Performance of Feedlot Cattle with reference to Carbohydrate Digestion of Maize versus Hominy chop.

by

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DECLARATION

I hereby declare that the results contained in this thesis are from my own original work and have not been previously submitted by me in respect of a degree at any other University.

R.H. van der Veen
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Chapter 1

Literature review

Grains make up a large proportion of feedlot diets. Different grains differ in the rate at which they are digested. van Niekerk (1993) pointed out that different grains might have the same digestibility and apparent energy value but don't necessarily give the same production response in the animal.

1. RATE OF CARBOHYDRATE DIGESTION

There is a large difference in the rate of breakdown between carbohydrates. The more soluble the starch is in the rumen, the greater the fermentation rate. A slow rate of rumen starch digestion in turn is associated with an increased amount of rumen bypass starch. The bypass starch is digested and absorbed 20-25% more efficiently than that which is fermented by rumen microbes. On average, 5-20% of starch consumed is digested postruminally, with digestion taking place in the small intestine and absorbed as glucose (Huntington, 1994).

The ability of the small intestine to digest and absorb bypass starch may be limited by the ability of the intestinal enzymes to digest starch (mainly pancreatic amylase)(Ørskov, 1986). These enzymes may be overwhelmed by large amounts of bypass starch. Furthermore, the capacity for absorption of glucose may limit starch digestion in the small intestine (Ørskov, 1986). In a review by Huntington (1994) it was noted that pancreatic amylase secretion in ruminants continued to increase as energy intake increased. Increased digestibility of starch in the small intestine is directly related to increased supply of protein to the small intestine. Ruminal digestion of starch therefore indicates a two fold benefit: 1) increased production and outflow of microbial protein from the rumen and 2) increased digestion

Starch effect

of starch that escapes the rumen as a result of the pancreatic response to more protein supply entering the small intestine (Huntington, 1994).

van Niekerk (1991 & 1993) and Henning (1991) both ranked the rate of ruminal digestion of raw materials commonly used in feedlot rations. Their ranking differs as shown in Table 1. In a comprehensive review by Huntington (1994) who showed that the starch content of wheat was the highest for grains (77%), followed by maize and sorghum (72% for both) and last by barley and oats (57 - 58%). Maize had a slow rate of starch digestion. Up to 40% of the starch content of maize can be classed as bypass starch. This figure can however be significantly lowered through processing such as steam flaking, cooking or mechanical action.

The byproducts listed in Table 1 (molasses, citrus pulp, defatted germ meal, hominy chop, brewers grain and wheat middlings) contain less starch than that of maize. Their principal energy sources are digestible fibre, protein, oil and fat. Fats and oils bypass the rumen where they are not digested (van Niekerk, 1991) but are digested post ruminally, while the digestible fibre is digested slowly in the rumen.

Three common energy sources used in feedlot rations are maize, hominy chop and sorghum.

Maize grain is very high in energy due to the high starch and its oil content, but low in protein, fibre and minerals. It is a very palatable raw material and can be used as the main energy source in a ration. Whole grain is poorly digested by ruminants as it is necessary to break the waxy external shell of the kernel to permit degradation in the rumen. Furthermore whole grain has a tendency to pass through into the manure without being digested. The energy value and consequently the starch available for digestion is better if the grain has undergone some kind of processing namely steam rolling, dry rolling, grinding, extruding, popping, or flaking (Cheeke, 1991; MacGregor, 1989)

Hominy chop is a major byproduct in the maize milling industry. This makes South Africa a large producer of Hominy chop (van Niekerk, 1984). Most hominy chop is available for the feed industry and a great part forms the basis of feedlot rations (van Niekerk, 1984; Mandisoza & Holness, 1985; Cheeke, 1991).

Table 1: Different rates of ruminal digestion. Adapted from van Niekerk (1991 & 1993) and Henning (1991)

van Niekerk (1991 and 1993)	Rate of ruminal digestion	Henning (1991)
Molasses	Fast	Molasses
Wheat		Wheat bran
Barley		Oats, ground
Oats		Barley, ground
Maize		Wheat, ground
Maize silage		Maize germ meal
Citrus pulp		Barley, rolled
Defatted germ meal		Maize bran
Hominy chop		Wheat, rolled
Whole soya		Hominy chop
Whole cottonseed		Sorghum, ground
Brewers grain		Maize, ground
Wheat middlings		Sorghum, rolled
Sorghum		Maize, ground
		Sorghum, rolled
		Oats, rolled
	Slow	Maize, rolled

Hominy chop can have a similar nutritive value when compared with maize and therefore makes this product a relatively inexpensive energy source. Most of the hominy chop which is a combination of maize bran and germ, is used for maize oil extraction. Hominy chop contains a considerable amount of fat. A good quality hominy chop can contain up to 9% fat. Most of the energy comes from the oil, with a little starch making up the balance (Evans & Johnson, 1995). It can provide 6% more energy than that of maize in feedlot diets primarily due to the higher oil content present (7.7% vs 4.2%) (Larson *et al.*, 1993). Low fat hominy chop can also be successfully included in livestock rations. Larson *et al.*, (1993) in trials with both sheep and cattle showed that expeller-extracted hominy feed (5.3% fat on DM basis) contained 1.35 Mcal of net energy for gain per/kg, or 87% of the energy of maize, when included at levels up to 40% of cattle finishing diets, despite its containing 20% less starch than maize.

Hominy chop has been classed as a fibrous byproduct but has the significant advantage of containing a fermentable fibre source. *In vitro* rate of starch disappearance was higher for hominy chop than that of maize (Personal communication: Henning, 1995 and Larson *et al.* (1993)). In spite of this animals fed a hominy based ration should be less prone to lactic acidosis due to the more digestible fibre present compared with a maize based ration (Henning, 1995). van Niekerk (1991 and 1993) on the other hand ranked hominy chop to have a slower rate of starch digestion compared to maize (Table 1).

Hominy chop is a variable product. Its composition differs from mill to mill depending on the mill design (wet or dry which influences the moisture percentage) and the extent of oil extraction. High fat together with varying and high moisture content of about 15% makes it susceptible to the development of rancidity, heating and deterioration of the nutritive value. This is particularly evident during the summer months which makes the storage of this raw material problematical.

Sweet (Tannin free) sorghum has a similar feeding value to that of maize (van Niekerk, 1984). However, sorghum starch has a very slow rate of fermentation (Table 1). This tends to be associated with an increased amount of rumen bypass starch. For the best results it is essential to at least break the grain. Care should be taken not to feed finely ground/milled sorghum as this has a negative effect on feed intake (Evans & Johnson, 1995). The most pronounced response is to steam flaking (Huntington, 1994).

Combinations of slowly and rapidly digested grains can have a synergistic effect on animal performance. If these synergistic effects suggested are real then it is clear that the possibility exists to use a variety of grains, grain byproducts and processing methods to mix rations with particular starch fermentation characteristics and hence optimal animal performance (van Niekerk, 1993).

2 METABOLIC DISORDERS ASSOCIATED WITH HIGH STARCH DIGESTION

2.1 Acidosis and Bloat

Acidosis, low rumen pH (which can lead to rumen atony and possible death) and rate of starch digestion are closely related. Britton & Stock (1986) regarded acidosis not to be a disease but rather a continuum of degrees of acidosis. They categorised acidosis to be acute or subacute. These categories represented both extremes and the actual point where subacute becomes acute is difficult to determine. Animals suffering from acute acidosis may be sick or even die or may have physiological function impairment (usually absorption with affects performance). Subacute acidosis is more subtle and difficult to access. Its major response is a reduction in intake with reduced performance.

High starch rations, which exceed the fermentive capacity of the rumen microbes results in the accumulation of glucose in the rumen. This leads to the rapid growth of lactic acid producing bacteria which in turn leads to high levels of lactic acid and hence decrease the rumen pH (Dugmore, 1995). This can also be attributed to too high levels of non structural carbohydrates (NSC, are sugars and starch in a diet which provide energy for microbial synthesis) and to little rumen degradable protein (RDP) present in a diet. Normally the ratio of NSC:RDP is between 35-40%:60-65% for dairy cattle. High levels of NSC in a diet can shift rumen fermentation towards lactic acid fermentation which in turn leads to acidosis. Low levels of RDP accompanied by high levels of NSC can reduce microbial synthesis and in turn affect DMI (Neitz and Dugmore, 1995).

The organisms that predominate under low pH conditions are the *Streptococcus bovis* spp. These bacteria produce lactic acid as their end product of fermentation, particularly D-Lactate which is poorly absorbed and metabolised. *Lactobacillus* spp. are also in abundance under these conditions. The accumulation of the lactic acid in the rumen and blood causes rumen and metabolic acidosis. Ruminal lactate could be a potential inhibitor of intake (Britton & Stock, 1986). Further consequences of a low pH are the corrosion of the rumen wall, parakeratosis (the peeling off of the rumen papillae) impaired absorption and invasion of the rumen wall by bacteria which may gain systemic entrance and result in a high incidence of liver abscesses (Cheeke, 1991).

Starchy constituents of feedstuffs are also responsible for gas production. From this it can be concluded that feedstuffs high in starch and therefore high in carbohydrates will cause a high production of gas relative to rations which contain less starch and more fibrous components. The total amount of gas is mainly made up of carbon dioxide (40%), methane (30-40%), hydrogen (5%) and small but varying amounts of oxygen and nitrogen (McDonald *et al.* 1988). Together with the gas, ammonia and the three main volatile fatty acids; acetic, propionic and butyric acid is produced (Mönnig and Veldman 1989). If the gas present in the rumen is in the form of small bubbles that become mixed within the feed, a frothy mixture of gas and feed will result. The animal is not able to get rid of the excess gas because gas does not separate from the feed. The size of the bubbles and how readily they burst is determined by the surface tension and the layer of fluid that surrounds them. So this in effect means that the lower the surface tension, the smaller the gas bubbles, the less readily they will aggregate into larger pockets and burst. In short, the lowering of the surface tension of rumen fluid, inevitably results in frothy bloat.

The amount of saliva secreted also plays an important role in the prevention of bloat. Salts in saliva act as a natural buffering agents maintaining the ruminal pH between 6 and 7. Saliva production is proportional to the amount of rumination that takes place. Diets high in concentrates and hence, low in long fibre do not produce large volumes of saliva compared to high roughage diets (Mönnig and Veldman, 1989). Feeds which tend to ferment rapidly and which lead to low ruminal pH reduce the buffering action. This is due to a lack of dietary fibre to stimulate rumination and the consequently lower the production of saliva to buffer the pH. The likelihood of acidosis and bloat is therefore eminent.

Various antibiotics are available as feed additives which combat the problem of acidosis and bloat. The most commonly used is an ionophore monensin sodium (Rumensin - 20% Monensin Sodium; Eli Lilly, JHB, RSA). Ionophores used for the control of acidosis inhibit the growth of *Streptococcus bovis* and *Lactobacillus* spp. In addition to this, the additive improves feed conversion ratios and average daily gains by altering the rumen fermentation pattern ie: lowering the acetate: propionate ratio. The advantage of this is that the propionic acid is more efficiently used in metabolism than acetic or butyric acid.

2.2 The Roller Coaster Effect

Animals fed high concentrate feeds are in a slight acidotic state because rumen fermentation is stimulated, resulting in an decrease in rumen pH (de Faria & Huber, 1984). Intake patterns are important barometers to subacute acidosis and can lead to acute acidosis (Britton & Stock, 1986). As already noted this effect is compounded by a reduction in saliva production due to the low forage content of the diet. Dry matter intake declines and the animal could stop eating. Maintaining ruminal pH above 5.6 seems critical to control subacute acidosis (Britton & Stock, 1986). If not too severe the rumen pH returns to normal after time and the animal starts eating again. The animal, having been off feed for a time becomes hungry as its metabolism returns to normal. This can lead to overeating. The whole process of a lowered rumen pH and "off feed" repeats itself. The peaks and troughs of feed intake can clearly be observed and represent the "Roller Coaster" on which the animal finds itself (Hoffman la Roche Inc 1993).

One way of overcoming this disastrous condition is to feed the animals small quantities of feed at a time spread throughout the day, to obtain a steady state of fermentation within the rumen (Hoffman la Roche Inc, 1993; Sutton *et al.*, 1986). It may also help to feed small quantities of long hay.

3. FACTORS AFFECTING DIET DIGESTIBILITY AND FEED INTAKE.

A relationship does exist between digestibility and rate of digestion which in turn leads to a relationship between digestibility and food consumption (McDonald *et al.* 1988). The more digestible the feed, the faster it is removed from the rumen. Consequently the greater the space is cleared in the rumen between meals, the more the animal can probably eat (McDonald *et al.*, 1988).

The main dietary factor that controls feed intake is the dietary energy concentration. Animals eat in an attempt to satisfy their energy requirements. The feed consumed is regulated in such a way that they are provided with a constant intake of digestible energy. If animals are on a low energy diet, feed intake is at gut capacity. Ruminants in particular are unable to increase intake on low energy diets to meet their requirements. The main limiting factor with low energy cattle diets, given in an unground form, is the rate at which the feed passes out of the rumen (Owen, 1991). Animals on a high energy diet that is in excess of their energy needs may reduce their intake. Figure 1 illustrates the two phases that can be seen in this association (Cheeke, 1991).

The lower limit of this relationship occurs where there is a distinct physical restriction on intake imposed by gut capacity and the limitation at which the rate of feed material is broken down and passes through the digestive tract (Cheeke, 1991). This is known as "Physical Regulation" and is controlled by the stretch and tension receptors present in the reticulo-rumen (McDonald *et al.*, 1988).

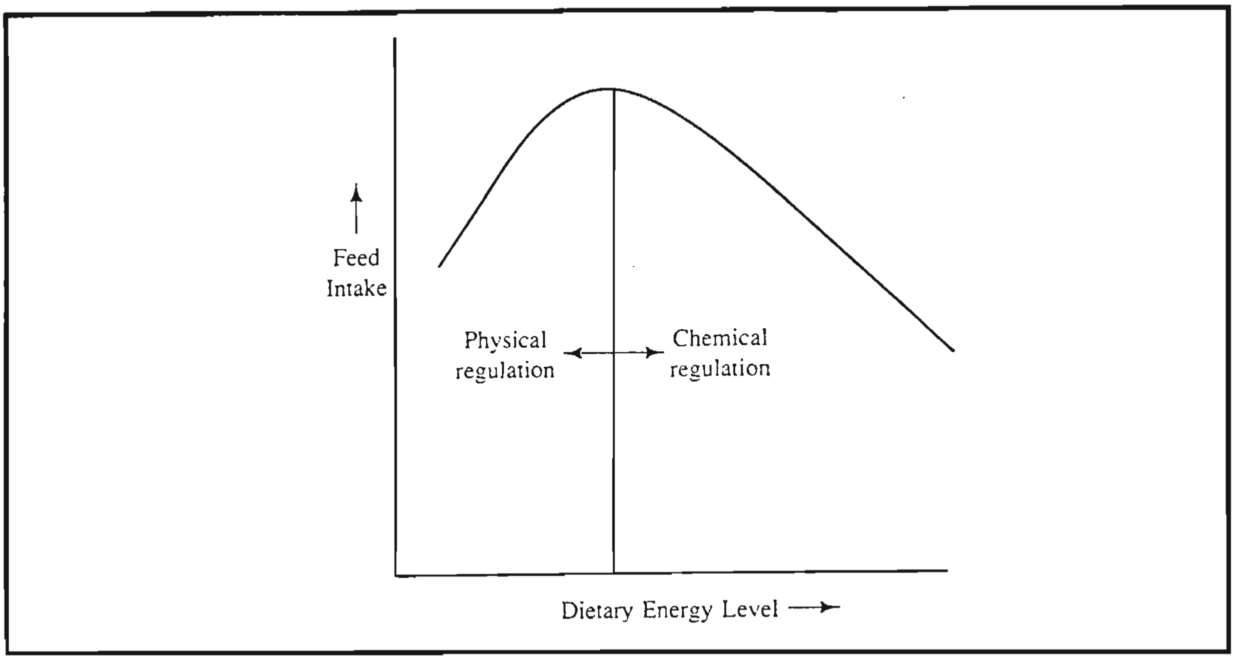

Figure 1: The relationship between feed intake and dietary energy levels (Cheeke, 1991)

Provided digestibility and/or rate of passage is not limiting, animals can adjust their voluntary intake to consume the required amount of energy per day (Cheeke, 1991). As the energy content of the feed increases, microbial fermentation increases, and the end products of fermentation can be absorbed or passed on to the rest of the digestive tract (Owen, 1991). At higher levels of dietary energy, the rate of passage of feed material out of the rumen ceases to be the limiting factor but the intake may still be physically limited by the rate of passage of material through the rest of the digestive tract. When this limitation is removed, the animal has then reached its maximum energy intake, which is metabolically determined by the animal's genetic capacity for production (e.g. growth) (Owen, 1991). This explains the second association of Figure 1, known as "Chemical or Chemostatic regulation".

In nonruminants blood glucose is the principal regulator of feed intake. In the case of ruminants this is controlled by the volatile fatty acids (VFA)(Cheeke, 1991). According to McDonald *et al.* (1988) the stretch and tension receptors present in the reticulo-rumen are of less importance with concentrate diets as the chemostatic sensory signals play a greater role in intake regulation. The amount of glucose absorbed from the digestive tract is relatively small and blood glucose levels show little relation to feeding behaviour. It seems that the glucostatic mechanism of intake control does not apply to ruminants. A chemostatic mechanism involving the three major fermentation volatile fatty acids (acetic, propionic, and butyric acid) could influence feed intake. According to McDonald *et al.* (1988) acetic and propionic acid depress intake of concentrate diets and it is suggested that receptors for acetate and propionic regulation of feed intake occur on the luminal side of the reticulo-rumen. Butyric acid *per se* is not an important factor in intake regulation.

There are many methods that can be used to improve the nutritive value of a feedstuff for beef cattle (NRC, 1987). Processing can be applied mainly in two forms:

i) Physical processing for example grinding and pelleting, and

ii) Chemical processing for example alkali treatment.

i) *Physical processing*

Since the intake of many forages is limited by the rate of passage out of the rumen, the grinding of these forages reduces particle size. Pelleting further breaks down the physical material and it condenses the material into dense packages, which is easily consumed and avoids the dustiness often associated with finely ground materials. Grinding and pelleting do not have an effect on the chemical components of the diet (Owen, 1991).

However according to Ørskov (1986), ground forages lose the physical properties of roughage which reduces the rumen motility. Ground roughages change the rumen fermentation pattern (The acetic:proprionic ratio may be decreased (NRC, 1987)). This could be beneficial to the growing beef animal (Owen, 1991).

ii) *Chemical processing*

Alkali treatments help break down cell wall constituents of poor quality roughages. This exposes the more digestible materials to the digestive processes (Owen, 1991) and increases the potential for cell wall digestion (NRC, 1987).

4. PHYSIOLOGICAL FACTORS AFFECTING FEED INTAKE

The biology of all beef cattle is similar. The application of basic nutritional principles depends on the rate of maturity and the size of the animal at maturity. It is also influenced by the environmental and conditions of management (NRC, 1987).

4.1 Body size & production demands.

The relationship of body size to feed intake has been a subject of much debate (NRC, 1987). It is frequently assumed that food consumption of grazing animals varies according to some function of their live mass. This relationship can be described by the allometric equation developed by Huxley (1939);

$$Y = ax^b \text{ or } \log y = \log b + a \log x$$

where Y = feed intake and x = live mass (Saubidet & Verde, 1976; MacDonald *et al.*, 1988).

Metabolic body size ($W^{0.75}$) is widely used in animal nutrition research such as for interspecie comparisons of feed intake (ie: sheep vs cattle or between heifers and bulls of the same breed) (Cheeke, 1991) and for the estimation of maintenance requirements (MacDonald *et al.*, 1988).

Metabolic body weight is related to fasting metabolism and in turn to the surface area of an animal. The surface area is proportional to two thirds power of the animals weight($W^{0.67}$).

This was later expressed as $W^{0.75}$ and is referred to as the metabolic weight of a animal (MacDonald *et al.*, 1988). Comparing fasting metabolism values of animals which differ in size is done by expressing them in relation to their surface area.

Fasting metabolism per unit of metabolic liveweight is higher in young animals than in old. The metabolic rate (hence the energy requirements and feed intake) of animals per unit of body weight decreases as body size increases. The relationship is influenced by factors such as sex, age, species, differences in endocrine regulation of metabolic rate (MacDonald *et al.*, 1988 and Cheeke, 1991). Forbes (1983) concluded that between species, voluntary feed intake of mature animals was related to $W^{0.73}$.

Saubidet & Verde (1976); Thornton *et al.* (1985), Hicks *et al.* (1986); Owen (1991) found that feed intake does not increase linearly with body mass, but showed a curvilinear relationship with body mass (Owen, 1991, & Thornton *et al.*, 1985). A simple relationship is not likely to exist because of differences in live mass due to previous nutritional levels of the animals or age or breed differences (Saubidet & Verde, 1976; Owen, 1991).

In general, beef cattle consume dry matter at a level of up to 3% of their body mass per day (van Ryssen, 1992). Chewning *et al.* (1990) attempted to group breed means for feed intake during postweaning feedlot performance (Table 2). Young cattle can be expected to have daily dry matter intakes of over 3% of their body mass (Hicks *et al.*, 1986). As cattle approach maturity these values can drop to 2%.

Plegge (1987) reported that intake peaked when cattle reached 88 percent of their slaughter mass. Intake then declined as the steers reached their slaughter weights. Hicks *et al.* (1986) and Thornton *et al.* (1985) showed that these intake curves were highly dependent on the initial mass when the steers enter the feedlot. Feed intake peaked and plateaued at higher points with cattle entering the feedlot at heavier masses. The general shape of the intake curves for all weights were very similar. Feed intake per unit of live mass declined consistently as cattle reached heavier weights. This occurred with fewer days on feed, for cattle at heavier than at lighter initial weights. Hicks *et al.* (1986) reported that intake reached a plateau after 28 days on feed, and remained steady at that point for the next 96 days. Thereafter, intake tended to decline slightly (Thornton *et al.*, 1985). This decrease in intake may be associated with increased mass and fat as steers approach slaughter mass. Animals that started in the feedlot at a lighter initial mass and or that have spent more than 140 days in the feedlot may also exhibit a decrease in intake.

Table 2: Least square means for daily feed intake as a percentage of body mass (FIP) by period[a] and breed of beef bulls during 140-day postweaning feedlot performance tests (Chewning *et al.*, 1990)

Breed	FIP, %/d	SE
Period 1		
Angus	3.08[b]	0.01
Hereford	2.92[c]	0.01
Polled Hereford	2.91[c]	0.01
Santa Getrudis	2.82[d]	0.03
Charolais	2.81[d]	0.02
Period 2		
Angus	3.06[b]	0.01
Polled Hereford	2.94[c]	0.01
Hereford	2.91[c]	0.02
Maine-Anjou	2.91[cd]	0.03
Brangus	2.90[cd]	0.02
Simmental	2.86[de]	0.01
Charolais	2.83[e]	0.02
Beefmaster	2.66[f]	0.03
Santa Getrudis	2.65[f]	0.03

[a] Period 1 = 1967 to 1976; period 2 = 1977 to 1986.

[b,c,d,e,f] Means within the same column and period without a common superscript difer.

Both groups of authors found that there was little overlap in intakes between mass groups. They found that for each 45kg increase in starting mass, mean daily feed intake increased by approximately 0.68 kg. In other words, when given free access to a high concentrate diet, the initial mass of the animals will dictate the level of feed intake (Hicks *et al.* 1986).

4.2 Mature size and mass

Cattle varying in mature size and of different gender (steer, heifer or bull) reach a given degree of fatness at different weights (NRC, 1987; Hicks *et al.*, 1990). It would be expected that these animals differ in the weights at which intake/$W^{0.75}$ begins to decline.

