Two successive pen feeding experiments of similar design were conducted at the DPI's Rocklea Animal Husbandry Research Farm between July and December 1995. The limitation of pen numbers required this phase of the project to be divided into two parts with different supplements included in each experiment. From here on, the experiments will be referred to as Experiment 1 and Experiment 2.

4.2.1 Animals, diets and treatments

One hundred Brahman crossbred weaner steers approximately 6 months of age were used in the two experiments. They were dipped to be free from ticks and drenched with oxfendazole (Systamex; Coopers Animal Health) at the recommended rate to reduce internal parasite burdens. The heaviest 50 steers were drafted off for Experiment 1 whilst the remainder grazed pastures on the research farm until the commencement of Experiment 2.

Experiment 1. The 50 steers were confined to pens in groups of five and fed Callide Rhodes grass (*Chloris gayana*) hay *ad libitum* for 7 d. They also received, daily, a 50:50 (w/w) mix of rolled barley and rolled sorghum including 1.0% by weight of urea, at the rate of 1.5 kg/steer/d, and had access to a molasses/urea (100:1, w/w) mix fed daily to provide 1 kg/steer/d. These supplements were fed in order to accustom the steers to the experimental rations. At the end of this preliminary period, the steers were weighed unfasted and fasted (24 h without food, 14 h without water) over successive days and allocated by stratified randomisation on the basis of this fasted liveweight to experimental treatments. During a 63 d experimental period, the steers received coarse-chaffed Rhodes grass hay *ad libitum* either unsupplemented (controls) or with supplements, fed at 0.5, 1.0, 1.5 and 2.0% of bodyweight (BW), of a barley mix (5B, 10B, 15B and 20B), a sorghum mix (5S, 10S, 15S and 20S) or a

molasses mix (5M, 10M, 15M and 20M). There were three control steers and three replications (steers) of each supplement treatment, making a total of 39 steers. The initial unfasted liveweight of the steers was 156.3 ± 0.13 (mean ± SEM) kg.

The grain-based mixes, hereafter referred to as barley and sorghum, consisted of (w/w as fed) 93.9% dry rolled grain, 2.0% bentonite, 1.74% urea, 1.0% limestone and 0.36% sulphate of ammonia. These ingredients were thoroughly mixed in a horizontal mixer prior to feeding. The molasses mix comprised 92.6% molasses, 2.8% urea, 2.8% added water, 0.93% salt (NaCl) and 0.93% dicalcium phosphate (170 g P/kg). This mixture was well mixed in a cement mixer to dissolve all soluble components prior to feeding out.

Experiment 2. The lighter 50 steers from the original draft grazed Rhodes grass pastures whilst Experiment 1 was underway, and for the second half of this grazing period were given access to limited amounts of the molasses mix used in Experiment 1, of CSM and of a molasses/fishmeal/water mix fed from separate troughs. These supplements were fed to acquaint the steers with the supplements to be fed in Experiment 2.

At the end of September, the steers were dipped and drenched (as above), confined to pens in groups of five and fed Rhodes grass hay *ad libitum* for 7 d. For the first 5 d they also received the molasses mix from Experiment 1 at 1 kg/steer/d and separately a molasses/fishmeal/water (8:3:2, w/w) mix at 1.3 kg/steer/d. These supplements were also fed to accustom the steers to experimental diets. At the end of the preliminary period, the steers were allocated to treatments in the manner described for Experiment 1. The initial unfasted liveweight of the steers was 164.9 ± 0.15 (mean ± SEM) kg. The treatments were Rhodes grass hay unsupplemented (control) or with supplements, fed at the intakes used in Experiment 1, of CSM (5C, 10C, 15C and 20C) and of the molasses mix (5M, 10M, 15M and 20M), and of a fishmeal mix (hereafter fishmeal) fed at the rates of 0.2, 0.4, 0.6 and 0.8% of BW (2F, 4F, 6F and 8F). The lower intakes of the fishmeal were used because of previous experience of the amount of this supplement animals would consume. The feeding period was 63 d.

The CSM was fed as received. The molasses mix was the same as that used in Experiment 1, this treatment being repeated in Experiment 2 because of the low intakes of supplement achieved in the former experiment. The treatment level of fishmeal was added to 1.5 kg of a molasses/water (1:2, w/w) mix and was fed as a slurry of all the components.

4.2.2 EXPERIMENTAL PROCEDURES

Experiment 1. The steers were confined to individual pens to which treatments were randomly allocated, and fed hay and their allocation of supplements once daily in the morning (8 am). Hay was fed in sufficient quantity to allow some residue on the following day, thereby ensuring *ad libitum* intake. The supplements were fed out in troughs separate from the hay. Intake of the grain mixes was slowly increased to treatment levels over one week to reduce the risk of digestive problems, and the shortfall in intake in this week was made up over the following week. Similarly, the concentration of urea in the molasses mix was gradually increased to treatment level over the first week. Each days supplement allocation was added to any left unconsumed from the previous days except on the one day a week when residues were collected (see below).

The amount of hay fed to the 20M steers was restricted to slightly less than *ad libitum* from week 3 to the end of the experiment in an effort to entice the steers to consume more molasses, as supplement intakes were below required rates.

Residue feed (hay and supplement) was collected, weighed, sub-sampled and discarded once weekly. Sub-samples of the hay and supplements were taken daily and separate

samples of each were kept for either DM determination or chemical analysis. Those kept for DM determination were pooled over 7 d and, except for the molasses, dried to constant weight at 100 ^{o}C in a forced-draught oven. Weekly residue feed samples were treated in the same way. Samples of the molasses feed or residue were weighed into scintillation tubes and mixed with a small quantity of distilled water. A weighed piece of No. 1 Whatman's filter paper was inserted into each tube and the tube was rotated so that the molasses mixture was absorbed onto the filter paper. This tube was then placed in a forced-draught oven at 100 ^{o}C for 2 d, and the DM content of the molasses was determined by weight change. Samples of other feeds kept for chemical analysis were pooled over *ca* 35 d, dried at 60 ^{o}C, ground through a 1 mm sieve and stored awaiting analysis. Chemical analysis of the molasses was carried out at the same frequency. Animals were weighed before feeding once weekly and a fasted weight was recorded at the beginning and end of the experiment. Supplement allocations for each steer were adjusted weekly on the basis of their current liveweight.

In the last week of the experiment, samples of rumen fluid were taken by stomach tube from the control steers and all steers receiving barley and sorghum, 3 h after providing animals with access to the supplement. Half of the animals were sampled on each of two successive days and feeding was staggered over time in order to sample as closely as possible to this 3 h time schedule. The rumen fluid was strained through nylon gauze and 4 mL sub-samples were collected into 4 mL of 0.2 N hydrochloric acid for NH_3-N determination, into 16 mL of formal saline for protozoa enumeration, or into McCartney bottles containing mercuric chloride for later volatile fatty acid (**VFA**) analysis. The samples collected for VFA analysis were centrifuged and the supernatant stored frozen awaiting analysis. During the sampling procedure, blood was withdrawn from the jugular vein into heparinised tubes, centrifuged, and the resulting plasma taken off and frozen (-20 ^{o}C) awaiting analysis. The plasma samples were analysed for urea-N and glucose concentration.

Experiment 2. The procedures used in this experiment were the same as those used in the previous one, except where indicated below. As intakes of molasses for the 20M group were generally below the desired levels, the hay allocation for this treatment group was slightly restricted from week 2 onwards to encourage greater intake of the supplement.

Whereas residues of the hay, CSM and molasses were handled in the same way as in Experiment 1, residues of fishmeal were collected daily, weighed, dried to constant weight in a forced-draught oven at 60 ^{o}C, and bulked over 7 d for each steer. After thorough mixing and sub-sampling, these bulked samples were ground through a 1 mm screen and stored awaiting analysis for N and OM. This analysis was used to determine the proportion of the mixed residue that derived from fishmeal as opposed to molasses.

Rumen fluid and blood samples were collected from steers of the control and CSM treatment groups 3 h after feeding on one day during the last week of the experiment. The molasses and fishmeal treatments were not sampled because intakes of supplement were generally below the required rates for these treatments and the steers consumed only a small proportion of the total daily intake in the first 3 h. The sampling procedures were the same as those described for Experiment 1.

4.3 Results

4.3.1 Animal health

No animals showed any signs of ill-health in either experiment despite quite high intakes of grain and of CSM.

4.3.2 FEED ANALYSIS

The chemical composition of the hay and supplements used during the experiments are shown in Table 4.1. The same hay and supplements were used in the metabolism experiment described in Chapter 4.

Table 4.1. Chemical composition of the feeds

Feed	N	OM	EE	NDF	ADF	IVOMD	ME
	(g/kg DM)					(%)	(MJ/kg DM)
Experiment 1							
Hay	9.2	902	15	713	372	51.4	7.0
Barley	24.1	974	21				13.3
Sorghum	22.4	986	26				13.8
Molasses	10.9	870					13.1
Experiment 2							
Hay	10.5	900	15	699	387	52.2	7.1
CSM	68.0	928	31	275			11.5
Fishmeal	115.2	829	97				11.8
Molasses	Same as in *Experiment 1*						

4.3.3 INTAKE

Supplements of barley, sorghum and CSM were readily consumed by most of the steers with the majority of the supplement eaten within the first 2 h after feeding for the lower intake treatments. At the higher feeding rates (1.5-2% BW), some steers required most of the 24 h period to consume all of the supplement and one animal from each of the high intake barley and sorghum groups regularly did not eat all of their daily supplement allocation. Intakes of molasses (both experiments) and fishmeal were highly variable with some steers consuming all of their daily allocation whilst others, especially those at higher rates of feeding, regularly failed to eat all of the supplement offered.

The results for the barley, sorghum and CSM treatments only will be given from here on owing to the low and variable intakes of the molasses supplement in both experiments, and because further chemical analyses are required on residues of the fishmeal/molasses mix to determine actual intakes of the two components separately. Actual mean daily intakes of supplement over the experimental period were, respectively as treatment levels increased from 0.5 to 2.0% BW, for barley: 0.81, 1.66, 2.64 and 3.03 kg/steer; for sorghum: 0.81, 1.59, 2.43 and 3.05 kg/steer; and for CSM: 0.83, 1.56, 2.58 and 3.49 kg/steer.

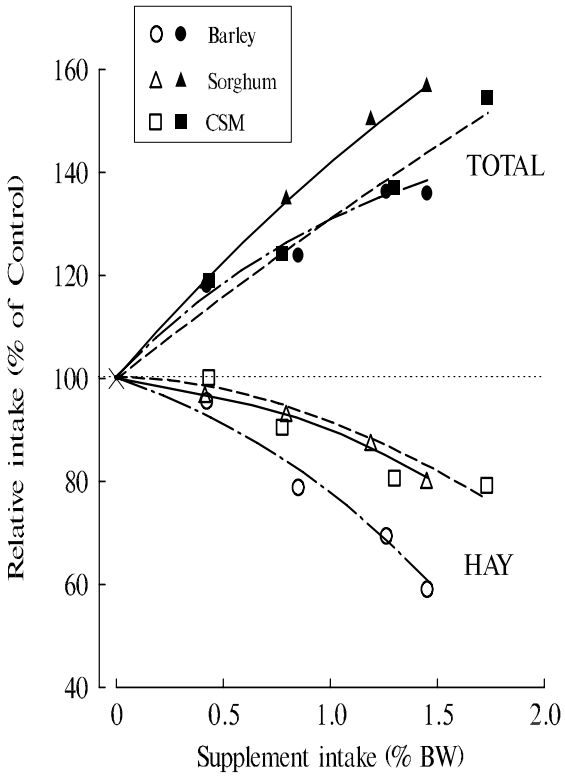

*Figure 4.1. Effect of supplements on the intake by steers of hay (dashed lines, open symbols) and total (solid lines, closed symbols) DM, calculated on a proportion of bodyweight (BW) basis and expressed relative to the intake for the unsupplemented control steers (***X***).* Data for hay intakes relating to the sorghum and CSM treatments, and for total intakes relating to the barley and CSM treatments, are represented by single lines. Points represent the mean value for three steers.

Unsupplemented steers ate 3.02 and 3.89 kg of hay (DM), which represented 1.89 and 2.30% of BW, in Experiments 1 and 2 respectively. Figure 4.1 shows the effects of supplements of barley and sorghum (Experiment 1) and of CSM (Experiment 2) on the intake of hay and total DM by steers, expressed on a BW basis relative to that of the respective control groups. When supplement intake exceeded 0.5% BW hay intake was depressed by all supplements but the greatest depression occurred with barley. At the highest rate of supplementation, hay DM intake was reduced by 41, 20 and 21% for barley, sorghum and CSM supplements respectively compared with that of the controls.

Total DM intake increased with increasing supplement intake for all supplements. Sorghum feeding was associated with the greatest increase in total intake, ie., 57% compared with 36% and 55% for barley and CSM respectively at the highest level of supplementation.

In Figure 4.2, intake data from the present experiments has been combined with DM digestibility estimates from the metabolism studies (following Chapter) to illustrate the effects of supplements on the estimated total intake of digestible DM by the steers. The assumed digestibilities for the hay, barley, sorghum and CSM were 52.1, 75.0, 57.2 and 63.3% respectively. Values presented in Figure 4.2 are expressed on a BW basis relative to the intake of the control group from Experiment 1. Thus, in view of the higher DM intake of the control group in Experiment 2, the digestible DM intake for this group is also considerably higher (22%) than for its counterpart in Experiment 1 (0.98 kg/ 100 kg W/d). Increasing intake of any of the three supplements was associated with increased intake of digestible

DM, with the regression lines representing the three supplements having similar slopes. Thus barley-supplemented steers had similar intake of digestible DM to their sorghum-supplemented counterparts despite having lower DM intakes. At the highest level of supplementation (2% BW), digestible DM intake for the barley, sorghum and CSM treatments were 70, 65 and 108% higher respectively than for the control group from Experiment 1. For CSM, digestible DM intake at this level of supplementation was 71% higher than for the control group of Experiment 2.

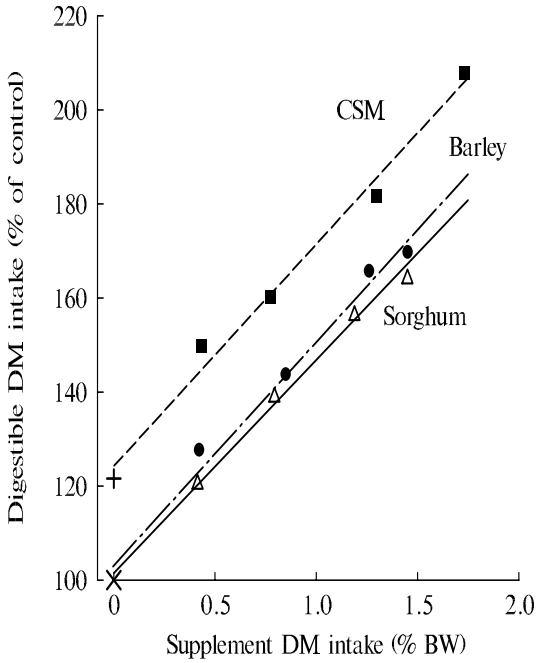

Figure 4.2. Effect of level of intake of supplements of barley (●), sorghum (△) and CSM (■) on the estimated digestible dry matter (DM) intake, calculated on a percentage of body weight (BW) basis and expressed relative to the unsupplemented control (X) from Experiment 1, by steers given a basal diet of Rhodes grass hay ad libitum. Points represent the means for three steers.

These effects of supplements on total digestible DM intake are separated in Figure 4.3 to illustrate the effects on hay as well as on total digestible DM intake. Data are presented on a BW basis, relative to the control group for Experiment 1. A single relationship has been drawn to represent the effects of all three supplements on the intake of total digestible DM. In Figure 4.3 (a) the supplement intake is expressed on a DM basis whereas in Figure 4.3 (b) the intake is expressed on a digestible DM basis. When supplement DM intake exceeded 0.5% BW, hay digestible DM intake declined for all three supplements but the depression was more severe with barley than with sorghum or CSM which had similar trends (Figure 4.3 a). Similarly, intake of hay digestible DM declined with increasing supplement intake when supplement digestible DM intake exceeded about 0.3 kg/100 kg W/d, but the trend was similar for all three supplements (Figure 4.3 b).

