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Milk production from cows grazing kikuyu – ryegrass pasture systems

By

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DECLARATION

I declare that this dissertation for the degree of MSc (Agric): Nutrition Science at the University of Pretoria, has not been submitted by me for a degree at any other University.

L. Erasmus
Pretoria
December 2009

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SUMMARY

Milk production from kikuyu pasture systems over-sown with italian, westerwold or perennial ryegrass

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Kikuyu is well adapted to the main milk producing areas of the Southern Cape region of South Africa. The strategic incorporation of different types of temperate grasses into kikuyu pastures can increase the seasonal dry matter production, pasture quality, and milk production attainable from these pastures. To determine whether there is production and economical differences between kikuyu based pasture systems, a trial was conducted on the Outeniqua Research Farm near George. The three pasture treatments, namely italian, westerwold, and perennial ryegrass over-sown into kikuyu, were tested. Forty-five Jersey cows were blocked and cows within blocks were randomly allocated to the treatments. The cows received 9 kilograms of pasture (on a dry matter basis) per cow per day, and four kilograms of concentrate per cow per day. Milk production was recorded daily, and milk composition was determined monthly. The cows were weighed and body condition scored monthly.

The perennial ryegrass pasture treatment had a higher milk production per hectare (32288 kg/ha) than the westerwold ryegrass pasture treatment (29761 kg/ha) but did not differ from the italian ryegrass pasture treatment (30446 kg/ha). The italian ryegrass pasture treatment had a higher milk protein percentage than the perennial ryegrass pasture treatment (3.84% vs. 3.64%) but did not differ from the westerwold ryegrass pasture treatment (3.75%). When the three pasture treatments were economically compared, the italian ryegrass pasture treatment had the highest margin over specified costs per hectare (R 36,565.03), followed by the perennial (R 33,889.14) and westerwold (R 29,468.09) ryegrass pasture

treatments. From the results it seems that the italian ryegrass pasture treatment is the best choice for a kikuyu based pasture system in the Southern Cape region of South Africa.

A high level of concentrate supplementation could increase energy intake of grazing dairy cows, but might also reduce fibre digestion within the rumens of high producing dairy cows. To test this hypothesis, two trials were conducted, one during October and November 2007, and the other during March 2008. In both trials twelve rumen cannulated cows were allocated to four groups. Two groups were allocated to each pasture treatment, namely perennial and westerwold ryegrass over-sown into kikuyu. Within each pasture treatment, one group received 4 kg of concentrate per cow per day, and the other 8 kg of concentrate per day. Pasture was allocated at 9 kg per day (DM). Cows were adapted for ten days, after which ruminal pH, and ammonia nitrogen and volatile fatty acid concentration data was collected. An *in sacco* study was conducted to determine the neutral detergent fibre degradability. After the data was collected, the two groups within each pasture treatment swapped concentrate levels; were adapted, and the same data as described above was collected.

During both trials reductions in ruminal pH were observed when a higher amount of concentrate was supplemented. During the first trial there was a significant increase in the time that the ruminal pH remained below pH 5.8 on the westerwold ryegrass pasture treatment (from 80 minutes when the cows received 4 kg of concentrate per day, to 375 minutes when it was increased to 8 kg of concentrate per day). A decrease in neutral detergent fibre degradability was also seen. During the second trial, the percentage of NDF disappearance decreased from 8.45% over a twelve hour period when 4 kg of concentrate was fed, to 4.51% when 8 kg of concentrate was fed on the perennial ryegrass pasture treatment. From the results it appears that feeding a higher level of concentrate supplementation to high producing dairy cows grazing kikuyu pasture systems has a negative effect on neutral detergent fibre digestion within the rumen. It appears that feeding a moderate level of concentrate supplementation when cows are on pasture based systems is more beneficial to the rumen environment and decreases the possibility of sub-clinical ruminal acidosis when cows grazed ryegrass dominant pastures, but had a less pronounced effect when the dominant pasture specie was kikuyu. Future research could examine the relationship between the level of concentrate supplementation and pasture specie more closely, as it would be interesting to find the optimal ratios for each pasture specie.

LIST OF ABBREVIATIONS

ADF	acid detergent fibre
ADIN	acid detergent insoluble nitrogen
ADIP	acid detergent insoluble protein
ADL	acid detergent lignin
BCS	body condition score
BF	butter fat content of milk
BF%	butter fat percentage of milk
BW	body weight
Ca	calcium
CF	crude fibre
CH_4	methane
CNCPS	Cornell Net Carbohydrate and Protein System
CO_2	carbon dioxide
CP	crude protein
DE	digestible energy
DIM	days in milk
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake
DP	digestible protein
EDTA	ethylenediaminetetraacetic acid
EE	ether extract
FCM	fat corrected milk production
GE	gross energy
H2SO4	sulphuric acid
H3PO4	phosphoric acid
IR	italian ryegrass pasture treatment
IVOMD	*in vitro* organic matter digestibility
KCl	potassium chloride
ME	metabolisable energy

MP	microbial protein
MUN	milk urea nitrogen
N	nitrogen
NDF	neutral detergent fibre
NDIN	neutral detergent insoluble nitrogen
NDIP	neutral detergent insoluble protein
NFC	non fibrous carbohydrates
NH_3-N	ruminal ammonia nitrogen
NPN	non protein nitrogen
NSC	non structural carbohydrates
OM	organic matter
OMD	organic matter digestibility
P	phosphorous
peNDF	physically effective neutral detergent fibre
PR	perennial ryegrass pasture treatment
PR4	perennial ryegrass treatment, 4kg of concentrate
PR8	perennial ryegrass treatment, 8kg of concentrate
Prot%	protein percentage of milk
RDP	rumen degradable protein
RFC	readily fermentable carbohydrates
RPM	rising plate meter
RUP	rumen undegradable protein
S	sulphur
SCC	somatic cell count
SEM	standard error of means
solCP	soluble crude protein
TDN	total digestible nutrients
TMR	total mixed ration
TNC	total nutrient content
VFA	volatile fatty acids
WOL	week of lactation
WR	westerwold ryegrass pasture treatment

WR4	westerwold ryegrass treatment, 4kg of concentrate
WR8	westerwold ryegrass treatment, 8kg of concentrate
WSC	water soluble carbohydrates

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CHAPTER 1

INTRODUCTION & MOTIVATION

CHAPTER 1

INTRODUCTION & MOTIVATION

Pasture is the base for profitable milk production in the Southern Cape region of South Africa (Meeske *et al*., 2006). The most important reason for this is the suitability of the environment for a large number of pasture species to this area. Kikuyu (*Pennisetum cladestinum*) is one of the pasture species well adapted to the main milk producing areas of the Southern Cape of South Africa. Although cows on pasture produce less milk than when fed a total mixed ration (TMR) system, the fact that pasture-based farming systems are a low input way of producing milk in the Southern Cape, making it more attractive system. Kikuyu is a sub-tropical C_4 grass and the main problems experienced with kikuyu are the seasonality of production and its relatively low nutrient quality (Marais, 2001). Compared to temperate grass (C_3) species, such as ryegrass (*Lolium* spp.), the forage quality of kikuyu is low and consequently the milk production per cow is also low (Marais, 2001). In general, most studies on cows grazing kikuyu pastures, reported milk production levels of less than 11 kg/cow/day (Reeves, 1997).

In order to increase production, cows grazing kikuyu based pastures need to be supplemented with concentrate feeds. The most likely nutrients to be limiting milk production from pasture based systems are low metabolisable energy (ME) (van Vuuren, 1993; Kolver & Muller, 1998; Marais, 2001), and high neutral detergent fibre (NDF). Kikuyu is also deficient in sodium (Na) and prone to calcium: phosphate (Ca: P) imbalances, as well as potassium (K): Ca plus magnesium (Mg) imbalances (Marais, 2001). However, concentrate supplementation is costly and also requires knowledge about animal nutrition to implement successfully. The strategic incorporation of different types of temperate C_3 grasses like ryegrass (*Lolium multiflorum* Lam.: Italian or Westerwold ryegrass) and perennial ryegrass (*L. perenne*) into kikuyu pasture can increase the seasonal dry matter (DM) production and nutritive value of the pasture (Botha *et al*., 2007a). Consequently, dairy farmers have to make decisions on species (annual or perennial) and type (italian or westerwold) of ryegrass to utilise in their production system. These decisions may have a major impact on the profitability of dairy farming. Unfortunately, limited information is available on the effect of over-sowing kikuyu with ryegrass species and grazed by animals

(Botha *et al*., 2007a) in South Africa. At present no applicable scientific data comparing different systems with annual or perennial ryegrass over-sown into kikuyu and grazed by dairy cows is available.

Another consequence of kikuyu pastures over-sown with ryegrass is the lack of production during the winter months. This is one of the most important restrictions in the fodder flow programs of farmers in the Southern Cape (Botha *et al*, 2006). Annual ryegrass species are resown each year by broad casting, followed by mulching the kikuyu. Perennial ryegrass is also resown each year, but the pastures are not always mulched beforehand, so the gap between planting and the first grazing period is shorter. Compared to annual ryegrass, perennial ryegrass over-sown into kikuyu increases the quality of the pasture during autumn and summer (Botha, 2003). This is due to the fact that perennial ryegrass is resown in April (Botha *et al*., 2006) and not in March, when the annual ryegrass species are resown. Perennial ryegrass is also present in the pasture for a longer period of time in the summer than the annual ryegrass species. However, there is no scientific data available to demonstrate that this is a more profitable system in the Southern Cape.

In a pasture-based dairy farming system, energy intake is the first limiting factor for milk production from pastures (van Vuuren, 1993; Kolver & Muller, 1998; Kolver, 2003). Concentrates are supplemented to cows grazing on pasture to overcome nutrient deficiencies (Donker *et al*., 1967), increase the stocking rate and milk production, maintain body condition and improve the overall profitability of dairy farming (Bargo *et al.*, 2003a). The level of concentrate feeding and the associated milk production response have a major effect on profitability of pasture based dairy farming systems (Meeske *et al.*, 2006). The milk response per kg concentrate fed tends to decrease as the level of concentrate fed to cows increases (Bargo *et al.*, 2003a; Meeske *et al.*, 2006).

A level of 4kg of concentrate per cow per day is considered a moderate level of concentrate supplementation. Supplementation above 4kg per cow per day decreases the milk production response significantly, which makes a higher level of concentrate supplementation to grazing dairy cows less appealing (Bargo *et al.*, 2003a). The reason for the decline in response to concentrate is that high levels of readily fermentable carbohydrates cause a decrease in rumen pH and fibre digestion. As little as 10-15% added readily fermentable carbohydrates can impair fibre digestion, but severe depressions are usually associated with readily fermentable carbohydrate or grain additions of 30% or more of the animal's dry matter intake (DMI) (Botha, 2003). The ideal pasture contains 40% NDF, 21 - 25% acid detergent fibre (ADF), and 20% crude protein (CP). A dairy cow can consume 1.2% of her live weight as NDF per day (Kolver, & Muller, 1998). This means that a 400kg dairy cow can consume 4.8kg of NDF per day (Kolver, & Muller, 1998). The NDF content of the diet determines the amount of concentrate that the animal is able to ingest without dramatically influencing rumen function. The amount of physically effective NDF in the diet is determined by the thickness of the fibre matt that forms on top of the rumen contents. This fibre matt stimulates rumination, which allows for a more buffered environment in the rumen as the saliva from rumination contains Na, potassium phosphate, and bicarbonate which provide buffering capacity to maintain a more stable pH in the rumen (Van Soest, 1994). Tropical grasses usually contain a higher level of NDF than temperate species (Botha, 2003). According to Marais (2001), perennial ryegrass has a NDF concentration of 546g/kg DM, whereas kikuyu has a NDF concentration ranging between 581-741g/kg DM. Because kikuyu contains a higher level of NDF than ryegrass, cows grazing kikuyu pastures should be able to consume a higher level of concentrate than cows grazing ryegrass pastures and still maintain a favourable environment in the rumen for fibre degradation.

Eight kilograms of concentrate per cow per day is considered to be a high level of concentrate supplementation when cows are offered pasture as the sole a source of fibre (Van Vuuren *et al.*, 1986; Meeske *et al.*, 2006). This amount of concentrate supplementation should reduce the amount of total physically effective NDF in the diet to a level where the fibrous matt on top of the rumen contents is not adequate to stimulate sufficient rumination. Thus the rumen has a lower saliva input, caused by a decrease in the time spent ruminating. This means that the rumen is less buffered and the rumen pH drops below pH 6 where fibre degradation is severely depressed (Mould *et al.*, 1984; Dixon & Stockdale, 1999).

The question therefore is whether a high level of concentrate supplementation will reduce the rumen pH of dairy cows to a level where fibre degradation of the pasture will be significantly depressed and whether there is a difference in fibre degradation between the pasture species used when a higher level of concentrate is fed.

A study was conducted at the Outeniqua Experimental Farm, near George in the Southern Cape region of South Africa was to determine (1) the milk production response, reproduction, live weight and condition score of Jersey cows grazing kikuyu pasture over-sown with perennial, italian or westerwold ryegrass; (2) the effect of two concentrate levels on rumen fermentation parameters and *in sacco* ruminal NDF digestion of cows grazing kikuyu over-sown with westerwold or perennial ryegrass; and (3) the economics of these three kikuyu based pasture systems.

The following hypotheses were tested in this study:

H_0 = Over-sowing of kikuyu pasture systems with italian, westerwold, or perennial ryegrass will improve milk production.

H_1 = Over-sowing of kikuyu pasture systems with italian, westerwold, or perennial ryegrass will not improve milk production.

H_0 = Fibre digestion will be negatively affected by feeding higher levels of concentrate to cows grazing kikuyu/ryegrass pastures.

H_1 = Fibre digestion will not be negatively affected by feeding higher levels of concentrate to cows grazing kikuyu/ryegrass pastures.

CHAPTER 2

LITERATURE REVIEW:

MILK PRODUCTION FROM KIKUYU OVER-SOWN WITH ITALIAN, WESTERWOLD, OR PERENNIAL RYEGRASS AND THE EFFECT OF CONCENTRATE SUPPLEMENTATION ON THE RUMEN PARAMETERS OF COWS GRAZING ANNUAL OR PERENNIAL RYEGRASS OVER-SOWN INTO KIKUYU

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Sown pastures are the base for profitable milk production in the Southern Cape region of South Africa (Meeske *et al*., 2006). The most important reason for this is the adaptability of many pasture species to this area. The temperate climate, availability of water for irrigation and the all-year-round rainfall in this area are some of the most important factors contributing to the inclusion of various grass and legume species in the fodder flow programs for this area (Botha, 2003).

Kikuyu is well adapted to the Southern Cape, and is the most important pasture specie in terms of summer forage production in this region. However, compared to temperate pasture species, milk production per from kikuyu pastures is low (Botha, 2003). The strategic incorporation of annual or perennial; ryegrass species into kikuyu pastures can potentially improve the nutrient composition of the pastures and increase the milk production potential of dairy cows grazing these pastures.

Energy intake is the first limiting factor for milk production from pastures (Van Vuuren, 1993; Kolver & Muller, 1998; Marais, 2001; Kolver, 2003). According to Kessler & Sphar (1964) the main justification for feeding high levels of concentrates is to increase the intake of total digestible nutrients (TDN) or other measures of productive energy and thus meet the requirements to produce a greater quantity of milk than would otherwise be possible. The level of concentrate feeding and the associated milk production response have a major effect on the profitability of pasture-based dairy farming systems, especially because the milk response per kilogram of concentrate fed tend to decrease as the level of concentrate supplementation increases (Bargo *et al.*, 2003a; Meeske *et al.*, 2006). The effect of readily fermentable carbohydrates on the rumen dry matter digestibility (DMD) of forages has been linearly related to their fibre content, and according to Dixon & Stockdale (1999) is more closely related to the NDF content of the forage than the cellulose or hemicellulose content.

Ultimately the energy value of the feed or diet is the most important to ruminant nutritionists, as it is the energy value of any diet that determines the maximum productivity of the ruminant animal to which the diet is fed (Robinson *et al*., 2004). It has long been recognized that the key components that determine the energy value of a ruminant feed is its content of fat, due to its high energy density, its content of non-fibrous carbohydrates (NFC), due to their high digestibility, and the content and digestibility of fibrous carbohydrates, due to their high level in many ruminant feeds (Robinson *et al.*, 2004).

2.2 Nutritive value of pasture species

Nutritive value relates to the digestibility of herbage ingested by the animal, and the efficiency with which the digestion end products are used. The major determinants of nutritive value of pastures are the botanical and morphological composition, the environment in which the pasture is grown, and the regrowth period or age of the herbage (Lambert *et al.*, 2000). The nutritive value of grass is most often evaluated in terms of its *in vitro* organic matter digestibility (ivOMD). This value is calculated on the assumption that fermentation of the degradable components is complete. In other words, that the cell contents, which are soluble, are always assumed to be 100% degradable (Williams *et al.*, 2000). The degradable cell wall fractions are considered to be the fraction that varies.

The chemical composition of grass may vary considerably and depends on a wide range of genetic and environmental factors, including grass species and variety, rate of fertilisation, solar radiation, rainfall and the maturity at the time of grazing or harvesting (Van Vuuren *et al.*, 1990). These factors not only influence composition but also the rate and extent of ruminal and intestinal degradation and as a result intake (Van Vuuren *et al*., 1990). The stage of growth is the most important factor influencing composition and nutritive value of pasture herbage (McDonald *et al.*, 2002). As the plant matures, the DMD and CP content decreases, and the fibre content increases. The basic determinant of digestibility is the plant's anatomy. Plant cell contents are almost completely digestible, but cell walls vary in digestibility according to the degree of lignification. Thus, digestibility decreases as plants mature and lignification increases, but the relationship between age and digestibility is confounded by season, especially the spring period. In the environmental conditions in the Western Cape province of South Africa during October herbage digestibility remains fairly constant (McDonald *et al.*, 2002). In summer, the reproductive stage, digestibility decreases dramatically as the leaf/stem ratio falls and the structural carbohydrate content increases. The decrease in digestibility with stage of growth is also reflected in the metabolisable and net energy values. The low net energy value of mature forage is not only due to a low OMD but is also associated with a high concentration of cellulose (McDonald *et al.*, 2002). In a pasture-based farming system, energy is usually the first limiting nutrient for milk production (Van Vuuren, 1993; Kolver & Muller, 1998). Efficient conversion of dietary protein to microbial protein within the rumen is energy dependant. The synthesis of microbial protein is decreased by a low energy intake, which causes a decrease in the amount of amino acids supplied to the animal from microbial protein. In the lactating dairy cow it is usually most important to maximise the supply of microbial protein from the rumen (Fulkerson *et al*., 2007).

2.2.1 Kikuyu

Kikuyu is a tropical pasture species with a C4 photosynthetic pathway. The nutritive value of kikuyu is dictated by its unique morphology, physiology, and chemical composition which vary according to stage of growth and environmental conditions during growth (Marias, 2001). A summary of the nutrient composition of kikuyu, as reported by various researchers, is shown in Table 2.1. The nitrogen concentration of kikuyu has been shown to be higher than that of most other grasses (Marais, 2001). In a comparative study of 14 grasses of tropical origin and 6 grasses of temperate origin which ranged in N concentration from 22.8 – 32.9 g/kg DM, kikuyu had the highest N concentration (Forde *et al*., 1976). Chemical analysis of kikuyu indicates a severe protein/energy imbalance, caused by a lack of readily digestible energy in the form of non-structural carbohydrates (NSC) (Marias, 2001). According to Fulkerson *et al.* (1998), the optimal NSC: DP (digestible protein) ratio for rumen microbial protein synthesis is about 2:1. In their research they obtained a NSC: DP ratio of 0.6:1 for kikuyu. The nutritive value of kikuyu is low, resulting in milk yields of below 11kg/cow/day (Reeves, 1997).

In a review by Marais (2001) of the factors affecting the nutritive value of kikuyu grass, he found a mean ME value for kikuyu of only 8.5 MJ/kg DM, based on an organic matter digestibility (OMD) of 645 g/kg DM. He also states that animal production on kikuyu can be improved by energy supplementation. According to Marais (2001) the milk production of Jersey cows grazing kikuyu pasture at a stocking rate of 4.94/ha can be increased by up to 20% by supplementing the animals with crushed oats as an energy source.

A limitation of the efficacy of energy supplementation is that ruminants tend to substitute supplement for grass, thus decreasing forage intake.