There is a relationship between fat and protein in the body of cattle as growth proceeds under adequate nutrition (Slabbert, 1990). As growth proceeds towards the mature mass, there is a shift in the use of nutrients from bone and muscle growth to fat deposition. The quantity of fat is equal to that of protein when the fat content is between 17 to 19%. After equilibrium is reached, the fattening phase begins and fat is deposited at an increasing rate while protein is deposited at a decreasing rate. Early maturing animals have a lower mature mass and thus at a given age generally use more of their nutrients for fat depositation (Kempster *et al.*, 1982; Fox & Black, 1984). According to Fox & Black (1984) body composition (the proportions of bone, fat and muscle) at a given mass varies with frame size. For any given body composition larger framed cattle will be heavier than smaller framed cattle of the same body composition.

Gender also has an influence on the mass at a given composition (Fox & Black, 1984). Heifers mature at a lighter mass than steers and bulls, and fatten earlier. If the fattening phase has been reached under similar feeding conditions, heifers will be fatter than steers at a given mass and steers fatter than bulls (Kempster *et al.* 1984).

Fox & Black (1984) cited Klosterman & Parker (1976) who found that heifers were about 85% of the mass of their steer contemporaries at the same body composition. Harpster *et al.*, (1978) compared heifers and steers of four breed types at 29.2% carcass fat. Heifers averaged about 80% of the steer mass irrespective of frame size or breed type.

According to NRC (1987) the degree of fatness and/or a reduction in the growth rate influences voluntary intake. There is a significant decline in intake with the degree of maturity.

Increased body fat reduces the appetite because of either reduced demand for growth, competition for abdominal space, or feedback from adipose tissue to the appetite control centre in the central nervous system (NRC, 1987; McDonald *et al.;* 1988; Fox, 1986). Dry matter intake declined with a corresponding increase in body fat (McDonald *et al.,* 1988; NRC, 1987). Fox & Black (1984) and Plegge (1987) postulated that intake per unit of metabolic mass begins to decline at about 350 kg average frame size steer equivalent mass, or at about 22% body fat.

4.3 Breed Type

Intake differences among beef cattle breeds and their crosses may largely be accounted for by their differences in mature size (NRC, 1987). Cross bred cattle average 2% greater intake than pure breeds fed to the same stage of growth. Other researches have found that there were no differences in intake/$W^{0.75}$ due to breed types (NRC, 1987).

Holsteins are an exception (NRC, 1987; Fox, 1986; Fox & Black, 1984). Holsteins at the same stage of growth as beef breeds are reported to consume an average of 8% more DM/$W^{0.75}$. Hicks *et al.* (1990) found that the mean DMI for Holstein steers was 8% to 15% greater (average 12%) than DMI of beef steers of equal starting mass. This higher DMI could be due to a higher maintenance energy demand.

Holsteins appear to have a higher proportion of organ and gut tissue which results in an increase in metabolic rate (Hicks *et al.*, 1990; Fox, 1986). According to Fox & Black (1984) Holsteins are energetically less efficient, having a larger net energy requirement for maintenance, and requiring more NE/kg gain when compared at equivalent body composition. It was further found that NE_m and NE_g requirements were increased by 12% for Holsteins after adjustments were made for frame size. The higher DMI of Holstein cattle, according to Hicks *et al.*, (1990) could be ascribed to their larger mature size and/or genetic or phenotypic selection of Holstein cattle for high milk production.

Chapter 2

Rate of Carbohydrate digestion

2.1 Introduction

As discussed in Chapter 1, different feed ingredients might have the same digestible energy values but do not necessarily lead to the same production response in the animal. Hominy chop can substitute up to 40% of the maize in cattle finishing rations even though estimates of its feeding value have not been established (Larson *et al.*, 1993). In view of their importance to the feedlot industry an experiment was planned to compare hominy chop and maize grain. It was suggested that, even with hominy chop of similar theoretical digestible energy as maize grain, there could be a difference in the performance of feedlot cattle if hominy chop substituted 100% of the maize in a feedlot ration (Personal communication: Prof H.H. Meissner, 1994). It was postulated that this could be due to different rumen digestibility rates and starch digestion rates between these two raw materials.

The objectives of the feeding trial were as follows:

1. Establish whether the differing digestibility characteristics of maize grain and hominy chop affects the growth rate and performance of feedlot cattle.
2. To obtain an estimate of the feeding value, especially metabolizable energy, of hominy chop.
3. Derive an equation to describe dry matter intake (DMI) for the conditions of the trial.

2.2 Procedures

2.2.1 Test Rations

Four rations were formulated to investigate the possible difference in overall performance of feedlot cattle, using either maize or hominy chop as a energy source. The objective was to have two high energy and two low energy diets using either maize or hominy chop as the principal energy source. It was also assumed that the rate of rumen fermentation of hominy chop was slower than that of maize meal.

The four rations or treatments were:

Ration 1 (HF13): 13 MJ ME/kg DM with maize meal (60% maize) as the principal energy source. It was also assumed that the carbohydrate fermentation rate of this ration would be faster than the next ration.

Ration 2 (SF13): 13 MJ ME/kg DM with ingredients with slowly fermented carbohydrates as the principal energy sources (55% Hominy chop and 10% sorghum).

Ration 3: (HF10): 10 MJ ME/kg DM made up of ingredients with rapidly fermented carbohydrates (31.5% maize). It was also assumed that the carbohydrate fermentation rate of this ration would be faster than the next ration.

Ration 4: (SF10): 10 MJ ME/kg DM made up of ingredients with slowly fermented carbohydrates (27% Hominy chop).

5 - 10

Based on NRC (1984) standards, an assumption was made that the animals would consume approximately 6 kg of feed at the beginning of the trial and would gain an average of 1.4 kg/day. According to NRC standards (1984) the daily theoretical requirements for medium frame growing steers were as follows:-

Protein - 141.90 g/kg, Calcium - 7.1 g/kg, Phosphorus - 3.0 g/kg.

Once the trial began no adjustments were to be made to the rations. This meant that animals would be overfed on protein, calcium and phosphorus towards the end of the trial.

Morpalm was included as an energy source in the high energy rations in order to achieve the desired target of 13 MJ/kg. Morpalm is a calcium soap with a very high ME value (28 MJ/kg ME DM). It is based on hydrogenated palmitic fatty acids (Personal communication: van Wyk, 1994). This fat bypasses the rumen without being changed and most importantly does not influence the rumen microbes and fibre digestibility to any significant degree (van Niekerk, 1991).

In the case of the two low energy rations the NRC standards for CP, Ca and P were maintained but the energy was dropped to an estimated ME of 9.5 MJ/kg DM. These rations contained 60% lucerne.

In the SF13 and SF10 rations small amounts of rolled sweet sorghum was included. This was done because of the slower rate of starch fermentation of sorghum (van Niekerk, 1993).

Urea was limited to less than 1.5 % of the ration (< 100 grams/head/day). In the case of HF13 a small amount of soya oil cake was included in order to achieve the desired crude protein level. Although soya beans contain urease, an enzyme that converts urea to ammonia it is insignificant as it is inactivated at a similar temperature to that which destroys trypsin inhibitors (McNaughton & Reece 1980).

The levels of Rumensin (20% Monensin Sodium) and Tylosin (Tylosin Phosphate 10%) used in Beefmaster's rations were included. Trace minerals and vitamins were added in the form of a premix (Premix SP811, Marine Oil Refineries DBN, RSA). Sodium bicarbonate was included in the two high energy rations to aid in rumen buffering.

In formulating the rations, with the exception of the principal carbohydrate sources, all other ingredients were varied as little as possible to commensurate with the need for them to be balanced for comparable levels of CP, ME, Ca and P. The rations are detailed in Tables 3, 4, 5 and 6 and the assumed nutrient composition of the ingredients used is shown in Table 7.

2.2.2 Experimental animals

Ninety five cross bred steers were purchased from five commercial breeders in the KwaZulu-Natal Midlands. They comprised mainly of Hereford, Sussex, Simmentaler, Charolais, Brown Swiss, Afrikaner and Brahman cross animals, weighing between 150-250 kg live mass. They were of uniform conformation and medium frame type with, condition scores between 1.5 - 2.0 (Score one being emaciated and five obese). On arrival they were weighed and then run together as a group on a pasture and fed a maintenance ration for a week.

2.2.3 Distribution of animals between treatments

The animals were tagged and ranked according to weight from heaviest to lightest. Starting at the second heaviest animal every ninth animal was selected for the initial slaughter group (n = 11). The four lightest animals were selected for the digestibility and pH trials (ave mass 151 kg ±6.63 SEM). They were kept separately from the rest of the animals at the Bull Testing Station (BTS). They were fed the left over waste meal supplemented with some of the high energy rations. The remaining animals were allocated to the four treatments (n = 20) using the weight ranking to get four evenly matched groups. Genotype was not considered in the allocation of the animals to treatments.

2.2.4 Bull Testing Station (BTS)

The trial was conducted at the Cedara Bull Testing Station. The station is partially sheltered and equipped with Kalan gates enabling individual feed intakes to be determined. The facilities consisted of 24 feeding plus 8 adaptation pens. Each pen housing a total of ten animals.

Table 3 - Ration 1 (HF13): HF13 MJ ME/kg DM made up of rapidly fermented carbohydrates

Raw Material	Percent	Nutrient	Unit	Level in Feed[c]
Maize (Crushed)	60.00	Dry matter	g/kg	886.52
Molasses	7.00	ME Ruminant	MJ/kg	11.83
Morpalm	4.50	Crude Prot.	g/kg	141.82
Soya Oil Cake	5.00	UDP	g/kg	28.75
Urea	1.37	TDN	%	74.74
Limestone	0.97	ADF	g/kg	87.36
Salt	0.40	NDF	g/kg	127.75
Sod Bicarb	0.50	Crude fibre	g/kg	53.38
Lucerne	20.00	Fat	g/kg	68.62
Min & Vit Premix[a]	0.10	Salt	g/kg	4.08
Monocalcium Phos	0.29	Calcium	g/kg	7.08
Rumensin (mg/kg)[b]	30	Phosphorus	g/kg	3.00
Tylosin (mg/kg)[b]	10			
Total	100.13			

** All rations are on a "as is" basis.

[a] Commercial premix

[b] Active ingredient

[c] Based on tabular values of feedstuffs. If expressed on a DM basis, protein, calcium and phosphorus requirements are slightly higher than what the animal requires.

Table 4 - Ration 2 (SF13): SF13 MJ ME/kg DM made up of by-products that contain slowly fermented carbohydrates

Raw Material	Percent	Nutrient	Unit	Level in Feed[c]
Hominy chop	55.00	Dry matter	g/kg	892.13
Molasses	7.00	ME Ruminant	MJ/kg	11.68
Sorghum	10.00	Crude Prot.	g/kg	141.95
Morpalm	4.50	UDP	g/kg	37.20
Urea	1.47	TDN	%	73.80
Limestone	1.10	ADF	g/kg	109.13
Salt	0.40	NDF	g/kg	233.76
Sod Bicarb	0.50	Crude fibre	g/kg	85.44
Lucerne	20.00	Fat	g/kg	99.16
Min & Vit Premix[a]	0.10	Salt	g/kg	5.47
Rumensin (mg/kg)[b]	30	Calcium	g/kg	7.04
Tylosin (mg/kg)[b]	10	Phosphorus	g/kg	4.17
Total	100.07			

** All rations are on a "as is" basis.

[a] Commercial premix

[b] Active ingredient

[c] Based on tabular values of feedstuffs. If expressed on a DM basis, protein, calcium and phosphorus requirements are slightly higher than what the animal requires.

Table 5 - Ration 3 (HF10): HF10 MJ ME/kg DM made up of rapidly fermented carbohydrates

Raw Material	Percent	Nutrient	Unit	Level in Feed[c]
Maize (Crushed)	31.50	Dry matter	g/kg	890.33
Molasses	7.00	ME Ruminant	MJ/kg	9.27
Urea	0.67	Crude Prot.	g/kg	141.32
Salt	0.30	UDP	g/kg	33.00
Lucerne	60.00	TDN	%	60.46
Min & Vit Premix[a]	0.10	ADF	g/kg	210.37
Mono sod phosphate	0.70	NDF	g/kg	262.01
Rumensin (mg/kg)[b]	30.00	Crude fibre	g/kg	150.22
Tylosin (mg/kg)[b]	10.00	Fat	g/kg	17.92
		Salt	g/kg	3.05
		Calcium	g/kg	7.28
		Phosphorus	g/kg	3.80
Total	100.27			

** All rations are on a "as is" basis.

[a] Commercial premix

[b] Active ingredient

[c] Based on tabular values of feedstuffs. If expressed on a DM basis, protein, calcium and phosphorus requirements are slightly higher than what the animal requires.

Table 6 - Ration 4 (SF10): SF10 MJ ME/kg DM made up of by-products that contain slowly fermented carbohydrates

Raw Material	Percent	Nutrient	Unit	Level in Feed[c]
Hominy chop	27.00	Dry matter	g/kg	892.66
Molasses	7.00	ME Ruminant	MJ/kg	9.27
Sorghum	5.00	Crude Prot.	g/kg	141.80
Urea	0.38	UDP	g/kg	38.47
Salt	0.30	TDN	%	60.59
Lucerne	60.00	ADF	g/kg	223.56
Min & Vit Premix[a]	0.10	NDF	g/kg	316.79
Rumensin (mg/kg)[b]	30	Crude fibre	g/kg	167.82
Tylosin (mg/kg)[b]	10	Fat	g/kg	32.76
		Salt	g/kg	3.78
		Calcium	g/kg	7.42
		Phosphorus	g/kg	3.27
Total	99.78			

** All rations are on a "as is" basis.

[a] Commercial premix

[b] Active ingredient

[c] Based on tabular values of feedstuffs. If expressed on a DM basis, protein, calcium and phosphorus requirements are slightly higher than what the animal requires.

Table 7: Estimated nutrient specifications of the raw materials used for the formulation of the test rations. All specifications are on an AS IS basis

Nutrient	Units	Hominy chop	Maize	Molasses	Sorghum	Morpalm	Lucerne	Soya O/C
Dry matter	g/kg	889	880	750	900	980	909	905
ME Ruminant	MJ/kg	12	12.33	9	12	30	7.97	11.18
Crude protein	g/kg	100	78	30	112	0	160	441.2
UDP	g/kg	45	28.86	0	44.8	0	40	69.54
TDN	g/kg	736	753	559	736	2467	550	730
ADF	g/kg	67.8	26.6	0	44	0	337.6	80
NDF	g/kg	262.8	70.4	0	92	0	400.9	110
Crude fibre	g/kg	60	20	0	25	0	250	45
Fat	g/kg	90	35.8	0	34	980	11.15	18
Salt	g/kg	2.6	0	0	0.26	0	0.1	1.28
Calcium	g/kg	0.55	0.2	7	0.4	0	11.25	2.55
Phosphorus	g/kg	5.8	2.35	3	3.3	0	2.2	6.65

2.2.5 Day of arrival at BTS & Processing

The slaughter group was sent immediately to Cato Ridge Abattoir for carcass evaluation. The remaining eighty-four animals underwent the usual introduction program as used by Beefmaster, which was the following:

1) Beefmaster ear tag in the left ear
2) Ralgro implant (Zeranol - Resorcylic Acid Lactone; Hoechst JHB, RSA)
3) 1 ml Anthrax (Vaccine)
4) 2 ml Bovishield (Vaccine against Bovine Respiratory Syncytial Virus (BRSV), Intra Bovine Rhinotracheitis (IBR), Para Influenza 3, Bovine Viral Diaree (BVD); SmithKline Beechem, JHB, RSA)
5) 5 ml Quarter evil and Botulism (Vaccine)
6) 10 ml Tylosin 200 (Tylan Base; Eli Lilly JHB, RSA)
7) 15 ml Engemycin 10 % (Oxy Tetracycline.HCL 10% solution; Intervet SA, JHB, RSA)
8) 25 ml Vit B complex
9) 25 ml Valbazen (Albendozol 7.5%; SmithKline Beechem, JHB, RSA) & Hi Dose (Vit A 500 IU/ml and Vit E 51 IU/ml; SmithKline Beechem, JHB, RSA)
10) Teething and weighing of the animal

All animals were checked for any abnormalities or defects. One animal was found to have a pharyngeal problem. When under stress it had difficulty in breathing but otherwise grew normally. This animal was allocated to the digestibility and pH trials as it was one of the lightest animals.

The pens used for the experiment were identical in every respect. Accordingly, to keep management as simple as possible and hence ensure that the right rations were fed to the right groups the treatment pens were simply allocated sequentially as set out in Table 8.

2.2.6 Feeding Procedures

2.2.6.1 Adaptation period

The adaptation period was from 17/6/94 to 7/7/94, a total of 20 days. The animals were placed in their respective pens and lucerne hay was placed in the feeding bins. The springs which automatically shut the Kalan gate when opened were disabled, so that the gate would open freely. All the gates were opened so that the animals could see the feed on entering the pens. For the following four days lucerne (approximately 3 kg) was fed in the morning and evening. After day four the springs that shut the gates were activated but without the catch. This meant that the animals had to physically push open the gate but did not have to trigger the solenoid to open the gate.

Table 8: Allocation of animals to specific feeding pens

Animal No	Pen number	Tag colour	Ration
A1 - A10	A	Yellow	HF13
A11 - A20	B	Yellow	HF13
B21 - B30	C	White	SF13
B31 - B40	D	White	SF13
C41 - C50	E	Orange	HF10
C51 - C60	F	Orange	HF10
D61 - D70	G	Green	SF10
D71 - D80	H	Green	SF10

Together with the lucerne approximately 2 kg of the test ration was fed in the morning and evening to the respective groups. On day ten of the adaptation period, all animals were fitted with a collar. Suspended from the collar hung a transponder. Each transponder opened a specific Kalan gate and each animal had to learn to open its own gate.

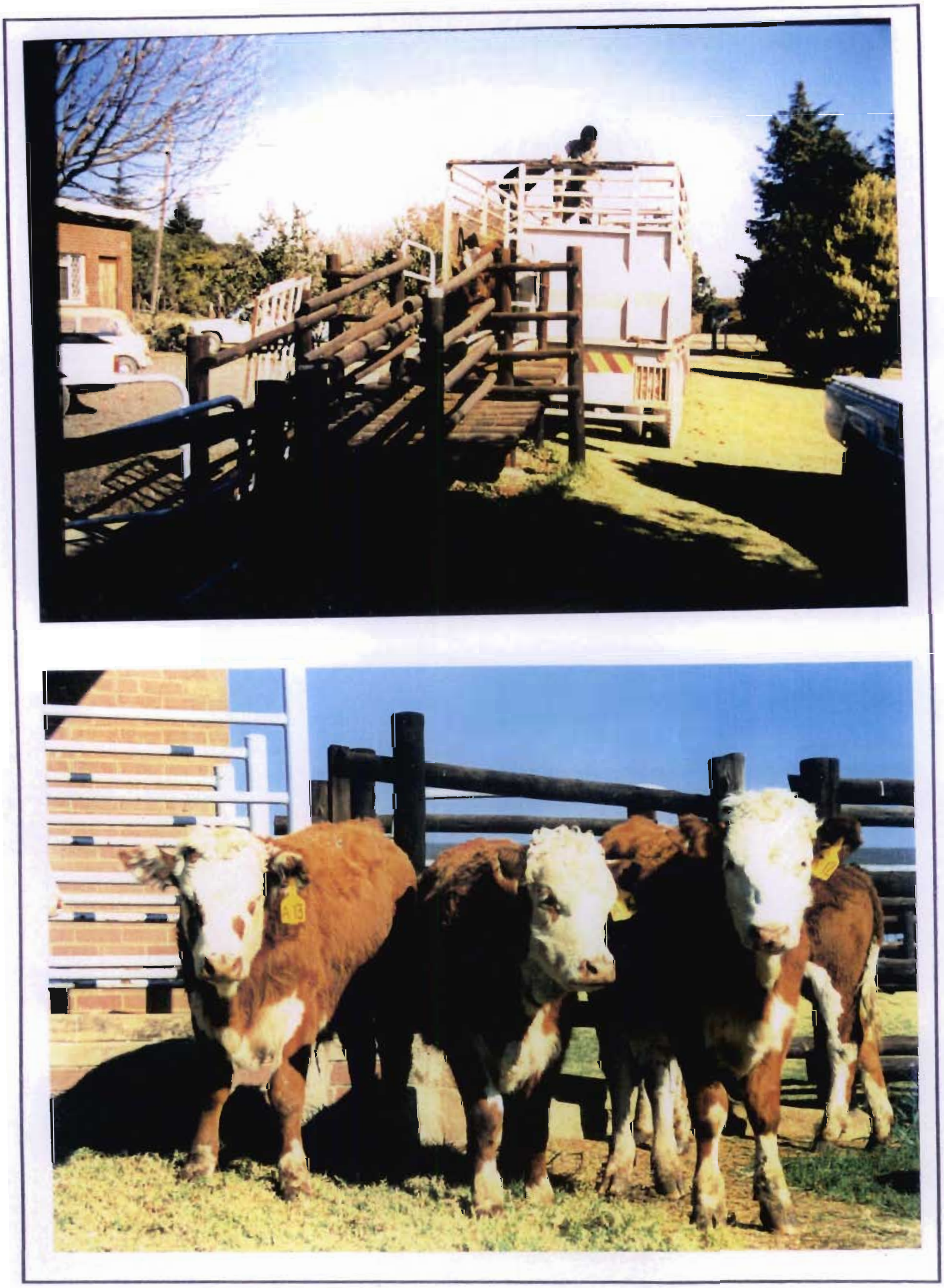

Plate 1: Animals on arrival at the Bull Testing Station and start of the adaptation period of the feeding trial

2.2.6.2 Feeding trial

As will be described, problems during the trial had the effect of dividing the trial into three distinct phases or periods. These were days 0-33, 36 to 68 and 71 to 99.

HF13 and SF13 rations were pelleted and bagged in 50 kg bags by Meadow feeds, Pietermaritzburg. The concentrate part of rations HF10 and SF10 were mixed and bagged by the same company, and the milled lucerne was supplied on its own. The concentrate and lucerne were then hand mixed at the BTS. Each animal had its own feed bag which were weighed before being tipped into the animals feed bin. For the first 42 days feed was allocated *ad libitum*, the bins being checked and filled twice per day.

Plate 2: The steers were all sorted according to the treatments

On days 39 to 41 a total of 19 animals bloated on the high energy rations (HF13 and SF13). Rumen contractions seemed to have had ceased and animals appeared to be "off feed" and experiencing the roller coaster effect.

On day 42 animal A5 died of severe acidosis and the effects of bloat. All the animals from these two treatments were taken to the adaptation pens for two days where they were fed hay (stalky Eragrostis) and water *ad lib.* On the second day in the adaptation pens all the animals were dosed with a *Yea Sacc* Bolus (*Sacchoronyces Ceoevisiae* - 10g/bolus; Alltech, Somerset West, RSA) which is a dry tablet containing yeast organisms.

Plate 3: A rear view of a few animals illustrating body condition during the adaptation period

In an attempt to prevent a recurrence of these events, on returning the animals to the treatment pens, they were fed five times per day and feed was allocated according to a system of "feed bunk scoring". The idea was to force the animals to spread their intakes more evenly throughout the day and from day to day. Thus, the expected daily intake of each individual was calculated and this intake was spread over the five feeds. This meant that at each feeding the feed from the previous feed would be finished or at least nearly finished. It would be impossible for an animal to eat in any day very much more than the average intake of the previous two days. The feeding times were 07h30, 09h00, 12h30, 16h00, 21h00. The night staff at the BTS finished work at midnight and as bloating could normally be expected to occur within two hours of a feed it was important to have the last feed for the day at least two hours before the staff at the BTS left for the night. Thus, these feeding times while not ideal, suited the daily routine of the BTS. Scheduled feeding was introduced on day 51 of the trial.