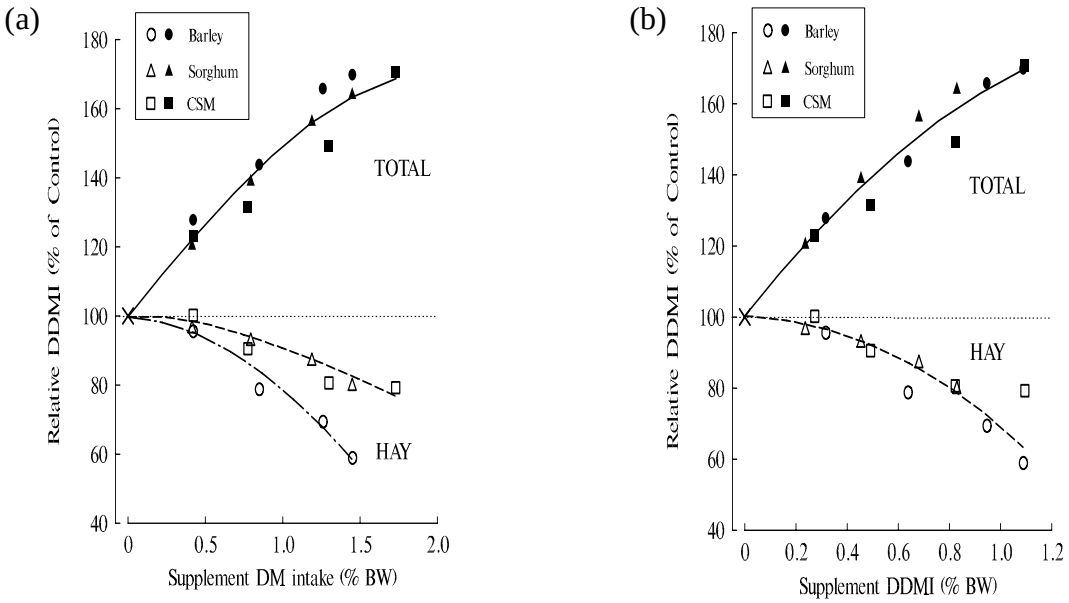

Figure 4.3. *Effect of intake of dry matter (DM; (a)) and of digestible DM (DDMI; (b)) from supplements on the intake by steers of hay (dashed lines, open symbols) and total (solid lines, closed symbols) DDM, calculated on a proportion of bodyweight (BW) basis and expressed relative to the intake for the unsupplemented control steers (***X***) for the respective experiments.* A combined curve represents data pertaining to all three supplements for total intake in both figures (a and b) and for hay intake in (b), but in (a) hay intakes relating to the sorghum and CSM treatments are represented by a combined curve but that of barley is presented separately. Points represent the mean value for three steers.

4.3.4 GROWTH RATES

The growth rates of control steers, and those receiving barley, sorghum and CSM are shown in Figure 4.4. Growth rates for the control steers were similar for the two experiments (0.09 and 0.07 kg/d) and are presented in the figure as a combined mean value for the two experiments. Average daily gain (ADG; kg) was linearly related to supplement intake (INT; %LW) for the sorghum (ADG=0.097+0.371 INT; R^2 =0.93, P<0.01) and barley (ADG=0.086 + 0.549 INT; R^2 =0.95, P<0.01) treatments, with different slopes for the two lines (P<0.01), but an asymptotic relationship best described the CSM treatment (ADG=1.187-1.11$e^{-2.65\ INT}$; R^2=0.91). This reflected the much steeper increase in growth rate for CSM compared with the grain sources.

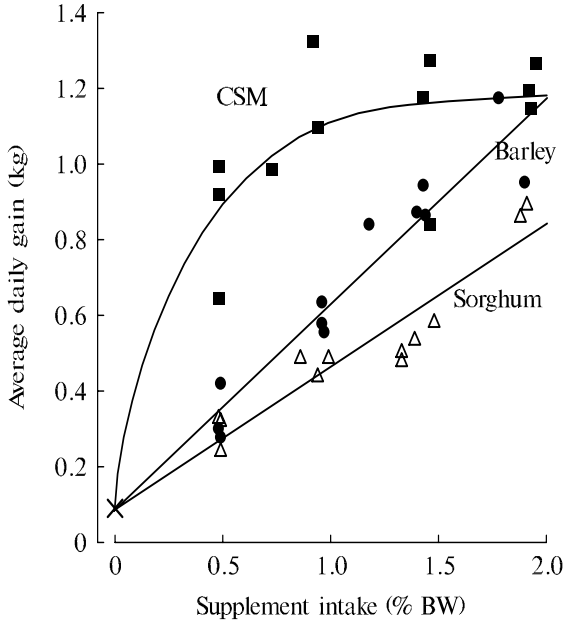

Figure 4.4. Effect of level of intake of supplements of barley (●), sorghum (△) and CSM (■) on the average daily gain of steers given a basal diet of Rhodes grass hay ad libitum. Points represent individual steers except for the controls (X) which is the mean for six steers, three from each of Experiments 1 and 2.

The linear relationship between ADG (kg/d) and the intake of DDM (DDMI; kg/ 100 kg W/d) by steers is presented in Figure 4.5, and is represented by the equation:

ADG = 1.245 DDMI - 1.19; (R^2 = 0.83).

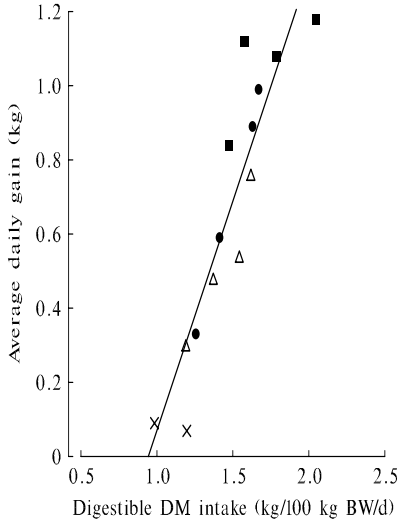

*Figure 4.5. Relationship between the estimated intake of digestible dry matter (DM) and the average daily gain for steers consuming a basal diet of Rhodes grass hay either unsupplemented (*X; *Experiments 1 and 2) or with supplements of barley (●), sorghum (△) and CSM (■).* Points represent the mean for groups of three steers receiving different amounts of supplement.

A single relationship has been used to represent all three supplement types.

4.3.5 RUMEN FLUID AND BLOOD METABOLITES

The concentrations of NH_3-N in rumen fluid, and of urea-N and glucose in blood plasma of steers unsupplemented or receiving supplements of barley, sorghum and CSM are shown in Table 4.2.

Control steers had very low concentrations of NH_3-N in rumen fluid but all supplements increased concentration of this metabolite in the first 3 h after feeding. For the grain-fed steers, the between-animal variability was very high but there was a trend for increased concentration with the first increment of supplement (0.5% BW) with little if any increase to further increments. With CSM feeding, there were incremental increases in concentration of NH_3-N in rumen fluid with each additional amount of CSM, plateauing at about 1.5% BW intake. Similarly, CSM feeding was associated with incremental increases in urea-N concentration in the blood plasma of steers and these concentrations were considerably higher than for the grain-based supplements especially at higher feeding rates. Nevertheless, the grain-based diets did increase urea-N concentrations even at low rates of feeding.

All supplements were associated with increases in the concentration of glucose in the plasma of steers, although with sorghum this increase was most evident only at higher intake levels (1.5-2.0% BW).

4.4 Discussion

In the absence of supplementation, steers given unrestricted access to the Rhodes grass hay consumed between 1.9% (Experiment 1) and 2.3% (Experiment 2) DM on a BW basis. The reason for the higher intake in the second experiment is not clear since the steers were from the same origin and there were only minor differences in chemical composition of the two lots of hay, which were cut from the same pasture at about the same time of year. Whilst Experiment 1 was underway, the Experiment 2 draft of steers grazed relatively dry, low quality pastures with minimal supplement intake (see above), and weight changes were relatively low, although positive, during this period. If the animals continued to grow in frame size at the expense of body condition during this period, and consequently increased in body weight only marginally, then the higher intake on a bodyweight basis may represent a compensatory effect when the animals had unlimited supply of hay in the pens. Compensatory growth is often associated with increased intake partly in response to an increased gut size. However, the growth rates of the controls in the two experiments were similar despite these differences in hay intake, with both groups barely maintaining liveweight. With inclusion of supplement in the diet they were able to grow at up to 1.2 kg/d, approaching growth rates achievable in the feedlot.

There were, however, pronounced differences between the supplements in terms of the nature of the growth response curves derived. The grain response curves were linear but with different slopes for the barley and sorghum, whilst that for CSM was curvilinear such that the response was highest to the first increment of supplement and subsequent increments only provided small changes in growth rate (see Figure 4.4). The reasons for these differences will be explored below.

Table 4.2. Effect of supplements on the concentration of ammonia-N (NH_3-N) in rumen fluid and on the concentration of urea-N and glucose in the blood plasma, of steers given a basal diet of Rhodes grass hay ad libitum

Ration	**Rumen fluid**	**Blood plasma**

	NH_3-N conc.		Urea-N conc.		Glucose conc.	
	Mean (mg/L)	*SEM*	Mean (mg/dL)	*SEM*	Mean (mg/dL)	*SEM*
Expr. 1						
Control	28	*9.9*	3.4	*1.13*	78	*4.3*
5 B	127	*10.1*	7.6	*0.16*	100	*10.5*
10 B	168	*44.5*	10.4	*1.44*	105	*9.7*
15 B	159	*10.5*	13.1	*1.94*	105	*5.7*
20 B	147	*36.0*	13.7	*2.87*	114	*5.3*
5 S	77	*13.8*	4.9	*0.65*	85	*2.6*
10 S	125	*42.6*	7.7	*0.52*	82	*8.7*
15 S	104	*10.9*	6.4	*1.28*	103	*2.1*
20 S	75	*33.2*	8.3	*0.83*	103	*8.2*
Expr. 2						
Control	26	*4.9*	4.8	*1.54*	83	*4.2*
5 C	120	*5.0*	11.1	*3.58*	101	*2.2*
10 C	208	*57.7*	17.5	*2.51*	116	*8.8*
15 C	369	*17.6*	23.0	*1.32*	112	*8.1*
20 C	357	*27.5*	27.7	*0.74*	112	*4.5*

Nutritional principles are underpinned by a general relationship between the intake of digestible nutrients and the growth rate of animals. This general relationship was supported in the present experiment where ADG was directly related to intake of DDM across supplement types (see Figure 4.5). Based on this relationship, it would be expected that the differences between the growth responses for the barley and sorghum supplements were related to differences in DDMI, but as Figure 4.2 illustrates, the differences between grain supplements in DDMI were small at similar supplement DM intake. A re-examination of the relationship described in Figure 4.5 indicates separate linear relationships between DDM intake and ADG for barley (ADG = -1.26 + 1.32 DDMI; R^2 = 0.96) and sorghum (ADG = -0.84 + 0.95 DDMI; R^2 = 0.96), although with limited data points upon which to establish these relationships. Nevertheless, the indication is that the slope of the line is less for sorghum than for barley.

The greater conversion of digestible nutrients to animal growth with barley is probably related to the site of digestion of the nutrients. It has been well established that the starch of barley is fermented to a greater extent in the rumen than is that of sorghum when the latter grain source is not highly processed. In our experiments the grains were merely cracked in a roller mill. This observation is consistent with our own in the metabolism studies (following chapter) in that sorghum had low digestibility in the total tract (average 57.2% DMD) and a large proportion of the starch passed through the animal into the faeces undigested (up to 25% starch in faeces). Results from the metabolism study further indicate that this greater ruminal digestion of barley is associated with greater production of microbial protein. This aspect is discussed at greater length in the following chapter. It appears though that the higher performance of steers given barley compared to sorghum is probably related to the higher proportionate digestion of barley in the rumen, and either the greater availability of protein for absorption or better balance of protein to energy in the substrates available for absorption.

The higher growth rates of steers receiving CSM, particularly at low supplement intakes, compared to their grain-fed counterparts appears to be largely related to the higher intake of DDM. When a linear relationship is fitted to the data presented in Figure 4.5 for the CSM treatments alone (ADG = -1.10 + 1.21 DDMI; R^2 = 0.72) it is apparent that the relationship is poor (low correlation coefficient for few points) and that the slope is slightly less than for barley. It appears that the relationship is probably curvilinear, but there are too few data points to clearly establish this fact. The higher DDMI for CSM relative to other supplements is partly related to the higher baseline level for the control group in Experiment 2, which is a product of the higher DM intake expressed on a BW basis. Once again though the high performance of steers fed CSM at low intake of supplement is probably related to the increased availability of protein (amino acids) for absorption as well as to greater intake of DDM, and perhaps also to a better balance between protein and energy in the absorbed nutrients.

A major impediment to increasing intake of digestible nutrient through supplementation is substitution, whereby intake of supplements is associated with a decline in intake of the basal ration such that total intake of nutrients does not increase in proportion with added nutrients. Figure 4.1 indicates a greater extent of substitution with barley than with sorghum or CSM. In fact, sorghum has the least effect on hay intake and total DM intake is greatest with this supplement. This difference between the grains is consistent with barley having the higher extent of digestion in the rumen and thereby resulting in greater depression of cellulolysis. This phenomenon has been well demonstrated with mixed grain/forage diets in other experiments and is related to a competition for substrates between cellulolytic and amylolytic microorganisms in the rumen. This proposition assumes that the negative effects of barley on hay intake are mediated in the rumen, and are of a physical nature.

This higher depression in hay intake with barley is further demonstrated in Figure 4.3 (a) when intake of DDM is considered in relation to supplement DM intake. However, this figure indicates that although hay intake is depressed to a greater extent with barley than with either sorghum or CSM, all supplement types achieved similar total DDM intakes at equivalent intakes of supplement DM. When the data are expressed in terms of DDMI (Figure 4.3 b) it is apparent that a level of DDMI from the supplement is matched by a depression in DDMI of the hay irrespective of supplement type. Substitution is thus occurring on an equivalent ME intake basis irrespective of supplement type in line with Weston' hypothesis (Weston 19xx). This appears to be the first experiment to have such extensive comparison of supplement types and levels and provides a basis for manipulating substitution. The data also questions whether the site of digestion of supplement is important. These data suggest it is not important and thus do not support the contention that the rumen is where substitution effects are mediated.

Regardless of the reasons for these differences in utilisation of the two grain sources, the higher growth rates with barley are very significant from a commercial and economic point of view, since the two grains usually differ little in price at any time. This higher performance with barley compared with sorghum has been alluded to elsewhere in the literature but not demonstrated previously over a range of intakes such as that used in the present study.

The concentration of NH_3-N in the rumen fluid of control steers was very low and a response to provision of a degradable form of N would have been expected. Concentrations in supplemented steers were considerably higher for grain-fed steers 3 h after feeding the supplements, presumably mainly in response to the provision of urea in the mixes. However, much of this additional rumen NH_3-N would have been directed towards fermentation of the grain carbohydrates and it is quite conceivable that there would have been a deficiency of this metabolite for optimal utilisation of the hay component of the diet. With CSM there was a much greater increase in NH_3-N concentration in the rumen, and this is also reflected in the higher concentrations of urea-N in the blood. Part of the reason for the sharp increase in growth rates with low levels of CSM intake may be attributable to the provision of rumen

degradable protein and the maintenance of higher concentrations of NH_3-N in the rumen. Blood glucose concentration was increased in response to feeding all three supplements, but control values do not indicate gross deficiency of this nutrient and it is questionable whether the higher growth rates of supplemented steers were associated with the increased glucose concentration in the blood.

4.5 Conclusions

From the experiments carried out here, it was obvious that liveweight gain was a function of DDM intake across diets. Cottonseed meal promoted a greater LW gain response than other supplements, especially at low supplement intakes, whilst barley provided a greater response than sorghum. These differences were primarily related to differences in DDMI. However, there also appeared to be differences between supplement types in the relationship between LW gain and DDMI, which may have been related to differences in microbial CP supply and the balance of MP/ME. Some of these issues were investigated in the next phase of the project (see Chapter 5). Substitution varied for different supplement types but the degree of substitution was similar when related to ME supply from the supplement. Site of digestion did not appear to be important with respect to substitution effects.

5. Metabolism study - Mt Cotton Research Farm

5.1 Introduction

This study was conducted to complement the major grazing study at Brigalow Research Station (Chapter 3) and the pen studies at Rocklea AHRF (Chapter 4). It was expressly designed to provide important information about the mode of operation of the supplements in terms of their effects on intake and digestion of a low quality basal diet, and of the total diet, but particularly to provide information on the effects of the various supplements on the production of microbial protein which is a key nutrient substrate for the ruminant grazing low quality pastures. In this way it was intended that the metabolism studies assist in explaining the growth responses achieved in the pen and grazing studies.

Prediction of growth rate in ruminants from feeding standards is based primarily on the metabolisable energy (**ME**) content of the diet, from which intake is predicted, and a knowledge of the ME requirements of the animal for growth. Secondary consideration is given then to protein content of the diet and the protein requirements of the animal for a particular rate of growth. On this basis, predictions of growth are similar for different 'energy sources' having the same ME and protein content, despite sometimes quite marked differences in the metabolism (e.g., site of digestion) and resulting end-products of fermentation of these energy sources, ie., as volatile fatty acids, glucose, lipids and amino acids. The importance of the composition and balance of these fermentation end-products is still not well understood but the feeding tables make no distinction between them by basing production primarily on ME intake.

The supplements used in this group of experiments represent different types of energy sources, viz., grains containing starch of high (barley) or low (sorghum) fermentability in the rumen, sugars rapidly and totally fermented in the rumen (molasses), and protein meals having varying degradability of protein (CSM, medium; fish meal, low (results not given here)) in the rumen but also containing a considerable amount of energy in the form of fibre, fat etc. (e.g., CSM, *ca.* 11 MJ/kg ME) available for rumen fermentation. Thus the supplements investigated were representative of the variability in types currently used in practical feeding systems. The aim was to determine whether these different supplement 'types' had different effects on the intake and digestion of the diet, and on the supply of nutrients to the animal.