Kikuyu, as all grass species, accumulates nitrogenous compounds to luxury levels and are in excess of animal requirements, in most cases. These nitrogenous compounds, such as nitrates, can adversely affect the rumen microbial population or require energy to be detoxified and eliminated in the urine of grazing animals. A high concentration of nitrates in the grass can also cause nitrate poisoning which can be lethal. High levels of N fertilization can cause an increase in the levels of nitrogenous compounds in kikuyu. Reeves (1997), recommends that N fertilizer should not be applied in excess of 50 kg N/hectare/month. Marais *et al.* (1990) states that sub-clinical levels of anti-quality substances present in kikuyu, such as nitrates, have been implicated in reducing the rumen digestibility of kikuyu grass high in N.

Marais (1990) found that due to kikuyu's higher protein and energy but lower nitrate, K, and lignin contents, kikuyu leaf material appeared to have a higher nutritional value than the stem tissue. As kikuyu matures the yield increases, but the leaf: stem ratio decreases, thereby reducing the nutritive value of the sward (Reeves, 1997). Marais (1990) concluded that both high N content and increased maturity are associated with an increased yield or DM production, but both are also associated with a decreased nutritive value and hence a decreased intake, as its well known that a higher fibre content leads to a decreased intake due to the limitation of rumen fill.

Kikuyu, like other tropical grasses, accumulates oxalic acid. Oxalic acid is known to bind with Ca and form oxalate crystals that have a low solubility. This causes the Ca in calcium oxalate to pass through the digestive system and be excreted in the faeces, thus lowering the amount of Ca available to the animal. The problem with bound Ca is that it creates an induced deficiency, i.e. the Ca levels in the kikuyu are reasonable but most is bound and thus unavailable. However, ruminants readily adapt to oxalate-containing forages through the proliferation of a rumen obligate anaerobe, *Oxalobacter forminogenes*, which converts oxalate to formate and carbon dioxide (Marais, 2001). Thus, adapted animals are unlikely to develop acute toxicity due to the interference of oxalic acid in energy metabolism, as well as the precipitation of oxalate crystals in the renal tubes.

Kikuyu grass is generally low in digestible energy (DE), as well as in readily digestible NSC which have long been known to stimulate bacterial protein synthesis in the rumen (Marais *et al*., 1990). According to Botha (2003), the lower DMI of dairy cows grazing kikuyu could be due to the high NDF content of kikuyu. In comparison with temperate pasture species, like ryegrasses, subtropical pasture species such as kikuyu have higher NDF levels (57.5% compared to 38.4%) and lower levels of protein (13.2% compared to 23%), soluble sugars (5.9% compared to 11.7%) and *in vitro* digestibility (66.6% compared to 84.0%) (Botha, 2003). The lignin levels of kikuyu can be as high as 60g/kg DM in late season kikuyu, in contrast to the lignin concentration of *Lolium perenne* of 28.4g/kg DM (Marais, 2001). The in vitro digestibility of 14 grasses of tropical origin and 6 of temperate origin was determined by Forde *et al*. (1976). *Lolium perenne* was the most digestible (749g/kg DM), while kikuyu had a digestibility of 673g/kg DM.

Table 2.1 A summary of the nutrient composition, presented on a dry matter basis, of kikuyu as cited by various authors

Reference	Season	DM	ME*	CP	NDF	ADF	EE	Ash	Ca	P
Marais *et al*. (1990)	-	13.1 ±2		16.9						
Dugmore & du Toit (1988)	-			18.7			2.85			
Joyce, (1974)	Summer			6.9		32.9		9.8	0.49	0.38
Fulkerson *et al*.(2007)	Summer		9.9	25.3	50.3	25.9	2.3			
	Autumn		9.2	29.3	53.5	23.1				
	Spring		9.5	22.8	63.9	26.6				
Botha *et al*. (2007a)	Summer		8.92	23.7	64.7				0.32	0.51
	Autumn		8.13	23.1	62.6				0.36	0.58
Reeves *et al*. (1996)				20.1	61.1	24.3		8.43	0.31	0.27
Fulkerson *et al*. (2006)			10.33	27.6	56.7	22.7				
Meeske *et al*. (2006)	Summer	18.7	8.7	15.7	68.2	32.2		8.8		
	Autumn	15.9	8.4	19.6	67.0	31.3		9.9		
	Winter	16.8	9.3	21.8	59.2	27.1		10.6		
	Spring	18.1	9.7	17.6	59.8	29.0		9.6		

DM = dry matter

ME = metabolisable energy

CP = crude protein

NDF = neutral detergent fibre

ADF = acid detergent fibre

EE = ether extract

Ca = calcium

P = phosphorous

2.2.2 Annual and Perennial ryegrasses

Annual and perennial ryegrasses are temperate grass species. Their primary growth period is in winter, so they can play an important role in fodder flow systems in the Southern Cape of South Africa. Table 2.2 contains a summary of the nutritive value of annual ryegrasses as obtained by other authors.

In a study conducted by Fulkerson *et al.* (2006), they found that the ME value of annual ryegrass was about 1 MJ/kg DM higher than that of kikuyu and associated this with the lower NDF content and a higher water soluble carbohydrate (WSC) content of annual ryegrass. According to Thom *et al*. (1996), italian ryegrasses (*Lolium multiflorum* Lam.) are capable of higher winter/early spring growth than perennial ryegrasses allowing dairy farmers to overcome feed shortages in mid July to September. The biennial italian ryegrass grows more rapidly at low temperatures than perennial ryegrass and has a higher soluble carbohydrate content (Reed, 1994). Lowe *et al*. (1999) stated that irrigated italian ryegrass pastures are highly productive both in terms of herbage produced and milk production per cow per hectare. However, they need to be re-sown annually, either into a fully prepared seedbed or by over-sowing into an existing pasture base.

Table 2.1 A summary of the nutrient composition of annual ryegrasses presented on a DM basis

Reference	**Season**	**DM**	**ME**	**CP**	**NDF**	**ADF**	**EE**	**Ca**	**P**
Lowe *et al*. (1999)	Summer		7.15-8.13	11.1 – 2.5	51.1-55.1	29.2-35.9			
	Autumn		8.13	23.1	50.5	30.6			
	Winter		9.93-10.53	26.1 –26.8	37.6-39.1	22.1-23.2			
	Spring		9.45	25.5	46.2	27.6			
Fulkerson *et al*. (2007)	Autumn		11.0	26.5-28.5	42.8-41.1	23.4-23.3	2.3-2.5		
	Winter		10.5-11.0	26.4-27.1	42.2-45.9	23.6-24.1	23.-2.5		
	Spring		9.7-10.4	24.7-25.6	53.1-49.5	26.2-27.7			
Botha *et al*. (2007a)	Spring		11.27	21.8	50.1			0.47	0.48
	Summer		9.52	18.9	66.9			0.42	0.54
	Autumn		7.87	23.1	67.4			0.40	0.44
Fulkerson *et al*. (2006)			11.30	22.3	44.4	22.1			
Meeske *et al*. (2006)	Autumn	11.9	9.5	25.6	51.0	29.0			
	Winter	14.0	10.8	25.1	45.0	24.1			
	Spring	14.7	10.9	18.0	49.0	28.0			

DM = dry matter

ME = metabolisable energy

CP = crude protein

NDF = neutral detergent fibre

ADF = acid detergent fibre

EE = ether extract

Ca = calcium, P = phosphorous

Perennial ryegrass pastures do not need to be re-sown every year. Table 2.3 shows the nutritive value of perennial ryegrass as reported by various authors. According to Tas *et al*. (2005), perennial ryegrass has a high DM yield per hectare and provides a high nutritive value feed to dairy cows at low cost. According to Taweel, (2004), because of its productivity, palatability, digestibility and nutritive value, perennial ryegrass is the most widely used forage for feeding dairy cattle in temperate environments. The nutritive value of perennial ryegrass varies throughout the growing season. The relatively poor digestibility of perennial ryegrass pasture in summer leads to the use of feed supplements to maintain dairy production (Smith *et al*., 1998). Water soluble carbohydrates provide the most readily available source of energy for grazing ruminants. Low concentrations of WSC in perennial ryegrass may also decrease the efficiency of protein utilization during autumn and winter (Dove & Milne, 1994). In a growth chamber study, Wilson *et al*. (1973) showed that the *in vitro* digestibility of perennial ryegrass declined with increasing temperature in growth chamber studies. At an early stage of maturity, perennial ryegrass is highly digestible and has a high nutritive value in terms of energy and protein (Van Vuuren, 1993). However, despite its high nutritive value, perennial ryegrass has two main disadvantages: (1) it has an unbalanced energy/protein ratio and (2) its low DMI by high producing dairy cows (Bargo *et al*., 2003a). The low DMI is though to be due to physical constraints such as clearance rate from the rumen and water in take due to the high water content of the pasture (Taweel *et al*., 2004a).

Table 2.3 A summary of the nutrient composition (% of DM) of perennial ryegrass as cited by various authors

References	Season	DM	ME	CP	NDF	ADF	EE	ADL
Reeves *et al*. (1996)				25.2	39.5	17.7		
Lowe *et al*. (1999)	Summer		8.38-7.35	18.6 – 19.4	51.4-56.0	32.1-34.2		
	Autumn		7.90	21.4	55.2	33.0		
	Winter		9.83-10.35	24 – 24.3	39.5-41.4	24.9-25.3		
	Spring		9.58	24	44.7	28.9		
Hoffman *et al*. (1993)				23.3	41.5	19.4		3.2
Fulkerson *et al*. (2007)	Summer		9.9	22.1	51.5	31.3	2.7	
	Autumn		10.0	24.0	49.7	26.6		
	Winter		11.4	24.3	48.9	23.2	2.7	
	Spring		11.1	26.3	55.2	25.9		
Clark & Kannegat, (1998)		18-24		18-25	40-50			
Taweel (2004)		17.1		15.8	42.4			1.6
Marais (2001)						25.8		
Ribeiro Filho *et al*. (2005)		17.0		17.2	55.3	25.8		

DM = dry matter
ME = metabolisable energy
CP = crude protein
NDF = neutral detergent fibre
ADF = acid detergent fibre
EE = ether extract
ADL = acid detergent lignin

2.2.3 Comparison of grass species

Lowe *et al.* (1999) found that italian ryegrass had a significantly (P<0.05) higher N content than perennial ryegrass. They also reported that the NDF content of the two ryegrasses was similar throughout the experimental period. Lowe *et al.* (1999) found that during the winter and spring, the ADF content of perennial ryegrass was significantly higher than that of italian ryegrass. According to Marais (2001), the hemicellulose concentration in perennial ryegrass is 30-40% lower than the cellulose concentration; however, kikuyu is atypical in that the hemicellulose concentration is equal, or slightly lower than the cellulose concentration. Fulkerson *et al*. (2007) conducted a study to compare the innate nutritive value of different grass species and legumes to that of perennial ryegrass. They found that the nutritive value of all species were high during the cool season months of autumn and winter with a progressive decline in nutritive value during late spring and summer, associated with reproductive development in temperate species, and the growth period of tropical species of relatively low nutritive value.

The CP content of perennial ryegrass commonly exceeds 25% and can be as high as 35%, while the CP content of kikuyu can exceed 20% (Fulkerson *et al*., 2007). When compared to the requirements stated in NRC (2001), it is clear that these pastures can provide CP well above animal requirements. Fulkerson *et al*. (2007) reported that, during summer, ADF comprised about 520g/kg of NDF for both kikuyu and perennial ryegrass and that both their ME values were at 9.9 MJ/kg DM. During autumn they reported the relatively low fibre content of annual ryegrass species in the early vegetative state to be problematic with regards to dairy cow nutrition associated with acidotic conditions in the rumen. In the lactating dairy cow it is usually most important to maximize ruminal microbial protein synthesis. This is achieved by providing a diet balanced with sufficient ME and aim to provide enough effective fibre to decrease ruminal passage rate and prevent extensive digestion of starch in the small intestine, which may lead to metabolic problems such as low milk fat synthesis. Fulkerson *et al* (2007) concluded from their study that all the forage species they investigated could provide sufficient microbial protein (95-173g MP/kg DM) for the maintenance of a 600kg dairy cow producing 30kg milk per day. According to the AFRC (1993), a 600kg dairy cow producing 30kg of milk per day, with 4.04% fat and 3.28% protein would require 1679g microbial protein (MP) and 220 MJ ME/cow/day. To meet this, the cow would need to consume 19.1 kg DM/cow/day of a feed containing 89g MP/kg DM and 11.5 MJ ME/kg DM. However Fulkerson *et al.* (2007) found that the ME value of all the grasses investigated in their study was below 11.5 MJ/kg DM, and conformed that energy is still the first limitation to milk production from pasture-based systems.

Botha *et al*. (2007) conducted an experiment in which kikuyu was over-sown with westerwold ryegrass. They determined its DM production, as well as its nutritive value for dairy cows. Their results illustrated that the ME content of the kikuyu-ryegrass was significantly higher in spring than summer and autumn when kikuyu became more dominant. They also reported a decrease in the Ca content of the kikuyu-ryegrass pasture during summer and autumn, which they attributed to the change in the pasture from ryegrass-dominant to kikuyu-dominant during this period. They concluded that the low ME content of kikuyu-ryegrass pastures during summer and autumn was the first limitation to milk production.

2.3 Factors that limit milk production from pastures

2.3.1 Protein/nitrogen content of the diet

According to Miller *et al*. (2001), levels of milk production from pasture are limited by low efficiency of use of pasture nitrogen (N) for milk production, largely as a result of poor conversion efficiency of forage N to microbial protein and consequential losses of N from the rumen. A significant proportion of dietary N can be lost from the rumen as ammonia because of the rumen microbial population's inability to capture the non-protein nitrogen (NPN) released during the proteolysis of plant proteins. This is partly because leaf proteins in grazed grass are highly soluble and rapidly degraded by plant and microbial proteases after ingestion. High levels of rapidly degrading protein results in a high concentration of ammonia in the rumen, which requires sufficient energy in order to be converted to microbial protein (Taweel *et al*., 2004a). Due to the lack of synchrony between energy and protein supply of grass, a large proportion of rumen ammonia will be absorbed trough the rumen wall and into the blood stream and be excreted in the urine leading to high N losses.

2.3.2 Fibre content of the diet

When ruminants consume fibrous forages as part of the diet, only 10-35% of energy intake contained in the forages is captured as net energy, because 20-70% of cellulose may not be digested by the animal (Varga & Kolver, 1997). Metabolisable energy is thought to limit milk production from forage diets (Van Vuuren, 1993; Kolver & Muller, 1998; Marais, 2001; Kolver, 2003). This is due to the imbalance in energy and protein supply in the rumen when fibrous forages are consumed. The high levels of rapidly rumen degradable protein and slowly fermentable fibre in grass is thought to be the primary cause (Taweel *et al*., 2004a). Slowly fermentable fibre resides in the rumen for a long time, occupying space and limiting the capacity for dry matter intake (DMI). The water content of the pasture also has a major influence on the pasture intake capacity of cows (Weston, 2002).

2.3.3 Intake per se

However some authors state that low DMI could be a major factor limiting milk production from high producing dairy cows under grazing conditions (Dalley *et al*., 1999; Gibb *et al*., 1999; Reis & Combs, 2000; Kolver, 2003). According to Taweel (2004), the low DMI, rather than energy content of the grass has been identified as the main factor responsible for the lower total energy intake and milk production. Kolver & Muller (1998) also cited low DMI of perennial ryegrass as a major factor limiting milk production of high producing dairy cows under grazing conditions.

2.4 Dry matter intake of the grazing ruminant

There are three factors that affect DMI of grazing cows: 1) nutrient requirements of the cow; 2) factors associated with distension of the alimentary tract; and 3) limits to the potential pasture DMI resulting from the combination of pasture and animal factors affecting grazing behaviour (Bargo *et al*., 2003a). Low pasture DMI has been identified as a major factor limiting milk production of high producing dairy cows within grazing systems (Kolver & Muller, 1998). In ruminants, DMI is a function of eating motivation and rumen capacity. Palatability is strongly related to eating motivation. In the grazing ruminant, DMI is influenced by sward structural characteristics, sward availability and grazing behaviour (Gross *et al*., 1993). Voluntary intake of forages by ruminants is largely dependant on feed retention time in the rumen, which is primarily affected by the fibre component of the diet. Nandra *et al*. (1993) found that DMI was affected by soluble fractions of ingested organic matter (OM), such as water-soluble carbohydrates. Given a choice, cattle will select diets that maximise their digestible DMI.

The nutrition of grazing cows is different from that of housed animals:

Firstly, the diet of cows grazing pasture is more variable due to the botanical composition of pastures. It’s also variable over time, for different species may grow at different times of the year, and even a single specie will change in composition and nutritive value as it grows to maturity (McDonald *et al*., 2002).

A second important feature of the grazing animal is that it has to spend time and energy harvesting its food. Therefore, the diet of the grazing animal is more difficult to evaluate. Taweel (2004) stated that herbage allowance was identified as one of the most important factors influencing pasture DMI by dairy cows. Pasture DMI increases as herbage allowance increases, but at a progressively lower rate, indicating that the relationship between herbage allowance and DMI is curvilinear and asymptotic.

Assuming perfect herbage allowance, feeding frequency, environment and management conditions, and good palatability, feed intake in the ruminant is most likely controlled by both physical and physiological factors. Physiological factors include end products of fermentation and intestinal digestion, rumen pH and osmolality, hormones secreted by the endocrine system such as insulin and glucagons, or secreted by the gastro intestinal tract, such as gastrin and cholecystokinin (Grovum, 1981). Physical factors include the fill capacity of the rumen (Tas *et al*., 2004). It is generally believed that, as the energy density of the diet increases and the fibre content of the diet decreases, physical factors pose less constraint on intake, and physiological factors become more important (Taweel, 2004).

Animal factors such as lactation status and nutritional demands have been shown to influence grazing behaviour and hence DMI (Gibb *et al*., 1999). There are also several plant characteristics which affect intake, namely: palatability, which relates to taste, odour and surface characteristics of the plant; leaf : stem ratio, which relates to the availability of green herbage; plant habit, meaning its accessibility to grazing animals; and the dimensions of the leaf and stem, which relates to the resistance to mastication (Stone, 1994; Taweel, 2004).

Selection of nutrients from pasture by the grazing ruminant is not constant because pastures vary in composition and herbage intake is affected by grazing management (Wales *et al*., 1998).

2.4.1 Estimating intake

A prerequisite to balancing nutrients in the diet of the grazing cow is the ability to predict nutrient intake from pastures (Wales *et al*., 1998). Estimation of DMI in grazing cows is more difficult and less accurate when compared to determination of DMI by cows on TMR systems (Bargo *et al*., 2002).

Estimating the intake of grazing ruminants is a difficult task. Grazing animals have the opportunity to select their diet and many factors interact to determine what they choose. The quantity of forage eaten each day depends on the time spent grazing, the rate of biting, and the size of each bite (Minson, 1990; Bargo *et al*., 2003a).

Pasture intake can be determined with animal-based techniques, pasture-based techniques, or equations. Animal- based techniques include the use of markers like alkanes, chromium oxide etc. Animal based techniques to determine intake were not used in this trial, therefore these techniques will not be discussed here. The pasture-based technique involves measuring the amount of pasture available before and after grazing (Kellaway *et al*., 1993). This can be done with a rising plate meter (RPM). The rising plate meter is based on the Ellinbank pasture meter (Earle & MacGowan, 1979) and manually records pasture height in 5mm increments with a counter (Sanderson *et al*., 2001). The rising plate meter is used as a non-destructive technique to measure the available herbage mass present on a pasture. The main disadvantage of pasture-based techniques is that pasture DMI is estimated for a group and not individually (Bargo *et al*., 2003). Malleson (2008) found that the RPM was not accurate enough to determine differences in pasture intake between cows on different treatments. Reeves *et al*. (1996b) also found that the RPM was not accurate enough to detect differences in pasture intake of cows fed different levels of concentrate.

Another method available for estimating pasture intake is the use of prediction equations using various animal and pasture variables. There are several equations available, but only three will be discussed here.

NRC (2001) predicts the dry matter intake with an equation using 4% fat corrected milk (FCM), body weight (BW) and week of lactation (WOL):

$$\text{DMI(kg/day)} = ((0.372)(\text{FCM}) + (0.098)(\text{BW}^{0.75}))(1\text{-}e^{(-0.192*(\text{WOL} + 3.67))})$$

Caird & Holmes (1986) used data from nine experiments conducted with cows grazing ryegrass pastures, consuming 1.2 kilograms of concentrate per day, and producing 21.5 kilograms of milk per day on average to predict total DMI. For rotationally grazed cows, the best equation ($r^2 = 0.68$) was:

$$\text{TOMI} = 0.323 + 0.177\text{MY} + 0.010\text{BW} + 1.636\text{CDMI} – 1.008\ \text{HM} + 0.540\ \text{PA} – 0.006\text{PA}^2 – 0.048\text{PA} * \text{CDMI}$$

Where CDMI = concentrate DMI in kg/day; MY = milk yield in kg/day; HM = herbage mass in tonne of OM/ha; and PA = pasture allowance in kg OM/cow/day (Bargo *et al*., 2003).