The scoring and feed allocation system was implemented as follows:-

1) Feed was allocated using a system of scoops. Rations HF13 and SF13 being pelleted and therefore less bulky, were measured out with a plastic scoop which held approximately 850g of feed. The HF10 and SF10 rations were measured out with a plastic bucket which held approximately 2kg feed. As the "scoops" were taken from each animal's previously weighed bag of feed, actual weights of feed eaten were accurately recorded.

2) The initial maximum daily allocation of feed for each animal was determined from the records of the previous 44 days of the feeding trial. After the initial few days on the new system, the maximum allocation per day was based on the average consumption of the previous two days. Potential increases in consumption were allowed for by rounding up the average by one scoop. This permitted animals to increase their daily consumption but prevented any dramatic increases and hence dramatic day to day fluctuations.

3) The maximum number of scoops or buckets that an animal was to receive for a day was calculated each morning. The maxima were determined according to the times between feeds but the actual allocation at any feeding depended how well the animal had cleaned up its feed from the previous feeding.

4) At each feeding, each bin was given a bunk score (in effect, a measure of feed eaten in the previous feeding period) and then feed allocated according to a combination of bunk score and permitted maximum number of scoops. The bunk scoring system was:

Score 1 No feed left in bin, licked clean.

Score 2 Some feed left in bin, bottom of bin covered with feed.

Score 3 Feed left, approximately 0.5 kg of feed.

Score 4 Feed in bin disturbed, some eaten.

Score 5 Feed in bin untouched.

The system devised to control these variables of allocations per day and per feed are set out in Tables 9 and 10 and the actual feed sheet forms used are illustrated in Appendix B.

Table 9: Feed distribution table.

MAX FEED[1]	6	7	8	9	10	11	12	13	14	15
07h30	2	2	2	3	3	3	3	3	4	4
09h30	1	2	2	2	2	2	2	3	2	3
12h30	1	1	1	1	1	2	2	2	3	3
16h00	1	1	1	2	2	2	3	3	3	3
21h00	2	2	2	2	3	3	3	3	4	4

[1] The top row represents the permitted maximum number of scoops for the day. The columns show the permitted maxima at any one feed.

Table 10: Feed allocation table. Scoops per feeding determined from bunk score and maximum number permitted per feed.

Bunk score ->		1	2	3	4	5
Maximum scoops per feeding	1	1	1	0	0	0
	2	2	1	0	0	0
	3	3	2	1	0	0
	4	4	3	1	0	0

Examples of how the feed program worked:

For the 12h30 feeding

Bunk score 1, Max feed in 10, Max scoops in 1, 1 scoop of feed fed

Bunk score 2, Max feed in 10, Max scoops in 1, 1 scoop of feed fed

Bunk score 3, Max feed in 10, Max scoops in 1, 0 scoops of feed fed

Bunk score 4, Max feed in 10, Max scoops in 1, 0 scoops of feed fed

Bunk score 5, Max feed in 10, Max scoops in 1, 0 scoops of feed fed

For the 07h30 feeding

Bunk score 1, Max feed in 15, Max scoops in 4, 4 scoops of feed fed

Bunk score 2, Max feed in 15, Max scoops in 4, 3 scoops of feed fed

Bunk score 3, Max feed in 15, Max scoops in 4, 1 scoop of feed fed

Bunk score 4, Max feed in 15, Max scoops in 4, 0 scoops of feed fed

Bunk score 5, Max feed in 15, Max scoops in 4, 0 scoops of feed fed

Plate 4: Bunk scoring. The upper photo illustrates a bunk score of one whilst the lower one illustrates a bunk score of three

Any animals treated for acidosis and boat after the implementation of the feeding program described above had their maximum daily feed allocation reduced. This was done to give the rumen time to return to normal. The animal would then be forced to take several days to work back up to its previous maximum feed intake.

On days 63 and 64 of the feeding trial animals again started to bloat and show signs of acidosis. On day 65 animal B31 died and six other animals were sick. On day 66 another eight animals became ill due to acidosis and bloat. The animals in HF13 and SF13 groups were taken off the rations for the second time and fed on stalky Eragrostis and water for the next two days and dosed with a *Yea Sacc* Bolus.

Milling and pelleting of the lucerne in the high energy rations could be expected to have a marked effect on the physical properties of lucerne leading to reduced rumen motility and digestive upsets (Ørskov, 1986; NRC, 1986). Prof Meissner (Personal communication, 1994), who had helped devise the trial, was consulted, and it was decided that the particle length of the fibre in the ration may have been inadequate due to the pelleting. So from day 67 the animals were fed the ration in unpelleted form. In addition, at the 07h30 feeding, the high energy groups were fed 0.5 kg of stalky hay per animal per day.

2.2.7 Weighing back feed

All feed fed to each individual was weighed off in bags before feeding. At 08h00 each Monday and Thursday any feed not eaten and any feed that had fallen below the feed bins was weighed back. In this way the intake of each animal was determined twice a week.

2.2.8 Mass of animals

Every Monday and Thursday at about 07h00, following a starvation period of ten hours, all animals were weighed.

2.2.9 Individual Performance of each Animal

Three linked spreadsheets, named *Feed.WQ1*, *Mass.WQ1* and *Mass_calc.WQ!*, were built to record and calculate the individual performance of each animal *viz:* average daily gains (ADG), daily feed intake and the ratio of feed intake to mass gain (see appendix A).

2.2.10 DMI as a % of live mass

Dry matter intake (DMI) as a percentage of body mass was calculated for the three periods and the whole trial. Statistical analyses of results were done according to the Two tail *t* test and only applied within the high or low energy levels and not across. (Rayner, 1967 and Johnson & Bhattacharyya, 1996). In an attempt to derive an equation in which live mass (independent variable) can be used to predict DMI (dependent variable), various multiple regression analyses using linear and quadratic models were carried out on spreadsheet (Microsoft Excel 5). For the linear and quadratic models, regressions were done for the three periods (0-33, 36-68, 71-99 days) and the whole trial (0-99 days).

2.2.11 Statistical analysis of group performance

Applying a Two tail *t* Test within the high and low energy levels (Rayner, 1967 and Johnson & Bhattacharyya, 1996), treatments, both overall and for each of the periods, were compared for dry matter intake per day (DMI/day), live weight gain, feed conversion ratio's (FCR) and average daily gain (ADG).

2.2.12 Carcass Evaluation

At the end of the feeding trial, all animals were slaughtered and graded according to the "Regulations regarding the classification and marketing of meat", (Agricultural Product Standards Act, 1990: Act no 119 of 1990) for overall fat, grade, conformation score, age and bruising. The ratio of the warm mass to the departure mass determined the slaughter percentage.

After 24 hours in the cold rooms the carcasses were further evaluated. The right side of each carcass was quartered between the 10th and 11th ribs. Fat thickness was measured 25 mm and 50 mm from the midline of the spinal column (C and D measurements). Eye muscle length and breadth (cm) was also measured (Slabbert *et al* 1992). A subjective evaluation of the following traits was made: carcass, buttock, back and fore quarter fat code (score 0 - 6), fore and hind conformation (Score 1 - 10), internal fat (Score 1 - 3) and marbling (score 1 - 3) (Meat Board, Pretoria, 1994).

Slaughter percentage, fat thickness (C + D) and eye muscle length and breadth measurements were analysed according to the Two tail *t* test (Rayner, 1967 and Johnson & Bhattacharyya, 1996). The assessments of grading, carcass, buttock, back and fore quarter fat code, fore and hind conformation, internal fat and marbling were analysed using the Chi squared test (Rayner, 1967). Again the tests of significance was only applied within the high and low energy levels and not across.

2.3 Results and Discussion

At the start of the actual feeding trial, animals had lost weight due to the adaptation period as they had to be taught how to open the Kalan gates. Nevertheless there was a non significant, even distribution of initial live mass within the four groups (HF13 - 207 kg, SF13 - 213 kg, HF10 - 218 kg and SF10 - 218 kg).

2.3.1 Combating the "Roller Coaster" effect

The scheduled feeding that was implemented to combat the "roller coaster" effect in the animals on rations HF13 and SF13, helped but was not in itself successful. When stalky hay (Britton & Stock 1986) together with an unpelleted ration was fed (Personal communication Meissner, 1994), the number of cases of acidosis and bloat was substantially reduced although some cases continued to occur. Scheduled feeding did have several advantages; acidosis and bloat became controllable, fresh feed put out at regular intervals was always available which in turn stimulated feed intake. For all practical purposes feeding was as close to *ad libitum* conditions as possible.

2.3.2 Death of animals and selected animals removed from treatments

Of the twenty animals per treatment which were assigned at the start of the experiment several either died or had to be withdrawn from the trial. On day 26, animal B39 from the SF13 group died due to severe acidosis (rumen pH 4.2) combined with bloat. Two more animals died, A5 on HF13 and B31 on SF13 rations resulting from the same metabolic disturbance. Eleven animals over the four treatments never mastered the opening of the Kalan gates. As a result they had very poor feed intakes and consequently ADGs. Their data was not used for the statistical analyses.

2.3.3 DMI as a percentage of live mass of the animal

Table 11 shows that an increase in the % DMI as a percentage of live mass did occur over the three periods as was expected as the animals were still growing. The observed values were substantially lower than those reported by van Ryssen (1992) and Hicks *et al.* (1986). However, towards the end of the feeding period, figures of > 2% were measured. This is in agreement with work done by Hicks *et al.* (1986).

Table 11: Dry matter intake (DMI) as a percentage of live body mass

	DMI as percent of live mass[1]			
Feeding period	**HF13**	**SF13**	**HF10**	**SF10**
0-33 days	1.819[a]	2.214[b]	2.280	2.255
36-68 days	1.898	1.855	2.335	2.093
71-99 days	2.286	2.159	2.591	2.598
0-99 days	2.024	2.072	2.424	2.330

[1] DMI as percent of live mass = mean DMI / mean Live mass * 100

[a,b] Means in the same row with different superscripts differ significantly ($p < 0.05$)

HF13, n=18; SF13, n=16; HF10, n=17; SF10, n=14.

During the 0-33 day period animals on the SF13 rations showed an significantly greater ($p < 0.1$) DMI as a percentage of live mass compared with the HF13 group.

2.3.3.1 Regression analysis of live mass vs DMI: HF13 vs SF13 rations

A simple relationship between live mass and DMI is not likely to exist because of differences in live mass due to previous nutritional levels of the animals or age or breed differences (Saubidet & Verde, 1976; Owen, 1991). Table 12.1 tabulates the regression analysis illustrating the relationship between DMI and live mass while Figures 2 and 3 show the actual data.

Table 12.1: Regressions of live mass vs DMI. Based on the model: $Y = \alpha + \beta x + \beta x^2 + \xi$ where y = DMI and x = live mass

Ration	Intercept	Live mass	Live mass^2	R^2	SE
HF13					
0-33 days	-243.225[b]	2.0999[b]	-0.0044[b]	72.68	0.9185
	-13.1716[a]	0.0836[a]	-	54.60	1.1075
36-68 days	-20.0306	0.1839	-0.0003	0.31	1.1620
	4.9343	0.0006	-	0.01	1.0886
71-99 days	-148.096	0.9071	-0.0013	88.06	0.5853
	-15.183[a]	0.0702[a]	-	81.70	0.6708
0-99 days	-1.4039	0.0105	0.0001	68.60	1.0986
	-5.2641[a]	0.0391[a]	-	68.41	1.0812
SF13					
0-33 days	-354.947[a]	2.9801[a]	-0.0061[a]	85.72	0.8342
	-19.1670[a]	0.1018	-	57.92	1.3796
36-68 days	-27.528	0.2462	-0.0005	5.23	0.9677
	9.3359	-0.0146	-	4.32	0.9095
71-99 days	-160.655	0.9574	-0.0014	88.54	0.5890
	-18.6921[a]	0.0788[a]	-	84.15	0.6415
0-99 days	2.4028	-0.0059	0.0001	44.29	1.3566
	-2.3914	0.288[a]	-	43.99	1.3151

[a] Test of significance ($p < 0.05$)

[b] Test of significance ($p < 0.1$)

The use of Quadratic models describing the data over the 99 day feeding period proved to be ineffective. Even with a low R^2 value for SF13 (HF13=68.41% vs SF13=43.99%), linear models using live mass, was found to be the only significant variable ($p < 0.05$) for both HF13 and SF13, which describes the data the best over this period.

Both the linear and quadratic models for the period 0-33 showed that live mass as a predictor of DMI was highly significant. High R^2 values for the quadratic models of both treatments were noted (HF13=72.68% vs SF13=85.72%). Regarding the quadratic models, the tapering off of DMI in relation to live mass could be contributed to the fact that the animals started to show the effects of the roller coaster phenomenon.

Nor linear or quadratic models could describe the data during the 36-68 day period. This was because firstly the animals lost a considerable amount of weight and secondly because there was a great variation in DMI per day. Figures 2 and 3 clearly illustrate the peaks and troughs regarding the DMI and hence the animals exhibiting the roller coaster effect. On days 40 to 47 and 64 to 71 a significant decrease in feed intake was recorded. The animals on these days were taken off the ration, fed hay and treated for acidosis and bloat. On these days a decrease in live mass was also noted. Scheduled feeding which was introduced on day 51 which also contributed to the change in feeding patterns.

On day 68 the new unpelleted ration together with the supplementation of 0.5 kg of hay each morning was introduced. With the scheduled feeding program, this way of feeding was too try and solve all the digestive upsets. During the 71-99 day period, the linear models only exhibited a significant live mass predictor of DMI ($p < 0.1$) and good R^2 values of 81,70% and 84.15% for HF13 and SF13 rations were recorded respectively. This illustrates that during the last period, when animal performance was not hampered by digestive upsets, and that there was, as expected, a relatively strong relationship between live mass and DMI.

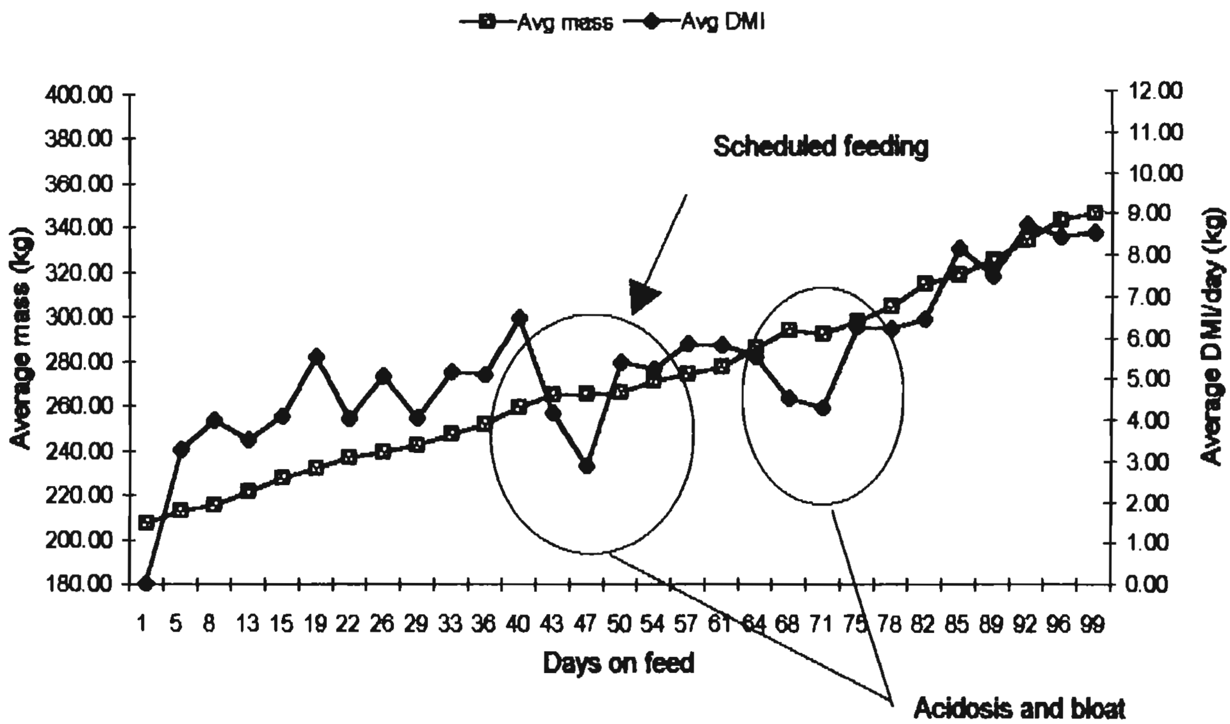

Figure 2: Actual live mass and DMI/day - Ration HF13

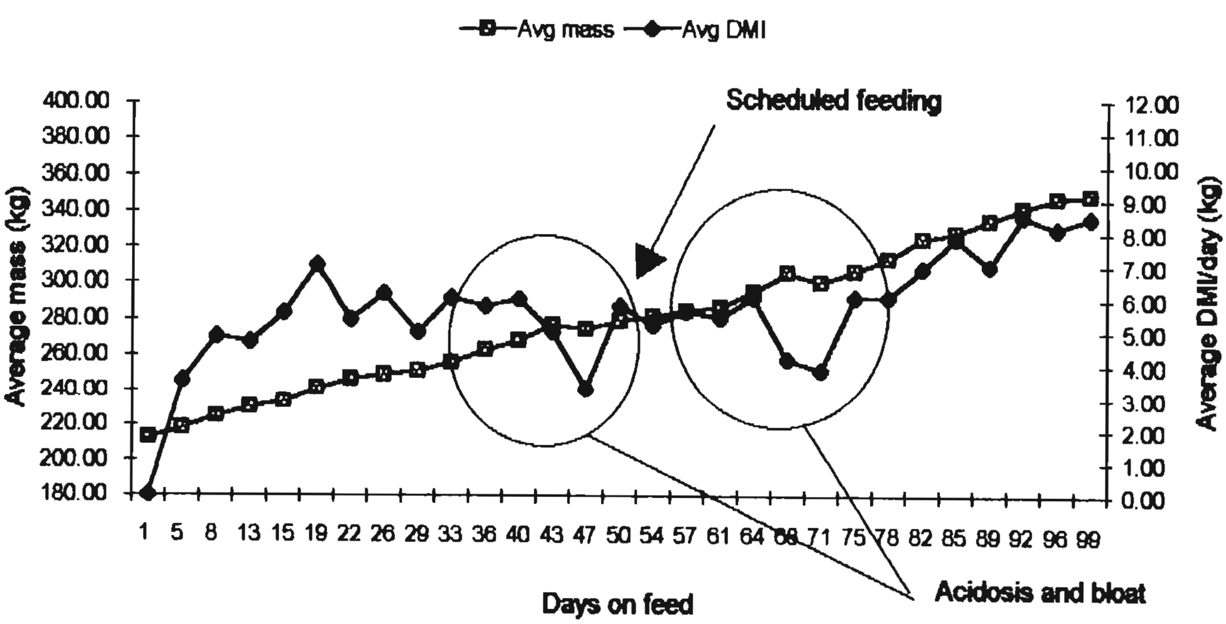

Figure 3: Actual live mass and DMI/day - Ration SF13

It is hypothesised that animals on SF13, which was made up of slowly fermented carbohydrates, should have had fewer digestive upsets than those on ration HF13, the ration with the more rapidly fermentable carbohydrates. Acidosis and bloat plagued all animals in both SF13 and HF13 treatments.

2.3.3.2 Regression analysis of live mass vs DMI: HF10 vs SF10 rations

For the period 0-99 days, the linear model was the only model that fitted the data the best for both treatments. Significant live mass variables ($p < 0.05$ and 0.1) and reasonable R^2 values (HF10=61.55 vs SF10=58.09) were noted (Table 12.2).

Table 12.2: Regressions of live mass vs DMI. Based on the model: $Y = \alpha + \beta x + \beta x^2 + \xi$ where y = DMI and x = live mass

Ration	Intercept	Live mass	Live mass^2	R^2	SE
HF10					
0-33 days	-371.540[a]	3.0617[a]	-0.0062[a]	67.23	1.2822
	-13.1046	0.0755	-	29.36	1.7611
36-68 days	82.3490	-0.4972	0.0008	11.17	0.9798
	10.3203[b]	-0.0112	-	4.58	0.9499
71-99 days	83.5814	-0.4488	0.0007	18.93	0.9763
	0.2246	0.0255	-	17.39	0.9124
0-99 days	-10.0581	0.082	-0.0001	62.07	1.3389
	-3.2172[b]	0.0348[a]	-	61.55	1.3228
SF10					
0-33 days	-495.231[a]	4.0903[a]	-0.0083[a]	85.46	0.9061
	-17.049[b]	0.0916[a]	-	43.68	1.6683
36-68 days	101.2119	-0.6959	0.0013	13.10	1.4908
	-2.6389	0.0303	-	10.00	1.4191
71-99 days	187.2382	-1.0772	0.0016	19.54	1.0145
	1.4703	0.0218	-	10.64	0.9898
0-99 days	-7.1218	0.0560	0.000	58.13	1.4690
	-4.7908[a]	0.0396[a]	-	58.09	1.4423

[a] Test of significance ($p < 0.05$)

[b] Test of significance ($p < 0.1$)

Live mass as a variable to predict DMI was found to be highly significant ($p < 0.05$) for the period 0-33 days, especially regarding the quadratic model. For the 36-68 and 71-99 day periods ($p < 0.05$ and 0.1) the live mass as a variable was found to be non-significant.

Even though no digestive disturbances were anticipated or experienced in the two low energy treatments, dips and troughs in the DMI curve were observed before and even after feeding scheduling (Day 57) was implemented (Figures 4 and 5).

Figures 4 and 5 show a clear decrease in DMI on day 61. Four days previously, the animals in these treatments were also introduced to the scheduled feeding program. This decrease in feed intake could have been be due to a change in the feeding patterns, as the animals now became "meal eaters" instead of feeding *ad libitum*. Another contributing factor to DMI intake variation may have been the scoop size used for the high roughage, low energy rations. The bucket used held approximately 2 kg feed and hence scheduled feeding in these groups was perhaps too crude when compared to the high energy treatments where a 850g scoop was used.

2.3.4 Group performance over the four treatments

Results of the trial are set out in Tables 13.1 and 13.2.

2.3.4.1 HF13 vs SF13 rations

There were no significant differences ($p < 0.05$) in live mass gain, ADG, FCR or DMI/day between treatments over the 99 day feeding period (Table 13.1) There was only one significant differences ($p < 0.1$) between the treatments for the 3 feeding periods (Table 13.2) *viz* FCR for period 0-33 days in favour of SF13.