The importance of microbial protein in the N economy of the grazing ruminant has already been alluded to, and having a research methodology to easily and reliably estimate microbial protein synthesis in the field is of high priority. Recent developments in the technique of using the concentration of purine derivatives in urine for estimating microbial protein synthesis have provided some confidence in the use of this method where total collections of urine can be made, but total collections of urine are not easily achieved under field conditions. An alternative proposal has been to take spot samples of urine and determine the ratio of purine derivatives to creatinine. Assuming there is a constant creatinine excretion per unit metabolic weight enables the calculation of purine excretion per day and hence daily microbial protein synthesis. This technique is yet to be rigorously tested in the field and a major emphasis in the current study was placed on evaluation and development of this potential research tool.

5.2 Research methodology

5.2.1 Experimental site/facilities

The experiment was conducted at the University of Queensland Mt Cotton Research Farm between the beginning of August and the end of December 1995.

5.2.2 Experimental animals, design and rations

Ten Brahman-crossbred weaner steers from the same draft as used in the pen experiments, and of mean liveweight 147 kg at commencement, were used in a response curve design experiment employing similar treatments to those used in pen studies at Rocklea. An introductory feeding and education period was undertaken in the month prior to the commencement of the trial to accustom steers to being led and housed in metabolism crates. The experiment was divided into six periods (runs), each of 28 d duration. Each run was further divided into a 21 d introductory period, to adjust steers to their allocated rations, and a 7 d collection period. Steers were housed in individual feedlot pens with access to a larger common yard during the introductory period and then in metabolism crates for the collection period.

In the first three (of six) periods, all steers were fed late-cut Rhodes grass hay *ad libitum* plus one of five levels, viz. 0, 0.5, 1.0, 1.5 and 2.0% BW, of either a sorghum-based mix (5S, 10S, 15S and 20S) or a barley-based mix (5B, 10B, 15B and 20B; one steer per treatment per run). By repeating this procedure over three runs, three replicates of each treatment were effectively achieved, albeit in different runs. Animals were randomly allocated to treatment between each replicate, with the restriction that no one steer was given the same ration more than once. Procedures were the same in the second three runs except that the supplements were CSM (5C, 10C, 15C and 20C) or a molasses-based mix (5M, 10M, 15M and 20M) instead of the grain supplements. The composition of barley, sorghum and molasses mixes was the same as that described earlier (Chapter 4) for the Rocklea pen feeding trials. The amount of non-protein-N (**NPN**) added to the grain rations as urea and ammonium sulphate was the equivalent of 1.9% urea.

5.2.3 Experimental procedures

Chaffed hay was fed once daily in the morning at a level designed to establish a refusal rate of 10-15% of that offered per day. The supplement was also fed once daily in the morning but was offered in a separate tray to minimise mixing of supplement and basal diet and thereby allow differentiation of the feed residue between supplement and hay. The amount of supplement offered was adjusted weekly on the basis of the most recent liveweights recorded. Supplement intakes were increased gradually during the introductory period but were at treatment levels for the final 5-7 d of this period in order to establish relatively stable feed intakes before moving the cattle to the metabolism crates. Feed refusals were collected each morning, weighed and bulked across days for each steer.

The total residue for each steer over the collection period was weighed and a sub-sample taken, dried in a forced-draft oven for 72 h at 65 ^{0}C for DM determination, ground through a 1 mm screen and stored for analysis. Daily sub-samples of the hay offered and of the grain and CSM supplements were also collected and bulked over the total collection period, and handled the same as feed residues. Faeces were collected and weighed daily and a 10% aliquot was stored frozen for each steer. At the end of the collection period, these samples were bulked for each animal, mixed thoroughly, sub-sampled and dried in the manner described above in order to determine faecal DM output. Part of the sample was freeze-dried and ground to 1 mm and stored.

Urine was collected into 10% (v/v) sulphuric acid. The pH was measured each morning to ensure the pH was below 3 and the quantity of acid adjusted if necessary. Urine weight was recorded and a 10 % aliquot taken, bulked for each steer across days, and stored in a refrigerator for subsequent N analysis. A sub-sample of the daily urine output was also collected from each steer for the determination of purine derivatives (**PD**) and creatinine (**Cn**) content. A 5 mL sample of the acidified urine was pipetted into a 50 mL graduated tube containing 1 mL of 1 mM allopurinol standard and made up to 50 mL with 0.1 M ammonium phosphate ($NH_4H_2PO_4$) buffer. The diluted sample was then frozen.

Spot samples of urine were also collected between 8.00 am and 8.00pm on consecutive days of each collection run (days 2 and 3), from one control steer and the four steers receiving either supplement type at the 1% and 2% BW levels. Collection of the spot samples was achieved by positioning sponges in the funnel-shaped collection tray above the collection bucket containing the acid. The samples were grouped for each animal according to the collection period, with the total period divided into six, 2-hourly segments, so that diurnal effects on excretion of purine derivatives and creatinine could be established.

In addition, 3-4 spot samples of urine were taken over 24 h on one day of the collection period from the same animals, and individual samples were analysed for PD and Cn. The total excretion of purine derivatives was determined for these animals over the same 24 h and estimates of microbial CP (**MCP**) production using both total and spot urine samples were made.

Rumen fluid and blood samples were collected 3 h post-feeding on the eighth day of the collection period and rumen fluid was collected again on the next day just before feeding (24 h after the previous feed; hereafter referred to as 0 h). Blood was collected from the jugular vein into a 10 mL tube containing lithium heparin and placed on ice. These samples were centrifuged at 3000 rpm for 10 min and the resulting plasma frozen awaiting analysis. Rumen fluid was collected from each steer using a stomach tube and vacuum pump and the sample sieved through two layers of stocking before sub-sampling. A 4 mL sub-sample was added to 16 mL of buffered neutral formalin for later protozoal enumeration, a further 4 mL was added to 4 mL of 0.2 N HCl and frozen prior to analysis for rumen NH_3-N concentration, and 4 mL was added to a bottle containing mercuric chloride and frozen for determination of VFA concentration and proportions.

The hay, supplements, feed refusals and faeces were analysed for OM and N content, and the grain samples were also analysed for crude fibre (**CF**) and ether extract (**EE**) content. The hay was also analysed for ADF and NDF content and IVOMD. Urine samples were analysed for total N, and separate samples were analysed for their content of PD and Cn. Based on these analyses, the ration digestibility and N balance were determined and MCP production estimated from the purine derivatives in urine.

5.2.3.1 Estimation of microbial protein production

The estimation of exogenous purine supply (X, mmol/d) attributable to the microbial population of the rumen can be estimated as the total purine excretion (Y, mmol/d) less the endogenous contribution to this total divided by a recovery factor. The literature suggests an endogenous purine contribution of 0.385 mmol/kg$W^{0.75}$ and a recovery coefficient of 0.85 for absorbed purines. The calculation becomes:

$$Y = 0.85\ X + 0.385\ W^{0.75}\ .$$

The value of X is then converted to estimated microbial N supply (EMNS, g/d) through the following equation:

$$EMNS = (70X) / (0.83*0.116*1000)$$

where 0.83 is the assumed digestibility of the microbial protein and 0.116 represents the ratio of purine nitrogen to total microbial nitrogen. A factor of 6.25 is applied to convert EMNS to microbial crude protein supply (g/d).

5.2.3.2 Calculation of ratio of purine derivatives to creatinine in urine

The ratio of **PD** to **Cn** in spot samples of urine was calculated on a molar basis (mol/mol), with creatinine concentration corrected for metabolic bodyweight ($W^{0.75}$, kg) according to the method of Chen *et al.* (1995).

5.3 Results

5.3.1 Feed analysis

The hay and supplements used were the same as those used in the pen feeding experiments, and have been described in that section.

5.3.2 Animal growth rates

Steers grew at a mean rate of 400g/d over the 130 d experimental period.

5.3.3 Hay, supplement and total intake

All steers receiving barley, sorghum or CSM consumed their total allocation of supplement. The molasses-fed steers also consumed all their supplement, except for one steer in the 2% BW treatment. This steer consumed 1.51% BW as molasses in run 4. For data presentation purposes, this steer has been included with those receiving, and eating, 1.5% BW of molasses.

The mean DM intake by the control steers over the six runs was 1.85 $\pm$ 0.078 ($\pm$ SEM)% of BW. The influence of increasing supplement intake as barley, sorghum, CSM or molasses on the intake of hay and total DM, relative to that of the control on a % BW basis, is presented in Figure 5.1. All supplements were associated with increased total DM intakes. There was little difference between the effects of barley, sorghum and molasses on total DM intake, but CSM increased total DM intake with the 2% BW treatment being 75% higher than controls. All supplements depressed hay intake with CSM having the least effect and barley and sorghum the greatest effect; molasses was intermediate. Feeding CSM actually increased intake of hay at the 0.5% BW level of feeding and only caused a depression in hay intake at the 2% BW level. The other three supplements caused no depression in intake of hay at the lowest intake level.

The rate of substitution of supplement for hay was represented by the slope of the linear regression line of hay intake against supplement intake, with both intakes calculated on a BW basis. The calculated substitution rates for barley, sorghum, molasses and CSM were 0.53, 0.57, 0.41 and 0.18.

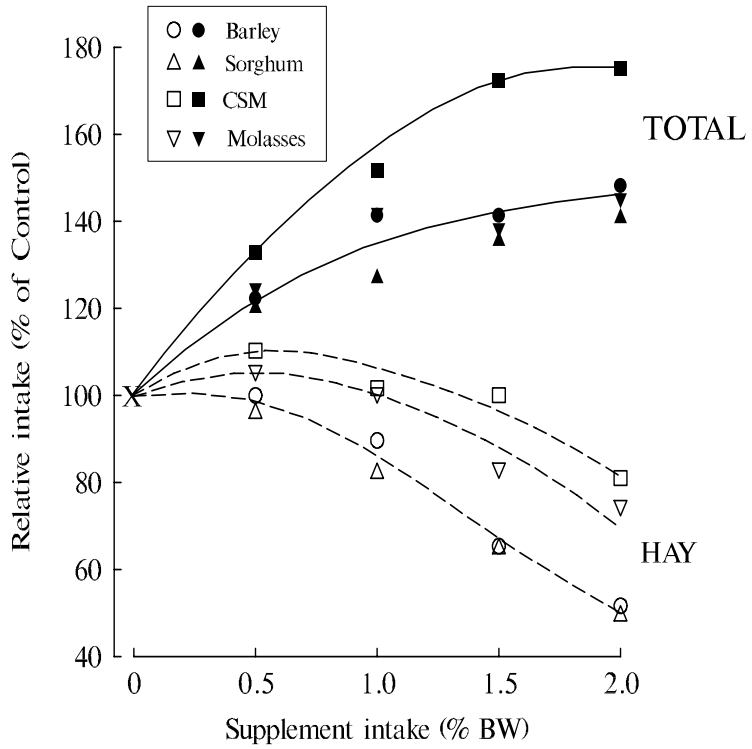

Figure 5.1. Effect of supplements on the intake by steers of hay (dashed lines, open symbols) and total (solid lines, closed symbols) DM, expressed as a proportion of bodyweight (BW), relative to the intake for the unsupplemented control steers. Data for hay intakes relating to the barley and sorghum treatments, and for total intakes relating to the barley, sorghum and molasses treatments, are represented by single lines. Points represent the mean value for three steers across runs except for the control (X) where the point represents the mean for 12 data points across runs.

5.3.4 ORGANIC MATTER DIGESTIBILITY

Changes in the *in vivo* OM digestibility (**OMD**) of the total ration with increasing intake of supplement as barley, sorghum, cottonseed meal and molasses, are presented in Figure 5.2. The OMD of Rhodes grass hay averaged 56.0 ± 1.1 for the six runs. The corresponding DM digestibility was 51.8 ± 1.4. Total OMD increased linearly with increasing amount of supplement consumed except with sorghum, where there was no increase with increasing supplement intake. The greatest response to supplement intake was with barley, whilst CSM and molasses were intermediate.

5.3.5 NITROGEN BALANCE

Nitrogen content in the faeces of control steers, averaged over the six runs, was 14.9 ± 0.045 g/kg DM. Faecal N content increased linearly with increasing intake of all supplements, although the slope of this linear relationship varied between them. Nitrogen retention (g/d) by steers increased linearly with increasing supplement intake for all rations, with the greatest effect occurring when CSM was used. The changes in N retention with increasing N intake are shown for all supplements in Figure 5.3. Cottonseed meal had the greatest effect, whilst barley had a greater effect than sorghum. Unsupplemented steers had a mean N retention of 7.0 ± 0.88 g/d over the six runs.

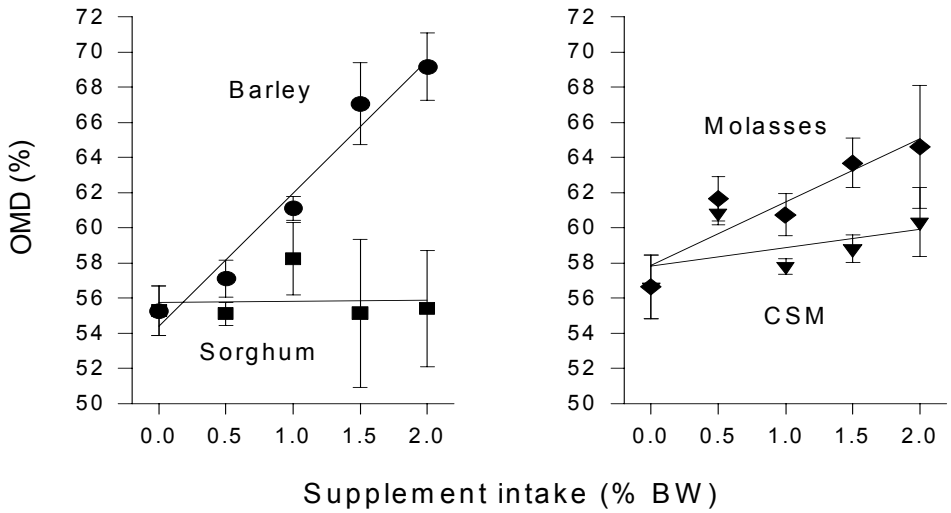

Figure 5.2. Changes in organic matter digestibility (OMD) with increasing intake of barley (●), sorghum (■), molasses (◆) or cottonseed meal (CSM; ▼). Points represent the mean for three steers across runs, with the standard error shown (bars).

5.3.6 MICROBIAL PROTEIN PRODUCTION

Excretion of purine derivatives in the urine of steers increased as digestible organic matter intake (**DOMI**) increased for all four supplement types. Predicted MCP production is a function of purine derivative excretion, as described in Section 5.2.3.1, and the relationship between DOMI (g/d) and MCP production (g/d), estimated from purine derivatives excretion in urine, is shown in Figure 5.4 (data from all treatments included). This relationship is described by the equation:

$$\text{MCP production} = 0.17 * \text{DOMI} - 129.4; \quad (R^2 = 0.66).$$

Similar data is presented in Figure 5.5 for MCP production in relation to the intake of the various supplements, with MCP production ranging from 77 to 533 g/d, but increasing linearly with supplement intake. In these relationships, barley and CSM had the greatest incremental effect (greatest slope for regression), and sorghum the least, for MCP production per unit level of supplement.

In Figure 5.6, the relationship is shown between MCP production estimated from purine excretion (present results) and that predicted from the feeding tables, i.e., predictions of AFRC (1992) based on DOMI. This line is represented by the following equation:

$$\text{MCP (AFRC)} = 0.61 * \text{MCP (PD urine)} + 168.3; \quad (R^2 = 0.68)$$

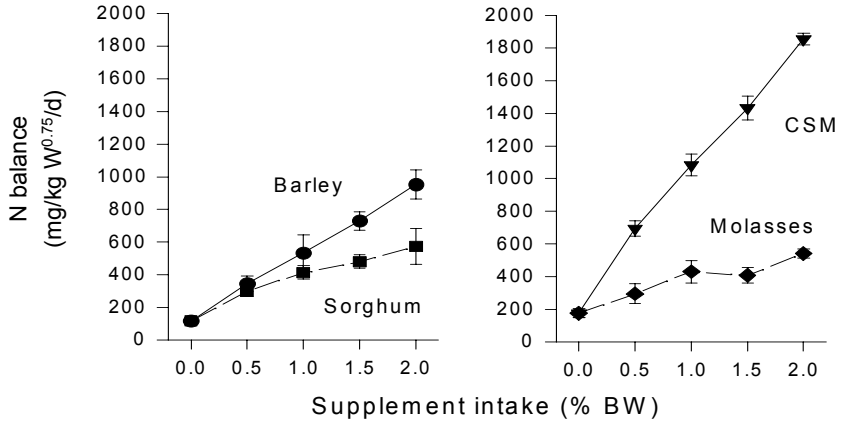

Figure 5.3. Changes in nitrogen (N) balance with increasing intake of barley (●), sorghum (■), molasses (◆) or cottonseed meal (CSM;▼). Points represent the mean for three steers, with the standard errors shown (as bars).

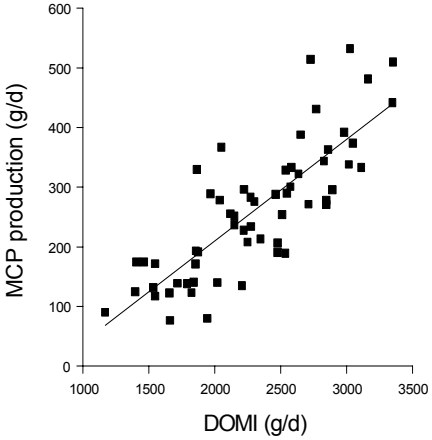

Figure 5.4. Relationship between production of microbial crude protein (MCP), as estimated from the excretion of purine derivatives in urine, and intake of digestible energy (DOMI) from all diets. Points represent data for individual animals within runs.

where MCP (AFRC) and MCP (PD urine) represent MCP production as predicted from AFRC (1992) and as estimated from the excretion of PD in urine in the current experiment respectively. The line representing absolute agreement between the two estimations of MCP is also shown (dotted line; Y=X). At higher production rates there was quite close agreement between the two methods of estimation but at the lower production rates, AFRC markedly overestimated MCP production.