Vanquez & Smith (2000) used data from 27 grazing studies with dairy cows to obtain regression equations to predict total and pasture DMI. The best equation for pasture DMI was:

PDMI = 4.47 + 0.14FCM + 0.024BW + 2.00CBW + 0.04PA + 0.022PASUP + 0.10SUP – 0.13NDFp – 0.037LEG

Where CBW = change in body weight in kg/day; PASUP = pasture allowance and total supplementation interaction; SUP = total supplementation in kg DM; NDFp = NDF in pasture available as %DM; and LEG = percentage of legumes in pasture. Bargo et al. (2004) compared the above three equations for estimating DMI. They found that the estimations of DMI with the equations of NRC (2001) and Caird & Holmes (1986) did not differ from the measured DMI ($P>0.05$), but the estimation with the equation of Vanquez & Smith (2000) was higher than the measured DMI. They also stated that the NRC (2001) equation had the advantage of being simpler to use and requiring animal factors only.

Another way of estimating intake is through the NDF content of the diet. Bargo et al (2002) found NDF intake to be 1.3% the of body weight of cows consuming 60% pasture and 40% concentrate. Fulkerson *et al*. (1998) found that the NDF intake of cows grazing low quality pastures such as kikuyu can be as high as 1.4% of body weight.

Malleson (2008) estimated pasture intake using the NDF as a percentage of body weight method. The cows in this trial consumed 5.5 kg of concentrate with a NDF content of 11.9%. According to this method, the cows in the above trial consumed 8.5 kg DM of pasture per day.

2.5 Dry matter yield of pasture species

The dry matter yield of the pasture species used in this study will not be discussed in this thesis, but can be found in Van Der Colf (ongoing MSc thesis). Thus only a short discussion on the factors influencing DM production will be included in this review.

The dry matter production or yield of a pasture specie is determined by genetic factors, such as grass specie and variety, and environmental factors, such as climate, soil type, fertilization level, and grazing management (Marais, 2001). The yield of pasture species varies due to three main factors: 1) the site class, which is defined by rainfall, soil type, and elevation; 2) the quality of the sward and 3) the supply of N (Castle, 1985).

According to Botha *et al*. (2007a), over-sowing kikuyu with annual ryegrass had no effect on the DM production of kikuyu during the summer and autumn. No data could be found on the effect of over-sowing perennial ryegrass into kikuyu.

2.6 Milk yield and composition of cows on pasture based production systems

Milk yield and composition are largely controlled by nutrient supply to the udder, which is in turn influenced by digestible dry matter intake (Miller *et al*, 2001). The digestible DMI and the chemical composition of the diet determine the amount and type of nutrients available for milk production (Tas *et al*., 2005). One of the main constraints for milk production in grazing systems is dry matter intake in highly productive dairy cows, resulting in an inability to meet their nutrient requirements for milk production (Smith *et al*., 2005).

There are two major nutritional barriers in utilising grazing systems for high milk production per cow. First, limitations are imposed by constraints to voluntary intake of fresh herbage provided *ad libitum*. One of the biggest constraints is the high moisture content which has a fill effect on the rumen, decreasing the amount of dry matter that the cow can consume. Second, energy and protein supplied by herbage, when consumed to appetite as the sole feed, may be insufficient to meet the requirements of highly productive animals (Muller, 1993). High producing dairy cows on pasture need supplemental energy to reach their genetic potential for intake and milk production (Bargo *et al.*, 2002). Cows that graze temperate pastures maintain a higher level of milk production than cows grazing subtropical pastures (Reeves & Fulkerson, 1995). This is mainly due to the higher nutritive value of temperate pasture species. No data could be found to indicate the effect of over-sowing temperate pasture species into subtropical pasture species on milk yield and composition.

2.6.1 Fat and protein

Concentrations of fat, protein, and lactose in milk are affected by energy intake, type of diet, breed of cow, genetic variation, time of year, and stage of lactation. Milk fat is the constituent of milk solids that can be most readily influenced by nutritional manipulation (Stockdale *et al.*, 2003). In general, dietary effects on milk protein content are far less than the effects on milk fat content (DePeters & Cant, 1992). For example, Sutton (1989) reported that milk fat can be altered by ± 3 percentage units through nutritional means, however, protein can only be altered by 0.6 percentage units and lactose can rarely be altered at all. Botha *et al.* (2007b) found that the milk fat content of cows grazing kikuyu pastures over-sown with annual ryegrass was higher ($P < 0.05$) than that of cows grazing pure kikuyu pastures. Pulido & Leaver (2001) reported that the fat content of milk decreased significantly ($P < 0.01$) as the level of concentrate fed to grazing dairy cattle increased.

The milk protein yield may be stimulated by propionate production in the rumen, a higher amount of glucose absorbed in the small intestine and/or a higher amino acid absorption in the small intestine (Tas *et al.*, 2005).

2.6.3 Milk urea nitrogen

Milk urea nitrogen (MUN) and blood urea nitrogen concentrations have long been used as indicators for protein status of animals (Jonker *et al.*, 1999). A MUN value below 10mg/dl indicates that the diet is protein deficient, while a value above 18-20 mg/dl indicates that the diet fed to the cows contains protein in excess of their requirements. A high milk urea nitrogen concentration is indicative of surplus CP in the diet when insufficient energy is available in the rumen to convert NH_3 into microbial protein. The excess NH_3 is then absorbed into the blood stream and transported to the liver where it is converted to urea. Some of the urea is circulated back to the rumen via saliva, but most is excreted in the urine and milk. Bargo *et al* (2002) examined the effect of concentrate supplementation on MUN when cows grazed at two pasture allowances. They reported that cows on a low pasture allowance that received concentrate supplementation had MUN concentrations of 11.6mg/dl. This was numerically lower than the average for the cows that did not receive concentrate supplementation (13.9 mg/dl). The optimum MUN level is between 12-18 mg/dl.

2.7 Estimating changes in body reserves

Managing body reserves is critical for successful cow management, and requires an accurate assessment of the cow's condition or energy reserves. Body weight alone is not a good enough indicator of energy reserves, as a certain weight might be considered adequate for a small breed cow (ex. Jersey), but could indicate severe depletion of body reserves in a large breed cow (ex. Holstein- Friesian). For example, Gibb *et al*. (1992) found that energy reserves varied by as much as 40% in cows of the same body weight and highlights the inaccuracy of relying on body weight alone as an indicator of cow condition. Because tissue mobilization in early lactation occurs as feed intake increases, decreases in body tissue weight can be masked by increased gut fill, such that body weight changes do not reflect changes in adipose and lean tissue weight (NRC, 2001). Scoring body condition and assessing changes in the body condition of dairy cattle has become strategic tools in both farm management and research (Roche *et al*. 2004).Changes in body condition measured over several weeks provide gross, but useful information about the cow's current nutrient intake relative to its requirements (Roche *et al.*, 2004).

Various systems of body condition scoring are in use, which use different numerical scales to assess body condition. In all of the scales lowest values represent emaciation and high values obesity.

However, body condition scoring is a subjective measure of energy reserves, and depends on the scorer's view of adequate and inadequate condition. Some animals are naturally sharper of bone or have a coarser tail head setting (Hutjens, 2003) which could be mistaken for the absence or presence of fat.

2.8 Substitution rate when concentrates are fed

The milk response to concentrate supplementation of dairy cows grazing pasture-based systems is affected by pasture quality, pasture allowance, nutritive value of the concentrate, level of concentrate supplementation, and the genetics of the cow (Kellaway & Porta, 1993; Bargo *et al.*, 2003a). Among these factors, the amount of pasture offered per cow per day or the pasture allowance has a major effect on substitution rate (Stockdale *et al.*, 1997; Bargo *et al.*, 2002). Farmers can influence pasture intake by controlling pasture allowance, the height/mass of pasture on offer and the amount of supplement fed (Wales *et al.*, 1999). High substitution rates may reduce profitability, due to inadequate use of the pasture available, unless stocking rates are also increased.

Substitution rate is defined as the decrease in pasture intake per kilogram of supplemental feed consumed (Kellaway & Porta, 1993), and is calculated as the pasture intake when cows are not supplemented minus the pasture intake when cows are supplemented, divided by the supplement intake. The objectives of supplementation include: 1) increase milk production per cow; 2) increase stocking rate and milk production per hectare; 3) improve the use of pasture with the higher stocking rate; 4) maintain or improve BCS to improve reproduction during pasture shortage (Bargo *et al.*, 2003b). Associative effects between forage and grain components of the diet will in some circumstances have important consequences for the efficiency of utilization of nutrients in grain and forage, and for product quality (Dixon & Stockdale, 1999).

While the objective of feeding supplements is to increase the total dry matter and metabolisable energy intakes, compared to those achieved on pasture alone, cows generally substitute some the supplement for some of the pasture they would have otherwise consumed (Stockdale, 2000). Dixon & Stockdale (1999) suggested that substitution rate is low when the energy intake of cows is low in relation to energy requirements. Substitution rate increases as the amount of supplementation increases. There is usually a negative relationship between substitution rate and milk response. When substitution rate is large, resulting in a small increase in DMI, milk response is low (Bargo *et al*, 2003b). Milk response to supplementation can be defined as the increase in kilograms of milk per kilogram of supplement DMI calculated relative to an unsupplemented treatment (Bargo *et al.*, 2003a). The level of concentrate supplementation and the associated milk response have a major effect on the profitability of pasture-based dairy farming (Meeske *et al.*, 2006). Meeske *et al* (2006) conducted a study to determine the long term effects of concentrate supplementation on milk yield and other parameters of Jersey cows grazing pasture-based systems and concluded that the return on concentrate feeding diminished as the level of concentrate supplementation increased.

There are other factors that will also affect pasture intake, like nutritive characteristics of the pasture, and the species composition of the pasture, which are more difficult to manage

(Stockdale, 2000). Kellaway & Porta (1993) have suggested that stocking rate increases with the amount of concentrate supplemented to grazing dairy cattle.

2.9 Neutral detergent fibre

The primary chemical components of feeds that determine their rate of digestion is the NDF content, which is itself a measure of cell wall content. There is a negative relationship between the NDF content of feeds and the rate at which they are digested (McDonald *et al*., 2002). Neutral detergent fibre is the residue after extraction with boiling neutral solutions of sodium lauryl sulphate and ethylenediaminetetraacetic acid (EDTA). It consists mainly of lignin, cellulose, and hemicellulose. Mertens (1994) suggested that NDF could be used to define the upper and lower bounds of dry matter intake. At high NDF concentrations in diets, rumen fill limits DMI, whereas at low NDF concentrations energy intake inhibitors limit dry matter intake. The minimum amount of dietary NDF needed is based largely on ruminal and cow health (NRC, 2001). The concentration of NDF is inversely related to ruminal pH because NDF generally ferments slower and is less digestible than NFC, and because the majority of dietary NDF in typical diets is from forages with a physical structure that promotes chewing and saliva production (i.e. buffering capacity). Diets with less than 25% total NDF and less than about 16% NDF from forages depressed milk fat percentage (Clark & Armentano, 1993; Depies & Armentano, 1995).

2.9.1 Effect on intake

Neutral detergent fibre concentration is considered to be the parameter most closely associated with voluntary intake by ruminants (Marais, 2001). Fulkerson *et al*. (1998) found that the NDF intake of cows grazing kikuyu can be as high as 1.4% of body weight, however according to Marais (2001) milk production of dairy cows is maximized when NDF intake is equivalent to 1.2% of the body weight. It should be noted, however, that this value was obtained on cows being fed mostly TMR's and as mentioned by Fulkerson *et al* (1998) the higher value of 1.4% is more applicable to C_4 grasses. The NDF concentration of low quality forages such as kikuyu is considered to be an important factor restricting the dry matter intake of cows grazing pastures (Marais, 2001). Hoover (1986) found a high correlation (-

0.76) between DMI and NDF content for all forage diets. According to Robinson & McQueen (1997) the properties of NDF in common feedstuffs differ in the limitations they impose on intake in dairy cows.

2.9.2 Effect on digestion

Four major factors regulate ruminant fibre digestion: 1) plant structure and composition, which regulate bacterial access to nutrients; 2) nature and the population densities of the predominant fibre digesting micro-organisms; 3) microbial factors that control adhesion and hydrolysis by complexes of hydrolytic enzymes of the adherent microbial populations; and 4) animal factors that increase the availability of nutrients through mastication, salivation and digesta kinetics (Cheng *et al*., 1991). The major fibrolytic bacteria in the rumen include *Fibrobacter succinogenes, Ruminococcus flavefaciens,* & *Ruminococcus albus* (Cheng *et al*., 1991). Fungi account for approximately 8% of the microbial biomass in the rumen. Fungi seem to have an important role in fibre digestion as they are capable of penetrating both the cuticle and the cell wall of lignified tissues (Varga & Kolver, 1997). Results from some *in vitro* studies have suggested that 19-28% of total cellulose activity in the rumen can be attributed to protozoa; however, digestion by protozoa seems to be limited to very susceptible tissues such as mesophyll cells (Varga & Kolver, 1997).

A strong negative correlation exists between NDF and the digestibility of grasses. Tropical grasses generally have higher NDF concentrations than temperate species. Marais (2001) reported a NDF concentration of 546g/kg DM for *L. perenne*, compared with the NDF concentration of *Pennisetum clandestinum* ranging from 581-741 g/kg DM. Hoffman *et al.* (1993) reported that forage species differed in their rates of ruminal NDF degradation. It is well known that the digestibility of forages is strongly related to cell wall content (NDF content) and its lignification (Van Soest, 1994). Neutral detergent fibre and acid detergent lignin (ADL) are thought to limit digestible DMI due to their effect on physical fill of the gastrointestinal tract and its effect on satiety. The stage of plant maturity affects the ruminal NDF degradation, as the plant matures, protein levels decrease, whereas cellulose and hemicellulose content increases along with lignin content. Hoffman *et al* (1993) also stated that both species and maturity affects all degradation fractions as well as the degradation rate.

Estimates of the minimum amount of NDF necessary to maintain rumen production of acetate and butyrate in sufficient amounts to avoid milk fat depression have ranged from 25-40% (Dixon & Stockdale, 1999). The lower estimate was made with cows grazing spring pastures, while the higher estimate was made with more intensive systems (Dixon & Stockdale, 1999).

2.9.3 Effect of concentrate supplementation on NDF degradation

Associative effects often occur when both grain and forage are included in the diet of ruminants due to digestive and metabolic interactions changing the intake of ME. Positive associative effects occur when ME intake is greater than that expected from the forage and grain components if they had been fed alone, while negative associative effects occur when ME intake is less than expected (Dixon & Stockdale, 1999). In the nutrition of dairy cows, most often associative effects are due to changing voluntary intake of the forage component and/or the digestion of the fibrous components of forage when grain is included in the diet. Positive associative effects usually occur when forages contain low concentrations of a limiting nutrient for either rumen microbes, like nitrogen or sulphur, or the animal, like phosphorous, is fed with a grain containing a high concentration of that nutrient, and the latter supplies sufficient amounts of this nutrient to balance the entire diet.

It appears that when negative associative effects occur with low to medium digestible forages, they are most commonly due to the readily fermentable component of grain reducing the rate of rumen microbial degradation of the fibrous components of the forage, this in turn may decrease the intake and/or the digestion of forages in the entire gastrointestinal tract. Ruminants can partially compensate for a decrease in the rate of digestion of forage fibre in the rumen by increasing the retention time of fibrous residues in the rest of the digestive tract, but this often leads to a decrease in forage intake. A change in the site of microbial protein synthesis from the rumen to the large intestine will decrease the supply of absorbed amino acids to the animal. Since little if any of the microbial protein synthesised in the large intestine will contribute to the absorbed amino acid supply (Dixon & Stockdale, 1999). According to Michalet-Doreau (2002), current data suggests that negative associative effects on fibre digestion can be attributed to several factors including ruminal characteristics, retention time of particles and ruminal microbial activity. In the rumen, the negative effect of supplementation on fibre digestion would be related a decrease in fibrolytic activity of solid-associated micro-organisms, without modifications in the concentration of solid-associated micro-organisms (Michalet-Doreau, 2002). Because fibre fermenting bacteria are limited by a ruminal pH of less than 6, depression in fibre digestion at high inclusion rates of concentrates can most likely be explained by the rapid degradation of non-structural carbohydrates (Varga & Kolver, 1997). Fulkerson *et al*. (2006) found that for every 9% increase in concentrate intake as a proportion of diet, there was an 8% decrease in pasture digestibility. Vadiveloo & Holmes (1979) showed that the severity of the depression depends on the quality of the forage; higher quality forages are affected more severely. This implies that mature ryegrass and other less digestible forage species, such as kikuyu, could be less prone to a depression in fibre digestion and intake (Meissner *et al*, 1991).

2.10 Effect of concentrate supplementation on rumen fermentation parameters of grazing dairy cows

The aim of concentrate supplementation is to increase the digestible nutrient intake of the cow to improve body condition, reproduction and milk production (Bargo *et al.*, 2003a). Another reason for concentrate supplementation is to overcome the nutrient deficiencies of forages. Concentrates are usually used to increase the ME content of the diet (Donker *et al.*, 1976). According to Van Vuuren *et al.* (1986), the surplus of nitrogen in herbage is balanced out to some degree by using concentrate mixtures that are low in protein but high in energy. These concentrate mixtures are mainly composed of ingredients that contain a high proportion of readily fermentable carbohydrates. The level of concentrate feeding and the associated milk production response have a major effect on the profitability of pasture based dairy farming systems, especially because the milk response per kilogram of concentrate fed tend to decrease as the level of concentrate supplementation increases (Bargo *et al.*, 2003b; Meeske *et al.*, 2006). A level of 4kg of concentrate per cow per day is considered a moderate level of supplementation. Above 4kg per cow per day the milk production response decreases dramatically, which makes a higher level of supplementation to grazing dairy cows less appealing to farmers (Bargo *et al.*, 2003b). A supplementation level of 8kg of concentrate per cow per day (fed in two parts; 4kg per milking) is considered to be a high level of concentrate supplementation when cows are offered only pasture as the primary source of fibre (Meeske *et al.*, 2006; Van Vuuren *et al.*, 1986).

When both forage and high readily fermentable carbohydrate (RFC) concentrates are fed to dairy cows, the rumen fibrolytic micro organisms have to compete with the RFC digesting micro organisms for substrates such as ammonia, peptides, and sulphur (S) necessary for growth. Since RFC fermentation primarily affects the digestion of fibrous components of forages, it is to be expected that the decrease in fibre digestion in the rumen will be directly related to the fibre content of the forage (Dixon & Stockdale, 1999). The effect of readily fermentable carbohydrates on the rumen DMD of forages has been linearly related to their fibre content and according to Dixon & Stockdale (1999) is more closely related to the total NDF content of the forage than the cellulose or hemicellulose content. According to Hoover (1986), the following theories have been used to explain the depressing effect of RFC on fibre digestion: a preference by rumen microbes for RFC rather than fibre components; a decrease in ruminal pH caused by rapid RFC fermentation with a resulting depression in fibre degradation; and competition for essential nutrients resulting in preferential proliferation of RFC digesting microbes.

As stated above, when RFC’s are added to forage diets, fibre digestion is depressed. As little as 10-15% of the diet as RFC can impair fibre digestion, but a severe depression is usually associated with RFC or grain supplementation of 30% or more of DMI (Hoover, 1985). In the following sections the effect of RFC additions to forage diets on the rumen pH, volatile fatty acid, and ammonia concentrations will be discussed.

2.10.1 Ruminal pH

Optimal digestion of the fibrous components of the diet in the rumen depends on maintaining the pH of this environment within a narrow range (Hoover, 1986). High levels of energy supplementation have been shown to disrupt normal rumen function by depressing rumen degradation of the fibre fractions of forages (Reeves *et al.*, 1996a). In this regard, a decline in ruminal pH, normally associated with cereal-grain supplements, results in a reduction in cellulolytic activity. Mould *et al.* (1984) described the effect of rumen pH on fibre digestion as biphasic, whereby a pH reduction from 6.8 to ±6.0 resulted in a moderate depression in fibre digestion, whereas a depression below 6.0 caused a severe decrease in fibre digestion. According to Taweel (2004), a low rumen pH severely reduces the activity of cell wall degrading bacteria (cellulolytic bacteria), leading to a lower clearance rate of fibre and particles, and hence a decreased throughput and DMI.