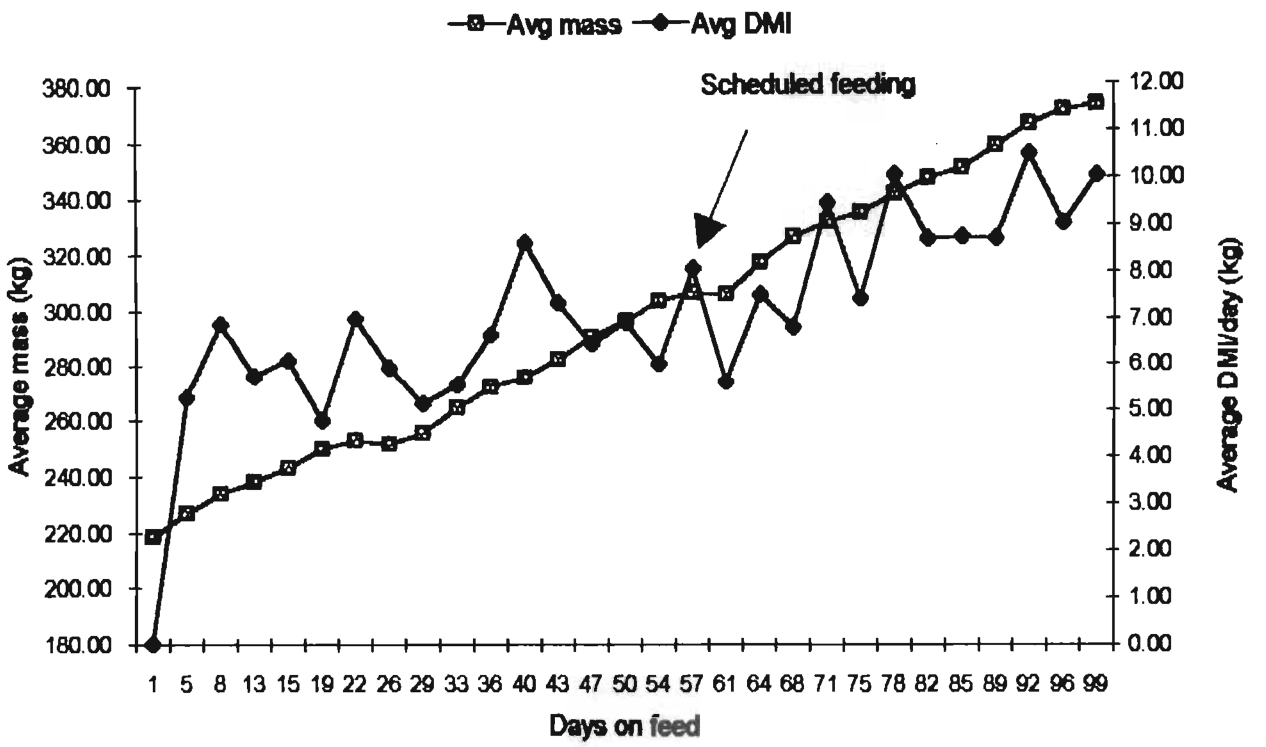

Figure 4: Actual live mass and DMI/day - Ration HF10

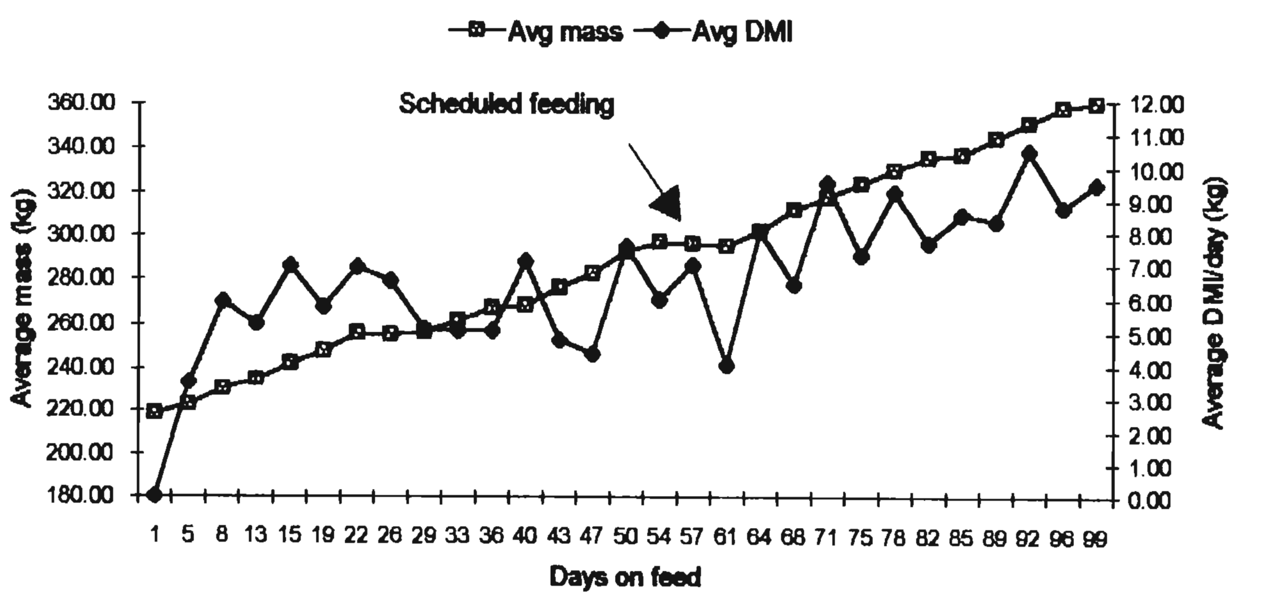

Figure 5: Actual live mass and DMI/day - Ration SF10

Table 13.1: Live mass gains and dry matter intakes for the overall feeding period of 99 days

Animal Performance	HF13	SF13	HF10	SF10
No Animals per treatment (n)	18	16	17	14
Average Initial Mass	207	213	218	219
Average Final Mass	344	348	372	359
Live weight gain	138	135	154	140
ADG	1.39	1.36	1.56	1.42
Average DMI per animal per day	5.44	5.76	7.17	6.68
FCR	4.82	4.71	5.01	5.11

ADG = Average daily gain = Final-initial mass of each animal/99 days
FCR = Feed conversion ratio = Avg feed intake per animal per day/Avg daily gain of each animal

Animal S96 showed from the start of the trial a poor ADG and DMI. During the 71-99 day period it actually recorded a negative ADG (-0.29kg/day), live weight gain (-9kg) and FCR (-17.44). The performance of this animal has influenced the performance parameters for HF13, particularly the FCR (HF13=3.46 vs SF13=5.20). This animal did however know how to open the Kalan gate and was therefore left in the trial. Later at the abattoir, it was revealed that this animal was infested with bladderworms/measles from *Taenia siginata*, which explains the poor performance.

2.3.4.2 HF10 vs SF10 rations

Similar to the high energy rations there was no significant differences ($p < 0.05$) in live mass gain, ADG, FCR or DMI/day between treatments over the 99 day feeding period (Table 13.1). Animals on the HF10 ration during the period 36-68 days showed a significantly better ADG and live weight gain ($p < 0.05$). A similar trend was observed for the rest of the parameters set out in Table 13.2 as that of the high energy rations and no further differences ($p < 0.05$) where found.

Table 13.2: Live weight gains, ADG, DMI/day and FCR per animal over the three feeding periods

Animal Performance	HF13	SF13	HF10	SF10
No Animals per treatment	18	16	17	14
Live weight gain (kg)				
0 - 33 days feeding	40.44	42.63	46.24	42.43
36 - 68 days feeding	41.83	42.94	53.94[a]	44.71[b]
71 - 99 days feeding	52.78	48.31	41.53	42.07
Ave Daily Gain (kg)				
0 - 33 days feeding	1.23	1.29	1.40	1.29
36 - 68 days feeding	1.20	1.23	1.54[a]	1.28[b]
71 - 99 days feeding	1.70	1.56	1.34	1.36
DMI/day (kg)				
0 - 33 days feeding	4.20	5.22	5.59	5.43
36 - 68 days feeding	5.08	5.19	6.96	6.01
71 - 99 days feeding	7.16	6.99	9.08	8.74
Feed Conversion Ratio (FCR)				
0 - 33 days feeding	3.76[c]	4.93[d]	4.72	4.68
36 - 68 days feeding	5.19	4.92	5.03	5.75
71 - 99 days feeding	3.46	5.20	7.54	7.19

[a,b] Means in a row with different superscripts differ significantly ($p < 0.05$)
[c,d] Means in a row with different superscripts differ significantly ($p < 0.1$)
ADG = Average daily gain = Final-initial mass of each animal in the period concerned/no days concerned in each period
FCR = Feed conversion ratio = Avg feed intake per animal per day/Avg daily gain of each animal

The ADGs of the animals in the low energy treatments was better than in the high energy treatments (HF10=1.56 and SF10=1.42 kg/day versus HF13=1.39 and SF13=1.36 kg/day) which was unexpected. The feed with the higher energy levels should have given better growth results. The main reason for better ADG values of the animals on the low energy rations must be attributed to more stable rumen functioning (due to the high lucerne content), especially pH. The result was a better feed intake and therefore growth.

2.3.5 Carcass Evaluation

At the start of the feeding trial eleven animals which were representative of the animals starting the feeding trial were sent to the abattoir. These animals were slaughtered for a carcass evaluation. This represented the initial carcass traits and which would be compared to the animals that finished the feeding trial. The data collected at Cato Ridge Abattoir for the initial and final slaughter measurements has been set out in Table 14.

There was, as expected, a great difference between the initial and final slaughter carcass evaluations. The initial carcasses were very lean, had a blue tint in colour and did not have adequate muscle conformation.

2.3.5.1 HF13 vs SF13 rations

The only significant difference ($p < 0.05$) regarding the slaughter %, fat C + D and eye muscle length and breadth measurements, was that of calculated slaughter % in favour of SF13. This shows that animals on SF13 rations had a slightly larger carcass than the animals on the HF13 ration. No significant differences ($p < 0.05$) were found for the rest of the carcass evaluations. In general SF13 was the better treatment although most of the measurements were non significant.

2.3.5.2 HF10 vs SF10 rations

There was a significant difference ($p < 0.05$) in the eye muscle length between the HF10 and SF10 groups. The remainder of the measurements were not significantly different ($p < 0.05$). The trends in the evaluations were similar to those found in the high energy rations.

In general HF10 treatment gave the more favourable results although there was no significant differences between most of the measurements.

Table 14: Carcass evaluation of the initial and final slaughter groups

Carcass Traits	Initial slaughter	HF13	SF13	HF10	SF10
No. Animals	11	18	15	17	14
Departure mass	208	345.17	347.07	368.18	359.93
Warm mass	105	188.56	194.20	197.71	191.43
Cold mass	101.64	184.11	189.47	193.47	187.21
Slaughter %	50.62	54.60^a	55.89^b	53.61	53.12
Fat C (mm)	0.64	4.07	4.51	5.42	4.09
Fat D (mm)	0.41	3.42	3.53	3.85	3.61
Eye muscle length (cm)	10.71	11.92	12.37	12.53^a	11.70^b
Eye muscle breadth (cm)	3.87	7.09	7.22	7.03	6.86
Grade/Class					
A0	7	-	-	-	-
A1	3	6	3	6	5
A2	1	10	10	7	5
A3	-	1	2	3	4
A4	-	1	-	-	-
A5	-	-	-	1	-

[a,b] Means in a row with different superscripts differ significantly ($p < 0.05$)

** Slaughter % = warm mass / departure mass * 100

** Grading: A refers to the Age class and the carcass has no permanent incisors. The numbers after the Age class refer to the fatness of the carcass, where 0 = No fat, 1 = lean, 2 = lean, 3 = medium, 4 = fat, 5 = slightly overfat, 6 = excessively overfat.

Chapter 3

Digestibility Studies

3.1 Introduction

The digestibility of a feed is defined as that proportion which is assumed to be digested and absorbed by the animal and thus available for metabolism. A chemical analysis is the starting point for determining the nutritive value of a feedstuff. The value of a feedstuff is not entirely dependent upon the amounts of several nutrients it contains. The actual value can only be made after making allowance for losses that occur during digestion, absorption and metabolism (Cheeke, 1991; MacDonald *et al.* 1987; Schneider & Flatt, 1975).

Plate 5: Animal S98 in the metabolic crate during the last digestibility trial. Once in the crate, the animal underwent a five day adaptation period before the collection of data over the following five days

3.2 Procedure

Three digestibility trials were performed. Metabolic crates stationed in the Metabolic House, Cedara Agricultural Development Institute, were used to run the three complete digestibility trials. Each crate was equipped with a water bucket, feed bin and two collection pans, one for urine and the other for faecal collection.

3.2.1 Allocation of animals to treatments

For the first digestibility trial, each animal was allocated to a specific test ration. Thereafter the animals were fed in a cross over design on one of the test rations. The arrangement of animals and allocated rations is set out in Table 15.

Table 15: Allocation of animals to a particular test ration

Animal Number	Digest Trial 1	Live Mass	Digest Trial 2	Live Mass	Digest Trial 3	Live Mass
S97 / D73	SF10	199	HF13	223	HF10	262
S98	HF13	211	SF10	242	SF13	261
S99	SF13	197	HF10	226	HF13	250
S100	HF10	196	SF13	233	SF10	278

For both the high and low energy rations two bags of feed per treatment were taken at random from the feed store. A feed sample was taken from each bag during the actual digestibility trial. These feed samples were chemically evaluated for crude protein, calcium, phosphorus, ADF, NDF, EE and gross energy. During the final digestibility trial and the first pH trials, rations HF13 and SF13 were not pelleted but was given in meal form. Animal S97 was replaced by animal D73 for the final digestibility trial. This was done because this animal had a pharyngeal problem and had difficulty in breathing when placed under the stress of entering the metabolic crate.

Before the animals were transported to the Metabolic House they were weighed and checked for general body condition. For the first two digestibility trials the animals were manhandled into the crates but during the last digestibility trial, the animals were tranquillised with 1 ml Chanazine 2% prior to loading.

3.2.2 Routine procedures

Once in the metabolic crates the animals were subjected to a five day adaptation period followed by a five day collection period. The animals were inspected twice a day. At 08h00 every morning faeces, urine samples and feed orts were collected, weighed and recorded.

3.2.3 Feeding times

Feeding commenced twice per day, at 08h00 and at 17h00. Enough feed was put out to last until the following feeding. The amount of feed fed was based on the previous day's intake but was not fed in accordance with the scheduled feeding regime as described in Chapter 2.

3.2.4 Faecal collection

Faeces that were collected over a 24 hour period were weighed and a 10% sample was taken. This was placed in a drying oven for a period of 16 hours at a temperature of 60°C. Thereafter, faeces samples were weighed again, placed in a brown paper packet and stored. A dry matter determination was done on every sample collected. At the conclusion of each digestibility trial all the faeces collected per animal were mixed and one sample was taken for further chemical analysis similar to the feed evaluations.

3.2.5 Urine collection

Urine was collected in plastic bottles. These were weighed and the total amount of urine voided was determined. 10 ml HCl (Concentration 1 Normal) was placed in each collection bottle, as a preservative. A 1.0% urine sample was taken from each days collection and pooled together in a separate plastic bottle. These were then kept out of the direct sunlight until the end of each digestibility trial. The urine was kept frozen until gross energy and nitrogen content of the urine could be determined.

The average feed intake, faecal and urine collection was determined over a five day period.

With the aid of a spreadsheet, various calculations were done to determine the digestible nutrients of the four different test rations. The resulting digestibility trial data for each animal are presented in Appendix K1,.K2...N2,.N4.

1) Amount of a nutrient in daily feed - Amount of that nutrient in daily faeces = Amount of that nutrient digested daily.

"Consumed" = Amount of a nutrient in daily feed = (Amount of feed eaten daily x % of nutrient in feed)/100.

"Excreted" = Amount of a nutrient in daily faeces = (Amount of faeces excreted daily x % of nutrient in faeces)/100.

"Digested" = Amount of a nutrient in daily feed consumed - Amount of that nutrient in daily faeces excreted

2) Digestibility Coefficient of any nutrient (%) = (Amount of that nutrient digested daily / Amount of the nutrient consumed daily) x 100.

3) Digestible nutrient (% or MJ/kg DM) in feed = (Coefficient of digestibility of that nutrient / 100 x % of that nutrient in the feed).

4) Energy lost via methane (Em) (MJ/day) = Gross energy of feed x 6% (McDonald *et al.*, 1988, pg 220).

5) Energy lost via urine (Eu) (MJ/day) = Gross energy of urine x urine voided per day (kg).

6) Energy lost via faeces (Ef) (MJ/day) = Gross energy of faeces x amount excreted per day (kg).

7) Digestible energy (DE) (MJ/day) = Gross energy of feed - Ef.

8) Calculated Metabolisable energy (ME) (MJ/kg DM):

$$[GE - Ef - Em - Eu] / DMI$$

3.3 Sampling and analyses of test rations

In total 13 feed samples throughout the feeding trial were analysed per treatment. These feed samples were sent to the University of Natal Feed Lab and were analysed for gross energy (GE), fat (EE), dry matter (DM), and total ash (AOAC 1980), Acid Detergent Fibre (ADF) & Neutral Detergent Fibre (NDF) (Goering & Van Soest 1970), and crude protein, calcium and phosphorus (Humbleton 1976). Three faeces samples per treatment were analysed in a similar fashion to the feed samples. Gross energy and protein values of the two urine samples per treatment were analysed according to AOAC (1980). Five feed samples from each treatment were analysed for ADIN (Acid Detergent Insoluble Nitrogen)(AOAC, 1980) at the Cedara Feed Lab. Total gas production (Pienaar, 1995) for five feed samples were determined at Irene Animal Production Institute, Centre for Animal Nutrition.

The significant differences between the high or low energy rations for CP, EE, NDF, NSC and ADIN within the feed were statistically tested within the high and low energy levels using the two tail *t* test (Rayner, 1967 and Johnson & Bhattacharyya, 1996).

3.4 Analyses of digestibility trials

As urine was not collected during the last digestibility trial, values used to calculate ME have been set out under a section "Values used to calculate ME (MJ/kg)" in appendices K4, L4, M4 and N4. Only two samples of feed, faeces and urine were used for this calculation.

The analysis of digestible nutrients regarding crude protein, EE, ADF, NDF, ash, NSC and digestible energy, three samples of feed and faeces were used per calculation. Statistical analyses were done within the high and low energy levels using the two tail *t* test (Rayner 1967, Johnson & Bhattacharyya, 1996).

3.5 Results and discussion

3.5.1 Test rations

Tables 16 & 17 show that the consistency of all the rations complied with the required specifications.

Differences in crude protein levels were non significant ($p < 0.05$) for both the high and low energy rations. EE levels in the two high and two low energy rations were as expected significantly different ($p < 0.05$). This is due to higher fat levels of hominy chop compared to maize (10.91 vs 8.41% DM) and was also found by Larson *et al* (1993) and Henning (1995).

Neutral detergent fibre measures the cell wall content. Larson *et al* (1993) pointed out that hominy chop has a much higher NDF than maize. It was therefore expected that SF13 would have a higher NDF than that of HF13 and was significantly ($p < 0.05$) different in favour of SF13 ration (26.27 vs 17.26 %). No significant NDF differences ($p < 0.05$) were found on the low energy rations. These rations contained 60% lucerne, possibly masking the true NDF values of maize or hominy chop.

Due to large differences in fat and NDF levels in the SF13 ration, significant difference ($p < 0.05$) in terms of NSC was found in favour of HF13 (52.30 vs 40.30 %). As NSC is a measure of simple sugars and starch, it revealed that HF13 had a higher starch content than that of SF13.

Acid Detergent Insoluble Nitrogen (ADIN) is the theoretical measure of the amount of nitrogen present in the feed that is not absorbed in the body of the animal and is excreted. Even though hominy chop has a higher UDP value (37 vs 27%) compared to maize (Erasmus, 1990) no significant ($p < 0.05$) difference in ADIN between the high or low energy levels were evident (Table 18). This indicates that protein irrespective of being RDP or UDP were equally digested.

Table 16: Feed analyses of HF13 and SF13 rations on DM basis (n=10 for each ration)

Description	% Moist	% CP	% Fat	% Ca	% Phos	% Ash	% NDF	% ADF	GE MJ/kg	% Calc NSC
HF13-FEED	8.22	15.34	8.4[a]	1.19	0.36	6.69	17.26[a]	11.85	19.08	52.30[a]
SF13-FEED	8.25	15.66	10.91[b]	1.05	0.41	6.87	26.27[b]	14.00	19.62	40.30[b]

[a,b] Means in a column with different superscripts differ significantly ($p < 0.05$)

CP = Crude protein

NSC = 100-NDF-CP-Fat-Ash (as %)

Table 17: Feed analyses of HF10 and SF10 rations on DM basis (n=10 for each ration)

Description	% Moist	% CP	% Fat	% Ca	% Phos	% Ash	% NDF	% ADF	GE MJ/kg	% Calc NSC
HF10-FEED	7.45	15.15	2.19[a]	0.90	0.35	7.88	38.85	31.91	18.16	35.93
SF10-FEED	7.33	15.28	3.71[b]	0.91	0.36	8.30	39.74	30.43	18.47	32.96

[a,b] Means in a column with different superscripts differ significantly ($p < 0.05$)

CP = Crude protein

NSC = 100-NDF-CP-Fat-Ash (as %)

Table 18: Summarized results of the ADIN analyses (Results on a DM basis, n = 5 per ration)

Treatment	HF13	SF13	HF10	SF10
Crude Protein (%)	15.34	15.66	15.149	15.283
ADIN (%)	3.466	3.062	4.282	3.870

3.5.2 Digestibility Trials

Tables 19.1 and 19.2 show the results of the three digestibility trials. Digestible EE in HF13 was significantly ($p < 0.05$) lower than SF13. Digestible NSC was significantly ($p < 0.05$) higher for HF13. This supports the point made by Larson *et al* (1993) for these two feedstuffs viz:- hominy chop contains more digestible fat and maize has more digestible NSC. There was surprisingly no significant difference ($p < 0.05$) between the digested NDF in the high energy rations. It was expected that SF13 would have a significantly higher NDF than that of HF13. It does have a higher value (HF13=6.72% vs SF13=12.53%) but it is non significant. This is attributed to the great variation in the NDF values obtained.

A possible reason why no differences were found in nutrient digestibilities in the low energy rations was the high lucerne content. This could have masked the actual digestibility values of maize or hominy chop.

An important aspect of the digestibility trial was to determine true metabolisable energy (ME) of maize and hominy chop and strictly speaking, can only be determined by calorimetry. The facilities for this are not normally available and assumptions have to be made about energy lost as methane. Therefore, digestible energy (DE) was determined in the trials and the assumption was made that methane energy amounted to 6 percent of the GE (McDonald *et al* 1988). With the energy in the urine measured, a calculated ME value could be determined.

Table 19.1: Results of the digestibility trials for ration HF13 and SF13. All results on DM basis

Digestible nutrients	HF13	SF13
DMI (kg/day)	4.43	4.75
Crude Protein (%)	10.64	9.75
EE (%)	8.06[a]	10.12[b]
NSC (%)	47.27[a]	31.70[b]
ADF (%)	4.28	4.94
NDF(%)	6.72	12.53
Calcium (%)	0.60	0.37
Phosphorus (%)	0.24	0.22
Digestible Energy (MJ/kg DM)	14.52	13.20
Calculation of Estimated ME values*		
DMI (kg/day)	4.70[a]	3.76[b]
GE intake (MJ/day)	90.01[a]	73.61[b]
GE in faeces (MJ/day)	23.90	22.30
Energy lost via Urine (MJ/day)	4.25	3.55
Energy lost via Methane (MJ/day)	5.41[a]	4.42[b]
Calculated ME (MJ/kg DM)	12.00	11.51

n = 3 except for *Calculation of estimated ME values in which case n=2. Refer to appendix K4 and L4 section "Values used to calculate ME (MJ/kg)" used to calculate the estimated ME values of the respective rations.

[a,b] Means in a row with different superscripts differ significantly ($p < 0.05$).

Obtaining DE values for maize meal and hominy chop used could have been done either by feeding the raw material on its own, or feeding the raw material in combination with a known amount of a basal feed. The first option seems the better of the two but this would cause digestive disturbances. The latter option requires preliminary digestibility trials to determine the DE of a basal feed used for the prevention of digestive upsets. With the digestibilities of the basal feed and in combination with the concentrate feed known, a calculation can be done to determine the DE of the concentrate feed (McDonald *et al* 1988 & Crampton and Harris, 1969). Thereafter a calculated ME value of the concentrate feed can be determined. A complete digestibility trial for lucerne as the basal feed was not done.

Table 19.2: Results of the digestibility trials for rations HF10 and SF10. All results on DM basis

Digestible nutrients	HF10	SF10
DMI (kg/day)	5.37	5.29
Crude Protein (%)	9.93	8.85
EE (%)	1.53	2.30
NSC (%)	33.65	30.11
ADF (%)	11.20	9.41
NDF(%)	15.59	12.84
Calcium (%)	0.42	0.35
Phosphorus (%)	0.16	0.14
Digestible Energy (MJ/kg DM)	11.31	10.43
Calculation of Estimated ME values[1]		
DMI (kg/day)	5.19	5.09
GE intake (MJ/day)	93.06	93.49
GE in faeces (MJ/day)	35.67[a]	43.31[b]
Energy lost via Urine (MJ/day)	3.66	4.59
Energy lost via Methane (MJ/day)	5.59	5.61
Calculated ME (MJ/kg DM)	9.22	7.85

n = 3 except for [1]Calculation of estimated ME values in which case n=2. Refer to appendix M4 and N4 section "Values used to calculate ME (MJ/kg)" used to calculate the estimated ME values of the respective rations.
[a,b] Means in a row with different superscripts differ significantly ($p < 0.05$).