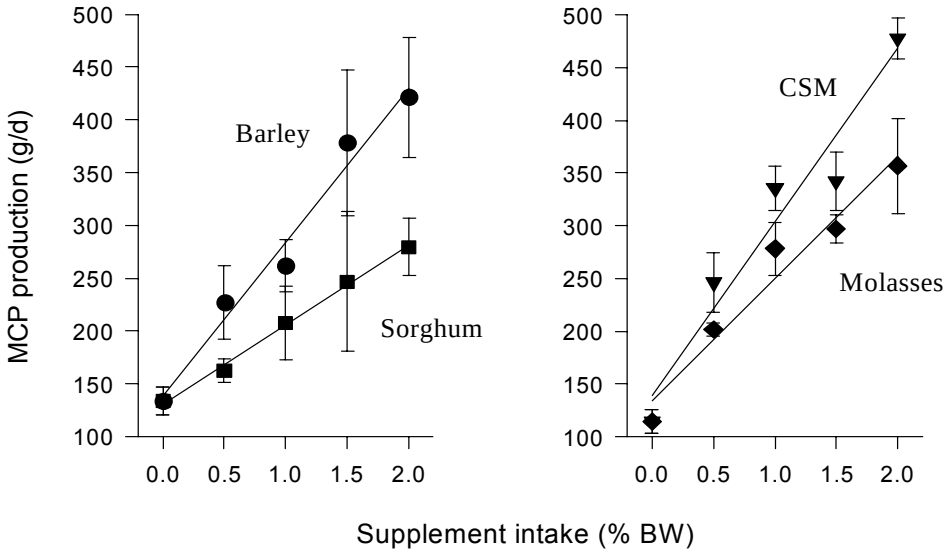

Figure 5.5. Relationships between production of microbial crude protein (MCP), as estimated from the excretion of purine derivatives in urine, and intake of supplements of barley (●), sorghum (■), molasses (◆) or cottonseed meal (CSM;▼). Points represent the mean for three steers across runs, with the standard error shown (as bars).

5.3.6.1 Creatinine excretion in urine

Creatinine excretion was also measured and the influence of DOM intake on Cn excretion is presented in Figure 5.7. The trend was for creatinine excretion, corrected for metabolic weight of the animal, to increase with increasing intake of DOM across all diets. The linear relationship between Cn excretion in urine (mg/kg $W^{0.75}$/d) and DOMI (g/d) is described by the equation:

$$\text{Cn excretion} = 0.018 * \text{DOMI} + 63.6; \quad (R^2 = 0.32).$$

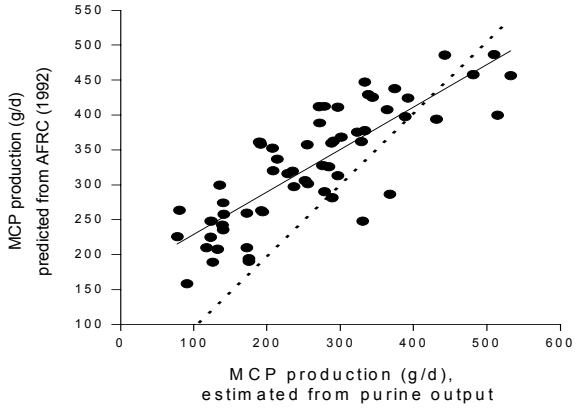

Figure 5.6. Relationship between production of microbial crude protein (MCP) estimated from excretion of purine derivatives in urine and that predicted from AFRC (1992; solid line). The dotted line represents Y=X. Points represent data for individual animals within runs.

5.3.6.2 Ratio of concentration of purine derivatives to creatinine in urine

The diurnal variation in the ratio of purine derivatives to creatinine (PD:Cn) in samples of urine collected at intervals during the second and third day of the collection periods is presented in Figure 5.8. Samples were grouped according to period of collection into six 2-hourly periods, between 8.00 am and 8.00 pm. The PD:Cn ratio for each steer was expressed as a proportion of the daily mean for that steer, according to the method adopted by Chen *et al*. (1995) for data with sheep, and these values were averaged across animals

within sampling periods (see Figure 5.8). Diurnal variation was small with the mean PD:Cn ratios for the various periods ranging from 0.97 to 1.03 of the daily mean.

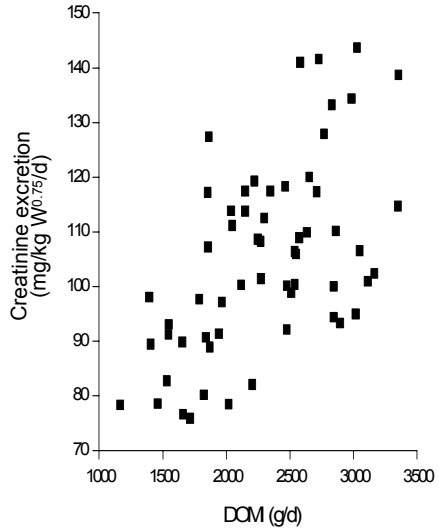

Figure 5.7. Relationship between excretion of creatinine in urine, and intake of digestible energy (DOMI) from all diets. Points represent data for individual animals within runs.

The ratio PD:Cn averaged for three or four samples taken over 24 h, and the total excretion of purine derivatives for that same period, is illustrated in Figure 5.9, and is represented by the equation:

$$PD:Cn = 36.5 + 0.54 \text{ PD excretion}; \quad (R^2 = 0.62),$$

where PD:Cn is the ratio of the concentrations of purine derivatives to creatinine in spot samples taken over 24 h (mol/mol/$W^{0.75}$.d), and PD excretion represents the total excretion of PD for the same 24 h (mmol/d).

5.3.6.3 Efficiency of microbial protein production

The effects of supplement type and level on the efficiency of MCP production, expressed in relation to DOMI (g/kg DOMI), are shown in Figure 5.10. Efficiency of production of MCP for unsupplemented steers was low in all runs, with some difference between runs 1-3 and runs 4-6 (62 vs 92 g/kg DOMI). For all supplements, efficiency increased with increasing intake of supplement. The rate of increase was greatest for the CSM and molasses supplements, but these treatments started at a lower level (controls, 62 g/kg DOMI) than the grain-based treatments (controls, 92 g/kg DOMI).

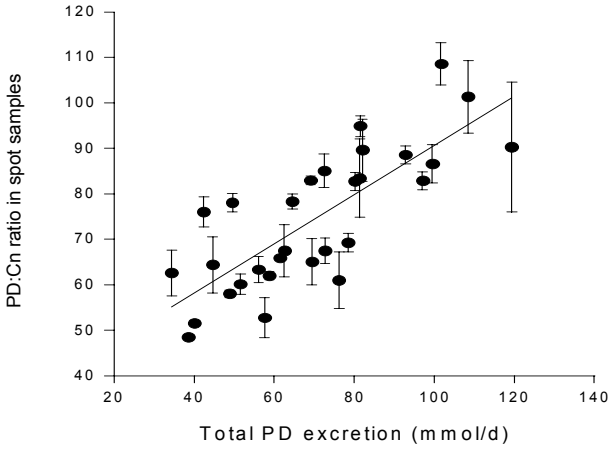

Figure 5.8. Diurnal changes in the ratio of purine derivatives (PD) to creatinine (Cn) in urine collected as spot samples, expressed as a proportion of the mean ratio for a sample collected over the total period on the same day. Periods 1-6 represent successive 2-hourly periods between 8.00 am and 8.00 pm for days 2 and 3 of the collection period. Points represent the mean for all animals sampled during the period, irrespective of treatment, with the standard error shown as a bar.

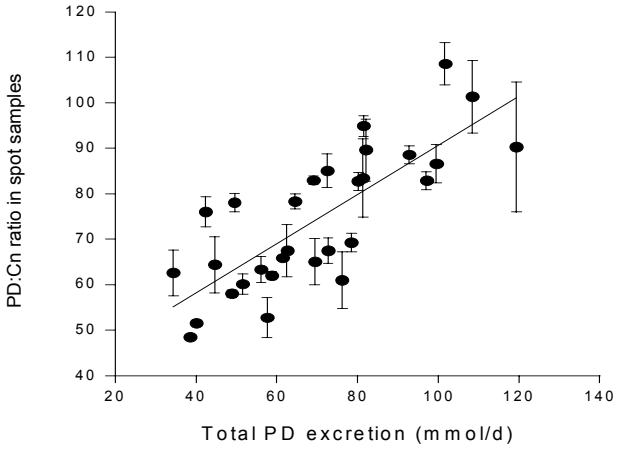

Figure 5.9. Relationship between the ratio of concentrations of purine derivatives (PD) and creatinine (Cn) in spot samples of urine taken over 24 h, and the total excretion of PD for the same 24 h period. Points represent the mean value for PD:Cn for 3-4 spot samples of urine taken for any one steer for a particular 24 h period, and the standard error of the mean over that data set.

5.3.7 CONCENTRATION OF NH_3-N IN RUMEN FLUID

The concentrations of NH_3-N in rumen fluid, just before feeding and 3 h post-feeding, are shown in Table 5.1. Separate control values are given for runs 1-3, in which barley and sorghum were the supplements used, and runs 4-6 when CSM and molasses were used. Concentrations of NH_3-N in rumen fluid were low for unsupplemented steers throughout (21-39 mg/L) but were markedly increased with all supplements 3 h after feeding. For the barley, sorghum and CSM treatments, concentration tended to increase with increasing increment of supplement but in the case of molasses, no increase in NH_3-N concentration resulted from increasing molasses intake beyond the 0.5% BW level. Concentrations were low at the 'before feeding' sampling for all supplements except CSM, for which concentrations increased in direct proportion to intake (see Table 5.1).

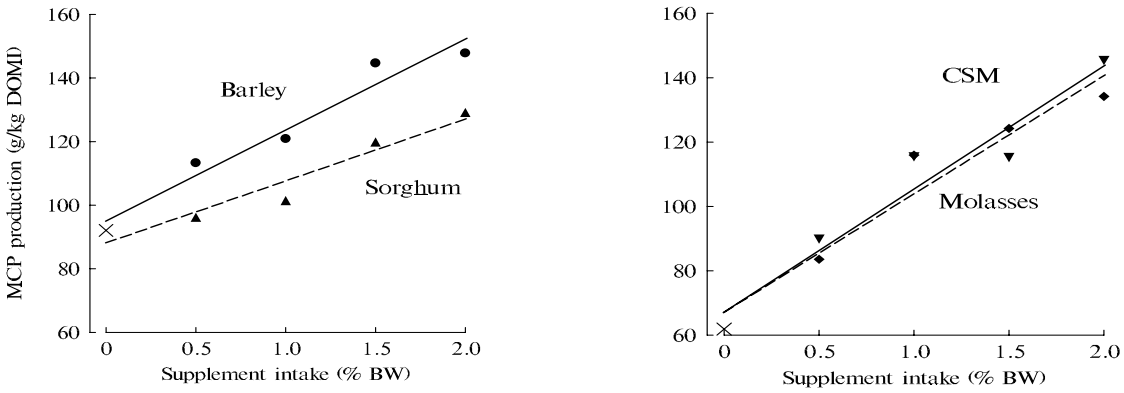

Figure 5.10. Changes in the efficiency of production of microbial crude protein (MCP) with increasing intake of barley (●; solid line), sorghum (■; dashed line), molasses (◆; dashed) or cottonseed meal (CSM;▼; solid). Points represent the mean for three steers across runs except for the controls (X) which are means for six steers.

5.3.8 PROTOZOA POPULATION DENSITY IN RUMEN FLUID

The population density of protozoa in the rumen fluid of steers, before and after feeding, are also shown in Table 5.1. Between-animal (within treatment) variability in population density was large. In general, protozoa numbers were greater before than after feeding. Grain feeding was associated with increased protozoa numbers before feeding, especially with barley supplementation where numbers tended to increase proportionally with intake of the supplement. Supplements of CSM and molasses had little effect on protozoa numbers relative to the unsupplemented controls, but there was a shift in population composition with molasses towards an increased proportion of holotrichs (*Isotricha* spp. and *Dasytricha* spp.). With grain supplements, the trend was for a much higher proportion of small entodinia (*Entodinium* spp.) relative to other treatments.

5.3.9 PLASMA METABOLITES

The urea-N concentrations in plasma, taken 3 h after feeding, are also shown in Table 5.2. For barley and sorghum rations, the trend was for an increase in concentration of plasma urea-N with the first increment of feeding (0.5% BW) but no or small increases with subsequent increments. Molasses supplementation was associated with a small increase in plasma urea-N concentration, whilst with CSM feeding concentration was directly proportional to supplement intake. Plasma glucose concentrations were variable within treatments but the trend was for higher glucose concentration at the highest grain intakes for both sorghum and barley. All levels of feeding of CSM (0.5-2.0% BW) were associated with increased glucose concentration in plasma relative to the control value, with no apparent difference between levels of feeding. Molasses supplementation had no effect on plasma glucose concentration.

Table 5.1. Effect of supplements and time of sampling on the concentration of ammonia-N (NH_3-N) and on the population density of protozoa in the rumen fluid of steers given a basal diet of Rhodes grass hay ad libitum

Ration	**NH_3-N concentration in rumen fluid**	**Protozoa population density**

	Before feeding		3 h post-feeding		Before feeding		3 h post-feeding	
	Mean (mg/L)	*SEM*	Mean (mg/L)	*SEM*	Mean (10^{-5}/mL)	*SEM*	Mean (10^{-5}/mL)	*SEM*
Control	39	*8.5*	34	*6.1*	2.3	*0.42*	7.4	*5.15*
5 B	36	*17.0*	109	*33.6*	10.0	*3.38*	10.3	*3.04*
10 B	52	*2.4*	195	*31.3*	10.3	*2.41*	11.9	*3.09*
15 B	52	*6.1*	264	*33.2*	21.4	*3.10*	16.0	*3.66*
20 B	69	*5.8*	204	*18.3*	31.1	*16.15*	18.3	*7.85*
5 S	39	*7.2*	94	*14.0*	2.6	*0.62*	3.6	*0.68*
10 S	60	*11.8*	175	*23.1*	9.0	*2.62*	6.3	*2.02*
15 S	56	*2.1*	235	*14.2*	9.6	*4.72*	8.1	*4.59*
20 S	57	*5.3*	253	*34.1*	16.0	*11.38*	8.1	*3.36*
Control	24	*8.1*	21	*6.2*	0.7	*0.11*	1.0	*0.26*
5 C	64	*2.5*	119	*9.8*	0.9	*0.11*	1.0	*0.16*
10 C	79	*5.7*	180	*11.7*	1.5	*0.29*	0.7	*0.23*
15 C	121	*25.9*	196	*33.2*	1.0	*0.15*	1.0	*0.26*
20 C	145	*14.2*	268	*18.3*	1.7	*0.50*	0.8	*0.43*
5 M	21	*4.2*	161	*20.7*	2.2	*0.97*	1.1	*0.01*
10 M	17	*4.2*	151	*16.7*	0.6	*0.06*	0.7	*0.27*
15 M	12	*2.6*	154	*40.4*	0.8	*0.13*	1.1	*0.47*
20 M	20	*12.4*	111	*7.1*	3.6	*2.91*	2.2	*1.62*

5.3.10 STARCH IN FAECES

The starch content (DM basis) in the faeces of unsupplemented steers averaged 0.7% for the first three runs of the experiment. Corresponding values for the barley treatments, with increasing intake of supplement, were: 1.1, 1.9, 2.5 and 6.1% and for sorghum were: 9.0, 16.3, 25.1 and 25.2% respectively.

5.4 Discussion

5.4.1 INTAKE

As would be expected from previous findings reported in the literature, feeding supplements in association with the low quality hay resulted in substitution of supplement for hay, but the degree of substitution varied markedly between supplement types in our experiment. Substitution rates are often calculated as the slope of the regression of hay intake against supplement intake, which assumes linearity between these parameters but in the present experiment this was not so. Nevertheless, the calculated substitution rates do highlight the fact that the grain supplements caused a greater depression in hay intake than molasses, which in turn depressed hay intake more than CSM (see Figure 5.1). The mechanisms involved in these substitution effects have been discussed in some detail in Chapter 4, and relate to equilibration of total ME supply. No further discussion on these principles is included here.

The stimulation of hay intake with CSM, at low rates of dietary inclusion, suggests that the protein meal supplement probably corrected a N deficiency in the rumen which was limiting

microbial growth in animals given the hay alone. This suggestion is supported by the marked increase in MCP production when CSM was fed. A similar intake response may have been achieved with urea at these low intakes, and this is suggested also by the lack of depression in hay intake when supplements of barley, sorghum and molasses, all containing urea, were fed at the lowest rate. This finding also highlights the problem with formulating supplements on the basis of a set percentage inclusion of urea (or an alternative protein source), based solely on the requirements for total fermentation of the supplement. At low rates of supplementation, the major component of the diet is the roughage source and if additional N is required to overcome a deficiency in this dietary component as well as ensure optimal use of the supplement, then higher levels of rumen degradable N are needed in the supplement. Thus a higher percentage inclusion of N is required with low supplement intakes and a minimum absolute intake of N should be specified to ensure adequate N for digestion of all components of the diet.