The threshold pH at which a depression in fibre digestion occurs is unclear from studying the literature. Mould *et al*. (1984) reports that when rumen pH decreases below 6.0, it results in a loss of fibrolytic activity by micro-organisms in the rumen. According to Dixon & Stockdale (1999), the optimal pH for microbial digestion of fibre is in the range of 6.6-7.0. They also state that digestion is severely reduced at a pH of less than 6.2 and is negligible at a pH of less than 6.0. Most authors agree that fibre digestion is severely depressed when rumen pH falls below 6.0 (Mould *et al*., 1984; Mould & Orskov, 1984 Dixon & Stockdale, 1999). According to Hoover (1986), most studies, both *in vivo* and *in vitro*, showed precipitous losses of fibrolytic activity below pH 6.0. Complete cessation of fibre digestion often occurred between pH 4.5-5.0, while moderate, transient depression, mainly caused by a reduction in the number of cellulolytic bacteria attached to fibre particles, was found between pH 5.8 and 6.2 (Meissner *et al*., 1991). This implies that lag time would increase, thereby impairing initiation of digestion.

The pH in the rumen is a consequence of a number of factors. Fermentation produces volatile fatty acids (VFA's) which reduce pH when production exceeds absorption through the rumen wall. Thus the rumen pH is often decreased due to rapid fermentation of RFC following their ingestion and the decrease tends to be linearly related to the level of RFC fed (Kennedy & Bunting, 1992). Malleson (2008) conducted two trials, one in which cows grazed annual ryegrass and one in which they grazed kikuyu. During both trials cows received 6 kilograms of concentrate supplementation per cow per day. When cows grazed annual ryegrass, this researcher found that the mean ruminal pH was 6.14, which did not differ from the ruminal pH of the cows that grazed kikuyu pastures (6.15).

Cajarville *et al.* (2006) conducted an experiment in which they investigated the effect of pulse grain supplementation of grazing dairy cows on ruminal pH. They observed that the minimum mean pH value occurred four hours post supplementation. Bargo *et al*. (2002) conducted an experiment in which the effect of concentrate supplementation on pasture degradation was investigated. They found that the highest rumen pH values occurred before concentrate feeding and the lowest values occurred a couple of hours after supplementation. The lack of consistency with the amount of concentrate supplemented on ruminal pH of dairy cows on pasture suggests that the relationship between the amount of concentrate supplementation and the ruminal pH of the animal is not simple (Bargo *et al*., 2003a). The interaction between the amount and type of concentrate supplemented and the pasture intake and quality may play a key role.

2.10.2 Volatile fatty acid concentrations

Volatile fatty acids are the end-products of fermentation in the rumen, along with carbon dioxide (CO_2) and methane (CH_4). The relative proportions in which the volatile fatty acids are present in the rumen depends on the diet fed to the ruminant. The three main VFA's produced from carbohydrate digestion are acetate, propionate and butyrate. Additional VFA'a are also formed in the rumen, generally in small quantities, by deamination of amino acids, these are isobutyric acid from valine, valeric acid from proline, 2-methylbutyric acid from isoleucine and 3-methyl butyric acid from leucine (McDonald *et al*., 2002). Mc Donald *et al*. (2002) reported the molar proportion of VFA's produced by cattle fed mature ryegrass herbage to be: acetate 0.64, propionate 0.22, butyric acid 0.11, others 0.03. The propionate is usually increased when cows are supplemented with concentrates; this is at the expense of acetate. However, acetate usually remains the VFA present in the highest proportion.

Reductions in ruminal pH with supplementation are associated with higher VFA concentrations in some studies (Bargo *et al*., 2003a). Results from most studies suggest that supplementation had no effect on the total volatile fatty acid concentration, even with a reduction in ruminal pH (Garcia *et al*., 2000; Reis & Combs, 2000). Van Vuuren *et al*. (1986) conducted a trial in which a low (1 kg) and a high (7 kg) level of concentrate were supplemented to dairy cows grazing perennial ryegrass pastures. They found that VFA concentrations decreased during the night and attributed this to low herbage consumption during this period. Bargo *et al*. (2002) conducted a trial in which they examined the effect of concentrate supplementation on milk production. In the rumen study they found that propionate concentration increased with concentrate supplementation. Concentrate supplementation also significantly increased butyrate concentration in the rumen. A linear reduction in acetate/propionate ratio was observed in grazing cows supplemented with 0, 5, or 10 kg of concentrate per day. Berzaghi *et al*. (1996) also reported that propionate concentration was increased when cows were fed maize, resulting in a lower ratio of acetate to propionate. Some studies only reported a reduction in acetate molar proportions (Khalili & Sairanen, 2000), or an increase in propionate molar proportions (Jones-Endsley *et al*., 1997) when the amount of concentrate supplemented was increased.

2.10.3 Rumen ammonia concentration

In the rumen, food proteins are hydrolysed to peptides and amino acids by rumen micro organisms, but some amino acids are degraded further to organic acids, ammonia (NH_3), and CO_2. The NH_3 in the rumen liquor is the key intermediate in microbial degradation and synthesis of proteins (McDonald *et al*., 2002). Rumen micro organisms utilize free NH_3 for synthesis of proteins for growth and fermentation of feeds (Erdman *et al*., 1986). If the diet is deficient in protein, or if the protein present in the diet resists degradation, the concentration of rumen NH_3 will be low (±50mg/l), and the growth of rumen micro organisms will be slow, hence breakdown of carbohydrates will be retarded (McDonald *et al*., 2002). If protein degradation exceeds synthesis, NH_3 will accumulate in the rumen liquor and the optimal concentration will be exceeded. When this occurs, NH_3 will be absorbed through the rumen wall into the blood stream and carried to the liver where it will be converted to urea. Some of the urea will be circulated back to the rumen via saliva, but the greater part will be excreted in the urine and ultimately wasted. According to McDonald *et al*. (2002), the optimal concentration of NH_3 in the rumen liquor varies widely, from 85 to over 300 mg/l. Hoover (1986) found that maximum cellulose digestion occurs when the rumen NH_3-N concentration reaches ±43mg/dl, while Satter & Slyter (1974) reported the minimum concentration of ruminal NH_3-N for maximum microbial protein synthesis to be 5 mg/dl.

A lower ratio of digestible N intake to digestible DMI is known to decrease NH_3-N concentration in the rumen (Van Vuuren *et al*., 1993). Moreover, a higher supply of readily available energy improves the rumen micro organisms' ability to utilise NH_3-N and reduces utilisation of amino acids as an energy source by these microbes (Nocek & Russel, 1988), reducing the NH_3-N concentration in the rumen (Taweel *et al*., 2004b). According to Bargo *et al*. (2003) the most consistent effect of concentrate supplementation on ruminal fermentation is a reduction in rumen NH_3-N concentration. They also suggest that the reductions in NH_3-N could be associated with a higher capture of NH_3-N from highly degradable pasture CP. In the experiment conducted by Cajarville *et al*. (2006), it was found that the maximum NH_3-N concentrations were observed 8 hours after the morning supplementation and that the maximum pH coincided with the minimum NH_3-N concentration. Furthermore, these researchers also found a low, but significant negative correlation between these two parameters when all measurements were considered ($r = -0.39$; $P<0.001$; $n = 185$). Elevated concentrations of ruminal NH_3-N are common when cows are fed fresh grass from temperate climates (Berzaghi *et al*., 1996). The N fractions of temperate pastures are rapidly and extensively degraded in the rumen, producing NH_3-N (Cajarville *et al*., 2006). Grains containing readily fermentable carbohydrates are suggested to improve the microbial incorporation of the NH_3-N produced from the pasture through optimizing synchronisation (Owens *et al*., 1997). According to Berzaghi *et al*. (1996), for cows grazing fresh perennial ryegrass pastures, ruminal NH_3-N peaked at 300mg/dl when 1 kg of an energy concentrate was supplemented and at 20mg/dl when 7 kg of an energy concentrate was supplemented.

2.10.4 Degradation rates of pasture species

Supplementation of concentrates to grazing dairy cows is intended to increase the overall energy intake and energy availability to the animal (Meissner *et al*., 1991). However, often the intake and digestion of forages are depressed; with the result that energy intake is either increased marginally, or not at all. Both the quantity and the fermentation rate of the supplement can affect the rumen environment and hence the utilization efficiency and degradability of the forage (Cajarville *et al*., 2006). Meissner *et al*. (1991), found a depression in both the rate and extent of cell wall degradation when ryegrass was supplemented with maize meal. They further showed that supplementation significantly reduced NDF disappearance when cows grazed kikuyu pastures. Cell wall degradation is severely depressed by energy supplementation only at NDF values below 55-60%. Disregarding supplementation, digestion of the cell wall is particularly slow or depressed when the NDF content is above 55-60% (Meissner *et al*., 1991). Van Soest (1976) and Mertens & Ely (1979) reported a similar level of NDF (55-60%) below which cell wall degradation was depressed by energy supplementation. The phenomenon was explained by suggesting that structural components are well-developed at cell wall contents above this level and that lignification has become a significant factor. The latter prevents fibrolytic digesters from gaining access to the fermentable tissues of the plant material. In the context of energy supplementation, these organisms are probably less active and multiply less vigorously while the competition for available nutrients between these organisms and the proliferating amylolytic bacteria is less severe (Meissner *et al*., 1991).

It would appear that the most likely reason for the depression in cell wall digestion and intake in young, actively growing pastures, such as annual ryegrasses, is the high demand for essential nutrients by proliferating amylolytic bacteria at the expense of slower growing cellulolytic organisms. In more mature forages, or forages with high cell wall contents, cellulolytic activity is comparatively lower. Cajarville *et al*. (2006) observed that supplementation only affected the fractional dry matter degradation rate of the forage, which they found to be lower when grain was fed, compared to pasture alone. Bargo *et al*. (2002) also found that concentrate supplementation decreased the rate of NDF degradation in the rumen.

2.11 Cornell net carbohydrate and protein system (CNCPS)

The CPM-Dairy uses two approaches to evaluate and formulate rations: a modification of the classical NRC system and the CNCPS. The CNCPS model has a mechanistic ruminal sub model that uses carbohydrate and protein degradation rates to predict the amount of feed that is fermented in the rumen and the amount that escapes undigested to the lower digestive tract (Anquino, *et al*., 2003).

The CNCPS model can be used to give relatively realistic predictions of ME and MP supplies and subsequently milk production when cows are grazing medium to high quality pastures as well as responses to changing variables such as DMI, NDF, lignin, NDF degradation and CP (Kolver & Muller, 1998, Malleson, 2008). Kolver *et al* (1998) reported that the milk production predicted using the CNCPS model was sensitive to changes in pasture lignin content, effective fibre, rate of fibre digestion, and the amino acid composition of the ruminal microbes. Malleson (2008) found the CPM-dairy model to under-predict ME supply from pasture-based systems, and that this model was not yet refined enough for use with cows grazing pasture-based systems.

The amount of inputs necessary to perform simulations using CNCPS is high and it requires methods of feed analysis that are not always available, such as NPN analysis

(Aquino *et al*., 2003). According to Fox *et al*. (2003) model validations indicated that the CNCPS model can provide realistic estimates of animal performance over a wide range of dietary ingredients.

2.12 Summary

In this literature review general aspects such as the nutritive value and milk production potential of kikuyu and ryegrass species were discussed. In addition the effects of concentrate supplementation on pasture and its effect on rumen fermentation parameters were reviewed. From the literature review it became clear that there is very little animal production data available on kikuyu based pasture systems over-sown with italian, westerwold, or perennial ryegrass which support the necessity and importance of the research trial as described in the following chapters.

CHAPTER 3

MILK PRODUCTION FROM KIKUYU PASTURE SYSTEMS OVER-SOWN WITH ITALIAN, WESTERWOLD, OR PERENNIAL RYEGRASS

CHAPTER 3
MILK PRODUCTION FROM KIKUYU PASTURE SYSTEMS OVER-SOWN WITH ITALIAN, WESTERWOLD, OR PERENNIAL RYEGRASS

3. Introduction:

This research study was conducted in two phases, namely a lactation production study and a rumen fermentation study using cannulated animals. The rumen fermentation study, however, was conducted concurrently with the lactation study. The lactation production study will be described in chapter 3 and the rumen fermentation study in chapter 4.

3.1 Materials & methods:

3.1.1 Location, Climate, and Soil

The study was conducted at the Outeniqua Research Farm near George in the Western Cape province of South Africa. The Research farm is situated at 201m above sea level at 33º 58'38" S, 22º 25'16" E. The long term average rainfall in this area is 728mm per annum. The total monthly rainfall and the mean monthly minimum, maximum, and daily temperatures for the duration of the trial were recorded (Weather SA, 2004). The soil type where the pastures were established was classified as an Escourt soil type (Soil Classification Workgroup, 1991).

3.1.2 Duration of the trial

The study took place from 1 June 2007 to 30 April 2008. The cows were allocated to their treatment groups during May 2007 for the westerwold ryegrass and italian ryegrass treatments and at the beginning of July 2007 for the perennial ryegrass treatment. The cows grazed the westerwold and italian ryegrass treatments from 1 June 2007 to 31 March 2008. The perennial ryegrass treatment was grazed from 11 July 2007 until 1 May 2008.

3.1.3 Lay-out of camps

Approximately nine hectares of irrigated kikuyu pasture was divided into 24 paddocks. The 24 paddocks were divided into 8 blocks consisting of three experimental paddocks per block. Each paddock has two grazing strips which are not indicated on the camp lay-out. The pasture treatments were randomly allocated to the experimental paddocks in each block. Thus each pasture treatment had 8 replications. Three of the eight blocks were randomly chosen as monitor camps. These were used to cut the grass for the establishment of the regressions and for sampling the pastures. Figure 3.1 shows the camp layout along with the treatment allocation to each block as well as the camp sizes.

3.1.4 Soil preparation

Soil samples were taken and analysed (Table 3.1) at the Elsenburg Production Technology Laboratory. Fertiliser was applied in accordance with soil analysis results to raise the soil phosphorous level to 35 mg/kg, the soil potassium level to 80 mg/kg and the soil pH (KCL) to 5.5. Treatments were top-dressed monthly with 55 kg nitrogen per hectare after they were grazed (Hardy, 2006). The fertiliser used was LAN (limestone ammonium nitrate).

Table 3.1: The chemical analysis of the soil samples taken before planting italian, westerwold and perennial ryegrass over-sown into kikuyu (n = 30 per camp)

Parameter	Level in soil	Optimum range
pH (KCl)	5.3	5-7
Resistance (ohm)	300	> 300
Texture	Sand/Sand	-
Acidity (cmol/kg)	1.01	-
Ca (cmol/kg)	5.19	1-10
Mg (cmol/kg)	2.69	0.3-3
K (mg/kg)	148	60-150
Na (mg/kg)	153	< 100
P (mg/kg)	112	30-100
Cu (mg/kg)	2.57	0.5-1
Zn (mg/kg)	19.59	0.5-1
Mn (mg/kg)	34.61	> 10
B (mg/kg)	0.45	0.3-1
S (mg/kg)	12.10	> 7
C (%)	3.69	-

Ca = calcium; Mg = Magnesium; K = potassium; Na = sodium; P = phosphorous; Cu = copper; Zn = zinc; Mn = manganese; B = boron; S = sulphur; C = carbon

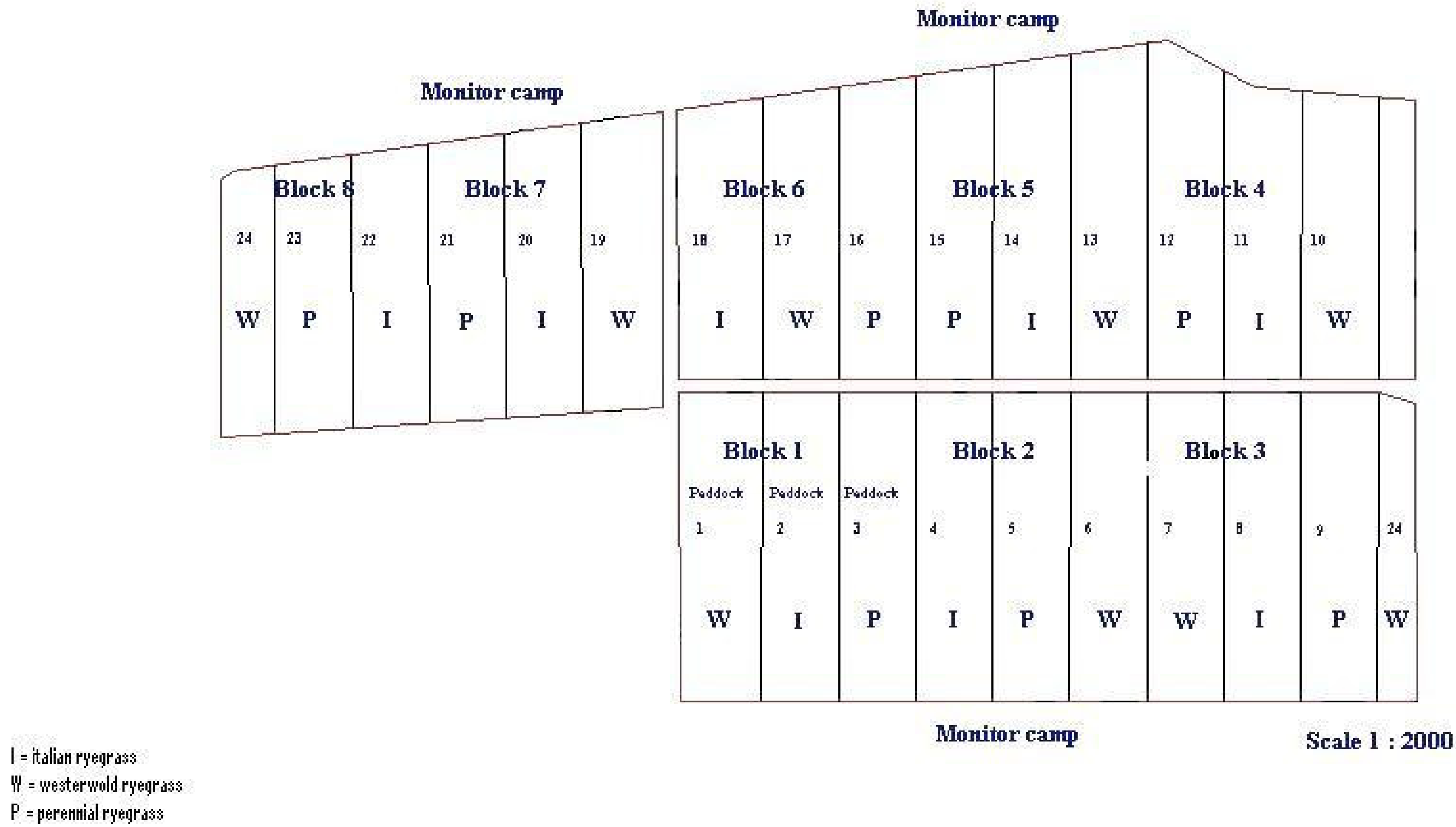

Figure 3.1: The camp lay-out for the trial which consisted of eight blocks which were divided into three paddocks per block

3.1.5 Treatments and over-sowing practices

The three pasture treatments were westerwold ryegrass (*Lolium multiflorum Lam.* var. *westerwoldicum*), italian ryegrass (*L. multiflorum Lam.* var. *italicum*), and perennial ryegrass (*L. perenne* L.) over-sown into kikuyu. Jersey cows strip grazed for four days on each paddock, resulting in a 28 day grazing cycle. A new strip was allocated to the cows after every milking. Irrigation was scheduled by means of tensiometers. Irrigation commenced at a tensiometer reading of -25 Kpa and was terminated at a reading of -10 Kpa (Botha, 2002). Perennial and italian ryegrass was over-sown into the kikuyu using an Aitchison seeder. The camps were grazed to 50 mm (a rising plate meter reading of 10), then the ryegrass was broadcats into the kikuyu bed, after which the pastures were mulched and rolled. Figure 3.2 to 3.4 show the implements used to establish the three pasture treatments. The westerwold ryegrass was over-sown into the kikuyu using broadcast seeding and a mulcher (1.6m Nobili with 32 blades). The camps were also grazed to 50 mm, then over-sown into the kikuyu bed, the pastures were mulched and rolled. The westerwold and italian ryegrass were over-sown in March 2007 and the perennial ryegrass was over-sown in April 2007 (Botha *et al*., 2006). Table 3.2 shows the cultivars, seeding densities and the over-sowing methods.