Calculated ME values for the high energy rations were 12.00 and 11.51 MJ/kg DM for maize and hominy based rations respectively. No significant difference ($p < 0.05$) was found for this value within the high and low energy rations.

Methane was calculated as a percentage (6%) of gross energy intake per day (MJ/day). Because there was a significant difference ($p < 0.05$) in the gross energy intake per day between the high energy rations, a significant difference ($p < 0.05$) regarding methane was expected and found.

Gross energy excreted in faeces for the low energy rations was significantly different ($p < 0.05$) from one another. This can be attributed to the great difference in faecal output (HF10 = 1.95 kg/day vs SF10 = 2.33) recorded between these rations.

Chapter 4

pH Trial and Total Gas Production

4.1 Introduction

The rate of gas production in the rumen is most prominent immediately after a meal. This can be as high as 30l/hour in a mature cow. The total amount of gas is mainly made up of carbon dioxide (40%), methane (30-40%), hydrogen (5%) and small but varying amounts of oxygen and nitrogen (McDonald *et al.* 1988). Together with the gas, ammonia and the three main volatile fatty acids (VFA); acetic, propionic and butyric acid are also produced (Mönnig and Veldman 1989).

Differing rates of starch digestibility affect fermentation rates and consequently rumen pH over time. The dietary energy stimulates rumen fermentative activity and probably accelerates microbial and substrate turnover rates, causing a shift towards higher concentrations of molar propionate (de Faria and Huber, 1981). With increased proportions of propionate, excessive accumulation of lactic acid occurs (Raun *et al.*, 1962; Putman *et al.*, 1966). Therefore a close inverse relationship exists between rumen pH and VFA production.

As differing rates of starch digestibilities affect fermentation rates and consequently rumen pH, rumen pH fluctuations over a 24 hour period were determined. Furthermore *in vitro* gas production for each ration was done to estimate the rate and extent of fermentation (Pienaar, 1995).

4.2 Procedures of pH measurements over time

The same four animals used in the digestibility trials were used to determine the rumen pH fluctuations over a period of 24 hours on four different days. For the first pH trial the animals were allocated to the same treatment as the last digestibility trial. For the last pH trial the animals were allocated to opposite energy treatments and base raw material (Table 20).

Table 20: Allocation of animals to a particular test ration

Animal number	pH Trial 1	pH Trial 2
D73	HF10	SF13
S100	SF10	HF13
S98	SF13	HF10
S99	HF13	SF10

Insertion of the rumen fistulas was done three weeks before the third digestibility trial. The rumen fistulas (45mm diameter fistula) were obtained from Burec Equipment, Benoni.

Various methods were considered on how to measure rumen pH over time. One was to insert a pH probe into the rumen directly and in this way overcoming the oxidation of the rumen fluid. Sampling of rumen content at different sites within the rumen was considered. It was finally decided that a sample of rumen content at one site, where the rumen fistula opened into the rumen would be taken (Personal communication P.G Stewart; J.B.J van Ryssen, 1994).

After an adaptation period of five days, similar to the adaptation period followed during the digestibility trials, two collection periods were done starting at 08h00, lasting a 24 hour period. During this time, 12 readings were taken every 2 hours. At each reading the plug of the rumen fistula was removed. The rumen pH was measured at the top layer of the rumen. The feed particles in this part of the rumen are buoyant and form part of a mat floating on top of the rumen fluid (Cheeke 1991). A sample of rumen content was collected once the rumen contracted so that the majority of rumen content was fluid. The ruen content/fluid was scooped from the rumen with a spoon and into a beaker. The pH would be determined with an electronic pH meter directly thereafter.

During the first pH trial three pH measurements were taken per beaker of rumen content/fluid collected (Plate 6). Oxidation of rumen content causes a decrease in rumen pH over time (Personal communication P.G Stewart; J.B.J van Ryssen, 1994). Three pH measurements could have a negative effect on these measurements whereas the first two readings would give a more constant result. This methodology was followed for the last pH trial.

Plate 6: Removal of rumen fluid was done after a rumen contraction

4.3 Statistical analysis of pH measurements and Total *in vitro* gas production.

All data collected for the pH measurements was statistically analysed by linear regression after the mean pH measurements over time were calculated. The data was analysed using Genstat (Version 5.1.3 1988, Lawes Agricultural Trust, Rothamstead Experimental Station, UK). The total gas production was analysed according to a Two tail *t* test (Rayner 1967, Johnson & Bhattacharyya 1996).

4.4 Results and discussion

4.4.1 pH measurements

Due to the poor design of the fistulas (which protruded 3-4cm out from the side of the animal) the fistula came out of place when the animal stood up, rubbing its side against the crate, causing some of the rumen content to leak out. When this occurred the fistula was washed and replaced, crate cleaned and continued with the pH measurements two hours thereafter. This caused ration HF13 to only have 36 pH measurements whilst all the other treatments have a total of 52.

Figures 6 to 9 shows the relationship of pH and fitted values of Y which predict the pH values measured over time for the individual rations. The model used is a third order polynomial where x represents time points: ie 8:00 is 1, 10:00 is 2 etc.

A significant decline ($p < 0.05$) in pH over time was found within both high and low energy rations. The largest decline was observed in the high energy rations, with HF13 showing the greatest decline. This phenomenon could be ascribed to: 1) the fermentation rate of HF13 which was assumed to be higher than that of SF13 (van Niekerk 1991 and 1993) and 2) due to the excessive amount of NSC in HF13 (HF13= 52,30% vs SF13=40.30%) which could have had an influence on the amount of lactic acid produced in the rumen.

Similar fermentation patterns and a small significant decline in pH regarding the low energy rations over time was noted. This again could be attributed to the high lucerne content of these rations possibly masking the effects of maize or hominy chop on rumen pH.

In general the decline in ruminal pH started about two hours after the first feeding at 8:00. The lowest pH points of 5.5 were noted at approximately 18:00, two hours after the evening feeding. After 18:00 a steady increase in pH was observed and peaked two hours before the morning feeding, similar to findings by Slabbert *et al.* (1992) and Goetsh *et al.* (1983). This steady increase was most predominant in the high energy rations. The return to normal rumen pH of 6.5 specially from 22:00 to 8:00 could be due to the large amounts of saliva recirculating through the digestive tract via rumination at night. Saliva contains sodium bicarbonate, a buffering agent which aids in maintaining an appropriate rumen pH (Church 1991). Another possibility is that the starch concentration within the rumen decreases as the digestive and fermentative processes progressed over time.

4.4.2 Total gas production

It was speculated by van Niekerk (1991 and 1993) that hominy chop has a slow rate of rumen fermentation. In an attempt to slow the ruminal fermentation rate of SF13 even more, 10% sorghum, which is known for its slow fermentation rate (van Niekerk 1991 and 1993), was included in this ration.

Differing rates of starch digestibilities affect fermentation rates and consequently rumen pH. The more soluble the starch is in the rumen, the lower the pH in the rumen, the greater the fermentation rate with a higher production of gas which in turn translates to a greater extent of total organic matter digested (Pienaar, 1995). In Chapter 3 it revealed that HF13 had a higher starch content than that of SF13. HF13 was found to have a significantly ($p < 0.001$) shorter mean fermentation time (MFT) than SF13 (Table 21). This demonstrates that maize has a higher rate of fermentation than that of hominy chop. This may explain the greater drop in rumen pH of the HF13 ration. Chapter 3 further revealed that the digestibility coefficient of HF13 was higher than that of SF13 (HF13=78.66% vs SF12=69.58%). Without looking at the rate of passage out of the rumen, from both the digestibility trials and total gas production, HF13 had a greater extent of organic matter digested than SF13.

Table 21: Results of *in vitro* gas production

	HF13	SF13	HF10	SF10
No observations	8	10	7	8
MFT	10.838^{a}	14.287^{b}	9.158^{c}	10.613^{d}

^{a,b} Means in a row with different superscripts differ significantly ($p < 0.001$)
^{c,d} Means in a row with different superscripts differ significantly ($p < 0.05$)
MFT = Mean Fermentation Time (Hours)

The MFT of the low energy rations significantly favoured ($p < 0.05$) HF10. Even though lucerne possibly masked most of the results obtained, maize might have a positive associative effect on fermentation rates when in combination with lucerne.

A great variation in MFT results was observed which could have had an influence on some of the contradictory finding (Personal communication, J.P Pienaar, 1995 and Voderingsverslae 1993/94, Irene Diereproduksie Instituut). This can also be attributed to the variation in hominy chop (van Niekerk, 1984; Mandisoa & Holness, 1985; Cheeke, 1991; Pienaar, 1995).

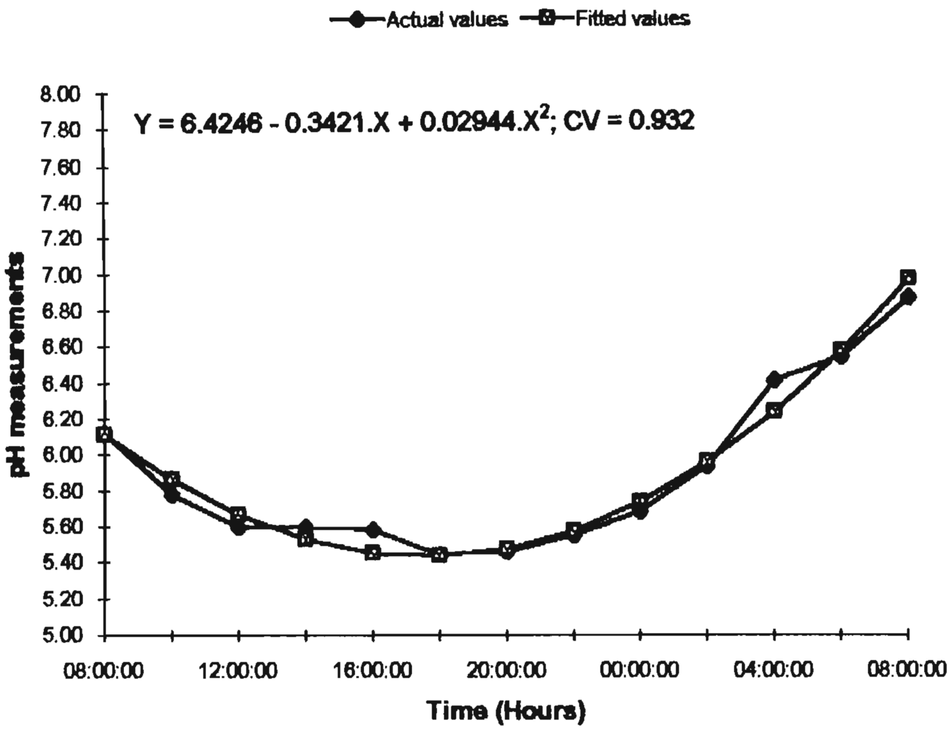

Figure 6: pH measurements - Ration HF13. Average over four periods. Each block represents four collection points

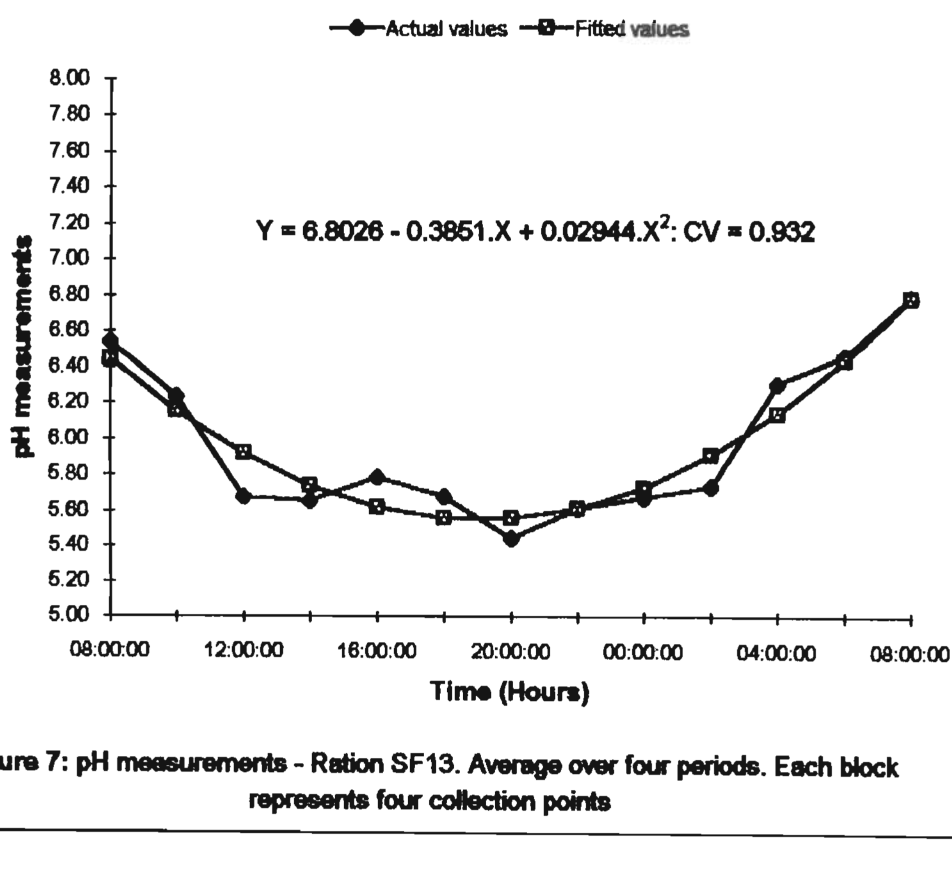

Figure 7: pH measurements - Ration SF13. Average over four periods. Each block represents four collection points

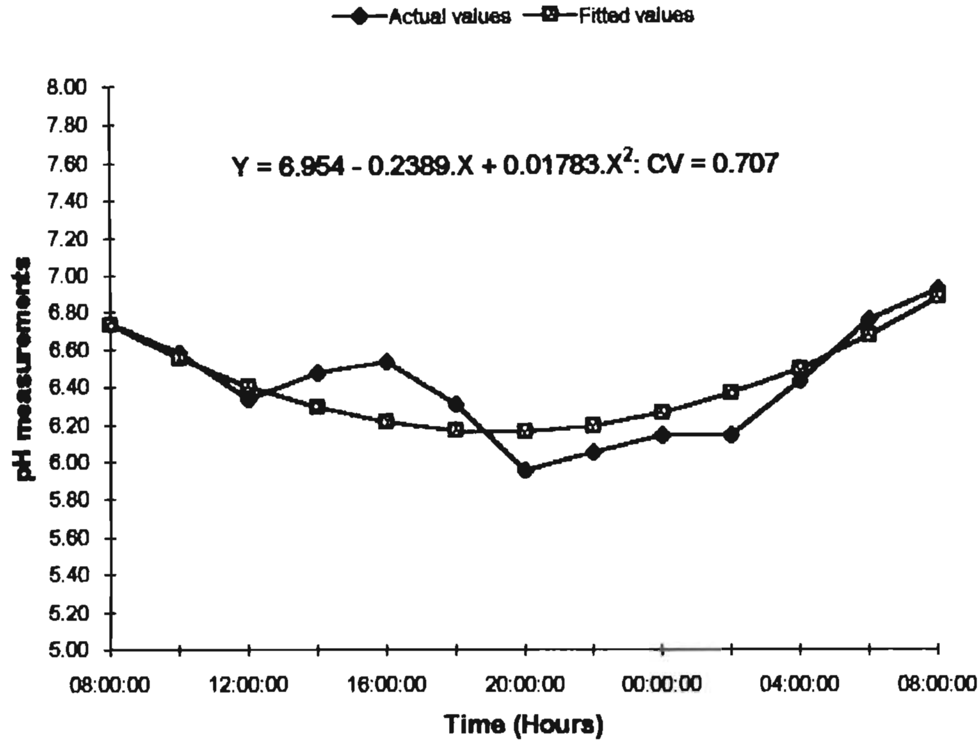

Figure 8: pH Measurements - Ration HF10. Average over four periods. Each block represents four collection points

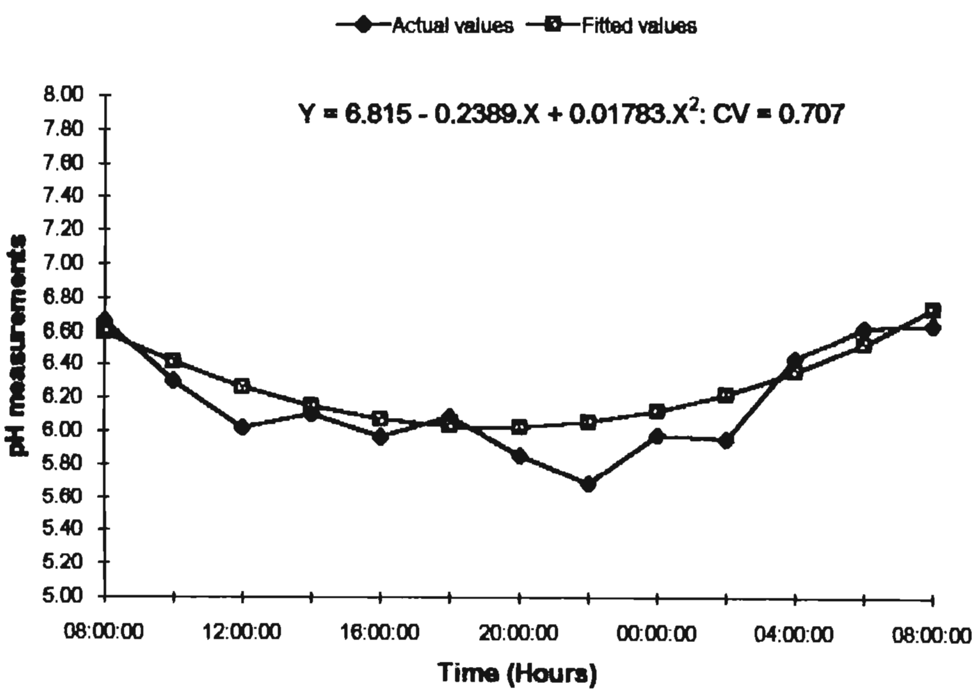

Figure 9: pH measurements - Ration SF10. Average over four periods. Each block represents four collection points

Chapter 5

Discussion and conclusion

Beefmaster's whole feedlot operation uses hominy chop as the principle energy source for their feedlot rations. Their main interest in this trial was to determine if hominy chop could be substituted 100% by maize or vice versa in their feedlot rations, and if so how would the performance of the animals be influenced.

Hominy chop compared to maize is an attractive feed for the feedlot operator for the following reasons: It has a similar ME value as that of maize. High NDF values result in high digestible fibre and low NSC levels. This theoretically reduces the incidence of lactic acidosis and possibly making it safer to feed in large quantities than maize. Hominy chop is a by product of the maize industry and can at times be approximately 10-15% cheaper than maize.

A major drawback using hominy chop is that it is a variable product. Regular analyses should be carried out to quantify the nutrient specifications. Due to the high fat and possible high moisture content, rapid rancidification can occur. This makes hominy chop a problematical raw material to store in large quantities over a long period of time. Not much information is available on hominy chop, specifically for South African conditions and more research could be focused on this issue.

With all the problems endured during the trial, substituting maize with a good quality hominy chop (with a similar nutrient profile compared to maize) and vice versa in feedlot rations should result in similar growth performances and feed intakes for similar types of feedlot animals. With hominy chop still being cheaper than maize, a change from a hominy chop to a maize based ration could prove to be less cost effective with the possible increase digestive disturbances.

Animals are variable and no two animals behave similarly. Using Kalan gates for feedlot research can be a useful tool if it is managed correctly. It allows one to observe differences among animals which can be measured. There is nothing wrong with the principle of feeding individual animals in a group housing environment. The problem comes in when all 80 animals commence with the actual trial after an initial 20 day adaptation period. During this adaptation period all the animals should have had to acquire the technique of opening the Kalan gates. Not all animals during this period learnt to open the gates. It can be argued that the adaptation period could have been longer, but this could have disrupted the initial group mass at the start of the actual trial. It has become clear from observing the animals, that the problem was partly due to submissive behaviour of the animals who failed to master the technique and partly due to unreliable functioning of some gates. If a gate did not open reliably every time, the animal would become confused and frustrated and give up trying. During feeding times the animals were in very close proximity with each other and animals low in the dominance hierarchy would likely be bullied. These animals would at times be reluctant to approach the Kalan gates and feed.

Feeding high energy, pelleted diets *ad libitum* in accordance with the procedures set out under the normal Phase C progeny testing, can cause more digestive upset and lower DMI values than that of a commercial feedlot. Overeating of the high energy rations (HF13 and SF13) caused the animals to get acidosis and bloat. This led the animals onto the "roller coaster" phenomenon where animals were sick and showed erratic feed intake patterns over time. The scheduled feeding program which was designed to address this problem, only solved some of the digestive disturbances experienced by the animals on the high energy rations. A great advantage of this type of feeding procedure is that there is always fresh feed available which stimulated feed intake. The grinding and pelleting of lucerne in the high energy rations had a marked effect on its physical properties which caused reduced rumen motility and the persistence of digestive upsets. This had a negative impact on animal production.

Predicting DMI as a percentage of body mass or as a regression equation proved to be a task on its own. Using Kalan gates should have simplified the formulation, as individual intakes could be determined and therefore limiting group variation. Due to the stumbling blocks encountered during the run of the main feeding trial as indicated in Chapter two, this was not the case. Physiological, environmental and dietary factors should have been considered in obtaining a good equation. In the regression equations, only live mass as a predictor of DMI was considered. The digestive upsets, physical form of the high energy rations and scoop size used in the low energy rations are but a few of the factors that influenced the accuracy of these equations. The equations derived from the available data do not reflect an accurate DMI equation.

The fistulas throughout the pH trials caused a lot of unnecessary troubles. The design was largely to blame, as the fistulas protruded 3-4 cm out from the side of the animal. A pity that the technique and design still had to be perfected. There has been some concern regarding the methodology of pH measurements. During the planning of the pH trails, the technique used seemed adequate and simple to do, even though only the top part of the rumen was sampled. Similar pH curves were obtained to that which can be found in the technical literature reviewed. It makes this technique, for its simplicity, adequate.

The method developed and used by Pienaar (1995) to measure *in vitro* gas production and to estimate the rate and extent of fermentation which reflects the rate of starch digestion is useful. Mean fermentation time (MFT)(hours) is directly related to total gas production and gas production is related to the total amount of organic matter digested *in vitro*. It must however only be used as an estimate because as reported, there is still a great variation in the measured rates of MFT. This can also be attributed to the variation in hominy chop and due to the method obtaining MFT, which to date, is not running as efficiently as it should (Pienaar, 1995). From the trial results however it shows that maize had a higher rate of fermentation than that of hominy chop.

Looking back on the feeding trail, using Kalan gates and the main purpose of the trial which was to determine the general performance of cattle fed rations which differ in a base raw material on an individual basis was very difficult, problematic and time consuming. A pen-fed trial, where a group of animals fed ration X are compared to a group of animals fed ration Y, would have been adequate. To determine DMI equations is a science on its own and should never have been included (even as a spin off with the available data collected) in this project. There are too many factors/variables affecting DMI which were not measured or taken into account. This resulted in poor equations that are not of much value to Beefmaster or for modelling purposes. The Kalan gates should be used for specific feedlot research where individual performance of a few animals is required, and where more time can be spent in paying attention to detail and technique rather than to a global picture as in the case of this trial.