Regardless of these substitution effects, supplementation resulted in large increases in total DM intake and even greater proportional increases in DOM intake by virtue of the higher digestibility of the supplements relative to the hay. Thus whilst substitution of supplement for pasture is undesirable on economic grounds, supplementation was still associated with increased intake of digestible nutrients which should be translated into increased growth rates. Substitution has further implications in terms of a 'pasture sparing' effect of supplements with reduced grazing pressure (or conversely the potential for higher stocking rates), which in turn should impact on the sustainable use of resources. Nevertheless, substitution reduces the overall responses to supplementation and reducing or removing its effect should result in greater growth responses.

5.4.2 DIGESTIBILITY

The effect of different supplements on the digestibility of OM and DM in the total tract was highly variable in our experiments. The largest increases in OMD were associated with feeding barley, where there was a linear increase in digestibility with increasing intake. Molasses feeding also increased OMD, although not to the same extent as with barley, whilst sorghum, by contrast, had no apparent effect on OMD at any intake level.

Table 5.2. Effect of supplements on the concentration of urea-N and of glucose in the blood plasma of steers given a basal diet of Rhodes grass hay ad libitum

Ration	**Plasma urea-N**		**Plasma glucose**	
	Mean	*SEM*	Mean	*SEM*

	(mg/dL)		(mg/dL)	
Control	7.3	*1.1*	88	*8.7*
5 B	11.0	*1.1*	85	*1.6*
10 B	15.3	*0.4*	94	*1.6*
15 B	14.9	*0.9*	113	*11.2*
20 B	15.2	*1.1*	104	*2.6*
5 S	10.7	*0.9*	86	*3.3*
10 S	12.3	*1.4*	79	*3.0*
15 S	11.9	*1.4*	90	*2.8*
20 S	15.3	*1.1*	100	*8.3*
Control	4.4	*0.9*	76	*2.5*
5 C	12.5	*0.9*	85	*4.8*
10 C	19.4	*1.6*	89	*1.2*
15 C	25.9	*1.3*	89	*0.6*
20 C	29.2	*1.0*	91	*5.3*
5 M	7.8	*2.0*	69	*3.9*
10 M	8.4	*1.0*	70	*2.1*
15 M	8.6	*1.7*	73	*7.4*
20 M	7.0	*0.9*	79	*2.2*

The different responses to barley and sorghum are obviously associated with differences in the degradability of starch in the rumen for the two grain sources. It has been well established that the barley starch is highly fermented in the rumen, with Zinn (1993) showing that about 76% is degraded in the rumen when the grain source comprised 75% of the total DM intake; OMD of the total diet was 78% under these feeding conditions. In our experiment, barley comprised 64% of total DM intake at the highest level of feeding (2% BW) and OMD was almost 70%. By contrast, a high proportion of the starch of sorghum is not degraded in the rumen but passes to the small intestines to be absorbed as glucose. Evidence of this low starch degradability in the rumen in the present experiment is given by (i) low MCP production in the rumen (see later) and (ii) low population density of protozoa in the rumen, relative to barley (see later). The low total OMD with sorghum suggests that a large proportion of the starch escaping rumen degradation also passes through the intestines undegraded and does not become available to the animal. This proposition is supported by the presence of high starch concentrations in faeces of steers consuming sorghum, whereas with barley it was only at the highest level of feeding that starch content of the faeces increased significantly and then not to the extent with sorghum. It appears, therefore, that the digestibility of this starch is limited by the decreased ability of the lower gastrointestinal tract to either hydrolyse the starch granules or take up the resultant glucose produced.

A factor that reduces the digestibility of starch in sorghum grain is the embedding of the starch granules in a protein matrix, such as in the corneous and peripheral endosperm. This can also impact on the degradability of the protein fraction in the sorghum and may account for the lower digestibility of N in sorghum compared to barley rations. Our results are consistent with the literature where it has been well documented that sorghum has a lower feeding value than corn or barley and needs more vigorous processing to achieve optimal digestibility. Nevertheless, these findings re-emphasise the inefficiencies associated with feeding cracked sorghum and highlight the need to account for this lower feeding value when rations are being formulated and predictions of growth rate are being made.

The increase in OMD of the total ration with increasing intake of molasses/urea reflects the rapid and complete digestion of molasses (and urea) in the rumen, presumably without major reduction in the digestibility of the roughage component of the diet. The surprising result was the small effect of CSM on the digestibility of OM, suggesting perhaps a rapid passage of the CSM through the tract since total DM intake was not greatly reduced with this supplement. The results overall heed a warning about the dangers of basing predictions of animal performance on the ME content of the diet, as has been largely the case with the feeding tables.

5.4.3 MICROBIAL PROTEIN PRODUCTION

Accurate and non-invasive prediction of MCP production in the rumen of cattle and sheep is required for more precise prediction of animal performance and better understanding of the responses to supplementation. Analysis of the concentration of PD in urine and calculation of estimated MCP production from this provides the basis of a useful tool for experimental work. In the field, however, it is not possible to measure total urine output directly. Thus recently there has been increased interest in using the ratio of concentrations of PD to Cn in spot urine samples to estimate MCP production, as Cn excretion is theoretically a biological constant related to the bodyweight of the animal. In addition to estimating MCP production from total output of PD in urine, the current experiment examined the legitimacy of using this PD:Cn ratio as an alternative to total collection.

Production of MCP, as estimated from total PD excretion, increased in a linear fashion with the supply of DOMI from the diets (see Figure 5.4). This finding is consistent with the relationships described in some of the major feeding standards in which MCP production is similarly related to some measure of digestible nutrient supply, e.g., DOMI and total digestible nutrients (TDN). However, there was considerable variation about the relationship established in the present experiment (R^2=0.66), with several possible explanations. Firstly, the digestion of OM in the rumen (or fermentable ME; AFRC (1992)) is not a fixed proportion of DOMI across all supplement types. This has been alluded to earlier and is illustrated by the different relationships between supplement intake and estimated MCP production for the four supplement types in Figure 5.5. In this figure, the slope of the linear relationship is greater for barley and CSM than for molasses, with that for sorghum lowest. That microbial N yield is not a constant function of DOM or TDN is recognised by AFRC (1992) feeding standards and the Cornell Net Carbohydrate and Protein System (Russell *et al*. 1992). Whilst the low yield of MCP from sorghum, relative to other supplements, can be explained in terms of low rumen degradability of starch, the reason for the lower MCP yield for molasses compared to barley is not readily apparent. This molasses supplement provided a readily fermentable source of carbohydrate and a soluble N source, but the low NH_3N concentrations in the rumen fluid of molasses-supplemented steers prior to feeding suggests that deficiency of this important nutrient for microbial growth may have limited MCP yield. Alternatively, low supply of amino acids may have depressed microbial growth with the molasses supplements.

The second factor contributing to the variability about the relationship illustrated in Figure 5.4 is that the efficiency of MCP production (ie., g/kg DOM) increased with supplement intake (see Figure 5.10). The reason for this trend is not readily apparent but probably stems from the greater proportionate digestion of potentially digestible OM in the rumen relative to the total tract, with increasing supplement intake. This finding again challenges the concept of a linear relationship between MCP production and the digestibility of OM in the total tract. Furthermore, this relationship between supplement intake and efficiency of MCP production tended to vary with supplement type.

What is also evident from this figure is the very low efficiency of MCP production with Rhodes grass hay alone (62-92 g/kg DOM). Only at the highest levels of intake of supplement did efficiencies approach the values assumed in the feeding standards (130-170

g MCP/kg DOM). This is also demonstrated in Figure 5.6 which showed agreement in the present experiment between MCP production estimated from PD excretion and that predicted from AFRC (1992) at higher levels of MCP production, and hence higher supplement intakes, whereas at lower production levels the AFRC (1992) predictions markedly overestimated actual production. The low efficiencies of MCP on these tropical pastures appear to be a major constraint to higher growth rates by grazing animals, but at the same time provide significant opportunity for improvement through efforts directed at increasing efficiency of MCP production. In a recent review paper by the current research team (Poppi *et al.* 1997), a small change in efficiency of MCP production from 100 to 130 g/kg DOM was calculated to provide sufficient additional MCP to increase growth rate of cattle by 300 g/d. The challenge is to determine the most efficient and practical ways to bring about these increases in efficiency.

The use of spot samples of urine together with determination of the PD:Cn ratio was only moderately successful as a substitute for total urine collection. Thus the linear relationship between PD excretion and estimated MCP production only accounted for 62% of the variability (see Figure 5.9). The assumption that Cn is a constant of liveweight independent of diet is obviously flawed as there was a trend for Cn excretion, calculated on a metabolic liveweight basis, to increase with DOMI (R^2=0.32; see Figure 5.7). Thus as supplement intake increased, so did both the concentration of PD and Cn so that the ratio of the two would have been less than expected if Cn concentration remained a constant. That the ratio PD:Cn varied only marginally throughout the day suggests that a single urine sample can be used for estimates of MCP production to be made, but the current results emphasise the accompanying need for some index of total urine excretion if the method is to be reliably used under grazing conditions.

5.4.4 RUMEN FLUID AND BLOOD METABOLITES AND PROTOZOAL POPULATION DENSITY

The concentration of NH_3-N in the rumen fluid of experimental steers was relatively low for the controls and all supplement treatments except CSM just prior to feeding. Based on past results, NH_3-N concentration in rumen fluid should exceed a 'critical level' of about 50 mg/L for maximum MCP synthesis, although there is evidence that this optimal level should be considerably higher when rapidly fermentable substrates such as starch and sugars are present or to support maximum digestion of the diet (> 100 mg/L). As mentioned earlier, concentrations were very low for the molasses-supplemented steers and this may help to explain the low production of MCP with this supplement relative to barley. Urea inclusion in the barley, sorghum and molasses supplements markedly increased NH_3-N concentrations in rumen fluid 3 h after feeding but the experimental approach provides no information about the duration over which concentrations exceeded the 'critical level' described above.

In the case of barley and sorghum, plasma urea-N concentration was increased with supplementation at the lowest level of intake but there was only a marginal increase in concentration with subsequent increments of supplement. This finding, coupled with earlier data relating to MCP production, suggests that the additional soluble-N fed as urea was utilised by the rumen microbes in the synthesis of protein, and raises the question of whether the animals would have responded to even higher concentrations of urea, especially at low intakes of supplement when hay was the major component of the diet. A similar trend was obvious with the molasses-based supplement except that plasma urea-N concentrations were generally lower than in the case of the grain-based supplements.

Feeding CSM resulted in a sustained increase in the concentration of NH_3-N in rumen fluid, and a linear increase in the concentration of urea-N in plasma for the experimental animals. It follows that the response to feeding this supplement may, under certain circumstances, be more attributable to the maintenance of this elevated concentration of NH_3-N than to the provision of bypass protein for direct absorption from the intestines. In most situations it would be the combination of effects that would be important.

Glucose concentrations in the plasma for steers was highly variable between-animals within treatment levels of feeding. For the control steers, glucose concentration ranged from 76 to 88 mg/dL, which is not indicative of highly deficient diets. The trend for increased plasma glucose concentration with barley supplementation is consistent with a high degree of starch fermentation to propionate (a major precursor of glucose) as the VFA end-product, whereas with sorghum it was only at the highest level of feeding (2% BW) that glucose concentration tended to increase, in keeping with a lower overall extent of starch fermentation. Some compensation for this low starch fermentation should have occurred through increased intestinal absorption of glucose, but the high faecal starch contents in sorghum-fed animals suggests that this route of glucose absorption was limited. Molasses and its resultant sugars are almost totally fermented in the rumen with acetate/butyrate as the main VFA products, and with this supplement there was no apparent increase in glucose concentration in the plasma at any level of feeding. It has been speculated in the past that glucose deficiency may limit growth on diets high in molasses content because of the low production of propionate and the very low absorption of glucose post-ruminally. However, high growth rates on molasses-based diets also require adequate supply of protein, and supplying additional protein provides amino acids which are also precursors of glucose. It is unlikely, therefore, that glucose will be the primary limiting nutrient for growing animals on these diets. The trend was for a slightly elevated plasma glucose concentration with all levels of CSM feeding, which may reflect a diversion of amino acids to glucose synthesis on this low quality basal diet.

Protozoal numbers in the rumen fluid are usually highest before feeding because the proportion attached to plant particles or sinking to the bottom of the reticulo-rumen after ingestion of starch/sugars increases markedly soon after intake of food. This was also the observation in the present experiment. The trend for increasing numbers of protozoa and a higher proportion of small entodinia (*Entodinium* spp.) on grain-based diets (compared with unsupplemented steers) is consistent with previous findings reported in the literature, although at very high intakes of grain there is often a reduction of numbers or complete defaunation due to the low pH of the rumen. It appears that this situation was not reached even at the highest level of feeding in the current experiment. Somewhat surprisingly, molasses-feeding was not associated with increased numbers of protozoa, but there was an increased proportion of the larger holotrichs (*Dasytricha* spp. and *Isotricha* spp.), which is also consistent with the higher ruminal concentration of soluble sugars which represent a major food source for this family of protozoa.

5.5 Conclusions

The main issues to arise from this and the previous pen feeding studies revolve around, firstly, the highly significant effect of substitution in reducing the efficacy of supplements designed to increase nutrient intake and thereby growth rate of animals, and secondly, the low production of MCP associated with these diets, this being considerably less than is predicted from feeding standards. An important result has been the demonstration of the widely varying extent of the substitution effect with different supplement types, which provides some opportunities for manipulation of nutrients to increase efficiency of feeding.

The experiments have demonstrated the low efficiency of production of MCP on tropical forages which may be in part related to low content of water soluble carbohydrates but also the low availability of rumen degradable N. The consequences of increasing the efficiency of production of MCP have been dealt with elsewhere (see Poppi *et al.* 1997) but can be summed up in terms of a significant increase in growth rate of cattle if efficiencies can be increased to near accepted feeding standard values. Such a manipulation probably requires supplementation to increase the availability of soluble carbohydrates, for instance with

molasses, but these manipulations have not always produced the expected response. The challenge is to understand why.

The other important result is that the supplements differed quite significantly in their per unit stimulus of MCP. This is partly due to the differences between supplements in their effect on the efficiency of production of MCP (g/kg DOM), partly because the supplements differ in the extent to which the available ME is available for microbial growth in the rumen. These differing effects are not predicted from the feeding tables.

6. Comparison of observed growth rates with those predicted from computer models based on the feeding standards

6.1 Introduction

The various feeding standards, e.g., SCA (1990), AFRC (1992) and NRC (1996) represent the summation of our current knowledge on the nutritional requirements of ruminants, and are the major tools nutritionists have available by which to predict the impact of diet quality and quantity, environment, management and genotype on nutrient utilisation and animal growth. If our nutritional knowledge is complete the feeding standards should allow the prediction, with reasonable accuracy, of the growth rates of animals grazing different pastures and receiving various types and levels of supplement. This would support the strong claims from some quarters that our nutritional knowledge is sufficiently complete in the area of response relationships to supplementation that no further research is warranted. The current "Target 300' data set provided a unique opportunity to test these assertions and at the same time evaluate the adequacy of the feeding standards for animals grazing tropical pastures.

Various computer models have been developed in association with the feeding standards (e.g., GrazFeed, Cambeef and NRC (1996)) and these in most cases present a user-friendly means of applying the mathematical relationships encapsulated in the feeding standards. This chapter provides comparisons of the measured growth rates from the grazing study at Brigalow Research Station and the growth predictions based on the three computer models mentioned above. This section has been mainly compiled by PhD student Mr Matt Bolam.

6.2 Methodology

The data sets used in these exercises were from the 1994/95 and 1995/96 wet season drafts of the grazing experiment (see Chapter 3). Descriptions of the animals and treatments used and composition of pasture components, supplements and diet (extrusa) are included in this earlier chapter. The three models used were GrazFeed version 2.0.5, Cambeef version 5.0 and NRC (1996). Growth rate predictions for unsupplemented (control) and supplemented steers were made using these models, and these predictions were compared with measured growth rates. For brevity, the inputs into the models in terms of environmental conditions, breed etc. are not shown in this report.

6.2.1 CONTROL STEERS - 1994/95 AND 1995/96 WET SEASONS

6.2.1.1 GrazFeed

The GrazFeed model requires information on the quality of the pasture grazed and quantity and composition of the supplements fed, on weather conditions and a description of the animals grazing the pasture. The main pasture information required is the yield of green and of dead material, and the mean DM digestibility (DMD) of these components, as well as the height of the pasture and the percentage of legume. The program then uses this information on the available pasture to make an estimate of diet quality. This it does by proportionately allocating the pasture yield to a standard distribution comprising six digestibility classes, ranging from 30 to 80% DMD in 10% increments. As mentioned above, this allows the

program to mimic the effect of selective grazing on the animal's diet because in most grazing situations no direct information on diet quality is available. However, in the grazing study information on diet quality was obtained from extrusa collected from oesophageal-fistulated (OF) animals. This diet data was also used in the model to test whether its use improved the precision of growth rate predictions. The growth of the control (unsupplemented) steers during the 1994/95 wet season was predicted using four different approaches to describe nutrient availability, viz. by using:

Run A - Standard GrazFeed approach of combining data on pasture presentation yield together with the proportions of green and dead plant material, and the nutrient composition and DMD of the buffel grass components for December 1994 when pasture quality was considered to be at its best.