Table 3.2: The botanical composition, seeding densities and over-sowing methods for italian, westerwold, and perennial ryegrass over-sown into kikuyu

Cultivars over-sown into Kikuyu	Species	Seeding density	Over-sowing methods
Perennial ryegrass cv. Bronsyn	*Lolium perenne* L.	20 kg/ha	Graze to 50mm Mulcher Seeder Land roller
Italian ryegrass cv. Jeanne	*Lolium multiflorum Lam* var.*italicum*	25 kg/ha	Graze to 50mm Mulcher Seeder Land roller
Annual ryegrass cv. Jivet	*Lolium multiflorum Lam.* var.*westerwoldicum*	25 kg/ha	Graze to 50mm Broadcast seed Mulcher Land roller

Figure 3.2: The mulcher used on the italian, westerwold and perennial ryegrass pasture treatments to create a seed-bed for the ryegrass seeds

Figure 3.3: The Aitchison planter was used to plant the italian and perennial ryegrass treatments into the kikuyu bed

Figure 3.4: The roller was used on all three treatments after the seeds were planted

3.1.6 Dry matter production and pasture yield

The dry matter production was estimated using the difference between pre- and post-grazing mass estimated with the Ellinbank rising plate meter (RPM) (Stockdale, 1984; Fulkerson, 1997). The RPM was calibrated by developing a linear regression between the meter reading and the herbage DM mass. The calibration equation, namely $y = mx + b$, was used to predict pasture mass, where y = yield (kg DM/ha), m = factor, x = pasture height and b = constant. The RPM was calibrated three times during each grazing cycle for all three the pasture treatments. Eighteen circles with an area of 0.098m² were cut at a stubble height of 30mm per treatment (paddock) in three of the eight blocks for pre- and post-grazing during each grazing cycle. This was done on pasture estimated as low (six cuttings), medium (six cuttings) and high (six cuttings) resulting in 18 calibration cuttings for each treatment. Pasture height was measured by taking the mean of 100 RPM readings per grazing strip for each paddock before grazing. To determine the pasture height after grazing, the mean of 105 RPM readings were taken per grazing strip for each paddock. Pasture yield was estimated by using pasture height and the cumulative regression for each treatment to determine the kilograms of DM present before grazing and left over after grazing and subtracting the two values from each other. The dry matter production and growth rate of each treatment was also determined and will be reported by Van der Colf (ongoing MSc study).

3.1.7 Nutritive value determination of pasture samples

For nutritive value determination, a representative sample of 1 kg wet material was collected before grazing in each of the three monitor blocks at a stubble height of 30 mm. The plant samples were weighed and dried at 60ºC for 72h (Botha *et al*., 2007), then weighed again to determine the DM content of the samples, and to ensure that a large enough sample was collected to perform all the analyses. The samples were milled through a 1mm sieve (Retch GmbH 5657, Laboratory Mill, Rheinische Strobe 36, Germany) and packed in sealed bottles. The samples were stored in a freezer at -16 °C until analyses at UP Nutrilab (University of Pretoria). The feed samples were analyses as follows: *in vitro* organic matter digestibility (ivOMD) (Tilley and Terry, 1963; using rumen fluid from a rumen cannulated sheep on Lucerne), dry matter (DM) (AOAC 2000, procedure 934.01), ash (AOAC 2000, procedure 942.05), ether extract (EE) (crude fat, AOAC 2000, procedure 920.39), gross energy (GE) (MC – 1000 Modular Calorimeter, Operators Manual), crude protein (CP) (N was determined using a Leco N analyser, model FP-428, Leco Corporation, St Joseph, MI, USA and CP was calculated as N * 6.25), neutral detergent fibre (NDF) (Van Soest *et al.*, 1991), acid detergent fibre (ADF) (Goering & Van Soest, 1970), calcium (Ca) (AOAC 2000, procedure 965.09) and phosphorous (P) (AOAC 2000, procedure 965.17). Metabolisable energy (ME) (MJ/kg DM) was calculated from IVOMD as follows: ME = 0.84(GE * OMD) for concentrates, and ME = 0.81(GE * OMD) for forages (ARC, 1984; MAFF, 1984).

The month of September 2007 was chosen to take samples to be analysed and used for the CNCPS modelling exercise and to indicate whether energy or protein were first limiting for milk production. These samples were analysed for the same fractions as the rest of the samples. The following fractions were also determined on these samples at

Nutrilab at the University of Pretoria: starch, acid detergent lignin (ADL) (Goering & Van Soest, 1970), non protein nitrogen (NPN) (Faichney & White, 1983), soluble crude protein (solCP), neutral detergent insoluble protein (NDIP), and acid detergent insoluble protein (ADIP) (Krishnamoorthy *et al.*, 1982). Two different *in vitro* methods for the determination of energy content were used to determine which method would give the best estimation of the energy value of fresh forage. The two methods used were the Tilley & Terry (1963) method, and the UC Davis technique (Robinson *et al.*, 2004). The UC Davis technique is a summative approach based on several chemical components and an *in vitro* estimate of NDF digestion at 30 hours of incubation. It uses a single unified equation for any potential ruminant feedstuff:

$$ME\ (MJ/kg\ DM) = ((1.01 * ((((CP-solCP-ADIP) * 0.098) + (solCP * 0.08) + ((fat - 0.01) * 0.098 * 2.25) + (NDF * dNDF30/ 10000) + ((1 - CP - fat - ash - NDF) * 0.098)) * 4.409)) - 0.45) * 4.1855$$

Where CP, ADIP, solCP, fat, NDF and ash are in g/kg of DM, and NDF30 is in g/kg of NDF (Robinson *et al.*, 2004). The comparison was done with the samples collected during September 2007.

3.1.8 Cows

Forty-five multiparous Jersey cows from the Outeniqua Research Farm herd were blocked based on calving date, 4% fat corrected milk production (FCM = [0.4 * 305 day milk production] + [15 * 305 day milk production * BF% / 100]) of the previous lactation, and lactation number. Cows within blocks were randomly allocated to the three different pasture treatments (15 cows per treatment) from June to July 2007. The cows allocated to the perennial ryegrass treatment calved later than the cows allocated to the other treatments. This is because the perennial ryegrass was only grazed from the middle of July and not from the beginning of June 2007 like the other two treatments. The groups were balanced for lactation number and 4% fat corrected milk production of the previous lactation. The cows were allocated to the treatments as they calved and grazed the same treatment for one lactation (305 days). All the cows in the trial were milked together, which means they had to be separated into their individual groups after milking. To facilitate this, each cow was marked with a coloured tag attached to a light chain around her neck. Yellow tags were used for the cows allocated to the italian ryegrass treatment, blue for the cows on westerwold ryegrass and red for the cows on perennial ryegrass. Each tag had a number to indicate to which block each cow was allocated. Cows had *ad libitum* access to clean water. The cows grazed 24 hours a day, except for during milking when they were collected as late as possible and returned to pasture as soon as possible.

3.1.9 Pasture allocation and concentrate supplementation

Pasture was allocated at 9kg DM per cow per day (above 30mm, rising plate meter height). The amount of pasture allocated was based on previous trial results where Jersey cows grazed kikuyu based pasture systems on the Outeniqua Research Farm (Malleson, 2008). The stocking rate of each camp was determined by the available DM present on each camp, which was calculated using the cumulative regression for each treatment. The cumulative regression was used because the seasonal regression for each treatment was only available at the end of each season.

To ensure effective pasture use, the number of cows was adjusted every second day. This was done by predicting the carrying capacity of each treatment in each block before the cows started grazing. If the carrying capacity exceeded the number of trial cows, extra cows were added according to the carrying capacity. If the carrying capacity of the treatment was lower than the number of trial cows, the required amount of trial cows were removed from each treatment. These trial cows were put on similar pastures and returned to the trial as soon as the carrying capacity allowed.

The daily stocking rate for each treatment was recorded and this was used to calculate the average cows per hectare for each treatment. The stocking rate was calculated by dividing the average number of cows carried per day by the size of the camp on a monthly basis, and then averaged per season.

Cows were fed 4 kg of dairy concentrate each day (2 kg during each milking on an "as is" basis). The nutritive composition of the dairy concentrate was adapted according to change in the nutritive value of the pasture. During the trial period three different dairy concentrates were fed. The first was fed from the beginning of the trial (June 2007) until the end of August 2007. The second was fed from the 1st of September 2007 until 24

January 2008, and the third concentrate supplement was fed from 25 January 2008 until the end of the trial. Table 3.3 shows the nutritive composition of each dairy concentrate as provided by NOVA feeds (Nova Feeds George, Industrial Area, George Western Cape, South Africa).

Table 3.3: The chemical composition of the concentrate supplements fed to the cows that grazed the italian westerwold, and perennial ryegrass pasture treatments for the duration of the trial, on a DM basis

Fraction	Concentrate 1 June 2007 – Aug 2007	Concentrate 2 Sept 2007 – 24 Jan 2008	Concentrate 3 25 Jan 2008 - end
DM%	88.27	88.59	89.52
ME (MJ/kg DM)	13.22	12.99	12.6
CP	13.79	12.99	14.53
UDP (as % of CP)	43.10	47.13	51.5
NSC	57.47	65.86	53.5
NDF	13.22	8.74	7.16
ADF	4.14	2.64	2.4
Fat	6.09	3.56	6.8
Ash	7.36	6.90	6.1
Ca	1.38	1.32	1.6
P	0.52	0.34	0.3

DM% = dry matter percentage

ME = metabolisable energy

CP = crude protein

UDP = undegradable digestible protein

NSC = non structural carbohydrates

NDF = neutral detergent fibre

ADF = acid detergent fibre

Ca = calcium

P = phosphorous

3.1.10 Milk production and milk composition

Cows were milked twice daily at 07:30 and 15:00 in a 20 point Dairy Master swing over milking parlour with weigh-all electronic milk meters (Total Patline Industries, 33 Van Riebeeck Street, Heidelberg, 6665). The daily milk production of each cow was electronically measured, and the data was downloaded from the milking parlour computer on a monthly basis. At the end of the trial period the 305 day milk production of each trial cow was calculated by adding the daily milk production of the cow as recorded by the weigh-all electronic milk meters. If a cow did not achieve a 305 day lactation, the ARC predicted the milk production at the end of the lactation for the cow from her data collected for the milk recording scheme (Animal Improvement Institute, Agricultural Research Centre (ARC), Olifantsfontein road, Irene). The rest of the lactation data was then estimated by comparing the average of the last weeks' recorded milk data for the cow with the end point supplied by the ARC. An average rate of decline was then calculated and applied to estimate the missing values. The monthly average milk production per group per day was calculated and used to estimate the milk production per hectare for each treatment. The 305 day lactation data was used to calculate 4% FCM production.

Individual composite samples to be analysed for milk composition were taken on a monthly basis. This was done by taking a composite sample for each cow. The milking intervals for the trial cows were 8h between the morning and afternoon milking and 16h between the afternoon and morning milking. In the afternoon 8ml of milk was collected from each cow, and in the morning 16 ml of milk was collected from each cow. The two samples were then composited to give a representative 24 ml sample for each cow. Samples were preserved in sodium dichromate. The milk samples were then flown over-night to Lactolab where the samples were analysed for milk fat (BF), protein lactose and milk urea nitrogen (MUN) using infrared technology by means of the Milcoscan 6000 (Foss Integrated Milk Testing FT 6000, Foss Electric, Hillerod, Denmark). The samples were also analysed for SCC using flow cytometry by means of the Fossomatic 5000 (Foss Electric, Hillerod, Denmark). The monthly milk composition results were used to determine the monthly average BF%, protein%, lactose%, SCC and MUN for each group. At the end of the trial this data was used to calculate the kg BF/ha, kg protein/ha, milk solids/ha, average kg BF/treatment, average kg protein/treatment, as well as other milk composition indicators. The production efficiency (kg milk solids/ kg metabolic body weight) of each group was also calculated (Macdonald *et al*., 2008).

Figure 3.5: Jersey cows strip grazing italian ryegrass over-sown into kikuyu

Figure 3.6: Jersey cow with a tag around her neck to help facilitate the sorting of the cows into their respective groups

3.1.11 Reproductive data

Reproduction data was recorded throughout the trial. Cows were observed for estrous in the morning before milking and then again in the afternoon before milking. Various people observed the cows for estrous to ensure that all heats were recorded. Cows were eligible to be inseminated for the first time after 55 days in milk (DIM). If a cow came into estrous before this time, the incident was recorded but the cow as not inseminated. The AM-PM rule, which states that cows first observed in oestrous in the morning should be inseminated late the same day and cows first observed in oestrous in the afternoon should be inseminated early the next morning (Bearden *et al.*, 2004) was applied. All incidents of estrous as well as inseminations were recorded and from this data the number of days to first oestrous, days open and inseminations per conception were calculated. The first estrous shown by every cow was used to determine days to first oestrous. As soon as cows were confirmed pregnant by the veterinarian, the last insemination date was used to calculate days open, unless the veterinarian confirmed that she conceived from a previous insemination.

3.1.12 Body weight and body condition scores

Cows were weighed and body condition scored after calving to obtain a start weight and BCS for each group and thereafter at the beginning of each month. This was done after the morning milking. The condition scoring was done by the herd manager, Mr. Gerrit van der Merwe throughout the trial, using the 5 point body condition score system (Roche *et al.*, 2004). The average monthly weight and BCS for each group was calculated by taking the average of the weight of the 15 cows allocated to each group. At the end of the trial all the cows were weighed and condition scored again to obtain an end weight and BCS for each group. If a cow dried off before the end of the trial, she was weighed and condition scored on that day. The start and end data was used to calculate the change in body weight and BCS during the trial period.

3.1.13 Concentrate sampling

Every Wednesday during the trial period, samples of the concentrate pellets were taken. The samples were always taken from the same feeder on the same side of the milking parlour. The samples were placed in plastic bags and stored in a freezer for preservation until they were analysed at UP Nutrilab at the University of Pretoria. The weekly concentrate samples were pooled monthly for the analyses. These samples were dried at 60ºC for 72h (Botha *et al*., 2007) to determine the DM content of the sample, then milled through a 1mm sieve using a Retch mill (Rheinische StraBe 36, Haan, Germany). The concentrate samples were analysed for the same nutrients using the same analytical techniques as for roughages (section 3.1.7). Metabolisable energy was determined using the equation stated under section 3.1.7 for concentrates (ARC, 1984). Similarly the concentrate samples were analysed for the nutrients as needed for inputs in the CNCPS model (section 3.1.7).

3.1.14 Modelling with CPM-Dairy

The milk yield of the cows during September 2007 were compared with what was predicted by the CMP-Dairy Beta model (CPM-Dairy, 1998). The average lactation number, body weight, BCS, milk fat and protein percentages, and days in milk for each group were used. Furthermore, the first calving age, calving interval and days pregnant were calculated for each group. Calf birth weight was estimated according to the average birth weight of calves on the Outeniqua Research Farm. The actual mean minimum and average daily temperatures for the two months were used as inputs, while the relative humidity and wind speed for the two months were provided by Weather SA (2004). Because the cows grazed continuously, the hours in sunlight was taken as the average day length for each month, which was provided by Weather SA (2004).

The model's default values were used for hair depth, time standing, and body position changes. The average distance walked was estimated by measuring the average distance to each camp from the milking parlour, the amount of times the cows walked to the water trough was measured over a 7 h period, from eight in the morning until 3 in the afternoon, for two days. The average was then taken along with the average camp length to estimate the average distance walked by a cow to drink water. The CNCPS inputs used for animal, environment, and management for the three treatments are listed in Table 3.4 to 3.6.

Table 3.4: Inputs used in CPM-Dairy model for describing the environment and management procedures for italian, westerwold, and perennial ryegrass over-sown into kikuyu

Item	Input
Environment	
Current temperature (ºC)	14.1
Current RH	78.2
Previous temperature (ºC)	12.9
Previous RH	71.6
Wind speed (mps)	1.5
Hours in sunlight	11.8
Storm exposure	Yes
Min night temperature (ºC)	8.8
Mud depth (cm)	0
Hair depth (tenths of cm)	0.63
Hair coat	No mud
Management	
Activity	Continuous grazing
Time standing (h/d)	18
Body position changes	6
Distance walked flat (m)	2787.8
Distance walked sloped (m)	0

RH = relative humidity

Table 3.5: Inputs used in CPM-dairy for describing the animal for italian, westerwold, and perennial ryegrass over-sown into kikuyu (September 2007)

Item	**Treatments**		
	Italian ryegrass	**Westerwold ryegrass**	**Perennial ryegrass**
Lactation	4	4	4
Current age (mo)	76	76	71
First calving age (mo)	28	27	27
Calving interval (mo)	390	378	370
Current weight (kg)	328	338	337
Mature weight (kg)	400	400	400
Calf birth weight	26	26	26
Days pregnant	25	24	3
BCS	2.32	2.23	2.33
Milk production (kg)	19.59	19.66	21.37
Fat %	4.66	4.35	4.15
Protein %	3.79	3.64	3.47
Days in milk	114	113	69

The mean nutrient composition of the three pasture treatments and the concentrate supplement for September was used for the feed inputs (Table 3.6). Three feeds, namely IR, WR, and PR, were created for the italian ryegrass, westerwold ryegrass and perennial ryegrass pasture treatments using GrssP24Cp40Ndf6Lndf from the CPM feed library by inserting the values listed in Table 3.8. The model default values of GrssP24Cp40Ndf6Lndf were used for the rates of carbohydrate fermentation in the rumen, as well as for protein degradation and the CHO A2 content. A value of 50% was assumed for the effective fibre content of the three ryegrass pasture treatments (Kolver et al., 1998).

The same procedure was followed for the concentrate supplement using CornGrainGrndMed from the CPM feed library. The model default values were used for the carbohydrate fermentation, as well as the protein degradation and the CHO A2 content. The effective fibre content of the concentrate supplement was assumed to be zero. Carbohydrate fraction A1 was assumed to be zero for all three the pasture treatments, as well as for the concentrate supplement. Apart from the Ca & P values, the model default values were used for all other minerals and all the vitamins. Model default values were used for all the amino acids.

Table 3.6: Chemical composition of the italian, westerwold, and perennial ryegrass pasture treatments and the concentrate supplement fed for September used as inputs in the CPM-Dairy model

Parameter	IR	WR	PR	CS
DM (%)	12.52	12.03	12.87	88.70
CP (%DM)	24.21	25.35	24.28	14.33
SolCP (%CP)	69.40	63.58	63.98	41.47
NPN (%SolCP)	0.69	0.89	0.89	0.06
ADIP (%CP)	3.37	3.17	3.39	6.71
NDIP (%CP)	10.78	12.07	13.56	6.40
ADF (%DM)	24.05	25.26	26.31	4.18
NDF (%DM)	41.20	42.09	44.73	10.84
peNDF(%NDF)	50	50	50	0
Lignin (%NDF)	8.03	9.50	9.78	1.40
Ash (%DM)	12.36	13.15	12.47	6.37
EE (%DM)	3.80	3.43	3.80	2.90
CHO A1 (Silage acids)	0	0	0	0
CHO A2 (Sugar; %DM)	42	42	42	2
CHO B1 (Starch; %DM)	0.20	0.25	0.04	55.78
CHO A2 digestion (%/h)	350	350	350	200
CHO B1 digestion (%/h)	45	45	45	25
CHO B2 digestion (%/h)	45	45	45	25
Protein B1 digestion (%/h)	200	200	200	135
Protein B2 digestion (%/h)	13	13	13	7
Protein B3 digestion (%/h)	2	2	2	0.1
Ca (%DM)	0.41	0.41	0.41	1.24
P (%DM)	0.40	0.42	0.42	0.34

IR = italian ryegrass
WR = westerwold ryegrass
PR = perennial ryegrass
CS = concentrate supplement
DM = dry matter
CP = crude protein
solCP = soluble crude protein
NPN = non protein nitrogen
ADIP = acid detergent insoluble protein
NDIP = neutral detergent insoluble protein
ADF = acid detergent fibre
NDF = neutral detergent fibre
peNDF = physically effective neutral detergent fibre
EE = ether extract
CHO = carbohydrate fractions
Ca = calcium
P = phosphorous

3.1.15 Statistical analysis

The experiment was a randomized complete block design with three treatments randomly allocated within each of the eight blocks. The block replicates of treatments were not independent as the blocks were grazed successively (Wilkens et al., 1995). A factorial analysis of variance was performed with seasons included as factors. The interactions for season x treatment were not significant, therefore, the means or totals over seasons were calculated for each variable and then subjected to a two-way analysis of variance. For the cow data, cows were used as replications in the analysis (Wilkens et al., 1995). Student's t-LSD (least significant difference) was calculated at a 5% significance level to compare treatment means. The "STATS" module of SAS version 9.13 was used to analyse the data (SAS, 1999).