Chapter 6

Summary

A total of 95 medium frame cross bred steers were used in a feeding trial, divided into 6 groups to establish the following objectives: 1) Establish whether the differing digestibility characteristics of maize grain and hominy chop affects the growth rate and performance of feedlot cattle. 2) To obtain an estimate of the feeding value, especially metabolizable energy of hominy chop. 3) Derive an equation to describe dry matter intake (DMI) for the conditions of the trial and 4) Determine ruminal pH and fermentation rates differences; if any between maize and hominy based diets

Groups 1-4, each of 20 animals with mean mass of 202kg were fed individually to determine the overall effect of maize or hominy chop in feedlot cattle. Four rations were used: Ration 1 (HF13): 13 MJ ME/kg DM with maize meal (60% maize, rapidly fermented carbohydrates) as the principal energy source. Ration 2 (SF13): 13 MJ ME/kg DM with ingredients with slowly fermented carbohydrates as the principal energy sources (55% hominy chop and 10% sorghum). Ration 3: (HF10): 10 MJ ME/kg DM made up of 31.5% maize. Ration 4: (SF10): 10 MJ ME/kg DM made up of 27% hominy chop.

In an attempt to derive an equation in which live mass (independent variable) can be used to predict DMI (dependent variable), various multiple regression analyses using linear and quadratic models were done for the three periods (0-33, 36-68, 71-99 days) and the whole trial (0-99 days). Dry matter intake (DMI) as a percentage of body mass was also calculated for the three periods and the whole trial.

Mass gain, DMI/day, ADG (average daily gain) and FCR (feed conversion ratio) were calculated and investigated. Steers in

these groups were slaughtered after a 99 day feeding period. Grading was done in accordance with "Regulations regarding the classification and marketing of meat", (Agricultural Product Standards Act, 1990: Act no 119 of 1990) for overall fat, grade, conformation score, age and bruising. Warm and cold mass, slaughter %, Fat C+D, eye muscle length and breadth of each steer was measured. Group 5, consisting of 11 animals, mean group mass of 202 kg were used for initial slaughter. Same carcass characteristics were investigated as for groups 1-4. Group 6, consisting of 4 animals with mean mass of 160 kg were used for the digestibility and pH trials. Three digestibility trials per treatment, four ruminal pH measurements over a 24 hour period were determined from these animals in metabolic crates. The animals were fed twice per day (08h00 and 17h00) in a cross over design on one of the four test rations. *In vitro* gas production for each of the rations was done to estimate the rate and extent of fermentation.

An increase in the % DMI as a percentage of live mass did occur over the three periods as was expected as the animals were still growing. A simple relationship between live mass and DMI did not really exist as there was a great variation in DMI per day especially for the animals on the high energy ration. The peaks and troughs regarding DMI clearly illustrated the roller coaster effect. Various multiple regression analyses using linear and quadratic models were used to describe and predict feed intake over the three and whole feeding period for both the high and low energy rations. The equations obtained with regards to the high energy rations were especially good during the last period of the trial. This can only be attributed to the scheduled feeding program, unpelleted high energy ration and the addition of stalky hay. In general, not enough information/data was collected, too many digestive upsets and other management factors hampered the feed intake patterns to formulate a good DMI equation or a suitable DMI percentage with regards to live mass.

No significant differences ($p < 0.05$) were recorded between the two high and low energy rations in mass gain, DMI/day, ADG and FCR for the 99 day trial period. Slaughter % was only significant ($p < 0.05$) in the high energy rations, in favour of SF13 (55.89% vs 54.60%). Eye muscle length in favour of HF10 (12.53cm vs 11.70cm) was significant between the two low energy rations. Between the high energy rations digestible NFE was significantly ($p < 0.05$) higher for SF13 whereas digestible NSC was significantly ($p < 0.05$) higher for HF13. This reiterates the point that hominy chop contains more digestible NFE and maize more NSC as their energy source.

Ruminal pH fluctuations were the greatest for the high energy rations. HF13 had a significantly lower ($p < 0.05$) ruminal pH over a 24 hour period than SF13. A small difference was also noted in the low energy rations. Mean fermentation time (MFT)(hours) which is directly related to total gas production was found to be highly significant ($p < 0.001$) in the high energy rations in favour of HF13 (HF13=10.83hrs vs SF13=14.38hrs). The same was found in the low energy rations (HF10=9.16hrs vs SF10=10.60hrs; $p < 0.05$)

Chapter 7

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Appendix A

Following is the information for the three spreadsheets used to calculate and graph individual performance of animals illustrating the relationship between feed intake and live mass gain.

Weighing back of feed

Information required from the user was 1) mass of bags weighed back of each animal and 2) the mass of feed (in bags) before being fed to each animal. This information is entered in the unprotected areas on the spreadsheet called *FEED.WQ1*.

Mass of animals

All this data collected was entered on a spreadsheet called *Mass.WQ1*.

Individual performance of each animal

To run this program, firstly load the spreadsheet *Mass_cal.WQ!* on Quattro pro (Version 4). Once loaded select "Load Supporting". This will then load the other two spreadsheets, namely *Feed.WQ1* and *Mass.WQ1*. Data is only entered in the first two mentioned spreadsheets. The calculation and graphs on *Mass_cal.WQ!* is automatically updated.

Appendix B - Feed Sheet

Feed allocation system used for scheduled feeding

MAX FEED IN	6	7	8	9	10	11	12	13	14	15
7:30	2	2	2	3	3	3	3	3	4	4
9:30	1	2	2	2	2	2	2	3	2	3
12:30	1	1	1	1	1	2	2	2	3	3
16:00	1	1	1	2	2	2	3	3	3	3
21:00	2	2	2	2	3	3	3	3	4	4

ANIMAL NO		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
	MAX FEED IN															
DATE	7:30															
	9:30															
	12:30															
	16:00															
	21:00															
	TOTAL															
	MAX FEED IN															
DATE	7:30															
	9:30															
	12:30															
	16:00															
	21:00															
	TOTAL															
	MAX FEED IN															

Appendix C - Mass of individual animals (kg) fed Ration HF13

Days on Feed	Animal No: S95	A2	A3	A4	S96	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	S94	A19	A20
1	274	262	247	205	228	238	217	194	199	223	204	201	187	169	178	188	142	167
5	277	267	252	208	234	242	223	203	200	233	219	200	198	177	190	191	143	167
8	285	278	253	216	240	245	225	201	204	236	215	206	191	175	192	193	150	169
13	296	288	257	225	242	252	234	207	213	246	224	210	193	177	191	207	153	172
15	297	300	274	231	249	259	240	212	223	248	221	221	201	176	199	206	162	178
19	297	310	273	243	252	270	246	202	232	256	233	225	200	180	198	203	173	185
22	299	311	279	243	256	268	252	212	244	263	217	236	208	186	198	211	177	197
26	302	313	280	249	260	269	258	208	244	265	227	229	220	186	201	214	181	199
29	307	309	281	259	259	276	272	212	247	278	236	228	217	189	198	213	183	202
33	306	321	285	265	260	279	280	216	247	284	243	232	221	192	204	222	186	208
36	305	323	296	274	261	282	286	216	254	289	250	237	228	192	213	217	193	211
40	294	338	305	287	265	282	286	229	266	307	259	242	241	193	225	223	198	221
43	305	344	312	289	277	285	299	240	274	306	286	250	245	201	216	226	206	217
47	301	350	312	301	266	292	300	226	273	305	267	258	243	203	216	225	208	221
50	293	349	320	303	254	286	302	231	272	304	271	254	249	205	219	231	215	222
54	306	357	321	306	260	291	311	239	276	317	275	254	250	205	232	233	215	222
57	304	361	323	310	265	294	318	240	278	322	280	254	259	204	235	235	218	221
61	306	365	328	318	261	305	312	240	281	331	277	263	269	206	239	233	222	224
64	309	370	337	321	267	309	330	266	293	336	296	265	262	218	250	238	234	230
68	322	378	347	331	272	312	337	257	308	351	297	282	293	226	256	243	237	232
71	316	384	341	332	262	316	336	266	300	346	300	277	284	228	252	248	236	239
75	318	397	336	324	259	331	343	250	301	366	317	282	284	238	257	256	247	248
78	319	395	344	332	265	334	349	259	310	376	325	290	295	242	268	262	250	253
82	332	407	366	344	274	337	362	256	323	375	336	297	305	259	276	269	262	264
85	332	419	360	342	270	346	377	256	328	389	334	302	312	262	279	273	269	264
89	338	427	366	355	268	352	373	265	347	399	342	311	324	268	291	281	262	271
92	343	434	380	369	269	356	382	269	358	406	359	320	342	275	299	278	274	281
96	366	436	389	372	264	360	397	279	359	410	372	345	349	284	312	289	274	289
99	362	454	391	375	253	372	406	274	365	416	377	347	351	285	314	294	279	296

Appendix D - Mass of individual animals (kg) fed Ration SF13

Days on Feed	Animal No: B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B32	B34	B35	B36	B37	B38
1	235	240	237	233	230	218	210	213	196	221	222	199	192	180	186	189
5	245	249	242	239	220	233	219	228	199	228	226	206	193	175	189	197
8	251	258	246	247	228	231	229	233	194	231	236	231	203	178	194	207
13	268	262	257	256	233	246	238	242	196	241	231	218	207	187	196	208
15	274	268	264	258	233	243	237	242	200	236	235	222	216	198	204	217
19	277	271	268	266	248	252	243	257	205	246	244	221	216	207	210	226
22	287	276	271	270	257	260	249	265	205	256	254	224	222	212	202	230
26	289	289	273	274	261	259	256	251	217	258	258	224	224	216	201	232
29	300	293	278	279	269	260	264	241	209	259	244	226	232	216	201	237
33	306	292	281	283	282	265	271	242	211	268	256	227	236	216	207	242
36	312	304	289	290	292	273	278	244	224	278	254	232	241	229	209	242
40	321	313	289	294	293	283	286	246	233	287	267	226	247	233	216	243
43	334	324	306	301	310	288	292	247	246	296	273	237	252	231	223	252
47	319	323	300	304	307	297	291	253	233	283	267	246	256	230	218	251
50	328	331	302	305	314	301	293	257	237	288	270	260	266	238	223	263
54	332	330	301	303	313	294	299	263	239	292	278	248	264	243	229	262
57	338	338	304	306	311	299	303	276	243	290	286	257	264	241	229	261
61	340	339	303	310	314	300	308	277	245	294	287	259	252	245	228	269
64	351	351	306	317	329	314	320	283	258	295	292	262	271	249	235	272
68	361	360	320	325	348	325	324	297	263	303	302	274	279	264	256	288
71	351	355	310	314	336	318	331	294	262	288	301	269	276	252	249	281
75	360	357	316	327	333	322	332	303	268	295	309	276	281	263	245	299
78	365	373	320	334	338	335	344	314	278	304	320	278	286	261	251	293
82	378	382	332	348	352	345	356	328	295	319	326	293	295	273	259	302
85	384	385	331	361	356	350	357	328	304	333	329	290	295	274	258	305
89	384	395	341	355	364	363	360	324	308	337	342	304	307	286	259	318
92	382	397	342	357	366	367	365	330	322	347	349	312	320	294	266	335
96	389	410	346	360	360	367	374	346	321	344	357	322	322	299	270	344
99	392	416	340	366	377	372	374	348	327	336	357	329	321	296	269	341

Appendix E - Mass of individual animals (kg) fed Ration HF10

Days on Feed	Animal No: C41	C42	C43	C44	C45	C46	C47	C48	C49	S93	C51	C52	C53	C54	C55	C57	C60
1	243	236	272	264	247	229	212	227	198	223	209	192	204	210	197	186	170
5	254	256	278	260	268	242	217	237	209	228	223	194	208	216	191	193	177
8	260	262	293	266	267	249	230	240	220	233	225	199	215	218	209	197	189
13	271	271	299	271	268	264	226	244	229	238	229	203	221	223	208	202	190
15	274	271	305	273	262	256	231	251	237	243	239	209	224	233	220	201	203
19	289	286	316	288	272	267	235	261	237	261	240	208	227	231	221	208	209
22	287	287	319	286	273	273	233	267	249	267	250	198	226	241	219	211	219
26	294	293	327	262	287	279	219	267	217	258	262	201	226	249	215	211	218
29	302	299	336	266	293	287	220	277	231	265	259	190	211	256	203	224	227
33	307	307	344	288	291	296	230	283	248	273	265	212	237	259	214	212	229
36	318	319	345	283	300	308	243	289	261	281	269	216	240	268	223	220	235
40	319	316	349	289	308	300	253	293	260	279	279	227	248	272	228	220	241
43	336	332	358	284	316	301	260	294	269	283	284	221	257	280	230	232	251
47	341	339	371	305	327	319	268	308	284	292	285	233	268	290	240	213	261
50	351	350	374	305	325	325	272	310	289	293	298	234	276	300	247	231	251
54	349	364	383	314	336	332	278	316	300	302	307	236	282	303	250	240	261
57	357	361	391	323	345	338	286	323	302	305	304	239	286	304	253	217	266
61	354	360	385	322	332	336	283	320	291	300	313	234	289	316	256	230	268
64	369	373	398	329	353	364	294	329	307	314	319	237	297	322	269	243	278
68	380	391	406	338	347	344	304	338	312	321	329	253	308	334	279	261	290
71	384	395	402	343	360	359	305	336	322	319	328	261	319	334	289	270	297
75	383	400	411	350	362	366	313	336	335	327	330	264	318	341	290	267	298
78	395	400	413	360	370	362	326	345	339	332	343	260	329	347	297	276	304
82	400	417	415	365	377	366	330	349	334	334	348	270	322	356	301	283	316
85	400	423	418	369	378	368	332	353	344	338	320	349	329	356	305	287	273
89	416	427	428	377	386	384	336	360	340	337	358	284	348	360	315	297	324
92	420	434	421	384	393	383	351	366	360	347	360	300	353	370	322	312	330
96	428	432	440	376	401	393	348	368	367	349	374	308	367	376	325	317	338
99	427	440	442	383	392	388	352	371	370	364	374	300	364	373	333	325	341

Appendix F - Mass of individual animals (kg) fed Ration SF10

Days on Feed	Animal No: D61	D62	D63	D64	D65	D66	D67	D68	D69	D70	D71	D76	D79	D80
1	243	266	260	256	222	213	226	247	167	214	183	181	207	176
5	251	280	263	264	223	216	229	251	169	209	188	184	212	181
8	252	289	271	268	232	219	240	257	178	226	197	191	219	186
13	264	301	280	273	242	219	248	269	179	213	204	196	219	186
15	257	302	280	283	245	232	250	276	191	237	216	204	220	196
19	271	302	294	284	263	232	259	283	205	236	218	201	224	204
22	278	318	300	295	264	234	264	292	204	248	222	209	240	207
26	269	322	307	301	265	236	269	286	196	250	210	215	236	211
29	267	332	314	308	251	227	276	280	201	237	225	217	242	213
33	276	338	321	310	263	237	286	281	197	247	225	219	252	212
36	280	335	327	312	257	247	288	295	206	260	227	225	254	218
40	282	340	337	320	257	242	294	298	207	264	227	231	225	222
43	293	369	341	330	257	261	298	300	218	264	234	232	256	226
47	306	364	364	337	265	267	314	310	235	256	229	244	256	233
50	308	366	368	341	280	270	316	325	234	282	247	252	273	236
54	318	374	356	349	274	275	325	332	241	294	248	251	277	234
57	321	366	334	351	270	278	328	331	243	292	248	259	273	245
61	320	377	326	356	262	277	323	322	243	299	257	257	259	244
64	320	384	333	363	266	280	331	318	260	301	262	270	275	251
68	325	392	347	367	291	294	333	345	271	310	278	277	272	255
71	319	398	335	374	298	307	345	344	277	323	288	278	287	260
75	327	400	363	374	300	305	352	346	284	325	295	287	298	264
78	339	401	375	383	303	314	353	355	291	331	300	290	306	267
82	348	418	366	386	316	317	360	362	301	335	304	293	308	271
85	346	407	375	385	315	317	362	365	304	336	310	295	308	275
89	365	422	376	395	314	333	375	360	300	343	314	305	326	285
92	355	425	386	399	317	332	381	373	321	347	318	319	333	292
96	364	437	399	409	334	337	378	378	323	365	332	319	334	294
99	364	435	396	410	331	346	386	384	334	356	335	320	334	291

Appendix G - Total feed intake (kg) of individual animals feed fed Ration HF13

Days on	Animal No:	Total feed intake (kg) over a three or four day feeding period																
Feed	S95	A2	A3	A4	S96	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	S94	A19	A20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	8	26.5	17	12.5	21.5	25	13	22	16	23	12.5	0	14	0	6	6	8	28
8	14	24.5	22	6.5	8.5	15	18	22	7	21	5.5	10	4	4	7	25.5	12	10
13	28	59	16	19	17.5	31.5	30	2	1	48	8	24	3	9	5	18.5	12	15.5
16	8	15.5	9	10	3.5	14.5	12.5	12	6.5	16	9	11	10.5	3	6.5	6.5	9	3
19	31	42.5	23	31	16	33	33.5	22	28.5	37	0	25	5.5	9	10.5	22.5	32	34
22	9	18	17	19	12	19	18	10	12	22	0	19	10	4	7	11	13	18
26	25	38	19	33	18	36	35	24	25	27	3	21	13	24	7	25	2	24
29	29	19	14	21	0	20	27	9	12	21	1	13	6	4	7	15	6	15
33	0	44	18	33	11	31	62	17	25	38	6	28	8	12	2	24	39	20
36	16	28	19	24	3	21	22	12.5	20	23	15	16	10	40	0	0	18	13
40	18	44	27	39	4	35	34	32.5	47	29	27	22	37	39	3	20	24	28
43	1	37	11	18	5	24	14	9	3	30	11	10	18	29	2	6	14	3
47	10	36	11	16	7	16	15	5	3	21	3	11	11	15	2	13	16	15
50	24	22	20	23	9	24	23	10	8	22	9	19	16	28	8	13	16	25
54	25	28	30	33	10	27	32	13	13	26	7	17	33	30	14	19	23	30
57	20	21	19	27	8	25	15	15	6	29	12	15	28	23	14	12	24	32
61	22	42	24	29	5	48	23	17	21	41	11	29	34	34	14	16	24	21
64	8	18	23	18	2	27	20	18	20	25	9	18	25	26	17	17	16	19
68	14	28	19	21	11	17	25	14	20	29	16	22	14	28	20	25	16	16
71	14	21	16	17	7	18	16	11	12	19	13	13	10	15	11	15	12	14
75	24	34	30	23	11	34	34	21	26	34	26	27	31	29	25	22	31	28
78	12	29	13	15	10	24	27	14	19	28	19	20	31	29	20	17	20	18
82	23	41	29	24	32	18	37	17	28	29	29	27	23	32	29	26	31	31
85	17	45	17	19	28	33	21	15	30	29	24	18	30	40	40	19	20	34
89	34	37	16	30	33	34	25	33	38	34	17	41	42	38	42	21	46	28
92	22	33	29	32	9	36	27	24	28	21	32	37	25	47	33	22	31	25
96	14	37	34	40	20	43	42	28	45	45	31	34	43	50	40	43	49	22
99	21	40	22	29	7	50	10	21	20	36	16	28	29	30	55	11	37	38

Appendix H - Total feed intake (kg) of individual animals feed fed Ration SF13

Days on Feed	Animal No: B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B32	B34	B35	B36	B37	B38
	Total feed intake (kg) over a three or four day feeding period															
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	6	22	24.5	19.5	9	22.5	14	25	5	29	26	3	8.5	5	13	17
8	0	22.5	19.5	20.5	2	14.5	22.5	37	5	28	18	12	23	5	5	22
13	3	16.5	34	39	21	29	38.5	66	8	14	24.5	21	61.5	9	7	33
15	1	23	6	11	7	9	9	25	5	27.5	12.5	7	12	11	12.5	17
19	3	43	32	38	32	35	36	39	49	36.5	31	17	27	22	22.5	28
22	5	26	18	20	15	13	20	27	18	31	18	14	18	17	5	17
26	5	48	26	26	42	24	35	3	37	31	25	19	23	31	16	39
29	0	35	18	19	30	19	22	0	26	25	16	9	10	18	8	8
33	32	30	28	33	36	27	36	6	14	37	27	19	26	28	16	29
36	22	19	22	22	28	18	20	4	12	28	19	11	18	20	20	22
40	34	32	29	28	32	26	30	5	22	39	28	11	33	24	21.5	24
43	6	20	19	20	21	14	23	0	14	13	24	24	21	15	12.5	16
47	4	14	21	20	15	19	13	15	7	18	18	11	19	15	8	16
50	13	23	14	19	14	21	25	19	11	21	20	14	23	24	20	22
54	24	28	30	19	29	17	30	25	16	26	23	12	21	20	22	22
57	17	22	17	18	19	25	24	20	13	21	25	11	21	15	10	18
61	23	24	15	29	27	25	29	34	15	19	29	25	13	25	19	28
64	26	13	24	22	28	17	23	28	11	22	26	13	16	9	22	17
68	17	20	16	19	12	20	25	17	22	14	24	12	24	24	5	20
71	16	11	13	16	12	10	17	17	11	12	15	10	11	11	10	11
75	25	28	18	28	29	32	26	31	29	11	31	25	28	32	20	31
78	19	19	25	23	15	19	25	17	33	11	30	12	20	18	14	17
82	34	27	29	38	27	33	44	36	37	26	34	24	31	20	19	26
85	28	22	30	13	26	17	29	35	41	31	37	21	22	22	17	20
89	27	31	35	33	29	19	30	48	36	26	26	28	41	23	20	37
92	11	27	42	26	22	20	26	40	35	28	26	24	35	30	17	37
96	35	35	48	29	34	28	40	37	40	29	38	36	36	39	24	39
99	10	35	36	40	36	32	31	14	20	31	48	26	23	15	23	25

Appendix I - Total feed intake (kg) of individual animals feed fed Ration HF10

Days on Feed	Animal No: C41	C42	C43	C44	C45	C46	C47	C48	C49	S93	C51	C52	C53	C54	C55	C57	C60
	Total feed intake (kg) over a three or four day feeding period																
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	25	38.5	42	34	19.5	19	4	27.5	15	30.5	19.5	30	3.5	22	22.5	18	19.5
8	38	41.5	28.5	38.5	12	16	1	24	18	21	26.5	23	10.5	36	20.5	20.5	5
13	49.5	28	37	44.5	43	29	4	39	20	37.5	16	32	44	38	24	31.5	11
15	14	7	18.5	20	10	11.5	14.5	16.5	2	17	14	13	19.5	16.5	2	19.5	8.5
19	27	23	31	23	34	17	4.5	12	27	19	28	0	25	1	15	41	25
22	26	27	31	1	49	42	34	28	16	22	22	2	22	25	0	16	23
26	30	14	22	5	10	52	30	34	26	43	33	12	9	38	11	30	36
29	46	12	40	3	5	28	2	24	9	15	21	3	6	23	4	23	20
33	39	26	44	4	17	41	1	30	21	36	17	9	8	46	8	45	18
36	22	40	34	9	26	40	19	28	26	30	26	16	10	1	7	10	23
40	22	41	38	33	49	16	30	52	63	47	44	20	14	47	34	25	60
43	24	27	34	11	28	7	19	33	47	26	26	12	7	21	16	16	50
47	34	37	36	15	38	18	14	36	69	21	26	14	9	20	20	11	66
50	24	29	15	14	27	23	24	26	37	30	29	27	7	31	12	7	20
54	29	32	35	26	30	21	17	24	25	22	25	23	22	44	12	26	28
57	18	34	36	21	48	15	24	10	32	28	21	32	33	44	18	8	24
61	22	38	50	22	40	21	14	21	26	23	20	8	39	40	5	13	12
64	27	22	52	22	31	29	26	7	26	40	24	23	16	37	5	17	11
68	39	22	18	20	43	32	23	52	35	20	35	27	21	37	22	26	28
71	24	48	34	39	26	28	28	36	32	38	8	43	37	21	28	23	28
75	37	29	23	47	34	34	36	37	16	34	33	18	41	37	36	34	21
78	26	29	44	34	36	31	31	27	38	30	47	16	40	33	33	33	26
82	46	52	46	30	30	45	40	39	38	41	42	27	31	44	37	38	12
85	28	36	25	30	28	43	31	25	30	12	27	20	34	35	33	20	25
89	43	48	35	36	44	49	40	34	36	32	39	30	49	33	21	28	43
92	36	47	24	25	41	35	38	35	25	38	24	38	33	42	28	40	30
96	40	52	46	30	55	32	33	40	37	34	43	37	28	56	24	50	26
99	43	38	35	38	36	39	38	31	29	33	33	28	28	30	23	26	24