Run B - Same as for Run A except that the pasture yield and composition inputs were those for buffel grass green leaf, and this information was applied to the standard distribution of DMD by the model in the usual way.

Run C - Yield and composition of green leaf alone, as for Run B, except that the values for composition of this component were set, thereby preventing the model from applying the data to the standard distribution, i.e., the green leaf yield was allocated to a single fixed DMD class of 70% at 11.1% CP.

Run D - Total presentation yield of pasture (green and dead; December 1994) and setting the composition and DMD to extrusa values for December 1994, thereby preventing the model from applying the data to the standard distribution, i.e., the total presentation yield was allocated to a single fixed DMD of 70% at 11.9% CP.

6.2.1.2 NRC (1996)

The inputs required to run this model include feed intake and quality, environmental conditions and animal type. Growth rate of unsupplemented steers was predicted for both wet seasons using this model. As intake of pasture was unknown, an assumed DM intake of 2.8% of BW was used in both years. Pasture quality was defined in two ways, viz.:

Runs E and F - Using the composition of buffel grass green leaf for December 1994 and November 1995 respectively.

Runs G and H - Using the composition of extrusa from OF steers for December 1994 and November 1995 respectively.

As the program provides separate predictions for growth rate based on the supply of ME and of metabolisable protein (MP), the lesser predictions were accepted on the basis that these corresponded with availability of the primary limiting nutrient.

6.2.1.3 Cambeef

Cambeef requires a description of animal types, environmental conditions, management and the feed offered or available in the pasture. The model can then be used to predict growth based on known feed intakes. Where intake data is not available, such as in grazing experiments, it will generate predicted intakes based on an analysis of the feed. Cambeef then makes its predictions of growth rate based on the availability of ME, protein as CP, RDP and UDP, and of calcium and phosphorus. If either ME or protein is limiting, the prediction of growth rate will be reduced. For instance, if the growth rate possible from the available CP, RDP or UDP is less than that possible from ME, then protein is limiting. Consequently, the predicted growth rate accepted must be the lowest indicated since this refers to that achieveable with the primary limiting nutrient. Predictions of liveweight gain for the control

steers for the 1994/95 and 1995/96 wet seasons were made using buffel grass green leaf (Runs I and J) and extrusa (Runs K and L), for December 1994 and November 1995 respectively, as previously described for NRC (1996).

6.2.2 SUPPLEMENTED STEERS - 1994/95 WET SEASON

The models were used to predict the growth responses of grazing steers to increasing levels of CSM and sorghum supplements during the 1994/95 wet season. In this exercise extrusa compositon was used to define diet quality in all models. In the case of GrazFeed, the approach used to describe the inputs was the same as that used in Run D. The composition of the supplements for all models was that included in the GrazFeed library, since there was some between-batch variability in supplement composition but in general chemical composition was similar to the library values. An adjustment was made for the N supplied as urea and sulphate of ammonia. The supplement intakes used in this exercise were the average (for three steers) intakes (on an 'as-fed' basis) for each treatment recorded over the whole wet season feeding period.

6.2.3 SUPPLEMENTED STEERS - 1995/96 WET SEASON

For the 1995/96 wet season, growth rate was predicted using GrazFeed alone. In this case the inputs were the same as above in terms of using total pasture presentation yield and extrusa composition, except that the model was allowed to allocate the pasture yield to the standard distribution of DMD classes in the usual way. This meant that diet quality estimated by the model was higher than that actually measured. Predictions of growth rate for steers receiving CSM supplements were made for two periods, viz., November 1995–February 1996 and February–April 1996.

6.3 Results and discussion

6.3.1 PREDICTION OF GROWTH RATES FOR CONTROL STEERS - 1994/95 AND 1995/96 WET SEASONS

6.3.1.1 GrazFeed

Predicted growth rates of unsupplemented steers for the 1994/95 wet season, together with predicted intakes of DM, CP and ME upon which this growth rate was derived, are shown in Table 6.1. This data illustrates the enormous variability between predictions depending on the inputs used to estimate diet quality. In most cases, predicted growth rate was considerably lower than that measured. Even using analytical values for extrusa resulted in underestimation of growth rate when the composition was fixed so that the model could not apply the standard distribution of DMD classes (Run D). The major exception in which prediction of growth rate exceeded that measured was when the green leaf component was used as the parameter of pasture quality and the model was allowed to allocate this yield according to the standard distribution of DMD classes (Run B). This resulted in the simulated diet being higher in quality than the green leaf component from which it was derived. Consequently, the predicted pasture intake was 7.8 kg/d DM, equivalent to 3.3% BW for 240 kg steers. The major factor determining growth rate with this model is predicted ME intake and in most cases ME intake is under-predicted resulting in poor growth rate predictions.

Table 6.1. Growth rates of unsupplemented steers grazing predominantly buffel grass pastures during the 1994/95 wet season, as measured experimentally and as predicted using GrazFeed and applying different values for pasture quality (Runs A to D; see Section 6.2.1.1 for definition). Output from the model in terms of predicted pasture intake and composition is also shown.

	Intake				Liveweight
	Pasture (kg DM/d)	Supplement (kg DM/d)	ME (MJ/d)	CP (g/d)	gain (kg/d)
Predicted					
Run A	6.18	0	47.7	659	0.13
Run B	7.79	0	86.5	1790	1.32
Run C	5.99	0	59.3	659	0.52
Run D	6.49	0	64.2	778	0.65
Measured					**1.04**

6.3.1.2 NRC (1996)

Growth rate predictions of unsupplemented steers for the two wet seasons using NRC (1996) are shown in Table 6.2, where Runs E and G include estimates of pasture quality based on the green leaf component whilst Runs F and H use extrusa values. Growth rate predictions based on extrusa were higher than for the green leaf predictions, but in all cases they were well below actual growth rates achieved. With this model it was generally MP rather than ME which was limiting growth rate.

6.3.1.3 Cambeef

The performance of control steers grazing in both the 1994/95 and 1995/96 wet seasons using the Cambeef model, are shown in Table 6.3. Based on diet quality attributes, the model predicts an intake of DM by the animals and then estimates the supply of various nutrients such as ME, CP, RDP and UDP, and finally predicts a growth rate based on the availability of these nutrients. Regardless of whether green leaf or extrusa was used as the input for diet quality, predicted growth rate was below measured growth rate when the former was determined on the basis of the growth allowed by availability of the primary limiting nutrient. In all instances, this primary limiting factor was ME intake, in contrast to indications from NRC (1996) discussed above. It is significant, nevertheless, that the predictions of growth rate of unsupplemented steers during the 1994/95 wet season were similar (600-700 g/d) using all three models when the extrusa composition was used to indicate diet quality.

Table 6.2. Growth rates of unsupplemented steers grazing predominantly buffel grass pastures during the 1994/95 and 1995/96 wet seasons, as measured experimentally and as predicted using NRC (1996) and applying different values for pasture quality (Runs E to H; see Section 6.2.1.2 for definition). Output from the model in terms of the growth rate allowed by the availability of metabolisable energy (ME) and metabolisable protein (MP) is shown

	DM intake	DIP	ME allowed	MP allowed	Actual

	Predicted (kg/d)	Set (kg/d)	balance (g/d)	LWG (kg/d)	LWG (kg/d)	LWG (kg/d)
Predicted						
1994/95						
Run E	4.93	6.72	133	0.80	**0.58**	
Run G	5.06	6.72	139	1.06	**0.69**	
						1.04
1995/96						
Run F	4.22	6.72	36	**0.32**	0.33	
Run H	5.04	6.72	-5	1.00	**0.62**	
						0.89

6.3.2 PREDICTION OF GROWTH RATES FOR SUPPLEMENTED STEERS - 1994/95 WET SEASON

The responses to increasing intake of CSM or of sorghum for the 1994/95 wet season, as measured and as predicted by GrazFeed, NRC (1996) and Cambeef, are shown in Figure 6.1. As indicated previously, the growth rate of unsupplemented control steers was grossly underestimated using all three models in both years. With NRC (1996), predicted growth rate for steers receiving CSM was higher than measured growth rate at all except the zero intake level whereas measured growth rate exceeded that predicted by Cambeef at all intake levels, and that predicted by GrazFeed at all except the highest intake levels. For steers receiving sorghum, growth rates predicted by the models were lower than measured growth rate except at the highest level of feeding (see Figure 6.1).

6.3.3 PREDICTION OF GROWTH RATES FOR SUPPLEMENTED STEERS - 1995/96 WET SEASON

The growth responses to CSM during the 1995/96 wet season, as measured experimentally and as predicted by GrazFeed are shown in Figure 6.2. The predicted growth rates of unsupplemented steers approximated those measured especially for the November-February period, and the response curve predicted for the February-April period followed the same pattern as that determined in the grazing experiment. These predicted growth rates were achieved by incorporating extrusa composition, and allowing the model to allocate the pasture yield to various DMD classes, thereby simulating a diet of higher quality than that actually determined. It appears that this is necessary in order to provide predictions of the same order as actual growth rates on these tropical pastures and is a consequence of an inappropriate intake / digestibility relationship in GrazFeed for tropical pastures.

Table 6.3. Growth rates of unsupplemented steers grazing predominantly buffel grass pastures during the 1994/95 and 1995/96 wet seasons, as measured experimentally and as predicted using Cambeef and applying different values for pasture quality (Runs I to L; see Section 6.2.1.3 for definition). Output from the model in terms of growth rates possible based on the sufficiency of ME, CP, RDP and UDP is shown

	Sufficient ME	Sufficient CP	Sufficient RDP	Sufficient UDP	Actual LWG (kg/d)
	for LWG (kg/d) of:				
Predicted					
1994/95					
Run I	**0.50**	1.20	1.00	0.70	

Run K	**0.60**	1.30	1.20	0.70	**1.04**
1995/96					
Run J	**0.20**	0.60	—	—	
Run L	**0.60**	0.80	—	—	**0.89**

6.4 General discussion

The summation of the accumulated knowledge on the nutritional requirements of ruminants and the nutritional value of pastures and supplements is encapsulated in the feeding standards such as SCA (1990). The principles of these feeding standards are further incorporated, for convenience, into various computer models such as GrazFeed, Cambeef etc. Application of these feeding standards or their derived models should enable reasonably accurate prediction of animal performance from a particular pasture and of the response by grazing animals to supplements. In the present exercise, none of the three models used provided reliable predictions of growth rate as judged by comparisons of these predictions with the growth rates actually measured for steers grazing buffel grass pastures at Brigalow Research Station. All models grossly underestimated growth rate of unsupplemented steers. This was true for GrazFeed despite efforts to increase the predicted growth rates by changing the inputs to reflect a higher quality diet than the model would usually select.

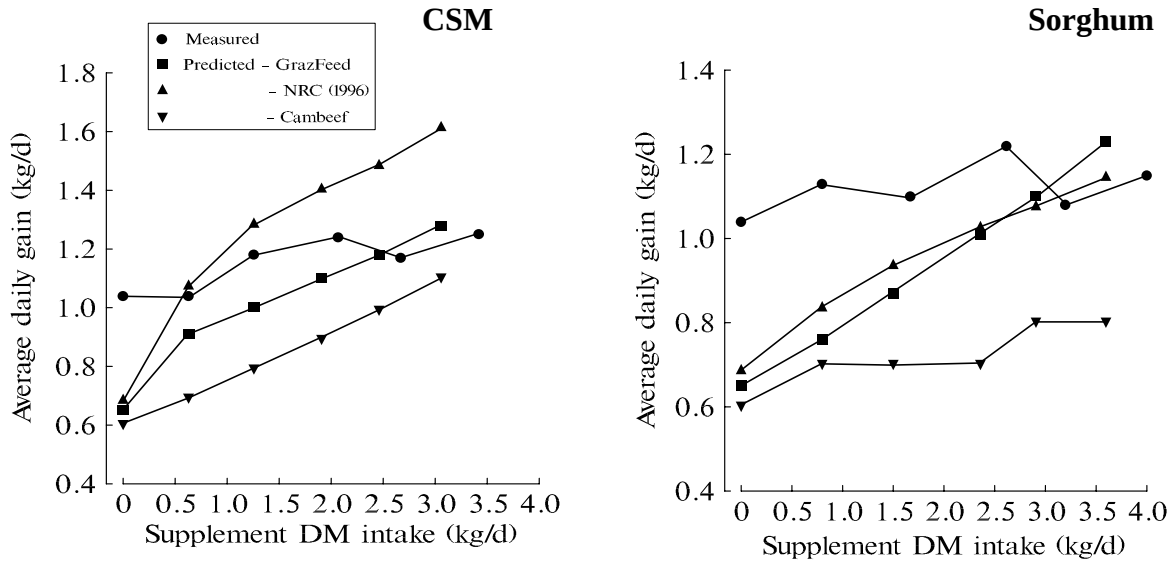

Figure 6.1. Responses to CSM (left) and sorghum (right) supplementation by steers grazing predominantly buffel grass pastures during the 1994/95 wet season, as measured experimentally and as predicted by GrazFeed, NRC (1996) and Cambeef, when the composition of the OF extrusa was used as the input for diet quality.

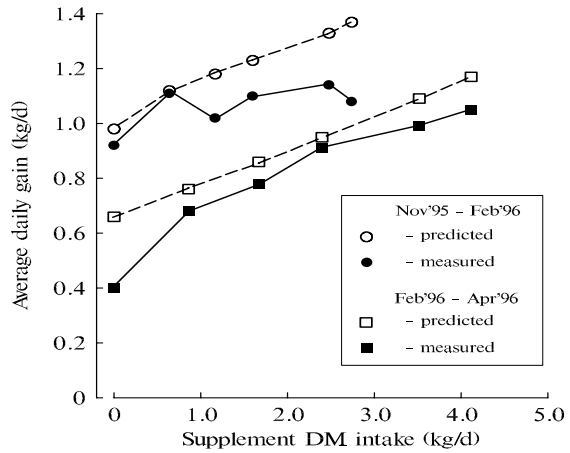

Figure 6.2. Responses to CSM supplementation by steers grazing predominantly buffel grass pastures during the November 1995-February 1996 and February - April 1996 periods of the 1995/96 wet season, as measured experimentally and as predicted by GrazFeed when the composition of the OF extrusa was used as the input for diet quality.

GrazFeed operates by assigning a diet quality based on the composition, in particular DMD, of the green and dead leaf components of the pasture. Based on this assigned diet quality (digestibility), it predicts an intake and uses this value to predict growth rate. The problem seems to be that the model predicts too low an intake based on this digestibility with the result that the growth rate is underestimated. The model is highly sensitive to digestibility, as is indicated by the simulations based on feeding different levels of CSM when the DMD varies between 50 and 65% (see Figure 6.3). Only when diet quality was artificially increased by substituting the composition of the green leaf component of the pasture or of the diet extrusa itself for that of the pasture components, did predicted growth rates approach that measured in unsupplemented animals. However, this process simulates a diet quality higher than that actually achieved, i.e., higher than the quality of the diet extrusa. It appears then that the discrepancies with GrazFeed relate to two factors. Firstly, the algorithms relating composition of green and dead leaf components of pasture to diet quality do not apply to tropical pastures in the same way they do for their temperate counterparts. Secondly, the relationship between digestibility and intake is obviously different for tropical compared with temperate pastures. Thus there is a need for modification of these models for application to tropical pastures, primarily related to more accurate prediction of intake based on composition of the pasture. Combined these factors result in gross underestimation of the growth rate of unsupplemented animals. Similar results were obtained with the other two models.

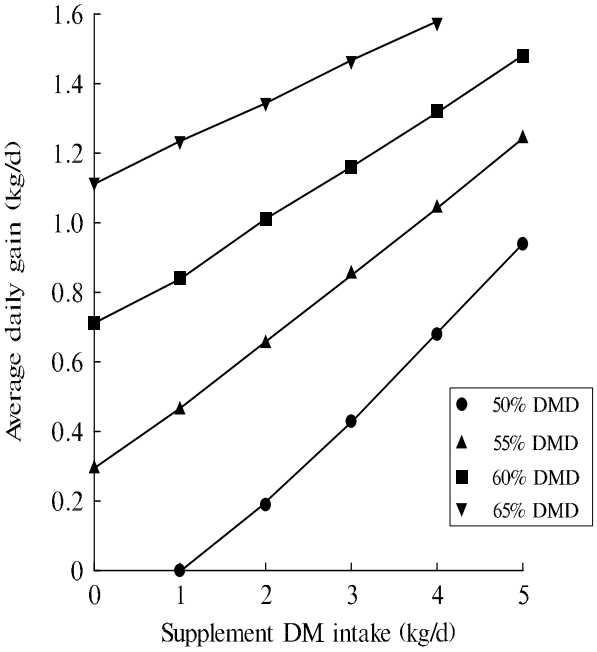

Figure 6.3. Effect of increasing intake of CSM on the growth rate of steers grazing tropical pastures of varying dry matter digestibility (DMD) as predicted by GrazFeed.