3.2 Results & Discussion

3.2.1 Climate

Table 3.7 contains the monthly rainfall for the duration of the trial, as supplied by Weather SA. As can be seen from the table, the region had rain throughout the trial period. The highest monthly rainfall occurred in November 2007 (491.4mm). During this month the Southern Cape experienced rainfall which led to flooding, however the trial was not affected and continued during this period. According to Weather SA, the annual rainfall for this area is 728mm per annum. During the trial a total of 1097.1mm of rain fell in this area. This higher than usual rainfall could be attributed to the floods in November 2007.

Table 3.7 The monthly rainfall for the George area from June 2007 until May 2008

Month	Rainfall (mm)
June	35.8
July	43.9
August	33.5
September	34.3
October	43.6
November	491.4
December	156.5
January	90.6
February	69.3
March	61.9
April	36.3

Table 3.8 contains the mean monthly minimum, maximum, and average daily temperatures for the George area for the duration of the trial. The temperatures peaked during February 2008, and the lowest temperatures were experienced during July 2007. The George area has a temperate climate, therefore the temperatures experienced during the trial are in line with what was expected.

Table3.8 Mean monthly minimum, maximum, and average daily temperatures for the George area from June 2007 until May 2008

Month	Minimum T (ºC)	Maximum T (ºC)	Average daily T
June	8.6	20.6	14.7
July	7.2	18.7	12.5
August	7.6	18.8	12.9
September	8.8	19.9	14.1
October	10.4	20.5	15.3
November	11.9	21.3	16.4
December	14.5	23.4	18.8
January	15.5	23.3	19.3
February	15.7	24.6	19.8
March	14.1	23.9	18.5
April	11.0	22.0	16.0

3.2.2 Pasture yield, intake, and composition

3.2.2.1 Regressions

During the trial, continuous regressions were used and are presented in Table 3.9. This was done because regressions were started fresh at the beginning of the trial, and established for each pasture treatment during the trial. The regressions are presented here because they were used to calculate pasture intake from the RPM readings. For further information on the regressions, see Van Der Colf (ongoing MSc thesis). For the intake calculations, however, the seasonal regressions will be used, and are given in Table 3.9. The difference between the seasonal and the cumulative regressions is that with the cumulative regressions, all the data collected throughout the trial was used to establish the regression. In other words, as the trial progressed, more data was available for the regression. However, with the seasonal regressions, only the data from that season was used. This also meant that the regression was only available at the end of the season, which is why the cumulative regressions were used to calculate the stocking rates during the trial. As can be seen from Table 3.9, the cumulative regressions had higher repeatability values (r^2) for all treatments throughout the trial. This is due to the fact that the cumulative regressions were based on more data points than the seasonal regressions.

Table 3.9 The pre-grazing seasonal and continuous regressions used to estimate DM yield for italian, westerwold, and perennial ryegrass over-sown into kikuyu pastures

Season	**Treatment**	**Type**	**N**	**m**	**B**	**r²**
Winter	IR	Seasonal	162	90.13	-691.85	0.89
		Cumulative	162	90.13	-691.85	0.89
	WR	Seasonal	160	97.45	-919.78	0.84
		Cumulative	160	97.45	-919.78	0.84
	PR	Seasonal	89	81.72	-516.13	0.73
		Cumulative	89	81.72	-516.13	0.73
Spring	IR	Seasonal	142	63.8	-483.83	0.73
		Cumulative	304	68.98	-415.51	0.76
	WR	Seasonal	144	64.16	-442.29	0.68
		Cumulative	304	76.54	-615.81	0.72
	PR	Seasonal	144	78.56	-661.80	0.76
		Cumulative	233	75.57	-494.71	0.77
Summer	IR	Seasonal	144	66.87	-324.54	0.65
		Cumulative	448	68.56	-397.25	0.74
	WR	Seasonal	143	72.22	-269.89	0.56
		Cumulative	447	77.08	-579.52	0.71
	PR	Seasonal	144	71.84	-209.22	0.46
		Cumulative	337	75.42	-430.55	0.64
Autumn	IR	Seasonal	36	66.48	-363.07	0.68
		Cumulative	484	68.38	-394.76	0.74
	WR	Seasonal	36	74.57	-518.70	0.69
		Cumulative	483	76.89	-576.17	0.71
	PR	Seasonal	54	42.95	-596.79	0.22
		Cumulative	431	70.96	-297.49	0.57

IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass

N = amount of points; m & b = regression equation variables; r^2 = repeatability

3.2.2.2 Stocking rates

The monthly stocking rates for the three treatments are presented in Table 3.10. There was no difference between the stocking rates of the italian and westerwold ryegrass treatments during June 2007. During July, August and September there was no significant difference between the stocking rates of the three treatments ($P > 0.10$). In October, the italian ryegrass treatment carried more animals (7.91 cows per hectare) ($P < 0.05$) than the westerwold and perennial ryegrass treatments (6.40 cows per hectare for the westerwold ryegrass treatment, and 6.42 cows per hectare for the perennial ryegrass treatment). During November the italian and perennial ryegrass treatments carried higher stocking rates (7.78 and 7.30 cows per hectare for the italian and perennial ryegrass treatments, respectively) than the westerwold ryegrass treatment (5.65 cows per hectare), ($P < 0.05$). During December the stocking rates of the three treatments did not differ ($P > 0.10$). In January, February and March, the westerwold and perennial ryegrass treatments carried higher stocking rates ($P < 0.05$) than the italian ryegrass treatment. During April, the perennial ryegrass treatment was the only treatment that was grazed as the other two treatments were replanted at the end of March. Throughout the trial the westerwold ryegrass treatment never had a statistically significant higher stocking rate than the perennial ryegrass treatment.

Table 3.10 The monthly stocking rates (cows/ha/month) for italian, westerwold and perennial ryegrass over-sown into kikuyu from June 2007 until May 2008

Month	Treatments			SEM	P-value
	Italian ryegrass	Westerwold ryegrass	Perennial ryegrass		
June	6.10	5.71	-	0.479	0.577
July	3.02	2.50	3.79	0.550	0.339
August	3.85	4.03	4.72	0.470	0.402
September	6.29	5.64	5.42	0.545	0.516
October	7.91^{a}	6.40^{b}	6.42^{b}	0.275	0.001
November	7.78^{a}	5.65^{b}	7.30^{a}	0.486	0.014
December	7.77	7.48	8.93	0.615	0.235
January	6.88^{b}	9.35^{a}	8.60^{a}	0.532	0.012
February	7.91^{b}	10.28^{a}	9.50^{a}	0.371	0.0006
March	6.54^{b}	7.78^{a}	7.65^{a}	0.307	0.019
April	-	-	5.98	0.316	-

ab means in the same row with different superscripts differ (P < 0.05)

SEM = standard error of means

Table 3.11 contains the seasonal stocking rate for the three pasture treatments. There was no significant difference between the three treatments during the winter (P > 0.10), however, the westerwold ryegrass treatment had the numerically lowest stocking rate (4.12 cows per hectare for the westerwold treatments, compared to 4.37 cows per hectare for the italian ryegrass treatment and 4.38 cows per hectare for the perennial ryegrass treatment). During spring, the italian ryegrass treatment had a higher (P<0.05) stocking rate than the westerwold and perennial ryegrass treatments, while during summer the italian ryegrass pasture treatment had a lower (P < 0.05) stocking rate (7.59) than the other two treatments (9.10 and 9.08 for westerwold and perennial ryegrass, respectively). During autumn, the westerwold ryegrass treatment had a higher (P<0.05) stocking rate (7.78 cows per hectare) than the italian and perennial ryegrass treatments (6.54 cows per hectare for the italian ryegrass treatment and 6.68 for the perennial ryegrass treatment). The perennial ryegrass treatment had a higher (P<0.10) average stocking rate (6.93 cows per hectare) for the duration of the trial than the italian (6.44 cows per hectare), or the westerwold (6.49 cows per hectare) ryegrass treatments.

Table 3.11 The total trial period average and seasonal stocking rates (cows/ha/season) for italian, westerwold and perennial ryegrass over-sown into kikuyu

	Treatments				
Season	**IR**	**WR**	**PR**	**SEM**	**P-value**
Winter	4.37	4.12	4.38	0.317	NS
Spring	7.43^{a}	5.90^{b}	6.44^{b}	0.317	0.05
Summer	7.59^{a}	9.10^{b}	9.08^{b}	0.317	0.05
Autumn	6.54^{b}	7.78^{a}	6.68^{b}	0.331	0.05
Average	6.44^{c}	6.49^{c}	6.93^{d}	0.182	0.10

ab means in the same rows with different superscripts differ (P < 0.05)

cd means in the same rows with different subscripts differ (P < 0.10)

SEM = standard error of means

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

3.2.2.3 Pasture intake estimation using the Rising Plate Meter

The intake estimations were done on a seasonal basis. Table 3.12 contains the seasonal intake for each treatment as estimated using the RPM. As can be seen from the table, the RPM seriously underestimated the daily intake of the cows on all three treatments, as 9 kg DM per cow per day was allocated in all the treatments throughout the trial. The results are in agreement with Malleson (2008) who reported the RPM to not be accurate enough to determine differences in pasture intake between cows on different treatments.

Table 3.12 Seasonal intakes (kg DMI/cow/day) for italian, westerwold and perennial ryegrass over-sown into kikuyu as estimated using the RPM

Season	Treatment		
	IR	**WR**	**PR**
Winter	6.01	6.21	6.15
Spring	5.68	5.88	6.58
Summer	6.85	6.82	6.42
Autumn	6.17	5.44	6.09

IR = italian ryegrass
WR = westerwold ryegrass
PR = perennial ryegrass

3.2.2.4 Pasture intake estimation using equations

Pasture intake estimation was done using the equation of NRC (2001) as well as estimations based on NDF intake. The equation of Caird & Holmes (1986) required a value for the interaction between pasture and supplementation which was not measured in this trial. The estimations using the equation of NRC (2001) are presented in Table 3.13. Since only 9 kg of DM per cow per day was allocated with each treatment, it is clear that the NRC (2001) equation over estimated pasture DMI of all three treatments. The results differ from those given by Bargo *et al*. (2002) who stated that intake estimation using the NRC (2001) equation was similar to the DMI measured.

Table 3.13 Estimation of DMI (kg/cow/day) of the cows grazing italian, westerwold and perennial ryegrass over-sown into kikuyu using the NRC (2001) equation

	Treatments		
Season	**IR**	**WR**	**PR**
Winter	10.63	10.95	10.36
Spring	10.88	11,28	11.12
Summer	10.06	10.43	9.85
Autumn	9.65	9.64	9.58
Average	10.31	10.58	10.23

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

The NDF intake as a percentage of body weight (BW) was assumed to be 1.3% of body weight, this is according to the findings of Bargo *et al* (2002). The average seasonal body weights of the three cow groups were calculated and are presented in Table 3.14. From these values an average body weight for each group was calculated and was 353 kg, 376 kg, and 360 kg for cows grazing italian, westerwold and perennial ryegrass, respectively. When NDF intake as a percentage of body weight is calculated from the above figures, the NDF intake for each group was 4.6 kg, 4.8 kg and 4.7 kg for italian, westerwold and perennial ryegrass respectively. To simplify the calculations, the NDF intake per cow per day of all three groups will be 4.7 kg. All three groups received 3.56 kg of concentrate on a dry matter basis which had an average of 11.4% NDF, which means that the NDF intake from concentrate supplementation was 0.4 kg per cow per day (11.4% of 3.56 kg is 0.4 kg). This leaves 4.3 kg of NDF intake to be consumed in the form of pasture.

Table 3.14 The seasonal average intake (kg DM) estimation for cows grazing Italian, westerwold and perennial ryegrass over-sown into kikuyu, using the NDF intake as percentage of body weight method (kg BW in paranthesis)

	Treatments		
Season	**IR**	**WR**	**PR**
Winter	11.3 (332)	11.5 (346)	10.5 (350)
Spring	9.4 (337)	8.8 (356)	8.8 (346)
Summer	7.6 (369)	6.9 (389)	7.3 (359)
Autumn	7.4 (374)	7.3 (415)	7.7 (383)
Average	8.9 (353)	8.6 (376)	8.5 (360)

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

As stated by Marais (2001), (section 2.9.1), the NDF concentration of low quality forages such, as kikuyu, is considered to be an important factor restricting dry matter intake of grazing dairy cows. This method yields values higher than the pasture allowance during winter, when the average NDF percentage of the pastures was low, and the water content high. As the NDF content of the pastures increases with age, the intake estimated by this method declines. The average intakes estimated for each group are similar to the intake estimation obtained by Malleson (2008). The average pasture intakes estimated over all the seasons seems reasonable (close to the 9kg/cow/day that was allocated) and will be used for any further calculations. However, to keep the groups equal the average DMI of 8.7 kg of pasture per cow per day will be used in all further calculations. This is the average of the three average intakes of the three groups.

3.2.2.5 Pasture composition

Because ryegrass grows mainly during the winter, and kikuyu grows mainly during the summer, data for the winter and spring months will be compared with regard to the ryegrass nutritive parameters and the summer and autumn months will be compared with regard to the kikuyu nutritive parameters (section 2.3).

The nutritive parameters that were not compared statistically are presented in Table 3.15. There were no differences between the three treatments in terms of monthly DM, EE, Ash, Ca, and P content. As can be seen from the table, the ash content increased with the maturity of the pasture species. There was a decrease in ash content when the kikuyu started dominating the three pasture treatments. When comparing the results of the annual ryegrass species to the literature, it is clear the EE values are considerably higher than the values reported by Fulkerson *et al* (2007) for autumn and spring grasses. The Ca and P values obtained in this trial differed from those reported by Botha *et al* (2007a), who reported Ca and P values higher than those observed in this trial for the annual ryegrass species.

Similar to the annual ryegrass species, the EE values obtained during this trial were higher than those reported in the literature (Table 2.3). There were no Ca and P values found in the literature to use as a comparison for the perennial ryegrass treatment during winter and spring.

The EE values for all three treatments obtained during summer were comparable to the values reported for kikuyu by Dugmore & du Toit (1988) and Fulkerson *et al* (2007). During the months when kikuyu was actively growing, the Ca values obtained for the italian and westerwold ryegrass treatments were comparable to the value of 0.32 g/kg DM reported by Botha *et al* (2007a). The Ca values found for the perennial ryegrass treatment during the summer months were higher than that of Botha *et al* (2007a), this could be due to the fact that the perennial ryegrass persisted in the pasture for longer than the two annual ryegrasses. All three treatments had lower Ca values than those reported by Joyce (1974).

Table 3.15 The monthly DM, ash, fat, Ca and P composition of italian, westerwold and perennial ryegrass over-sown into kikuyu, as a percentage of dry matter, pooled over each month of the year, n = 3 per month

Month	DM			EE			Ash			Ca			P		
	IR	WR	PR	IR	WR	PR	IR	WR	PR	IR	WR	PR	IR	WR	PR
July	13.4	12.3	13.8	3.8	3.8	3.9	11.7	11.9	11.7	0.36	0.37	0.43	0.43	0.46	0.40
August	13.6	12.6	14.8	3.7	3.8	3.8	11.9	12.2	11.7	0.36	0.42	0.40	0.40	0.44	0.42
September	12.5	12.0	12.9	3.80	3.4	3.8	11.7	12.5	11.9	0.41	0.41	0.41	0.40	0.42	0.42
October	12.8	14.2	12.9	3.2	3.0	3.4	13.6	12.2	12.2	0.45	0.46	0.43	0.39	0.38	0.40
November	12.7	15.8	14.1	3.1	2.5	3.1	11.1	10.0	11.2	0.36	0.38	0.38	0.39	0.35	0.37
December	16.8	17.2	18.3	2.7	2.4	3.3	10.2	9.1	12.0	0.33	0.32	0.37	0.35	0.32	0.36
January	14.9	15.4	17.5	2.7	2.1	2.6	11.1	9.7	10.1	0.33	0.34	0.35	0.40	0.37	0.36
February	15.2	14.2	17.1	2.8	2.4	2.6	11.7	11.4	11.6	0.36	0.33	0.39	0.38	0.36	0.38
March	13.3	12.7	13.0	2.4	2.0	2.6	11.5	11.9	11.7	0.36	0.35	0.40	0.37	0.38	0.39
April	-	-	14.1	-	-	2.1	-	-	11.6	-	-	0.41	-	-	0.36

IR = italian ryegrass
WR = westerwold ryegrass
PR = perennial ryegrass
DM = dry matter
EE = ether extract
Ca = calcium
P = phosphorous

The perennial ryegrass treatment was the only productive pasture treatment during April 2008, so no statistical analysis was done on the nutritive value data of April 2008.

Table 3.16 contains the mean monthly CP content of the three pasture treatments. During July 2007, there was no significant difference ($P > 0.10$) between the three pasture treatments in terms of CP content, however during August 2007, the perennial ryegrass treatment had a significantly lower ($P < 0.05$) CP content (24.5%), than the italian (30.8%) and westerwold (33.2%) ryegrass treatments. There was no significant difference ($P > 0.10$) in CP content between the three pasture treatments for the remainder of the trial.

The CP values obtained for the italian and westerwold ryegrass treatment in this trial were higher than those reported in the literature (section 2.3.2) during winter and lower than the values reported in the literature for spring. The CP values obtained in this trial were similar to those reported by Meeske *et al* (2006) for kikuyu during summer and autumn. The CP values obtained for the perennial ryegrass treatment were comparable to those reported in the literature (Fulkerson *et al*., 2007). Whether or not the treatments are comparable to the values stated in the literature depends on the amount of N applied. However, as the N application level in this trial was moderate, the results should be comparable to the work done by Fulkerson *et al* (2007).

Table 3.16 Average crude protein concentration (% DM) of italian, westerwold and perennial ryegrass over-sown into kikuyu, as a percentage of dry matter, n = 3 per treatment per month

	Treatments			
Month	**Italian ryegrass**	**Westerwold ryegrass**	**Perennial ryegrass**	**SEM**
July	30.1	31.3	27.1	1.97
August	30.8^{a}	33.2^{a}	24.5^{b}	1.58
September	24.2	25.4	24.3	1.58
October	22.6	22.5	20.8	1.58
November	21.4	19.6	20.9	1.58
December	17.9	17.5	17.3	1.94
January	19.7	18.7	17.9	1.58
February	21.4	21.2	18.4	1.58
March	22.3	23.1	22.8	1.82
April	-	-	23.3	-

ab means in the same rows with different superscripts differ (P < 0.05)

SEM = standard error of means

Table 3.17 contains the average monthly ME concentration of the three pasture treatments. During July – October 2007, there was no significant difference (P > 0.10) in the ME concentration of the three pasture treatments. During November 2007, the westerwold ryegrass treatment had a significantly lower ME concentration (9.97 MJ ME/kg DM) compared to the italian ryegrass treatment (10.7 MJ ME/kg DM) (P < 0.10), however there was no significant difference (P > 0.10) between the perennial ryegrass treatment (10.69 MJ ME/kg DM) and the two annual ryegrass treatments. During

December 2007, the italian ryegrass treatment had a significantly higher ME concentration (10.7 MJ ME/kg DM) compared to the westerwold (9.55 MJ ME/kg DM) and perennial (9.61 MJ ME/kg DM) ryegrass treatments ($P < 0.10$). There was no significant difference between the three pasture treatments in terms of ME concentration for the remainder of the trial ($P > 0.10$).

The ME concentrations reported for the three pasture treatments in this trial for the summer and spring periods were comparable to those reported for kikuyu by Fulkerson *et al* (2007), and higher than the ME values reported by Botha *et al* (2007a) and Meeske *et al* (2006). The ME concentrations obtained for the annual ryegrass species in this trial were higher than those reported in the literature (Lowe *et al*., 1999). The same was true for the ME concentrations of the perennial ryegrass treatment.