Appendix J - Total feed intake (kg) of individual animals feed fed Ration SF10

Days on Feed	Animal No: D61	D62	D63	D64	D65	D66	D67	D68	D69	D70	D71	D76	D79	D80
	Total feed intake (kg) over a three or four day feeding period													
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	3	35	11	27.5	13	12	14	7	2	12.5	8	19.5	29.5	19.5
8	25	24	24.5	24	6	12.5	27	26.5	19	10.5	18	14	19	20.5
13	15	46	42	15	13	21	41	43.5	38.5	17.5	34.5	4.5	35.5	33.5
15	11	26	22.5	18	9	16.5	17.5	21	16.5	16.5	8.5	13.5	5.5	11.5
19	15	37	51	32	3	18	15	31	47	12	35	24	16.5	15
22	23	34	47	5	28	11	27	22	9.5	6	23	33	11	39
26	27	62	43	23	16	15	39	12	63	12	33	34	9	20
29	20	28	32	23	5	15	25	7	13	8	10	15	14	19
33	23	29	44	35	15	14	21	7	15	13	20	44	25	5
36	10	13	32	27	10	14	28	12	1	12	14	34	1	23
40	23	35	49	45	22	13	41	22	35	15	21	42	12	58
43	13	22	31	25	17	20	9	13	17	13	5	11	0	23
47	28	28	44	17	12	2	18	11	36	9	9	16	19	18
50	26	47	32	12	20	10	35	18	16	35	20	26	28	20
54	38	49	32	22	13	6	17	15	38	21	26	32	20	36
57	44	39	26	12	8	6	15	25	31	21	19	21	25	27
61	22	48	23	34	5	3	33	5	10	9	14	17	6	17
64	27	38	16	36	17	13	34	26	23	15	27	32	34	29
68	10	47	34	16	19	22	35	44	51	20	5	45	7	36
71	37	54	31	47	43	7	12	25	27	34	42	24	28	22
75	34	49	16	38	22	24	35	22	49	17	34	43	36	25
78	33	37	25	35	47	15	28	11	37	45	26	28	20	34
82	43	51	34	30	31	26	40	27	38	32	10	27	43	33
85	32	43	30	31	19	9	41	29	34	15	22	26	26	32
89	57	45	43	38	43	35	35	25	41	16	32	34	36	27
92	34	42	41	32	43	36	27	28	45	38	25	19	33	34
96	34	42	42	36	35	34	34	36	52	38	30	40	45	34
99	25	39	25	31	22	33	36	36	34	26	25	26	40	31

Digestibility trial number 1 : Appendix K1

Feed type:	HF13			
Animal no:	598			
Starting Mass:	211.00			
End Mass:	214.00			
Avg feed intake (kg):	5.33		Avg DM intake (kg):	4.87
Avg faeces collected (kg):	4.40		Avg faecal DM excreated (kg):	1.19
Avg urine collected (kg):	6.30			

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	8.55	91.45	14.12	7.81	10.44	15.56	0.98	0.30	5.67	17.56	48.29	85.78
Feed "Dry matter" basis :		100.00	15.44	8.54	11.42	17.01	1.05	0.33	6.20	19.20	52.80	93.80
Faeces "as is" basis:	72.85	27.15	3.98	0.49	9.14	12.60	0.63	0.11	2.74	5.53	7.34	24.41
Faeces "Dry matter" basis :		100.00	14.65	1.80	33.68	46.40	2.33	0.40	10.10	20.37	27.05	89.90
Urine (DM basis):			3.93							0.70		

Calculations

Average DMI 4.87

Average DM feaces excreated 1.19

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	4874.29	752.60	416.27	556.45	829.35	51.17	15.99	302.21	93.59	2573.86	4572.07
Excreated (g)	1194.60	298.80	21.50	402.10	554.29	27.83	4.78	120.65	24.33	323.14	1073.95
Digested (g)	3679.69	453.79	394.77	154.35	275.05	23.33	11.21	181.56	69.26	2250.72	3498.13
Digestability coefficients (%)											
	75.49	60.30	94.83	27.74	33.17	45.60	70.12	60.08	74.00	87.45	76.51
Digestible nutrients (% or MJ/kg)											
		9.31	8.10	3.17	5.64	0.48	0.23	3.72	14.21	46.18	71.77

Calculated Digestible Energy (MJ/kg DM): 14.21

Estimated energy loss from methane (MJ/day): 5.62

Energy loss from Urine (MJ/day): 4.43

Calculated Metabolizable Energy (MJ/kg DM): 12.15

Digestibility trial number 2 : Appendix K2

Feed type:	HF-13		
Animal no:	597		
Starting Mass:	223.00		
End Mass:	222.00		
Avg feed intake (kg):	4.93	Avg DM intake (kg):	4.53
Avg faeces collected (kg):	3.64	Avg faecal DM excreated (kg):	1.16
Avg urine collected (l):	8.30		

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	8.10	91.90	15.78	8.69	10.32	14.30	1.04	0.34	6.50	17.53	46.63	85.40
Feed "Dry matter" basis :		100.00	17.17	9.46	11.23	15.56	1.13	0.37	7.07	19.08	50.74	92.93
Faeces "as is" basis:	68.21	31.79	3.64	0.66	9.37	13.44	0.56	0.11	2.43	5.51	8.17	29.36
Faeces "Dry matter" basis :		100.00	13.42	2.42	34.51	49.49	2.12	0.40	8.96	20.26	25.71	92.35
Urine (DM basis):			2.27							0.49		

Calculations

Average DMI 4.53

Average DM feaces excreated 1.16

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	4530.67	777.95	426.42	508.78	704.99	51.27	16.76	320.45	86.42	2298.86	4210.22
Excreated (g)	1157.16	155.29	26.00	399.33	572.68	24.53	4.63	103.68	23.47	297.50	1068.61
Digested (g)	3373.51	622.66	400.41	109.44	132.31	26.74	12.13	216.77	62.96	2001.35	3141.61
Digestability coefficients (%)											
	74.46	80.04	93.46	21.51	18.77	52.15	72.39	67.65	72.85	87.06	74.62
Digestible nutrients (% or MJ/kg)											
		13.74	8.84	2.42	2.92	0.59	0.27	4.78	13.90	44.17	69.34

Calculated Digestible Energy (MJ/kg DM): 13.90

Estimated energy loss from methane (MJ/day): 5.19

Energy loss from Urine (MJ/day): 4.07

Calculated Metabolizable Energy (MJ/kg DM): 11.65

Digestibility trial number 3 : Appendix K3

Feed type:	HF13
Animal no:	5100
Starting Mass:	250.00
End Mass:	Slaugther
Avg feed intake (kg):	4.14
Avg faeces collected (kg):	2.29
Avg urine collected (l):	0.00

Avg DM intake (kg): 3.89

Avg faecal DM excreated (kg): 0.66

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	6.00	94.00	11.16	7.27	11.64	16.94	1.30	0.31	6.46	17.69	52.17	87.54
Feed "Dry matter" basis :		100.00	11.87	7.73	12.38	18.02	1.38	0.33	6.87	18.82	55.50	93.13
Faeces "as is" basis:	71.16	28.84	4.60	0.76	8.22	10.25	1.05	0.19	4.86	5.34	6.66	23.98
Faeces "Dry matter" basis :		100.00	17.68	2.89	30.26	37.76	3.87	0.69	17.89	19.66	23.78	83.16

Urine (DM basis): No collection done.

Calculations

Average DMI 3.89

Average DM feaces excreated 0.66

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	3891.60	462.02	300.98	481.90	701.32	53.62	12.85	267.44	73.24	2159.64	3624.16
Excreated (g)	660.44	116.77	19.09	199.85	249.38	25.56	4.56	118.15	12.98	157.05	549.21
Digested (g)	3231.16	345.26	281.89	282.05	451.94	28.26	8.28	149.29	60.25	2002.79	3074.95

Digestability coefficients (%)

83.03	74.73	93.66	58.53	64.44	52.51	64.49	55.82	82.27	92.73	84.85

Digestible nutrients (% or MJ/kg)

8.87	7.24	7.25	11.61	0.73	0.21	3.84	15.48	51.46	79.02

Calculated Digestible Energy (MJ/kg DM): 15.48

Estimated energy loss from methane (MJ/day): 4.39

Summary of digestibility trials HF13: Appendix K4

Feed analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	15.44	6.54	11.42	17.01	1.05	0.33	6.20	19.20	52.80	93.80
Digest 2	17.17	9.46	11.23	15.56	1.13	0.37	7.07	19.08	50.74	92.93
Digest 3	11.87	7.73	12.38	18.02	1.36	0.33	6.87	18.82	55.50	93.13
Average	14.83	6.58	11.68	16.87	1.19	0.34	6.72	19.03	53.01	93.28
STD	2.21	0.70	0.51	1.01	0.14	0.02	0.37	0.16	1.95	0.37

Urine analysis (DM basis)

	Crude Protein (%)	Gross Energy (MJ/day)
Digest 1	3.93	4.43
Digest 2	2.27	4.07
Average	3.10	4.25
STD	0.83	0.18

Methane analysis

	Estimated energy lost via methane (MJ/day)
Digest 1	5.62
Digest 2	5.19
Digest 3	4.39
Average	5.07
STD	0.51

Faeces analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	14.65	1.80	33.66	46.40	2.33	0.40	10.10	20.37	27.05	89.90
Digest 2	13.42	2.42	34.51	49.49	2.12	0.40	8.98	20.28	25.71	92.35
Digest 3	17.68	2.69	30.26	37.76	3.87	0.69	17.89	19.66	23.78	83.16
Average	15.25	2.37	32.81	44.55	2.77	0.50	12.32	20.10	25.51	88.47
STD	1.79	0.45	1.84	4.96	0.78	0.14	3.97	0.32	1.34	3.89

Digestible nutrients

	Intake (kg)	Faeces (kg)	Urine (l)	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Digestible Energy (MJ/kg DM)	NSC (%)	Organic Matter (%)	Energy Faeces (MJ/day)	Energy Methane (MJ/day)	Energy Urine (MJ/day)	Calc ME (MJ/kg DM)
Digest 1	4.87	1.19	6.30	9.31	8.10	3.17	5.64	0.48	0.23	3.72	14.21	46.18	71.77	24.33	5.62	4.43	12.15
Digest 2	4.53	1.16	8.30	13.74	8.84	2.42	2.92	0.59	0.27	4.78	13.90	44.17	69.34	23.47	5.19	4.07	11.85
Digest 3	3.89	0.66		8.87	7.24	7.25	11.81	0.73	0.21	3.64	15.48	51.46	79.02	12.98	4.39		
Average	4.43	1.00	7.30	10.64	8.06	4.28	6.72	0.60	0.24	4.12	14.53	47.27	73.38	20.26	5.07	4.25	12.00
STD	0.41	0.24	1.00	2.20	0.65	2.12	3.63	0.10	0.02	0.47	0.69	3.07	4.11	5.16	0.51	0.18	0.15

Digestibility coefficients (%)

Digest 1	80.30	94.83	27.74	33.17	45.60	70.12	60.08	74.00	87.45	76.51
Digest 2	80.04	93.46	21.51	18.77	52.15	72.39	67.65	72.85	87.06	74.62
Digest 3	74.73	93.66	58.53	64.44	52.51	64.49	55.82	82.27	92.73	84.85
Average	71.69	93.99	35.93	38.79	50.09	69.00	61.16	76.37	89.08	78.66
STD	6.34	0.61	16.18	19.07	3.16	3.32	4.89	4.20	2.59	4.44

Values used to calculate ME (MJ/kg)

	DMI (kg/day)	Faeces (kg/day)	Urine (l/day)	GE in feed (MJ/kg)	GE intake (MJ/day)	GE in faeces (MJ/kg)	GE excreted (MJ/day)	GE in urine (MJ/day)	GE in methane (MJ/day)	Digestible Energy (MJ/kg DM)	Calculated ME (DM) (MJ/kg)
Digest 1	4.87	1.19	6.30	19.20	93.59	20.37	24.33	4.43	5.62	14.21	12.15
Digest 2	4.53	1.16	8.30	19.08	86.42	20.28	23.47	4.07	5.19	13.90	11.85
Average	4.70	1.18	7.30	19.14	90.01	20.33	23.90	4.25	5.41	14.05	12.00
STD	0.17	0.02	1.00	0.06	3.59	0.04	0.43	0.18	0.21	0.16	0.15

Digestibility trial number 1 : Appendix L1

Feed type:	SF-13		
Animal no:	599		
Starting Mass:	197.00		
End Mass:	192.00		
Avg feed intake (kg):	4.16	Avg DM intake (kg):	3.83
Avg faeces collected (kg):	3.15	Avg faecal DM excreated (kg):	0.84
Avg urine collected (kg):	5.46		

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	8.05	91.95	14.23	10.13	12.34	25.34	0.93	0.34	6.09	17.90	36.16	85.86
Feed "Dry matter" basis :		100.00	15.48	11.02	13.42	27.56	1.01	0.37	6.62	19.47	39.33	93.38
Faeces "as is" basis:	73.42	26.58	4.41	0.54	8.88	14.42	0.56	0.14	2.45	5.40	4.76	24.13
Faeces "Dry matter" basis :		100.00	16.58	2.05	33.41	54.25	2.10	0.53	9.21	20.32	17.91	90.79
Urine (DM basis):			3.49							0.66		

Calculations

Average DMI	3.83
Average DM feaces excreated	0.84

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	3825.12	591.97	421.41	513.34	1054.14	38.69	14.14	253.34	74.48	1504.26	3571.78
Excreated (g)	837.27	234.10	17.16	279.73	454.22	17.58	4.44	77.11	17.01	149.96	760.16
Digested (g)	2987.85	357.87	404.24	233.61	599.93	21.11	9.71	176.23	57.45	1354.30	2811.62
Digestability coefficients (%)											
	78.11	60.45	95.93	45.51	56.91	54.55	68.63	69.56	77.15	90.03	78.72
Digestible nutrients (% or MJ/kg)											
		9.36	10.57	6.11	15.68	0.55	0.25	4.61	15.02	35.41	73.50

Calculated Digestible Energy (MJ/kg DM):	15.02
Estimated energy loss from methane (MJ/day):	4.47
Energy loss from Urine (MJ/day):	3.59
Calculated Metabolizable Energy (MJ/kg DM):	12.91

Digestibility trial number 2 : Appendix L2

Feed type:	SF-13		
Animal no:	S100		
Starting Mass:	233.00		
End Mass:	235.00		
Avg feed intake (kg):	4.04	Avg DM intake (kg):	3.69
Avg faeces collected (kg):	4.25	Avg faecal DM excreated (kg):	1.33
Avg urine collected (l):	5.21		

Analysis of feed and faeces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	8.70	91.30	13.37	10.00	13.91	26.46	0.84	0.38	6.04	18.01	35.43	85.26
Feed "Dry matter" basis :		100.00	14.64	10.95	15.24	28.98	0.92	0.42	6.62	19.73	38.81	93.38
Faeces "as is" basis:	68.66	31.34	3.36	0.78	8.36	13.10	0.37	0.10	2.26	5.50	8.36	29.08
Faeces "Dry matter" basis :		100.00	12.63	2.93	31.45	49.27	1.39	0.39	8.50	20.70	26.67	92.79
Urine (DM basis):			4.31							0.67		

Calculations

Average DMI	3.69
Average DM faeces excreated	1.33

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	3688.52	540.15	404.00	561.96	1068.98	33.94	15.35	244.02	72.76	1431.37	3444.50
Excreated (g)	1331.95	168.23	39.03	418.90	656.25	18.51	5.19	113.22	27.57	355.23	1235.93
Digested (g)	2356.57	371.92	364.97	143.07	412.73	15.42	10.16	130.80	45.19	1076.14	2208.57
Digestability coefficients (%)											
	63.89	68.86	90.34	25.46	38.61	45.44	66.16	53.60	62.11	75.18	64.12
Digestible nutrients (% or MJ/kg)											
		10.08	9.89	3.88	11.19	0.42	0.28	3.55	12.25	29.18	59.88

Calculated Digestible Energy (MJ/kg DM):	12.25
Estimated energy loss from methane (MJ/day):	4.37
Energy loss from Urine (MJ/day):	3.51
Calculated Metabolizable Energy (MJ/kg DM):	10.12

Digestibility trial number 3 : Appendix L3

Feed type:	SF13		
Animal no:	598		
Starting Mass:	281.00		
End Mass:	Slaugther		
Avg feed intake (kg):	7.27	Avg DM intake (kg):	6.72
Avg faeces collected (kg):	9.63	Avg faecal DM excreated (kg):	2.47
Avg urine collected (l):			

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	7.58	92.42	13.51	10.61	13.71	25.93	1.04	0.37	6.70	18.32	35.67	85.72
Feed "Dry matter" basis :		100.00	14.62	11.48	14.83	28.06	1.13	0.40	7.25	19.82	38.60	92.75
Faeces "as is" basis:	74.31	25.69	3.47	1.13	7.22	12.52	0.71	0.19	3.63	5.40	5.63	22.06
Faeces "Dry matter" basis :		100.00	13.05	4.26	27.17	47.11	2.67	0.70	13.66	20.30	21.92	85.87
Urine (DM basis):												

Calculations

Average DMI	6.72
Average DM feaces excreated	2.47

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	6718.93	982.18	771.35	996.72	1885.11	75.61	26.90	487.09	133.19	2593.21	6231.84
Excreated (g)	2473.95	322.85	105.39	672.17	1165.48	66.05	17.32	337.94	50.22	542.29	2124.30
Digested (g)	4244.99	659.33	665.96	324.55	719.63	9.55	9.58	149.15	82.97	2050.92	4107.55
Digestability coefficients (%)	63.18	67.13	86.34	32.56	38.17	12.64	35.62	30.62	62.29	79.09	65.91
Digestible nutrients (% or MJ/kg)		9.81	9.91	4.83	10.71	0.14	0.14	2.22	12.35	30.52	61.13

Calculated Digestible Energy (MJ/kg DM): 12.35

Estimated energy loss from methane (MJ/day): 7.99

Summary of digestibility trials SF13: Appendix L4

Feed analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	15.48	11.02	13.42	27.56	1.01	0.37	6.62	19.47	39.33	93.38
Digest 2	14.64	10.95	15.24	28.98	0.92	0.42	6.62	19.73	38.81	93.38
Digest 3	14.62	11.48	14.83	28.06	1.13	0.40	7.25	19.82	38.60	92.75
Average	14.91	11.15	14.50	28.20	1.02	0.40	6.83	19.67	38.91	93.17
STD	0.40	0.23	0.78	0.59	0.08	0.02	0.30	0.15	0.31	0.30

Urine analysis (DM basis)

	Crude Protein (%)	Gross Energy (MJ/day)
Digest 1	3.49	3.59
Digest 2	4.31	3.51
Average	3.90	3.55
STD	0.41	0.04

Methane analysis

	Estimated energy lost via methane (MJ/day)
Digest 1	4.47
Digest 2	4.37
Digest 3	7.99
Average	5.61
STD	1.68

Faeces analysis (DM basis)

Digest 1	16.58	2.05	33.41	54.25	2.10	0.53	9.21	20.32	17.91	90.79
Digest 2	12.63	2.93	31.45	49.27	1.39	0.39	8.50	20.70	26.67	92.79
Digest 3	13.05	4.28	27.17	47.11	2.67	0.70	13.68	20.30	21.92	85.87
Average	14.09	3.06	30.68	50.21	2.05	0.54	10.46	20.44	22.17	89.82
STD	1.77	0.91	2.61	2.99	0.52	0.13	2.28	0.18	3.58	2.91

Digestible nutrients

	Intake (kg)	Faeces (kg)	Urine (l)	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Digestible Energy (MJ/kg DM)	NSC (%)	Organic Matter (%)	Energy Faeces (MJ/day)	Energy Methane (MJ/day)	Energy Urine (MJ/day)	Calc ME (MJ/kg DM)
Digest 1	3.83	0.84	5.46	9.36	10.57	6.11	15.68	0.55	0.25	4.61	15.02	35.41	73.50	17.01	4.47	3.59	12.91
Digest 2	3.69	1.33	5.21	10.08	9.89	3.88	11.19	0.42	0.28	3.55	12.25	29.18	59.88	27.57	4.37	3.51	10.12
Digest 3	6.72	2.47		9.81	9.91	4.83	10.71	0.14	0.14	2.22	12.35	30.52	61.13	50.22	7.99		
Average	4.74	1.55	5.34	9.75	10.12	4.94	12.53	0.37	0.22	3.46	13.21	31.70	64.84	31.60	5.61	3.55	11.52
STD	1.40	0.68	0.13	0.30	0.31	0.91	2.24	0.17	0.06	0.98	1.28	2.68	6.15	13.85	1.68	0.04	1.40

Digestibility coefficients (%)

Digest 1	60.45	95.93	45.51	58.91	54.55	68.63	69.56	77.15	90.03	78.72
Digest 2	68.86	90.34	25.46	36.61	45.44	66.16	53.60	62.11	75.18	64.12
Digest 3	67.13	86.34	32.56	38.17	12.64	35.62	30.62	62.29	79.09	65.91
Average	65.48	90.87	34.51	44.57	37.54	56.80	51.26	67.18	81.43	69.58
STD	3.62	3.93	8.30	8.73	18.00	15.01	15.98	7.05	6.28	6.50

Values used to calculate ME (MJ/kg)

	DMI (kg/day)	Faeces (kg/day)	Urine (l/day)	GE in feed (MJ/kg)	GE intake (MJ/day)	GE in faeces (MJ/kg)	GE excreted (MJ/day)	GE in urine (MJ/day)	GE in methane (MJ/day)	Digestible Energy (MJ/kg DM)	Calculated ME (DM) (MJ/kg)
Digest 1	3.83	0.84	5.46	19.47	74.46	20.32	17.07	3.59	4.47	15.02	12.90
Digest 2	3.69	1.33	5.21	19.73	72.76	20.70	27.53	3.51	4.37	12.25	10.13
Average	3.76	1.09	5.34	19.60	73.61	20.51	22.30	3.55	4.42	13.64	11.51
STD	0.07	0.25	0.13	0.13	0.85	0.19	5.23	0.04	0.05	1.38	1.39

Digestibility trial number 1 : Appendix M1

Feed type:	HF-10		
Animal no:	S100		
Starting Mass:	196.00		
End Mass:	197.00		
Avg feed intake (kg):	6.23	Avg DM intake (kg):	5.80
Avg faeces collected (kg):	8.52	Avg faecal DM excreated (kg):	1.97
Avg urine collected (kg):	5.40		

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	6.88	93.12	13.00	1.84	30.54	37.14	0.73	0.29	6.67	16.63	34.47	86.45
Feed "Dry matter" basis :		100.00	13.96	1.98	32.80	39.88	0.78	0.31	7.16	17.86	37.02	92.84
Faeces "as is" basis:	76.87	23.13	2.92	0.40	10.85	13.20	0.28	0.13	2.57	4.32	4.03	20.56
Faeces "Dry matter" basis :		100.00	12.62	1.75	46.91	57.08	1.19	0.55	11.11	18.67	17.44	88.89
Urine (DM basis):			4.27							0.69		