Some of the comparisons made between the predicted responses to CSM or sorghum supplements and the measured responses indicated the models would predict the shape of the response curve in some circumstances. The main discrepancy in these situations was again the low base-line production predicted relative to the actual growth of unsupplemented steers. Nevertheless, this indicates that the underlying principles were sound and the main emphasis needs to be placed on improving the prediction of growth rate of unsupplemented animals. It could be argued that, providing the model will predict the shape of the response curve, the output could be artificially altered by adjusting the digestibility until the base-line growth rate (unsupplemented) was at the correct level. However, in other situations the predicted response curve was markedly different to that recorded. An example of this is given in the simulated response curves for CSM shown in Figure 6.3, in which liveweight gain is shown to increase with increasing intake of CSM irrespective of the baseline level of production. Results from the grazing experiment and from a review of the world literature (Poppi and McLennan 1995) show that this is not the case. This uncertainty about the accuracy of the models in different circumstances reduces confidence in their use for predictive purposes.

Clearly there are problems in applying the current feeding standards to animals fed tropical diets. Nevertheless, we believe the principles encompassed in the feeding standards and the models are sound and provide a suitable framework to provide sound nutritional advice. However, the current study has indicated problems in predicting intake, digestibility and microbial protein production. These could be easily rectified by altering the equations. The current data set provides a framework upon which to initiate this change. This was facilitated by the experimental approach taken here. In designing the experiments, a conscious effort was made to collect the appropriate information, by regularly sampling of pasture and diet and weighing animals, and by employing the response curve approach encompassing a range of supplement intakes and hence of nutrients. We strongly believe that it should be a priority with any future grazing experiments in the tropics to include, as an objective, the collection of key information which can be used to further test and subsequently improve the feeding standards.

7. Feeding strategies for improved performance in pasture-based systems - Case Studies

7.1 Introduction

This aspect of the project represented Milestone 10 and was carried out by Mr Ross Clarke, DPI Toowoomba. It is the subject of a separate report and the findings will only be summarised here. The Case Studies component of Target 300 arose out of a recognition that some producers in the endowed zone were already achieving the target growth rate (300 kg/year) by employing a variety of feed year plans and that other producers may benefit from a collation of the information derived from these various systems.

7.2 Methodology

Extension officers from DPI identified relevant producers who were consistently high performers in terms of annual growth rates of cattle and these were approached to be included in the Case Studies. Altogether there were 15 producers representing 20 selected groups of cattle included. Data was collated from existing property records including slaughter age and weight, and a description of the feed year plans used for that group of cattle; feedlotting was excluded. Growth rates were estimated over the total period; there was no breakdown of liveweight change over various components of the feed year plan. The main report includes a full description of the various feed year plans used, and the growth rates estimated as well as predicted 365 d growth rates. The latter are open to considerable error where the actual monitoring period was short.

7.3 Results

The main findings can be summarised as follows:

- The survey revealed the diverse range of feed plans with widespread use of improved pasture, particularly as specialist areas, but limited use of grain and protein meal supplements when prices of these supplements were high. This exercise illustrated the wide range of different systems by which the target growth rate could be achieved.

- Drought conditions prevailed through most of the survey period and although production rates were high, many of the systems failed to reach the target. Nevertheless, there were assurances that they did so in ‘normal’ seasons.

- A common goal of these producers was a desire to maximise growth rates, as high as seasons and resources would allow, throughout the lifetime of the animals by deploying a range of feed systems.

- Despite this desire to maximise production, there was little objective information on which to base the formulation of the feed year plan.

7.4 Future directions

An extension of the above process is needed to fully realise its potential for improving production and the efficiency of production within the industry. This could take the form of:

- Extending the range of producers surveyed to include systems not already included.

- Encouraging and facilitating the collection of liveweights of cattle (by the producers) at key points of the feed year plan, for instance as cattle move from one system to another. This would have the effect of:
  - providing the producer with more objective information about the performance of animals on particular feed plan components;
  - provide useful information about the way various short-term components of the feed year plan interact, i.e., the effect of performance for one system on that in the next, towards developing the most economically efficient and sustainable system;
  - allowing some economic analysis of the feeding system and its components.

This process could be facilitated using a decision support program such as Feedman to provide a method of evaluating the options available.

- Establishing a 'Club 300' group of producers who are already successfully achieving the high growth rates as the focal point for (i) identifying the information needed for increasing growth rates of cattle, and (ii) facilitating information flow within the group and eventually to other producers.

- The knowledge by which to link these short term strategies into production systems, on a longer term basis, which provide access to the desired market in the most economically efficient and sustainable way, taking cognisance of the impact on the whole property profitability.

8. Industry recommendations and product delivery

8.1 Industry Recommendation

8.1.1 RESPONSE CURVES

The major objective of the project was to develop strategies for producers to increase growth rates of cattle in the endowed zone, with a specific annual growth rate target set at 300 kg. In pursuing this goal, growth response curves to supplements of CSM or grains have been established for young, growing steers. Separate curves have been presented according to the growth rate of unsupplemented steers, that is, when unsupplemented steers have growth rates which are (a) low (maintaining or losing weight), (b) medium (growth rate of 0.2–0.6 kg/d), or (c) high (growth rate 0.8–1.0 kg/d). These curves were established by combining response data from various drafts and periods of the grazing experiment, and from the pen feeding study (low growth rate group). The equations describing these response curves are given below, and the curves are illustrated in Figures 8.1 and 8.2 for CSM and barley.

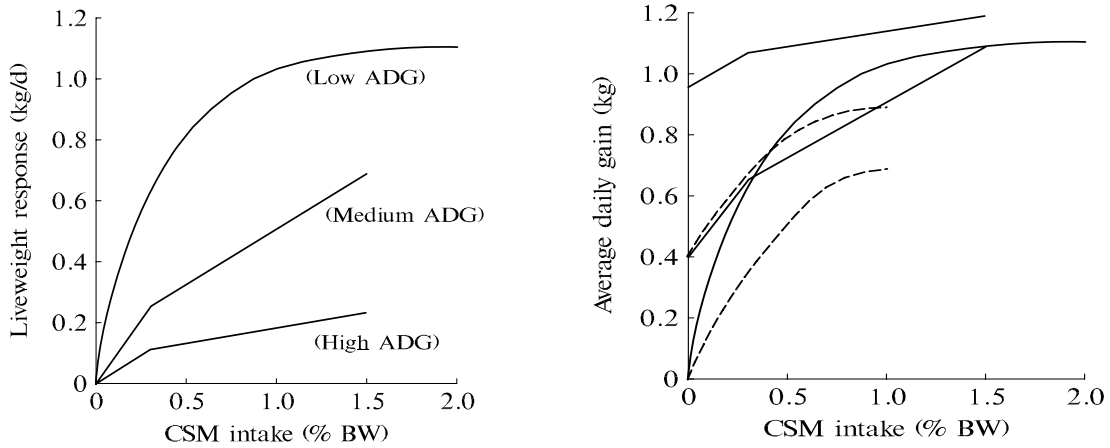

Figure 8.1. Response curves showing (a) the predicted growth rate response (above unsupplemented controls) to increasing intake of cottonseed meal (CSM) by young growing steers when the controls are growing at low, medium and high rates, and (b) the actual growth rates from the current project (solid lines) compared with those predicted recently in an extension booklet (dashed line; see text for details), when the control steers are growing at 0 (low), 0.4 (medium) or 0.8 (high) kg/d.

CSM:

High growth rate:	LWR = 0.084+ 0.098 Intk	(R^2 = 0.05; NS)
Medium growth rate:	LWR = 0.147 + 0.361 Intk	(R^2 = 0.40; P<0.001)
Low growth rate	LWR = 1.187 - 1.11$e^{-2.65\ Intk}$	(R^2 = 0.91)

Barley:

High growth rate:	LWR = 0.087 + 0.071 Intk	(R^2 = 0.10)
Medium growth rate	LWR = 0.311 + 0.122 Intk	(R^2 = 0.13; P<0.05)
Low growth rate	LWR = 0.086 + 0.549 Intk	(R^2 = 0.95; P<0.01)

where LWR is the liveweight response (above control; kg/d) and Intk is daily supplement intake (% of BW). Some general comments about these response curves are as follows:

- The low correlation coefficients recorded in some cases reflect the large between-animal variability encountered, especially during the wet season when responses were small. This is not uncommon with growth rate data when collected on an individual, as opposed to group, basis.

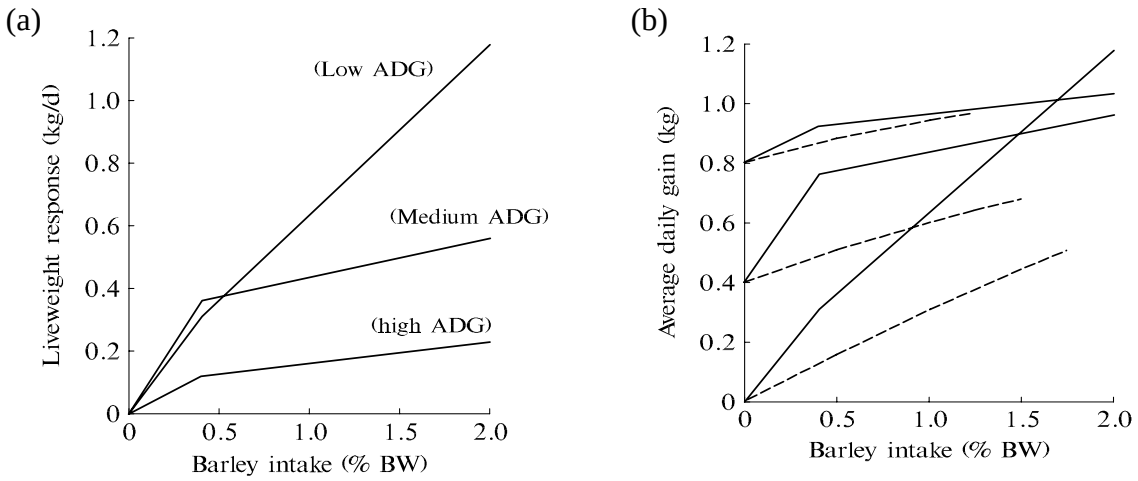

Figure 8.2. Response curves showing (a) the predicted growth rate response (above unsupplemented controls) to increasing intake of barley by young growing steers when the controls are growing at low, medium and high rates, and (b) the predicted growth rates from the current project (solid lines) compared with those predicted recently in an extension booklet (dashed line; see text for details), when the control steers are growing at 0 (low), 0.4 (medium) or 0.8 (high) kg/d.

- Quadratic and exponential functions were fitted to the various data sets but in all cases except for the CSM pen data (low growth rate; exponential curve), the relationships were not significant and the data were best represented by the linear models shown above.

- As the Y-axis in these linear relationships represented liveweight response (above controls), there was no data relating to intakes of supplement less than 0.3% BW. Thus although the equations describing the linear relationships indicate a positive intercept on the Y-axis, this is outside the range of the data used. In the response curves presented, the line fitting the data has been drawn to indicate that it passes through the origin, inflecting at the 0.3% BW point for CSM and at 0.4% BW for barley. Although not strictly correct, this representation is biologically meaningful and is consistent with the higher response to feeding often recorded with the first increment of supplement, suggestive of the amelioration of a nutrient deficiency by a small amount of supplement.

- The response curves produced in this project highlight the generally low response levels achievable under grazing conditions. Whilst this is variable, even under relatively dry conditions (medium growth rate) the conversion of CSM supplement to animal growth was only 0.36 kg/d additional liveweight gain for each 1% BW extra supplement intake, which for a 250 kg steer is equivalent to 2.5 kg/d of CSM. These low conversion rates needs to be recognised when feeding strategies are being developed. The pen results indicate that higher response levels can be achieved with low input of CSM in particular when unsupplemented steers are either only maintaining or are losing weight. Individual producers will put different values on this information according to their situations and the need to meet market targets.

- The above response curves can be applied to supplements of similar type. For instance, grains with similar starch degradation properties to barley are represented by the same

response curve and likewise for protein meals of similar ruminal degradability to CSM. This will markedly extend the range of the research results.

- These response curves derived through experimentation follow similar trends to those established through an extensive search of, and collation of data from, the world literature, as published in recent review papers by members of the project team (Poppi and McLennan 1995; Poppi *et al.* 1997).

The response curves are compared with those recently proposed in an extension booklet partly funded by MRC, i.e., "Nutritional and Managerial Opportunities for Meeting Beef Markets" (Cheffins 1996), which describes some of the outcomes of MRC project DAQ.065 (see Figures 8.1 and 8.2). However, at the time of publication, there was very limited data upon which to base these response curves. The current project thus provided an opportunity to validate, or modify, these proposed response relationships. The major similarities and discrepancies between the current and published response curves can be summarised as follows:

- The response curves proposed by Cheffins (1996), in agreement with GrazFeed, suggest that animals on higher quality pasture, i.e., with a higher growth rate unsupplemented, will always maintain a growth rate advantage over those on lower quality pasture regardless of the amount of supplement fed. These response curves tend to be parallel for animals growing at different rates unsupplemented, so that even with CSM fed at 1% BW, growth rate of steers differed by 0.1 kg/d for every 0.2 kg/d difference in the absence of supplementation. This represents a major deviation from the current predictions in which differences in growth rates became very small or negligible at higher intakes of supplement, irrespective of the growth rate allowed by the pasture unsupplemented. It stands to reason that as supplement intake increases, and pasture becomes a smaller component of the total diet, differences in growth rate will diminish.

- For CSM, the predicted response curve from Cheffins (1996) was similar to that of the current project for animals growing at the medium growth rate (0.4 kg/d; see Figure 8.1), which was not unexpected since some of the early data from Target 300 was included in its derivation. At the lower growth rate, the Cheffins (1996) curve markedly underestimated the response relationship predicted in the current study, although it should be remembered that the latter was derived from pen feeding studies. Based on the predictions of Cheffins (1996), steers which only maintain liveweight without supplement will grow at a maximum rate of about 0.75 kg/d when higher levels of CSM are fed. In the pen studies of current project, growth rates approaching 1.2 kg/d were achieved by steers receiving CSM at 2% BW whilst their unsupplemented counterparts were growing at about 0.1 kg/d.

- With grain supplementation, the response curves proposed by Cheffins (1996) also markedly underestimated those derived in the current project, except on the higher quality pastures.

8.1.2 OTHER RECOMMENDATIONS

Some other recommendations arising from the results of this project work include:

- When fed as dry-rolled grains, the response to sorghum should be discounted by about 33% when compared with barley, based on the pen study results.

- The protein content in grain-based supplements must be sufficiently high to ensure optimum utilisation of the grain as well as of the associated pasture component of the diet, thereby also maximising microbial protein synthesis. Inadequate supply of protein (or

zero inclusion in many instances) would explain the poor performance of animals often reported when 'energy' supplements are fed. The common practice of including protein in the diet as a fixed proportion by weight of the grain (e.g., 1% urea in grain), irrespective of the grain intake or the proportion of the total diet this constitutes, ignores this interaction between the supplement and pasture components of the diet with potentially deleterious effects on total diet utilisation and animal production. The alternative is to estimate the absolute requirements of the animal for protein based on the estimated diet composition including both the supplement and the pasture. Calculations from the feeding standards suggest that the protein requirements for total utilisation of the grain alone are equivalent to about 2-3% urea in grain (w/w); hence this should be the minimum level of inclusion considered in the supplement and higher rates should be included when grain intake is low. Practical methods of safely feeding this or higher levels of urea in grain need to be determined. One option is to replace urea with protein meal (see below) but this increases the cost of feeding.

- Barley-based supplements can be substituted for CSM under the following conditions:
  - at all levels of feeding on medium to high quality pasture (ADG >0.4 kg/d);
  - at high levels of intake (>1.5% BW) on pasture of all qualities;

  but not:
  - at lower levels of intake on poor quality pasture supporting low growth rates.

- Based on the results of the project, an appropriate supplementation strategy for low quality pastures would be a combination of protein meal and grain (including urea), with the proportion of protein meal declining from 100% at low intakes to zero at high intakes of supplement. This strategy exploits the high response to protein meal at low intake and the requirement for adequate protein in 'energy' supplements whilst acknowledging the small differences in response to grain and protein meals at higher intakes and the cost advantage of grain over protein meal. As intakes of supplement increase, the main arbiter of composition would be cost, within the framework of an adequate supply of protein for optimal utilisation of the supplement.

- Feeding supplements of the types examined in this project are unlikely to be cost-effective during the main wet season period when responses are small. However, responses may be economic during the wet/dry transition phase when the growth rate of unsupplemented animals declines to 0.5 kg/d or less.

8.2 Product delivery

The main products of this project work are outlined above. Essentially, they are the response curves to different supplement types which have been linked to the growth rate of unsupplemented animals, as a broad indicator of pasture quality. The response curves can be used in their current format by producers and their advisers but should eventually be provided in a form which can be readily incorporated into whole property management plans. Several avenues of delivery will be pursued:

1. Various decision support systems such as BeefLink and Feedman are being developed to facilitate the decision making process on an individual property basis. BeefLink provides the first stop, generic information to meet market specifications, whilst Feedman is the logical next stage providing a more focused, property level, interrogative analysis. These systems operate by targeting specific markets, by identifying the key decision making points in the production cycle, and by providing some options to meet the growth targets in the short term. The growth response curves developed within the Target 300 project represent key decision tools in the framework of these whole property models, which in

turn represent a valuable means of disseminating the information most widely and effectively. The response curves also provide critical information for extending the range (into the tropics) of growth prediction models such as GrazFeed.