Table 3.17 Metabolisable energy concentration (MJ/kg DM), of italian, westerwold and perennial ryegrass over-sown into kikuyu, n = 3 samples per month per treatment

	Treatments			
Month	**Italian ryegrass**	**Westerwold ryegrass**	**Perennial ryegrass**	**SEM**
July	11.8	12.2	12.5	0.385
August	12.1	11.8	11.8	0.309
September	11.4	11.4	11.4	0.309
October	10.6	10.3	11.0	0.309
November	10.7^{c}	10.0^{d}	10.7^{c}	0.309
December	10.5^{a}	9.6^{ab}	9.6^{b}	0.379
January	9.9	9.4	8.9	0.309
February	9.8	9.3	9.3	0.309
March	10.0	9.7	9.4	0.356
April	-	-	8.8	-

ab means in the same rows with different superscripts differ ($P < 0.05$)
cd means in the same rows with different subscripts differ ($P < 0.10$)
SEM = standard error of means

Table 3.18 contains the average monthly NDF values (as a percentage of DM) for the italian, westerwold and perennial ryegrass treatments obtained during the trial. There was no significant difference in the NDF% of the three pasture treatments during July 2007. During August 2007, the perennial ryegrass treatment had a significantly higher (P < 0.05) NDF% (42.24%) than the italian (37.21%) and westerwold (36.75%) ryegrass treatments. There was no significant difference (P > 0.10) in the NDF% of the three pasture treatments during September and October 2007. During November 2007, the italian ryegrass treatment had a significantly lower NDF% (51.21%) than the westerwold ryegrass pasture treatment (56.27%) (P < 0.05), however there was no significant difference (P > 0.10) between the perennial ryegrass treatment (52.50%) and the two annual ryegrass treatments. During December 2007, the westerwold ryegrass treatment had a significantly higher NDF% (64.10%) than the italian (56.99%) and perennial (57.96%) ryegrass treatments (P < 0.05). During January 2007, the westerwold ryegrass treatment had a significantly higher NDF% (62.14%) than the italian ryegrass treatment (55.56%) at a significance level of P < 0.05. At a significance level of P < 0.10, the perennial ryegrass treatment had a significantly higher NDF % (59.65 %) than the italian ryegrass treatment. There were no differences (P > 0.10) in the NDF% of the three pasture treatments for the remainder of the trial.

When the NDF values obtained during the trial were compared to the values reported in the literature, the values for the summer and autumn months were comparable to the values reported by most authors for kikuyu (Meeske *et* al, 2006; Botha *et al*, 2007a). During the winter, the values reported by most authors were lower than the NDF values obtained for the annual ryegrass treatments in this trial (Meeske *et al*, 2006; Fulkerson *et al*, 2007), but comparable to those reported by Lowe *et al* (1999). The NDF values for the perennial ryegrass treatment were in the range reported by Lowe *et al* (1999) for winter, but lower than the value reported by Fulkerson *et al* (2007).

Table 3.18 Neutral detergent fibre concentration of italian, westerwold and perennial ryegrass over-sown into kikuyu, on a dry matter basis

Month	Treatments			SEM
	Italian ryegrass	Westerwold ryegrass	Perennial ryegrass	
July	38.6	37.9	39.4	2.128
August	37.2[a]	36.6[a]	42.2[b]	1.711
September	41.2	42.1	44.7	1.711
October	45.2	48.4	48.9	1.711
November	51.2[a]	56.3[b]	52.6[ab]	1.711
December	56.9[a]	64.1[b]	58.0[a]	2.095
January	55.6[a]	62.1[b]	59.7[ab]	1.711
February	57.8	60.1	59.4	1.711
March	57.9	58.6	57.4	1.967
April	-	-	57.4	-

ab means in the same row with different superscripts differ ($P < 0.05$)

SEM = standard error of means

Table 2.19 contains the ADF values (as a percentage of DM) for the italian, westerwold and perennial ryegrass treatments obtained during the trial. There was no significant difference in the ADF% of the three pasture treatments for July 2007 ($P > 0.10$). During August 2007, the perennial ryegrass treatment had a higher ADF% (26.36%) than the italian ryegrass treatment (20.02%), ($P < 0.05$), and tended to be higher in ADF% than the westerwold ryegrass treatment (20.77%), ($P < 0.10$). There were no further differences in the ADF% of the three pasture treatments for the remainder of the trial ($P < 0.10$).

The ADF values obtained for the three treatments for the duration of this trial were similar to those reported in the literature for kikuyu in the summer and for the ryegrasses in the winter (Joyce, 1974; Lowe *et al*., 1999; Fulkerson *et al*., 2007).

Table 3.19 Acid detergent fibre concentration of italian, westerwold and perennial ryegrass over-sown into kikuyu, on a dry matter basis, n = 3 samples per month per treatment

Month	Treatments			SEM
	Italian ryegrass	Westerwold ryegrass	Perennial ryegrass	
July	20.5	20.5	21.1	1.27
August	20.0[a]	20.8[ab]	26.4[b]	1.02
September	24.1	25.3	26.3	1.02
October	27.3	28.5	29.3	1.02
November	29.5	31.1	30.6	1.02
December	31.8	32.7	32.8	1.25
January	31.7	33.6	33.5	1.02
February	30.2	30.4	32.2	1.02
March	29.3	29.2	29.8	1.17
April	-	-	29.9	-

ab means in the same rows with different superscripts differ ($P < 0.05$)

SEM = standard error of means

The results from a comparison of three *in vitro* methods to estimate the ME content of the three pasture treatments are presented in Table 3.20. All three pasture treatments showed differences between the two procedures ($P < 0.05$), with the UC Davis method (Robinson *et al.*, 2004) predicting lower ME values than the Tilley & Terry (1963) method. There was no significant difference in the ME values predicted for the concentrate supplement. From these results and comparing it to literature values (Robinson *et al.*, 2004) it appears that the UC Davis method underestimates the ME concentration of pastures but accurately predicts the ME concentration of concentrate supplements.

Table 3.20 The energy values predicted by two methods, Tilley & Terry (1963) and UC Davis, for italian, westerwold, and perennial ryegrass over-sown into kikuyu, as well as the concentrate supplement fed to the cows during September 2007, n = three samples per pasture treatment

	Tilley & Terry	NDF_{30}	SEM
Italian ryegrass	11.41^{a}	9.21^{b}	0.210
Westerwold ryegrass	11.43^{a}	9.11^{b}	0.210
Perennial ryegrass	11.43^{a}	8.88^{b}	0.210
Concentrate	12.86	12.88	0.364

ab means in the same rows with different superscripts differ ($P < 0.05$)

SEM = standard error of means

NDF30 = the UC Davis method based on neutral detergent fibre digestion within 30 hours

3.2.3 Concentrate composition

Table 3.21 contains the monthly concentrate composition. All the samples taken throughout the trial were pooled monthly and analysed. The same concentrate was fed to all three groups of cows. Concentrate composition was adjusted according to pasture composition throughout the trial.

Table 3.21 The monthly nutritive composition of the concentrate supplement fed to the cows grazing italian, westerwold and perennial ryegrass over-sown into kikuyu, as a percentage of dry matter

	Chemical fractions								
Month	**DM**	**Ash**	**CP**	**ME**	**EE**	**NDF**	**ADF**	**Ca**	**P**
July	88.37	6.91	17.63	12.91	5.41	14.04	5.31	1.34	0.51
August	88.17	6.62	14.34	12.49	3.92	12.12	4.43	1.28	0.37
September	88.70	6.37	14.33	12.86	2.90	10.84	4.18	1.24	0.34
October	88.66	6.52	15.01	12.74	2.88	12.00	4.34	1.28	0.35
November	88.24	6.31	13.55	12.64	2.55	11.11	3.91	1.15	0.33
December	88.26	6.24	13.64	12.92	2.24	10.96	3.86	1.31	0.32
January	89.07	6.86	13.90	12.22	4.83	10.91	4.55	1.53	0.36
February	89.96	9.25	12.36	12.35	4.97	9.05	3.89	2.80	0.29
March	90.19	7.04	14.21	12.74	4.94	9.73	3.72	1.77	0.31
April	89.48	6.70	16.40	12.71	4.39	12.69	5.09	1.32	0.41

DM = dry matter

CP = crude protein

ME = metabolisable energy

EE = ether extract

NDF = neutral detergent fibre

ADF = acid detergent fibre

Ca = calcium

P = phosphorous

The concentrate intake per hectare was calculated for each of the three pasture treatments and is presented in Table 3.22. There was no difference in concentrate fed per hectare between the three pasture treatments (P >0.10), which were 7808 kg/ha for the italian ryegrass, 7881 kg/ha for the westerwold ryegrass, and 8200 kg/ha for the perennial ryegrass pasture treatments.

Table 3.22 The concentrate fed per hectare for the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu on an as is basis

	Treatments				
	Italian ryegrass	**Westerwold ryegrass**	**Perennial ryegrass**	**SEM**	**P-value**
Concentrate intake/ha	7808	7881	8200	200.1	0.355

SEM = standard error of means

3.2.4 Total Diet composition

Appendix A contains the nutrient requirements of the lactating dairy cow. This was used to estimate whether the diet provided adequate nutrients to the cows grazing the three treatments. The composition of the pastures during the winter months (June, July, August), was used to calculate requirements during early lactation, and the composition of the pasture for the remainder of the trial was used to calculate the requirements during mid to late lactation. The pasture intake of all three groups was taken as 8.7 kg per cow per day (section 3.2.2.4) and the concentrate intake as 3.56 kg per cow per day on a dry matter basis (4kg per cow per day on an "as is" basis).

The seasonal total diet composition of the italian ryegrass over-sown into kikuyu treatment will be used as an example to illustrate how the experimental diets supplied compared to the NRC (2001) nutrient requirement recommendations. The same trend was observed for the other two treatments as well.

The seasonal total diet composition of the italian ryegrass treatment is shown in Table 2.23. In general, CP was oversupplied throughout the trial due to the high and variable CP content of the pastures. The NDF content of the total diet was comparable to NRC recommendations during winter and spring but much higher during summer and autumn. The ME content of the total diet was comparable to the NRC recommendations although higher than the recommendations during winter. However, it should be noted that there is still not consensus on the "ideal" method to estimate the energy content of feeds, and there are significant differences between results obtained when different techniques are compared (Robinson *et al*., 2004). The Ca: P ratios ranged between 2.19:1 and 1.52:1, and is in general agreement with NRC recommendations although P was slightly oversupplied in winter, and Ca slightly oversupplied in summer/autumn.

This example once again illustrates the nutritional imbalances in pasture as the sole feedstuff and the complexities of maintaining a balanced diet throughout the season by constantly adjusting the composition of the concentrate.

Table 3.23 The nutritive value (% of DM) of the total diet fed to the cows that grazed italian ryegrass over-sown into kikuyu on a seasonal basis

	Winter	Spring	Summer	Autumn
DM	35.18	34.66	36.94	35.51
Ash	11.03	12.23	10.69	10.69
CP	26.26	20.28	17.79	20.29
ME	12.22	11.46	10.79	10.78
EE	4.03	3.19	3.12	3.04
NDF	30.70	35.86	43.31	44.35
ADF	15.79	20.35	23.37	22.11
Ca	0.64	0.64	0.79	0.71
P	0.42	0.38	0.36	0.37

DM = dry matter
CP = crude protein
ME = metabolisable energy
EE = ether extract
NDF = neutral detergent fibre
ADF = acid detergent fibre
Ca = calcium
P = phosphorous

3.2.5 Milk production and composition

3.2.5.1 Milk production

The average daily milk production of the three treatments throughout the trial is illustrated in Figure 3.7. Production followed a typical lactation curve with peak milk production 30-60 days *post-partum* and thereafter a steady decline in production of around 10% per month (Hutjens, 2008). At a first glance it would seem that cows on the perennial ryegrass treatment produced more milk, there were, however, no significant difference (P > 0.10) in 4% FCM (Table 3.24).

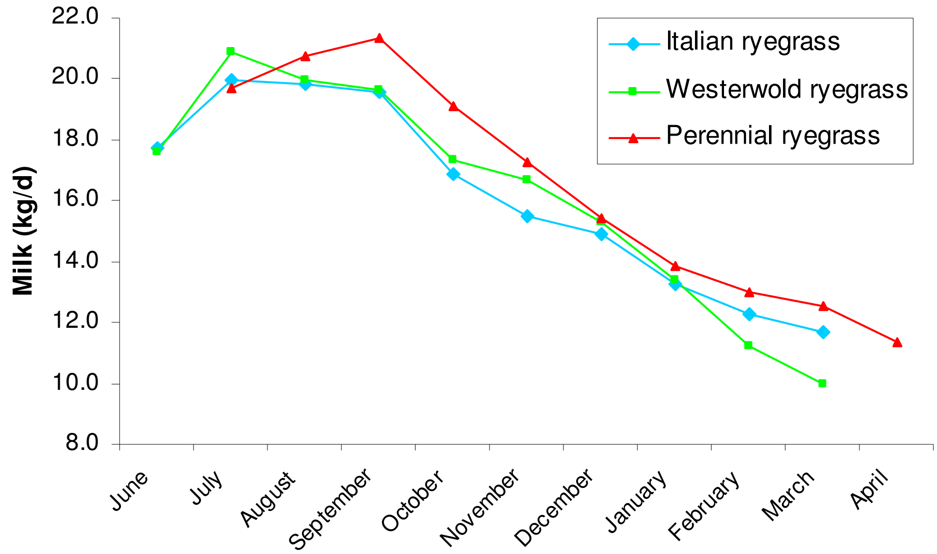

Figure 3.7 Average daily milk production for the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu pastures for the whole lactation

The cows grazing the italian and westerwold ryegrass treatments had an average daily milk production just below 18 kilograms per cow per day at the start of the lactation, whereas the cows grazing the perennial ryegrass treatment started the lactation at just below 20 kilograms per cow per day. This could be due to the fact that the cows grazing the annual ryegrass treatments started their lactations at a lower body condition score. The higher CP% of the diets that were fed to the cows that grazed the italian and westerwold ryegrass treatments could have played a role in the numerically lower peak milk production of these groups, as excess protein in the diet needs to be converted to urea and excreted from the body, a process which requires energy which could otherwise have been directed towards milk production (Hutjens, 2008).

The milk production parameters of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu are shown in Table 3.24. There was no significant difference (P > 0.10) between the three treatments in terms of 305 day milk production, or four percent fat-corrected milk production. The cows that grazed the perennial ryegrass treatment produced more (P < 0.05) milk per hectare than the cows that grazed the annual ryegrass treatments; however there was no significant difference (P < 0.10) between the three treatments in terms of fat-corrected milk production per hectare. There was also no difference in the kilograms of milk production per hectare between the three treatments. The literature reviewed revealed that most researchers used cows in peak production only, in other words they replaced the cows on the trial every 3-4 months (Botha *et al.*, 2007b). This made the milk production per hectare reported by these researchers higher than the amounts reported in this trial.

Table 3.24 The milk production parameters of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu

Item	Treatments			SEM	P-value
	IR	WR	PR		
305 day milk production	4827	4944	4944	101.6	0.655
4% FCM	5504	5658	5396	137.7	0.406
Milk/ha	30446^{cd}	29761^{d}	32288^{c}	889.2	0.140
FCM/ha	34556	34057	35268	1006.4	0.697
Milk solids/ha	2627	2566	2639	76.1	0.771

cd means in the same row with different superscripts differ (P < 0.10)

4%FCM = four percent fat-corrected milk production

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

SEM = standard error of means

3.2.5.2 Milk composition

The average monthly milk fat percentage of the milk produced by the cows that grazed italian, westerwold and perennial ryegrass is illustrated in Figure 3.8. The average butterfat percentage of the milk produced by the cows that grazed the perennial ryegrass treatment was lower than the other two treatments throughout most of the lactation, except in August when it was slightly higher than that of the other two treatments. The cows that grazed the italian and westerwold ryegrass treatments had a final butterfat percentage above 5.50% at the end of the lactation. The cows that grazed the perennial ryegrass treatment had a final butterfat percentage of 5.00%. The higher milk fat percentage at the end of the lactation was expected due to the decline in daily milk production. Malleson (2008) reported a mean butterfat percentage of 3.97% for jersey cows that grazed annual ryegrass pastures, and an average butterfat percentage of 3.71% for jersey cows that grazed kikuyu pastures. Both these values were lower than the percentages reported in this trial.

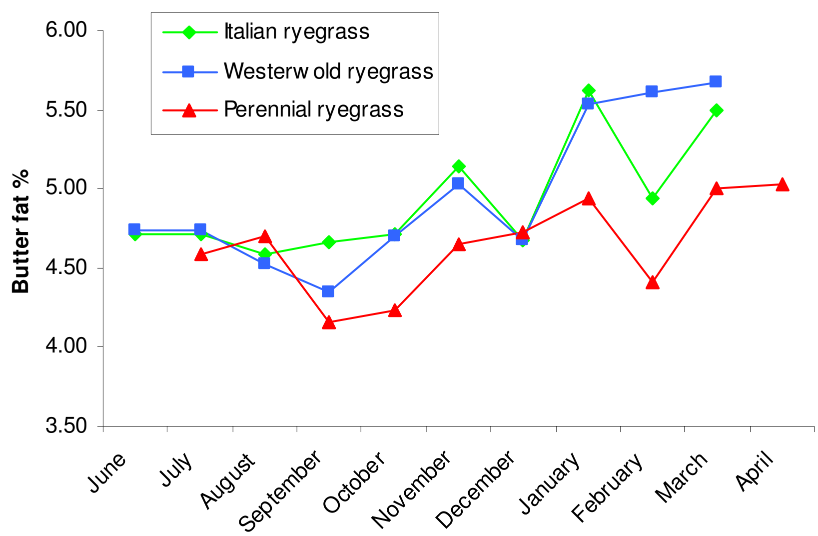

Figure 3.8 The average monthly butter fat percentage of the milk produced by the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu

The average monthly protein percentage of the milk produced by the cows that grazed the italian, westerwold, and perennial ryegrass treatments is illustrated in Figure 3.9. The cows that grazed the perennial ryegrass treatment had a numerically higher milk protein percentage at the start of the lactation than the other two treatments. However, the cows that grazed the perennial ryegrass treatment had produced milk with a numerically lower milk protein percentage than the annual ryegrass treatments during the rest of the lactation. As stated by Sutton (1989), milk protein percentage can only be altered by nutritional means to a maximum of 0.6 percentage units. There was an uncharacteristic increase in the milk protein percentage of the three treatments during September 2007.

This was likely due to an analytical error in the analysis of the milk protein percentage, as the milk protein percentage increased dramatically for all three treatments during this month and dropped down again at the next analysis.

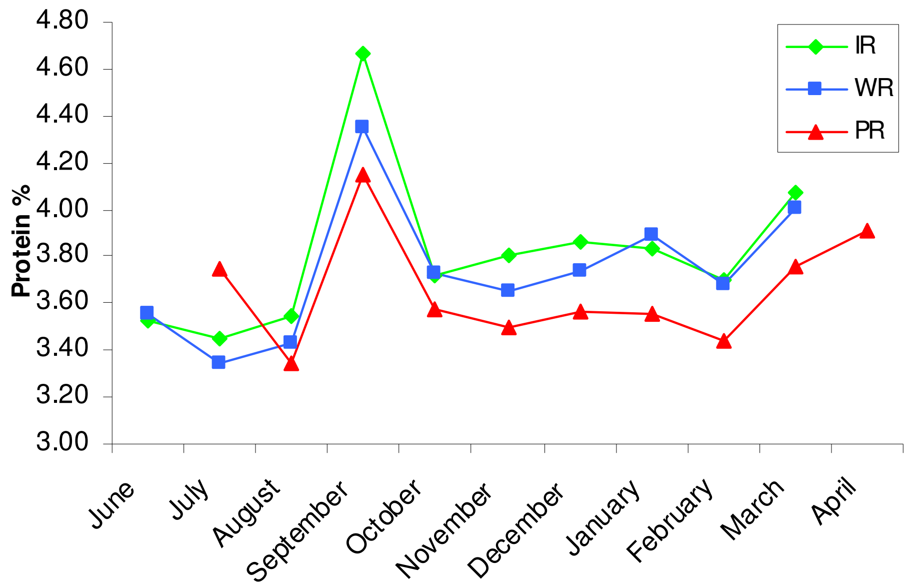

Figure 3.9 The average monthly milk protein percentage of cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu. IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass

The average monthly MUN concentration of the cows that grazed the three pasture treatments are illustrated in Figure 3.10. The cows that grazed the italian and westerwold ryegrass treatments produced milk with a higher average MUN concentration in June 2007, when compared to the rest of the lactation. However, the average MUN concentration decreased in July 2007 and stayed within the acceptable range (12-18 mg/dl) until November 2007. During December 2007, the MUN concentration of all three treatments fell below the acceptable level, however when the total diet nutrient composition is compared to the MUN concentration data, there seems to be no clear answer for the decrease. This decrease continued for the westerwold and perennial ryegrass treatments well into February 2007, and again when this was compared to the total diet nutrient composition, there seems to be no reason for this decrease as protein is either sufficient or in excess during these months. The ME concentrations of the total diets were also within the acceptable range (Appendix A). Although the initial recommendation for optimal MUN concentration is 12 – 18 mg/dl, it has recently been lowered to 10 – 14 mg/dl (Ferguson, 2000). The MUN values from the cows in this study falls within this range (Table 3.25). And although there were significant differences ($P < 0.05$), it is of little biological significance.