Calculations

Average DMI	5.60
Average DM feaces excreated	1.97

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	5801.38	809.90	114.63	1902.64	2313.82	45.48	18.07	415.54	103.60	2147.48	5385.84
Excreated (g)	1970.68	363.99	34.49	924.44	1124.86	23.45	10.84	216.94	36.79	343.69	1751.73
Digested (g)	3830.70	445.91	80.15	978.20	1188.96	22.03	7.23	196.60	66.81	1803.80	3634.10
Digestability coefficients (%)											
	66.03	55.06	69.92	51.41	51.39	48.44	40.01	47.31	64.49	84.00	67.48
Digestible nutrients (% or MJ/kg)											
		7.69	1.38	16.86	20.49	0.38	0.12	3.39	11.52	31.09	62.64

Calculated Digestible Energy (MJ/kg DM):	11.52
Estimated energy loss from methane (MJ/day):	6.22
Energy loss from Urine (MJ/day):	3.71
Calculated Metabolizable Energy (MJ/kg DM):	9.81

Digestibility trial number 2 : Appendix M2

Feed type:	HF-10		
Animal no:	599		
Starting Mass:	226.00		
End Mass:	225.00		
Avg feed intake (kg):	4.95	Avg DM intake (kg):	4.57
Avg faeces collected (kg):	6.39	Avg faecal DM excreated (kg):	1.92
Avg urine collected (l):	5.89		

Analysis of feed and faeces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	7.60	92.40	15.26	2.53	22.71	28.30	0.83	0.38	7.05	16.69	39.26	85.35
Feed "Dry matter" basis :		100.00	16.52	2.74	24.58	30.63	0.90	0.41	7.63	18.06	42.49	92.37
Faeces "as is" basis:	69.93	30.07	3.32	0.87	11.54	11.91	0.34	0.15	3.81	4.16	4.44	26.26
Faeces "Dry matter" basis :		100.00	14.36	2.90	49.89	51.51	1.47	0.66	16.48	18.00	14.75	87.32
Urine (DM basis):			4.20							0.61		

Calculations

Average DMI	4.57
Average DM feaces excreated	1.92

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	4573.80	755.37	125.23	1124.15	1400.85	41.09	18.81	348.98	82.62	1943.37	4224.83
Excreated (g)	1921.47	275.92	55.72	958.62	989.75	28.25	12.68	316.66	34.59	283.42	1677.90
Digested (g)	2652.33	479.45	69.51	165.52	411.10	12.84	6.13	32.32	48.03	1659.95	2546.93
Digestability coefficients (%)	57.99	63.47	55.51	14.72	29.35	31.25	32.58	9.26	58.14	85.42	60.28
Digestible nutrients (% or MJ/kg)		10.48	1.52	3.62	8.99	0.28	0.13	0.71	10.50	36.29	55.69

Calculated Digestible Energy (MJ/kg DM):	10.50
Estimated energy loss from methane (MJ/day):	4.98
Energy loss from Urine (MJ/day):	3.61
Calculated Metabolizable Energy (MJ/kg DM):	8.63

Digestibility trial number 3 : Appendix M3

Feed type:	HF10		
Animal no:	D73		
Starting Mass:	262.00		
End Mass:	Slaugther		
Avg feed intake (kg):	6.11	Avg DM intake (kg):	5.74
Avg faeces collected (kg):	8.24	Avg faecal DM excreated (kg):	1.79
Avg urine collected (l):			

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	6.10	93.90	15.07	2.19	25.68	32.41	0.98	0.36	7.42	16.84	36.81	86.48
Feed "Dry matter" basis :		100.00	16.05	2.33	27.35	34.52	1.04	0.38	7.90	17.93	39.20	92.10
Faeces "as is" basis:	78.25	21.75	3.28	0.47	10.53	12.76	0.32	0.12	2.45	4.45	3.92	19.30
Faeces "Dry matter" basis :		100.00	14.17	2.04	45.52	55.15	1.40	0.50	10.61	19.24	18.03	88.72
Urine (DM basis):												

Calculations

Average DMI 5.74

Average DM feaces excreated 1.79

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	5737.29	920.78	133.81	1569.05	1980.25	59.88	22.00	453.36	102.89	2249.09	5283.93
Excreated (g)	1792.20	253.95	36.56	815.81	988.40	25.09	8.96	190.15	34.48	323.13	1589.98
Digested (g)	3945.09	666.82	97.25	753.24	991.85	34.79	13.04	263.21	68.41	1925.96	3693.95
Digestability coefficients (%)											
	68.76	72.42	72.68	48.01	50.09	58.10	59.26	58.06	66.49	85.63	69.91
Digestible nutrients (% or MJ/kg)											
		11.62	1.70	13.13	17.29	0.61	0.23	4.59	11.92	33.57	64.38

Calculated Digestible Energy (MJ/kg DM): 11.92

Estimated energy loss from methane (MJ/day): 6.17

Summary of digestibility trials HF10: Appendix M4

Feed analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	13.96	1.98	32.80	39.88	0.78	0.31	7.16	17.88	37.02	92.84
Digest 2	16.52	2.74	24.58	30.63	0.90	0.41	7.63	18.06	42.49	92.37
Digest 3	16.05	2.33	27.35	34.52	1.04	0.38	7.90	17.93	39.20	92.10
Average	15.51	2.35	28.24	35.01	0.91	0.37	7.56	17.95	39.57	92.44
STD	1.11	0.31	3.41	3.79	0.11	0.04	0.31	0.08	2.25	0.31

Urine analysis (DM basis)

	Crude Protein (%)	Gross Energy (MJ/day)
Digest 1	4.27	3.71
Digest 2	4.20	3.61
Average	4.24	3.66
STD	0.03	0.05

Methane analysis

	Estimated energy lost via methane (MJ/day)
Digest 1	6.22
Digest 2	4.96
Digest 3	6.17
Average	5.78
STD	0.58

Faeces analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	12.82	1.75	46.91	57.08	1.19	0.55	11.11	18.67	17.44	88.89
Digest 2	14.36	2.90	49.89	51.51	1.47	0.66	16.48	18.00	14.75	87.32
Digest 3	14.17	2.04	45.52	55.15	1.40	0.50	10.61	19.24	18.03	88.72
Average	13.72	2.23	47.44	54.58	1.35	0.57	12.73	18.64	16.74	88.31
STD	0.78	0.49	1.82	2.31	0.12	0.07	2.86	0.51	1.43	0.70

Digestible nutrients

	Intake (kg)	Faeces (kg)	Urine (l)	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Digestible Energy (MJ/kg DM)	NSC (%)	Organic Matter (%)	Energy Faeces (MJ/day)	Energy Methane (MJ/day)	Energy Urine (MJ/day)	Calc ME (MJ/kg DM)
Digest 1	5.60	1.97	5.40	7.69	1.38	16.86	20.49	0.38	0.12	3.39	11.52	31.09	62.64	36.79	6.22	3.71	9.81
Digest 2	4.57	1.92	5.89	10.48	1.52	3.62	8.99	0.28	0.13	0.71	10.50	36.29	55.69	34.59	4.96	3.61	8.63
Digest 3	5.74	1.79		11.62	1.70	13.13	17.29	0.61	0.23	4.59	11.92	33.57	64.38	34.48	6.17		
Average	5.37	1.89	5.65	9.93	1.53	11.20	15.59	0.42	0.16	2.89	11.31	33.65	60.90	35.29	5.78	3.66	9.22
STD	0.57	0.08	0.24	1.65	0.13	5.58	4.85	0.14	0.05	1.62	0.60	2.12	3.76	1.06	0.58	0.05	0.59

Digestibility coefficients (%)

	Crude Protein	Fat	ADF	NDF	Calcium	Phos	Total Ash	Digestible Energy	NSC	Organic Matter
Digest 1	55.06	69.92	51.41	51.39	48.44	40.01	47.31	64.49	84.00	67.48
Digest 2	63.47	55.51	14.72	29.35	31.25	32.58	9.26	58.14	85.42	60.28
Digest 3	72.42	72.68	48.01	50.09	58.10	59.26	58.06	66.49	85.63	69.91
Average	63.65	66.03	38.05	43.61	45.93	43.95	38.21	63.04	85.01	65.89
STD	7.09	7.53	16.55	10.10	11.10	11.24	20.94	3.56	0.73	4.09

Values used to calculate ME (MJ/kg)

	DMI (kg/day)	Faeces (kg/day)	Urine (l/day)	GE in feed (MJ/kg)	GE intake (MJ/day)	GE in faeces (MJ/kg)	GE excreted (MJ/day)	GE in urine (MJ/day)	GE in methane (MJ/day)	Digestible Energy (MJ/kg DM)	Calculated ME (DM) (MJ/kg)
Digest 1	5.60	1.97	5.40	17.88	103.58	18.67	36.78	3.71	6.22	11.52	9.81
Digest 2	4.57	1.92	5.89	18.06	82.55	18.00	34.58	3.61	4.96	10.50	8.63
Average	5.19	1.95	5.65	17.96	93 06	18.34	35.67	3.66	5.59	11.01	9.22
STD	0.61	0.03	0.24	0.10	10.52	0.34	1.11	0.05	0 63	0 51	0.59

Digestibility trial number 1 : Appendix N1

Feed type:	SF-10		
Animal no:	397		
Starting Mass:	199.00		
End Mass:	202.00		
Avg feed intake (kg):	5.70	Avg DM intake (kg):	5.34
Avg faeces collected (kg):	8.57	Avg faecal DM excreated (kg):	2.36
Avg urine collected (kg):	6.42		

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	6.25	93.75	14.01	2.74	32.08	40.90	0.93	0.27	8.36	17.19	27.74	85.39
Feed "Dry matter" basis :		100.00	14.94	2.92	34.22	43.63	0.99	0.29	8.92	18.34	29.59	91.08
Faeces "as is" basis:	72.47	27.53	3.64	0.55	12.74	16.01	0.37	0.12	3.20	5.10	4.13	24.33
Faeces "Dry matter" basis :		100.00	13.22	1.99	46.28	58.16	1.34	0.44	11.62	18.51	15.01	88.38
Urine (DM basis):			4.77							0.80		

Calculations

Average DMI	5.34
Average DM feaces excreated	2.36

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	5343.75	798.57	156.18	1828.56	2331.30	53.01	15.39	476.52	97.98	1581.18	4867.23
Excreated (g)	2359.32	465.02	46.95	1091.89	1372.18	31.61	10.38	274.15	43.67	354.13	2085.17
Digested (g)	2984.43	333.55	109.23	736.67	959.12	21.40	5.01	202.37	54.31	1227.05	2782.06
Digestability coefficients (%)											
	55.85	41.77	69.94	40.29	41.14	40.36	32.55	42.47	55.43	77.60	57.16
Digestible nutrients (% or MJ/kg)											
		6.24	2.04	13.79	17.95	0.40	0.09	3.79	10.16	22.96	52.06

Calculated Digestible Energy (MJ/kg DM):	10.16
Estimated energy loss from methane (MJ/day):	5.88
Energy loss from Urine (MJ/day):	5.14
Calculated Metabolizable Energy (MJ/kg DM):	8.10

Digestibility trial number 2 : Appendix N2

Feed type:	SF-10		
Animal no:	598		
Starting Mass:	242.00		
End Mass:	239.00		
Avg feed intake (kg):	5.16	Avg DM intake (kg):	4.83
Avg faeces collected (kg):	7.97	Avg faecal DM excreated (kg):	2.29
Avg urine collected (l):	6.26		

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	6.40	93.60	15.13	4.20	26.33	34.15	0.87	0.34	7.73	17.26	32.39	85.87
Feed "Dry matter" basis :		100.00	16.16	4.49	28.13	36.49	0.93	0.36	8.26	18.44	34.60	91.74
Faeces "as is" basis:	71.25	28.75	3.61	0.61	14.10	17.25	0.37	0.14	3.15	5.16	2.83	25.60
Faeces "Dry matter" basis :		100.00	13.12	2.93	51.20	62.66	1.35	0.51	11.43	18.75	9.86	89.06
Urine (DM basis):			4.97							0.64		

Calculations

Average DMI 4.83

Average DM feaces excreated 2.29

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	4829.76	780.71	216.72	1358.63	1762.14	44.89	17.54	398.87	89.06	1671.32	4430.89
Excreated (g)	2291.38	300.63	67.14	1173.16	1435.78	30.93	11.69	261.90	42.96	225.93	2040.58
Digested (g)	2538.39	480.08	149.58	185.44	326.36	13.96	5.86	136.96	46.10	1445.39	2390.31
Digestability coefficients (%)											
	52.56	61.49	69.02	13.65	18.52	31.09	33.39	34.34	51.76	86.48	53.95
Digestible nutrients (% or MJ/kg)											
		9.94	3.10	3.84	6.76	0.29	0.12	2.84	9.54	29.93	49.49

Calculated Digestible Energy (MJ/kg DM): 9.54

Estimated energy loss from methane (MJ/day): 5.34

Energy loss from Urine (MJ/day): 4.03

Calculated Metabolizable Energy (MJ/kg DM): 7.60

Digestibility trial number 3 : Appendix N3

Feed type:	SF10		
Animal no:	S100		
Starting Mass:	278.00		
End Mass:	Slaugther		
Avg feed intake (kg):	6.09	Avg DM intake (kg):	5.69
Avg faeces collected (kg):	8.26	Avg faecal DM excreated (kg):	1.87
Avg urine collected (l):			

Analysis of feed and feaces

	(%) Moisture	(%) Dry Matter	(%) Crude Protein	(%) Fat	(%) ADF	(%) NDF	(%) Calcium	(%) Phos	(%) Total Ash	Gross Energy (MJ/kg)	(%) NSC	(%) Organic Matter
Feed "as is" basis :	6.60	93.40	14.31	2.20	24.78	30.59	0.92	0.41	7.44	16.58	38.86	85.96
Feed "Dry matter" basis :		100.00	15.32	2.36	26.53	32.75	0.99	0.44	7.97	17.75	41.61	92.03
Faeces "as is" basis:	77.44	22.56	4.15	0.49	13.35	15.87	0.52	0.20	3.54	5.16	2.85	19.02
Faeces "Dry matter" basis :		100.00	15.06	1.79	48.49	57.65	1.89	0.72	12.86	18.80	12.64	84.31
Urine (DM basis):												

Calculations

Average DMI	5.69
Average DM feaces excreated	1.87

	Dry Matter (g/day)	Crude Protein (g/day)	Fat (g/day)	ADF (g/day)	NDF (g/day)	Calcium (g/day)	Phos (g/day)	Total Ash (g/day)	Digestible Energy (MJ/day)	NSC (g/day)	Organic Matter (g/day)
Consumed (g)	5688.06	871.48	133.98	1509.10	1862.93	56.03	24.97	453.10	100.97	2366.57	5234.96
Excreated (g)	1867.97	281.32	33.44	905.78	1076.88	35.30	13.45	240.22	35.12	236.11	1574.83
Digested (g)	3820.09	590.16	100.54	603.32	786.05	20.72	11.52	212.88	65.85	2130.46	3660.14
Digestability coefficients (%)	67.16	67.72	75.04	39.98	42.19	36.99	46.14	46.98	65.22	90.02	69.92
Digestible nutrients (% or MJ/kg)		10.38	1.77	10.61	13.82	0.36	0.20	3.74	11.58	37.45	64.35

Calculated Digestible Energy (MJ/kg DM): 11.58

Estimated energy loss from methane (MJ/day): 6.06

Summary of digestibility trials SF10: Appendix N4

Feed analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	14.94	2.92	34.22	43.63	0.99	0.29	8.92	18.34	29.59	91.08
Digest 2	16.18	4.49	28.13	36.49	0.93	0.36	8.26	18.44	34.60	91.74
Digest 3	15.32	2.36	26.53	32.75	0.99	0.44	7.97	17.75	41.61	92.03
Average	15.48	3.26	29.63	37.62	0.97	0.36	8.38	18.18	35.27	91.62
STD	0.51	0.90	3.31	4.51	0.03	0.06	0.40	0.30	4.93	0.40

Urine analysis (DM basis)

	Crude Protein (%)	Gross Energy (MJ/day)
Digest 1	4.77	5.14
Digest 2	4.97	4.03
Average	4.87	4.59
STD	0.10	0.55

Methane analysis

	Estimated energy lost via methane (MJ/day)
Digest 1	5.88
Digest 2	5.34
Digest 3	6.06
Average	5.76
STD	0.31

Faeces analysis (DM basis)

	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Gross Energy (MJ/kg)	NSC (%)	Organic Matter (%)
Digest 1	13.22	1.99	46.28	58.16	1.34	0.44	11.62	18.51	15.01	88.38
Digest 2	13.12	2.93	51.20	62.66	1.35	0.51	11.43	18.75	9.86	89.06
Digest 3	15.06	1.79	48.49	57.65	1.89	0.72	12.86	18.80	12.64	84.31
Average	13.80	2.24	48.66	59.49	1.53	0.56	11.97	18.69	12.50	87.25
STD	0.89	0.50	2.01	2.25	0.26	0.12	0.63	0.13	2.10	2.10

Digestible nutrients

	Intake (kg)	Faeces (kg)	Urine (l)	Crude Protein (%)	Fat (%)	ADF (%)	NDF (%)	Calcium (%)	Phos (%)	Total Ash (%)	Digestible Energy (MJ/kg DM)	NSC (%)	Organic Matter (%)	Energy Faeces (MJ/day)	Energy Methane (MJ/day)	Energy Urine (MJ/day)	Calc ME (MJ/kg DM)
Digest 1	5.34	2.36	6.42	6.24	2.04	13.79	17.95	0.40	0.09	3.79	10.16	22.96	52.06	43.87	5.88	5.14	8.10
Digest 2	4.83	2.29	6.29	9.94	3.10	3.84	6.76	0.29	0.12	2.84	9.54	29.93	49.49	42.96	5.34	4.03	7.60
Digest 3	5.69	1.87		10.38	1.77	10.61	13.82	0.36	0.20	3.74	11.58	37.45	64.35	35.12	6.06		
Average	5.29	2.17	6.36	8.85	2.30	9.41	12.84	0.35	0.14	3.46	10.43	30.11	55.30	40.58	5.76	4.59	7.85
STD	0.35	0.22	0.06	1.85	0.57	4.15	4.62	0.05	0.05	0.44	0.85	5.92	6.48	3.87	0.31	0.55	0.25

Digestibility coefficients (%)

	Crude Protein	Fat	ADF	NDF	Calcium	Phos	Total Ash	Digestible Energy	NSC	Organic Matter
Digest 1	41.77	69.94	40.29	41.14	40.36	32.55	42.47	55.43	77.60	57.16
Digest 2	61.49	69.02	13.65	18.52	31.09	33.39	34.34	51.76	86.48	53.95
Digest 3	67.72	75.04	39.98	42.19	36.99	46.14	46.98	65.22	90.02	69.92
Average	56.99	71.33	31.31	33.95	36.15	37.36	41.26	57.47	84.70	60.34
STD	11.06	2.65	12.49	10.92	3.83	6.22	5.23	5.68	5.22	6.90

Values used to calculate ME (MJ/kg)

	DMI (kg/day)	Faeces (kg/day)	Urine (l/day)	GE in feed (MJ/kg)	GE intake (MJ/day)	GE in faeces (MJ/kg)	GE excreted (MJ/day)	GE in urine (MJ/day)	GE in methane (MJ/day)	Digestible Energy (MJ/kg DM)	Calculated ME (DM) (MJ/kg)
Digest 1	5.34	2.36	6.42	18.34	97.91	18.51	43.68	5.14	5.88	10.16	8.09
Digest 2	4.83	2.29	6.29	18.44	89.07	18.75	42.94	4.03	5.34	9.54	7.61
Average	5.09	2.33	6.36	18.39	93.49	18.63	43.31	4.59	5.61	9.85	7.85
STD	0.25	0.03	0.06	0.05	4.42	0.12	0.37	0.55	0.27	0.31	0.24

Appendix O - Average pH readings

Determination of rumen pH fluctuations over a 24 hour period on four different cycles

Ration HF13

	Trail 1		Trail 2			
	Part 1	Part 2	Part 1	Part 2	Avg	STD
8:00:00	6.43	6.45		5.47	6.12	0.46
10:00:00	6.28	5.59		5.46	5.78	0.36
12:00:00	5.85	5.70		5.23	5.59	0.26
14:00:00	5.65	5.73		5.41	5.60	0.14
16:00:00	5.63	5.77		5.34	5.58	0.18
18:00:00	5.43	5.53		5.37	5.44	0.07
20:00:00	5.55	5.48		5.34	5.46	0.09
22:00:00	5.55	5.64		5.45	5.55	0.08
0:00:00	5.59	6.07		5.38	5.68	0.29
2:00:00	6.01	6.33		5.45	5.93	0.36
4:00:00	6.17	6.63			6.40	0.23
6:00:00	6.53	6.52			6.53	0.00
8:00:00	6.54	7.17			6.86	0.31

Ration SF13

	Trail 1		Trail 2			
	Part 1	Part 2	Part 1	Part 2	Avg	STD
8:00:00	6.67	5.58	7.03	6.89	6.54	0.57
10:00:00	6.27	6.25	6.32	6.09	6.23	0.09
12:00:00	5.49	5.48	6.14	5.58	5.67	0.27
14:00:00	5.21	5.32	5.67	6.40	5.65	0.47
16:00:00	5.39	5.50	5.96	6.26	5.78	0.35
18:00:00	5.32	5.59	5.83	5.95	5.67	0.24
20:00:00	5.17	5.48	5.64	5.45	5.44	0.17
22:00:00	5.14	5.54	5.61	6.13	5.61	0.35
0:00:00	5.33	5.55	6.06	5.71	5.66	0.27
2:00:00	5.43	5.60	6.30	5.57	5.73	0.34
4:00:00	5.73	6.19	6.67	6.59	6.30	0.37
6:00:00	5.90	6.55	6.74	6.61	6.45	0.32
8:00:00	6.80	6.77	6.89	6.64	6.78	0.09

Ration HF10

	Trail 1		Trail 2			
	Part 1	Part 2	Part 1	Part 2	Avg	STD
8:00:00	6.48	6.78	6.68	7.00	6.74	0.19
10:00:00	6.46	6.74	6.65	6.47	6.58	0.12
12:00:00	6.08	6.21	6.59	6.43	6.33	0.20
14:00:00	6.27	6.15	6.78	6.67	6.47	0.26
16:00:00	6.23	6.23	6.82	6.83	6.53	0.30
18:00:00	5.92	6.05	6.60	6.62	6.30	0.32
20:00:00	5.65	5.73	6.15	6.29	5.96	0.27
22:00:00	5.98	5.70	6.31	6.19	6.05	0.23
0:00:00	6.04	5.62	6.66	6.21	6.13	0.37
2:00:00	6.04	5.77	6.76	5.96	6.13	0.38
4:00:00	6.16	6.50	6.86	6.11	6.42	0.31
6:00:00	6.64	6.53	6.93	6.89	6.75	0.17
8:00:00	6.77	7.04	7.00	6.82	6.91	0.11

Ration SF13

	Trail 1		Trail 2			
	Part 1	Part 2	Part 1	Part 2	Avg	STD
8:00:00	6.69	5.84	6.66	6.60	6.45	0.35
10:00:00	6.59	6.33	6.30	6.40	6.41	0.11
12:00:00	5.95	6.02	6.02	6.25	6.06	0.11
14:00:00	6.27	6.06	6.10	6.29	6.18	0.10
16:00:00	6.53	5.89	5.96	6.56	6.24	0.31
18:00:00	6.32	5.97	6.08	6.50	6.22	0.21
20:00:00	5.90	5.74	5.85	6.03	5.88	0.10
22:00:00	6.29	5.88	5.68	6.04	5.97	0.22
0:00:00	6.41	5.81	5.97	6.13	6.08	0.22
2:00:00	6.55	5.85	5.95	6.21	6.14	0.27
4:00:00	6.75	6.29	6.43	6.45	6.48	0.17
6:00:00	6.91	6.59	6.62	6.58	6.68	0.14
8:00:00	6.95	6.57	6.63	6.61	6.69	0.15