2. Traditional methods of direct information dissemination on a need or demand basis will continue to be employed. The information provided in the current study is only part of the total information base on supplements and responses to nutrients and the combined product will be made available through information centres, farmfaxes, newsletters etc.

3. An extension of the Case Studies aspect of the current project is recommended. This has been outlined in detail in Chapter 7.

Regardless of the methods employed, there will be a need for interaction between the producer and the adviser to develop appropriate strategies based on all the available information. One of the major needs, therefore, will be that the advisers are fully conversant with the technology and the underlying principles involved. If this knowledge is not currently available, priority should be given first to the upgrading of knowledge and skills of those likely to be the major contacts with the industry.

9. Intellectual property

There is no intellectual property arising from the project which could be directed towards commercial development or exploitation.

It is recommended that the results and outcomes of the project be freely available to the Australian beef industry and community as a public service.

10. Future research needs

10.1 Major needs

The current Target 300 project represents a rigorous examination and comparison of the various supplement types and at the same time an evaluation of the feeding standards in terms of their underlying principles as well as quantitative output. We know of no other work in the world where the same aspects have been combined into a research endeavour. The approach we used was not to test every supplement but to evaluate broad supplement groupings, as has been outlined earlier. The response curve approach was justified on the basis that two extensive invited reviews of the world literature by members of the research team (Poppi and McLennan 1995; Poppi *et al.* 1997) uncovered no comparative information on which to base our strategies.

Based on the findings of the current research, and cognisant of other published information, three main issues were identified for further research attention. These are:

1. the substitution effect associated with supplementary feeding;
2. the low efficiency of microbial protein production on tropical pastures; and
3. the low efficiency of use of absorbed protein for growth.

These are not new issues but are ones for which, we believe, there is a need for quantitative change and we believe that change is biologically achievable in the context of the grazing situation encountered in northern Australia. This has been expanded on in our review to the International Grassland Congress in Canada (Poppi *et al*. 1997).

Substitution has a major impact on the efficiency of use of supplements and thus on the cost-effectiveness of this practice. This was well demonstrated in the current project whereby much higher conversion rates of supplement to additional liveweight gain occurred on the lower quality compared to higher quality pastures. This result thereby effectively excludes the use of supplements to increase growth rate on higher quality (e.g., wet season) pastures. Much work has been done in defining the substitution effects, and this has indicated that the effects vary with supplement type and are thus open to manipulation. The key principles of substitution are still not well understood, except perhaps for the effects on rumen function. However, we believe that Weston's model of intake regulation (Weston 1996), Ketelaar and Tolkamp's model of 'trade-off' strategies (Ketelaar and Tolkamp 1991) and Kyriazakis' model of nutritional wisdom (Kyriazakis 1995) provide a basis for examining these key principles and of developing ways to manipulate substitution in practice. The approach of using metabolism models has been successful in identifying some of the underlying constraints and provoked considerable debate in the literature (Poppi *et al*. 1990, 1994). The current project provides much of the initial data required to conduct such a study but further manipulations are needed to build on this base. In particular, manipulations of the protein/energy ratio and in the type of energy substrate are needed as these are key issues in this area. This is an important field of research since the potential to increase growth is great as is the prospect of formulating better supplements needed in smaller amounts because they supply the limiting nutrients without a major substitution effect.

Perhaps the most surprising finding of the current study was the low efficiency of microbial protein production (g MCP/kg DOM) recorded, which provides ample scope for improvement with consequences for increased growth rate. This possibility has been expanded upon in the International Grassland Congress paper (Poppi *et al.* 1997), the basis of the calculations used there being the data produced in the current project. Whilst aspects of microbial protein

have often been suggested previously as a strategy for improving animal performance, the issue of efficiency of production has tended to be ignored but in our opinion it could potentially be exploited to realise significant outcomes for little input. The basic hypothesis is that soluble carbohydrates and possibly amino acids provide the key for changing efficiency and that supplements are one way of increasing supply of these nutrients. We are aware that in some experiments, not set up to examine this aspect but nonetheless providing a good opportunity to do so, the expected responses have not occurred. This problem needs to be addressed but the chances of successfully improving efficiency are, in our opinion, high. There are now methods available by which microbial protein production can be studied in intact animals, which will enable more strategies to be examined quickly. This whole area of ruminant nutrition deserves high priority.

The low efficiency of use of absorbed protein has been identified in many studies world-wide. Our results provide no direct evidence of such an effect other than by calculation indirectly from liveweight gain and based on the degradation characteristics of our supplements. There appears to be an interaction of protein/energy and possibly energy substrate type involved. We consider this research issue the least important of the three identified for our attention, and consider that it could be investigated as a side issue when these other aspects are under investigation.

10.2 Other research needs

In examining various broad groupings of supplement, one class which was not represented was protein sources with high-lipid content, e.g., copra meal, palm kernel expeller meal and whole cottonseed. These should be included in subsequent evaluations not only to make the study complete but because they represent relatively inexpensive supplement options for which there has been little rigorous evaluation. With the removal of meat meal from the list of available protein meals, there are limited options available to producers. In the reviews of literature carried out there was little information on these supplements upon which to base industry recommendations with any confidence. The impact of this high lipid content on substitution over a range of intakes, in comparison with other protein sources such as CSM, has not been determined.

A preliminary evaluation was carried out using molasses in the pen and metabolism experiments but low voluntary intakes in the former restricted the comparisons with other 'energy' sources. However, in view of the large cost advantage of molasses over these other grain-based sources in northern Australia, and the potential of molasses to provide soluble carbohydrates to stimulate microbial protein synthesis, a more rigorous examination of this supplement option over a range of intakes is urgently required.

Seasonal conditions were used to provide a range in pasture quality for evaluation of supplements in the current study, but favourable rainfall conditions meant that the lower range of pasture quality was rarely achieved and then only for very short periods. An extension of the current research approach, albeit with different supplement treatments, may provide the links with the lower end of the scale of pasture quality, as for instance is commonly experienced in the dry season in the intermediate zone of Queensland.

The current response curves are linked to pasture quality in a rudimentary way by presenting different curves according to the growth rate of unsupplemented animals. This process will be developed further in the future using existing information to identify aspects of pasture quality which correspond to the various response curves. However, a major impediment to uptake of the response curves generated is the inability of producers to quantify pasture (or diet) quality at any point in time, and therefore to know which response curve is applicable. There is a need for a simple, inexpensive tool by which pasture or diet quality can be

assessed by individual producers. The use of Near Infrared Spectrophotometry (NIRS) screening of faecal samples to provide an indication of diet quality presents some promise in this regard, but the technology requires considerable development before any confidence can be placed in it at this stage. Samples from the current project have been provided to the research team developing this technology to assist in setting up the necessary calibration curves.

All future supplementation studies need to be developed in line with best practice sustainable grazing principles. The close scrutiny of pasture availability, composition and quality undertaken in the current project needs to be included in any future supplementation studies so that the impact on the pasture can be monitored and sustainable management practices developed. This is also essential from the point of view of further testing the feeding standards under varying conditions. This will precipitate necessary changes to these feeding standards.

An important development in ruminant nutrition in recent years has been the establishment of the MP system which recognises the separate requirements of animals for RDP and UDP. One of the important outcomes of the project was the documentation of the RDP and UDP contents in the diet of the grazing animals across seasons. There is little comparable data available in the literature, especially with tropical pastures. The importance of this process is that it provides a better understanding of the nutritional requirements of the grazing animal at different times of the year, which in turn allows more accurate supplement allocation. It is proposed that similar information is required with some of the legume-based pastures used in northern Australia, especially stylo pastures, as the legume has been included in the pasture largely for its protein input. The extent to which the needs of the grazing animal for RDP and UDP are met on these pastures has not been determined.

The research carried out in this project has involved young, growing animals. However, a major target group under commercial grazing systems will be the finishing animal. Strategies are needed to increase growth rates in the last few months prior to slaughter, usually occurring in the wet/dry season transition period, to ensure that market specifications are met. These animals, by virtue of their changing body composition featuring greater fat and lower muscle deposition, will have different nutritional requirements to the younger growing animal and will respond to added nutrients in a different way. Some future research should be directed at this class of animal. Furthermore, greater emphasis will need to be placed on changes in carcase composition rather than using liveweight change as the sole response indicator. This links in well with the goals of the Cattle and Beef CRC.

The goals of the current project were such that emphasis was placed on determining the growth responses by cattle to supplements provided over discrete periods, usually of four months or less duration. It is well recognised that when nutritional treatments are imposed on animals at a young age, part or all of the response to that treatment may be eroded in the post-treatment period. This can severely reduce the response and compromise the economics of the exercise. Any such treatment must therefore, from a practical view-point, be considered also in the context of the whole-of-life production of that animal. This raises questions about not only which treatment to apply but of the most appropriate time to apply them in the life-time of the animal, in terms of optimising the efficiency of treatment but still achieving the required market specifications. For instance, the age at which growth is restricted can have a significant effect on final carcase composition. Research is needed to define the important principles in terms of producing the most appropriate growth curve for cattle, from the point of view of economic efficiency and meeting market specifications, for the major markets available.

In conjunction with the above, the feed plan approach to planning and management needs to be developed and encouraged within industry. These feed plans would include the setting of targets and be subject to decision rules such that the target is attained or alternatively, at

points along the growth path, decisions are made as to what alternative markets are available or more appropriate. They would be developed recognising that inputs may be needed to attain production goals and that they may be in the form of supplements or new pasture species. It is important that the inclusion of new pasture species is not viewed simply as pasture introduction in the traditional sense of incorporating a new species into an existing pasture community over a wide area but will increasingly be viewed as small areas intensively developed to meet a nutritional requirement in the feed plan. This has the advantage of posing lower risk to the biodiversity existing in the native grasslands. Research needs to develop or catalogue a suite of options for use in feed plans as adoption of technology is largely about recognising the need to set targets and minimising the risks associated with the adoption of that particular piece of technology. Different suites of technology, and feed plans, will suit different users and are required to satisfy the financial and technical capability of the users. Any further supplementation strategies would therefore be seen in the context of being an input into a feed plan.

10.3 Research balance: increased production versus sustainable grazing practices

The beef industry will continue to rely on pasture as the main feedbase and its sustainable use poses the major problem facing the industry as it seeks to maintain a resource for its own use, whilst at the same time fielding criticism from the wider community about the environmental consequences of its practices. This has prompted a re-direction of resources into the field of sustainable grazing management, with a concomitant reduction in the more traditional 'production' research. The question is whether the correct equilibrium has been reached.

It is highly unlikely that the results of sustainable grazing experiments will meet industry expectations in terms of providing new strategies to consistently meet increasingly-more stringent market specifications. At best, modest increases in per animal productivity can be expected from the interventionist strategies employed in experiments into sustainable grazing, for instance stocking rate manipulations or burning. To achieve the high growth rates necessary to meet many of the existing market specifications, major increases in the plane of nutrition are often necessary. The challenge is to be able to achieve the necessary increases in production whilst abiding by best-practice sustainable grazing principles. A combined approach is required to meet these dual needs of industry.

A major upward shift in the plane of nutrition of grazing animals will in most cases require the use of supplements or of plants of higher nutritional value than native species, perhaps in conjunction with genetic changes in the animals used. Contentions that our nutritional knowledge is sufficiently complete to meet these challenges are not supported by the poor predictions of growth rate (see Chapter 5) using the feeding standards (or their associated models) which embody current knowledge on nutrition. These feeding standards need further testing under differing circumstances to determine where they do and do not work. This will allow them to be improved, with flow-on benefits in terms of increased confidence in their use and better predictions of the likely economic benefits of various nutritional strategies. The increasingly-more difficult challenge of improving animal performance profitably will require new strategies in nutritional manipulation, and this will require a sustained research effort in the future. A suite of options needs to be developed to cater for the diverse financial and technical capabilities of the end-user.

With the pressures currently on the beef industry, and those likely to be encountered in the future, a major reduction in production research seems short-sighted. A re-evaluation of the current balance between production research and sustainable grazing research is

encouraged to reflect the needs of industry for increased capacity for production increases in association with best practice sustainable grazing principles.

11. Conclusions

The major achievements of the project can be summarised as follows:

1. Establishment of growth response curves for young, growing cattle to various supplement types, viz. CSM, representing protein meals containing protein of medium degradation in the rumen, and cereal grains having high or low starch degradation in the rumen. The significance of these response curves is underlined by the following:

    - They represent a significant addition to the suite of management tools currently available to producers, and their advisers, upon which they can base objective decisions on strategies to increase growth rates of cattle. Previously there were either no response curves available or they were highly speculative, being based on very limited data.

    - The responses to supplement were not accurately predicted from the feeding tables and their associated models. This highlights the importance of the current research findings, and the need to continue research to extend the scope of the response relationships and also to provide information on which to upgrade the feeding tables for more reliable use with cattle grazing tropical pastures.

2. Better characterisation of the changes in chemical composition of tropical grass pastures, and resulting diets, across seasons, in particular relating to the separation of the protein into its main components which contribute to the metabolisable protein available for absorption by the animal, i.e., rumen degradable and undegraded dietary protein. Such information was previously not available for tropical pastures in northern Australia, but is crucial for identifying nutrient limitations and formulating nutritional interventionary procedures.

3. Documentation of the low production, and the low efficiency of production, of microbial protein on tropical pastures, and the major effects supplements have in improving both parameters. Most importantly, this has highlighted opportunities for substantial increases in cattle growth in the tropics through improvements in efficiency of microbial protein production, potentially with small nutritional manipulations.

4. Detailed comparisons of different supplement types in terms of their different substitution effects when fed in conjunction with low quality hays. The study also provided a significant advancement in the understanding of the principles involved in determining the extent of this substitution effect, thereby increasing the possibility of exploiting these differences between supplements and improving the efficiency of feeding.

12. Project publications

12.1 Current publications

12.1.1 JOURNAL / CONFERENCE PAPERS

Bolam, M., Poppi, D.P., McLennan, S.R. and Connors, M. (1997). Variability in microbial protein supply under different supplement strategies. In *Recent Advances in Animal Nutrition in* Australia 1997. In preparation.

Manuel, J., Poppi, D.P. and McLennan, S.R. (1996). Level of urea for grain based supplements. *Proc. Aust. Soc. Anim. Prod*. **21**: 489.

McLennan, S.R., Kidd, J.F., Poppi, D.P., Connell, J.A., Bolam, M.J. and Blight, G.W. (1996). Effects of varying intakes of sorghum, barley and cottonseed meal on liveweight performance of weaner steers. *Proc. Aust. Soc. Anim. Prod.* **21**: 495.

McLennan, S.R., Kidd, J.F., Hendricksen, R.E., Jeffery, M., Poppi, D.P. and Martin, P.M. (1997). Seasonal changes in the degradability of protein in a tropical grass pasture. In *Recent Advances in Animal Nutrition in* Australia 1997. In preparation.

12.1.2 ASSOCIATED REVIEWS

McLennan, S.R., Poppi, D.P. and Gulbransen, B. (1995). Supplementation to increase growth rates of cattle in the tropics. In *Recent Advances in Animal Nutrition in* Australia 1995, pp. 89-96 (J.B. Rowe and J.V. Nolan eds). University of New England Press, Armidale.

Poppi, D.P., McLennan, S.R., Bediye, S, de Vega, A. and Zorrilla-Rios, J. (1997). Forage quality: strategies for increasing nutritive value of forages. *Proc. XVIIIth Inter. Grassld Congr.*, July 1997, Winnipeg, Saskatoon, Canada (In Press).

12.2 Proposed publications

McLennan, S.R., Jeffery, M., Poppi, D.P., Hendricksen, R.E., Kidd, J.F., Answer, S., and Martin, P.M. (1998). Effect of various supplement types and seasonal conditions on the growth rate of steers grazing tropical pastures in northern Australia.
Publication target: J. Anim. Sci. - May 1998.

McLennan, S.R., Poppi, D.P., Kidd, J.F., Bolam, M., and Doogan, V. (1998). Effects of various supplements on the intake and digestion of a low quality tropical grass hay by weaner steers.
Publication target: Anim. Sci. - May 1998.

Bolam, M., Poppi, D.P., McLennan, S.R., Connors, M. and Doogan, V. (1998). Effect of various supplements on microbial protein supply in weaner steers given low quality tropoical grass hay.
Publication target: Anim. Sci. - July 1998.

Hendricksen, R.E., Jeffery, M., McLennan, S.R., Poppi, D.P., Answer, S., Kidd, J.F. and Martin, P.M. Changes in the digestibility and chemical composition of a buffel grass pasture and in the diet of steers across seasons in northern Australia.
Publication target: Aust. J. Exp. Agric. - May 1998.

12.3 Extension activities

Several short articles have been released in rural newspapers, and in the Beeftalk magazine distributed throughout south-eastern Queensland. The results have been discussed at a field day at Proston and with a grazier group at Roma. At several other venues, e.g., the Australian Cattle Veterinarians Conference in Toowoomba and a management workshop in Rockhampton, the results and underlying principles have been discussed with producers.

It is intended that the results of the project and the underlying nutritional principles will be 'workshopped' with DPI extension staff throughout the Queensland Beef Industry Institute late in 1997. This will serve to update the knowledge of extension staff and also expedite extension of the information to producers.

The results will be incorporated in the Feedman decision support model to replace existing growth response curves. This will extend significantly the scope of the extension of the findings.

The results have also been offered to the modellers involved in producing GrazFeed with the view of improving this model for use with cattle tropical pastures.

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