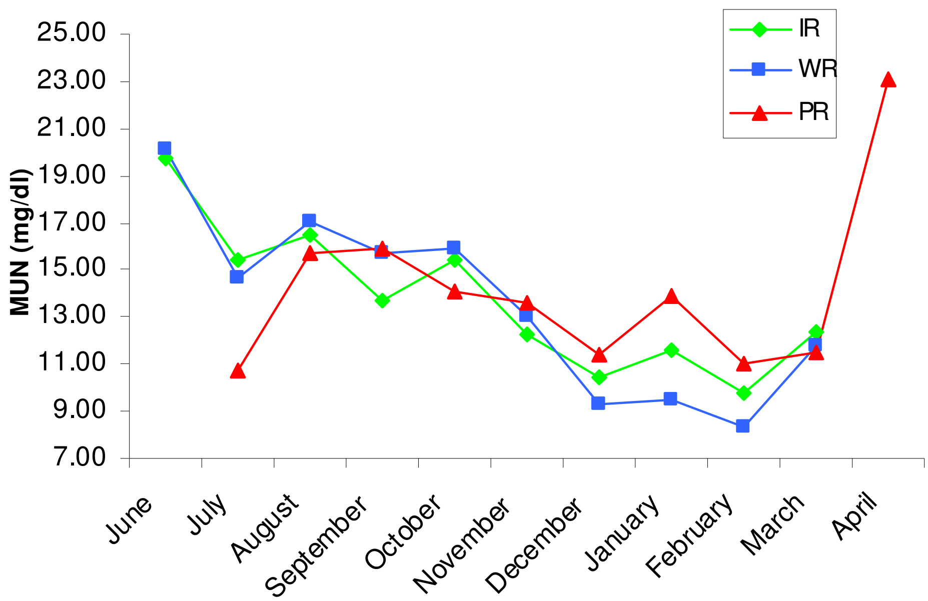

Figure 3.10 The average MUN concentration (mg/dl) of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu. IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass

The average monthly somatic cell count of the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu is illustrated in Figure 3.11. The high somatic cell count of the cows that grazed the perennial ryegrass treatment during July 2007 could be partially explained by the increase seen after calving (Natzke *et al*., 1972; Reichmuth, 1975), however the average SCC of all three groups were acceptable and is still below the 300,000 cells/ml. Milk with a SCC higher than 300,000 cells/ml is considered abnormal (de Villiers *et al*., 2000).

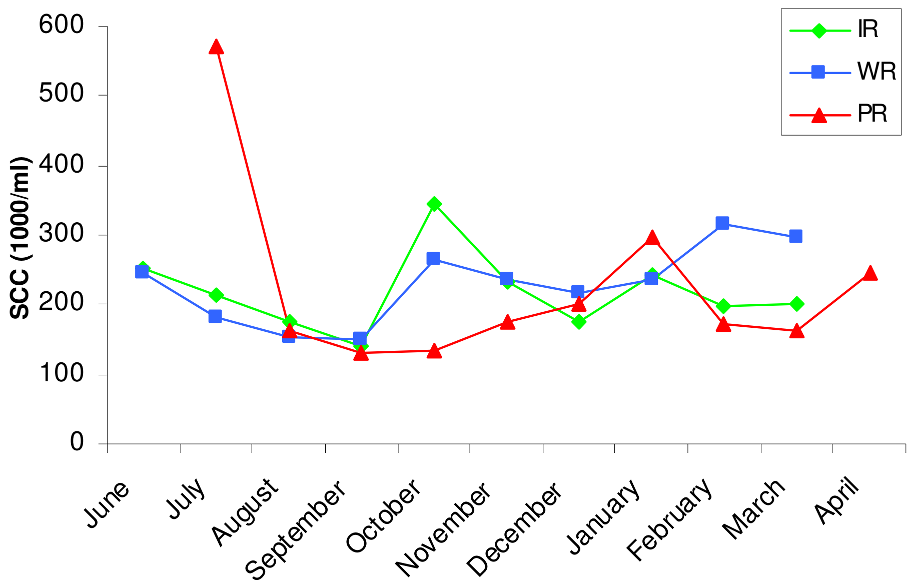

Figure 3.11 The average monthly somatic cell count (1000/ml) of cows that grazed italian, westerwold, or perennial ryegrass over-sown into kikuyu. IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass

Table 3.25 contains the milk composition parameters of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu. Cows grazing the perennial ryegrass treatment had a significantly lower milk protein percentage ($P < 0.05$) than the two annual ryegrass treatments (3.64 % for the perennial ryegrass treatment, versus 3.84 % for the italian ryegrass treatment and 3.75% for the westerwold ryegrass treatment). There was no significant difference in terms of butterfat percentage ($P > 0.05$) between the three treatments, which were 4.94, 4.97 and 4.63 percent for the italian, westerwold and perennial ryegrass treatments, respectively. The cows that grazed the italian and westerwold ryegrass treatments had an average butterfat percentage of 4.94 and 4.97 respectively, while the cows that grazed the perennial ryegrass treatment had an average milk butterfat percentage of 4.63, which is numerically lower compared to the annual ryegrass treatments. Meeske *et al* (2006) conducted a trial in which they investigated the effect of concentrate supplementation on the productivity of Jersey cows grazing high quality pastures. These researchers reported an average butterfat percentage of 4.46 %, and protein percentage of 3.56 %, which is lower than the values reported in this trial. Bargo *et al* (2002) reported average butterfat percentages of 3.29 – 3.82 %, and protein percentages of 2.93 – 3.11 % when cows received different levels of pasture allowance and concentrate supplementation. these values were also lower than the values reported in this trial.

The average kilograms of butterfat produced per cow that grazed the perennial ryegrass treatment was lower (227.9 kg) than that of the cows that grazed the italian (238.2 kg) and westerwold (245.4 kg) ryegrass treatments ($P < 0.10$). There was no difference between the average kilograms of milk protein produced, as well as the average milk solids produced per cow from the three treatments ($P > 0.10$). The kilograms of fat and protein per hectare did not differ significantly between the italian, westerwold, and perennial ryegrass treatments ($P > 0.10$). The cows that grazed the perennial ryegrass (14.14 mg/dl) had a significantly higher ($P < 0.10$) MUN concentration than the cows that grazed the westerwold ryegrass treatment (12.85 mg/dl), however, the MUN concentration of the cows that grazed the italian ryegrass treatment (13.08 mg/dl) did not differ significantly from the other two treatments. The average MUN concentration of all three treatments was within the optimum range of 12-18 mg/dl. There was no difference in the somatic cell count of the cows that grazed the three treatments ($P > 0.10$). The cows that grazed the italian ryegrass treatment had a higher productive efficiency (kg milk solids per kg metabolic weight) than the cows that grazed the perennial ryegrass treatment ($P < 0.05$).

Table 3.25 The butter fat percentage, protein percentage, somatic cell count, MUN and lactose percentage, averaged over the lactation, of the milk produced by the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu, as well as other milk composition parameters

	Treatments				
Item	**IR**	**WR**	**PR**	**SEM**	**P-value**
Protein%	3.84^{a}	3.75^{ab}	3.64^{b}	0.058	0.071
Butterfat %	4.94	4.97	4.63	0.135	0.161
Lactose %	4.64	4.65	4.66	0.017	0.806
Kg butterfat	238.2^{cd}	245.4^{c}	227.9^{d}	7.21	0.234
Kg protein	184.8	185.6	179.8	4.35	0.582
Kg milk solids	422.9	430.9	407.6	11.07	0.332
Kg butterfat/ha	1492	1477	1491	43.5	0.964
Kg protein/ha	1135	1090	1147	32.7	0.421
MUN	13.08^{cd}	12.85^{c}	14.14^{d}	0.462	0.105
SCC	214.86	225.46	213.13	39.709	0.975
Kg milk solids^{-1} kg metabolic weight	5.23^{a}	4.98^{ab}	4.81^{b}	0.091	0.013

ab means in the same row with different superscripts differ (P < 0.05)

cd means in the same row with different subscripts differ (P < 0.10)

IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass

SEM = standard error of means

MUN = milk urea nitrogen (mg/dl)

SCC = somatic cell count; X 1000

3.2.6 Body weight and condition score change

3.2.6.1 Monthly results

Figure 3.12 illustrates the average monthly cow weights of the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu. The cows that grazed the italian and westerwold ryegrass treatments lost between 40 and 70 kg of weight during the first month of lactation. this was expected since cows typically utilise body fat as a source of energy since DMI peaks later than milk production (Huntjens, 2008).

However, all three groups regained the weight during the rest of the lactation to end at an acceptable weight before calving. The cows that grazed the perennial ryegrass treatment did not lose as much weight as the cows that grazed the italian and westerwold ryegrass treatments. This was due to the fact that they calved when the environmental conditions were more favourable.

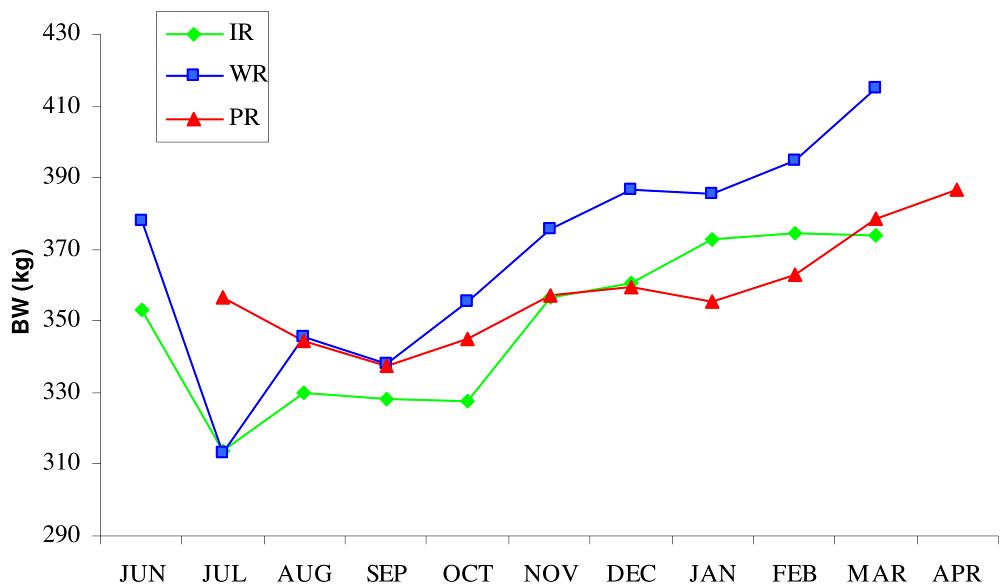

Figure 3.12 The average monthly cow weights of the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu. IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass; BW = body weight

Figure 3.13 illustrates the average monthly BCS of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu. In general the cows increased in BCS as the lactation progressed, to a lesser extent, however, for the cows that grazed the perennial ryegrass treatment. Furthermore, these cows started their lactation in a better condition than the cows that grazed the italian and westerwold ryegrass treatments. It should be kept in mind that body condition scoring is a subjective measurement. As stated in section 2.7, body condition scoring is used as a tool to manage body reserves to ensure that the cows are in a good condition at conception, and that they calve with sufficient body reserves to ensure that the days to first oestrous is reasonable. When the BCS data was compared to the reproduction data in Table 3.27, it could clearly be seen that the cows that participated in the trial had sufficient body reserves to return to oestrous and reconceived within an acceptable time.

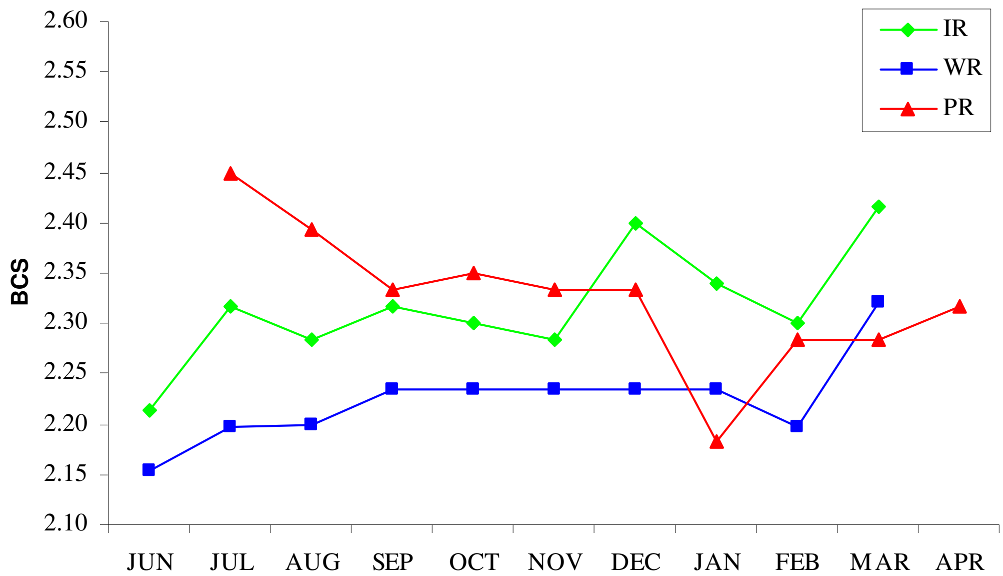

Figure 3.13 The average monthly cow body condition scores of the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu. IR = italian ryegrass; WR = westerwold ryegrass; PR = perennial ryegrass

3.2.6.2 Total lactation results

In Table 3.26 is shown the total lactation body weight and condition score change. There were no significant differences in the start and end weights of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu, which were 353 kg, 378 kg, and 357 kg at the beginning of the trial ($P > 0.10$), and 396 kg, 423 kg, and 408 kg at the end of the trial for the italian, westerwold and perennial ryegrass treatments, respectively ($P > 0.10$). The cows that grazed the perennial ryegrass treatment gained more ($P < 0.05$) weight over the lactation (51.1 kg) than the cows that grazed the italian (42.6 kg) and westerwold (45.2 kg) ryegrass treatments. The cows that grazed the perennial ryegrass treatment started the trial in a better condition (BCS 2.45) than the cows that grazed the italian (BCS 2.22) and westerwold (BCS 2.18) ryegrass treatments ($P < 0.05$), however the final average body condition scores of the three groups, which were 2.55, 2.58, and 2.47 for the italian, westerwold, and perennial ryegrass treatments respectively, did not differ (P > 0.10). The cows that grazed the perennial ryegrass treatment had a lower change in body condition score change over the lactation (+0.02) than the cows that grazed the italian (+0.33) and westerwold (+0.40) ryegrass treatments. This is due to the fact that the cows that grazed the perennial ryegrass treatment started the trial in a better condition than the other two groups.

Table 3.26 The average body weight (kg) and body condition score at start, end, and change of the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu

	Treatments				
Item	**IR**	**WR**	**PR**	**SEM**	**P-value**
Body weight					
Start	353	378	357	11.7	0.117
End	396	423	408	12.1	0.136
Change	$+42.6^{a}$	$+45.2^{a}$	$+51.1^{b}$	7.64	0.715
Body condition score					
Start	2.22^{a}	2.18^{a}	2.45^{b}	0.073	0.047
End	2.55	2.58	2.47	0.111	0.746
Change	$+0.33^{a}$	$+0.40^{a}$	$+0.02^{b}$	0.102	0.025

ab means in the same row with different superscripts differ (P < 0.05)

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

SEM = standard error of means

3.2.7 Reproductive data

Table 3.27 contains the reproductive parameters of the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu. The cows that grazed the perennial ryegrass treatment had a lower (P < 0.05) average days to first oestrous (52.1 days) than the cows that grazed the westerwold ryegrass treatment (75.8 days); however there was no difference between the cows that grazed the italian ryegrass (65.6 days) and westerwold ryegrass pasture treatments. There was no significant difference between the three pasture treatments in terms of days open, which were 110.9 days, 108.4 days, and 91.6 days for the cows that grazed the italian, westerwold and perennial ryegrass treatments, respectively. The cows that grazed the westerwold ryegrass treatment had a lower ($P < 0.05$) number of inseminations per conception (1.57 inseminations per conception), than the cows that grazed the italian ryegrass treatment (2.57 inseminations per conception). From the data presented in Table 3.27, it can be concluded that the cows were not severely over or underfed which could have affected reproductive performance. It is generally not recommended to draw any meaningful conclusions from such a small number of replications when dealing with reproductive data, and therefore does not warrant any further discussion. The percentage of cows inseminated at 80 DIM and pregnant at 100 DIM, however, were in line with norms that are accepted as good management practices (Hutjens, 2008).

Table 3.27 The reproductive parameters of the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu

Item	Treatments			SEM	P-value
	IR	WR	PR		
Days to first oestrous	65.60^{ab}	75.80^{b}	52.06^{a}	5.305	0.013
Days open	110.9	108.4	91.6	10.30	0.356
Inseminations per conception	2.57^{a}	1.57^{b}	1.73^{ab}	0.310	0.077

ab means in the same row with different superscripts differ ($P < 0.05$)

SEM = standard error of means

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

Table 3.28 contains reproductive management parameters for the cows in the study. The italian and perennial ryegrass treatments both had acceptable percentages of the cows that had been inseminated at 80 DIM. However the westerwold ryegrass treatment had a percentage of cows inseminated at DIM of 46.7%, which is well below the 61% indicated for poor management. The perennial ryegrass treatment had 73.3% of cows pregnant at 100 DIM, which is well above the 58% which is indicated as the percentage for good management. All the cows that grazed the perennial ryegrass treatment were pregnant before 200 DIM, while the cows that grazed the italian ryegrass treatment had the highest percentage of cows not pregnant at 200 DIM (13.3%); however this figure is well below the 19% that indicates poor management.

Table 3.28 The reproductive performance of the cows that grazed italian, westerwold, or perennial ryegrass over-sown into kikuyu

Item	Treatments			Good management	Poor management
	IR	WR	PR		
% of cows inseminated at 80 DIM	86.7	46.7	66.7	73.0	<61
% of cows pregnant at 100 DIM	53.3	46.6	73.3	58	<45
% of cows not pregnant at 200 DIM	13.3	6.6	0	13	<19
Inseminations per conception	2.57	1.57	1.73	1.96	<2.32

IR = italian ryegrass

WR = westerwold ryegrass

PR = perennial ryegrass

DIM = days in milk

3.2.8 CPM-dairy prediction

Table 3.29 contains the predictions of the CMP-Dairy Beta Model for the cows that grazed italian, westerwold and perennial ryegrass over-sown into kikuyu.

Table 3.29 The CPM-Dairy model predictions for the cows that grazed italian, westerwold, and perennial ryegrass over-sown into kikuyu

	Treatments		
Parameter	**IR**	**WR**	**PR**
Target milk (kg/d)	19.6	19.7	21.4
ME allowable milk (kg/d)	16.1	15.8	16.1
MP allowable milk (kg/d)	19.9	20.7	21.2
DMI predicted (kg/d)	12.6	12.5	12.6
DMI actual (kg/d)	12.3	12.3	12.3
Predicted ruminal pH	6.04	6.05	6.09
Diet RDP (%CP)	63.5	63.4	63.0
MP from bacteria (g/d)	664	642	653
MP from RUP	835	869	840
Predicted MUN (mg %)	14	15	15
Days to lose 1 BCS	69	66	49
Weight change due to reserves (kg/d)	-0.69	-0.74	-0.98
ME (Avail-Reqd; MJ/d)	-17.90	-19.32	-25.66
MP (Avail-Reqd; g/d)	17	54	-9

IR = italian ryegrass
WR = westerwold ryegrass
PR = perennial ryegrass
ME = metabolisable energy
MP = microbial protein
DMI = dry mater intake
RDP = rumen degradable protein
RUP = rumen undegradable protein
MUN = milk urea nitrogen
BCS = body condition score

From the results in Table 3.29 it appears that ME was limiting milk production from all three pasture treatments. The actual milk production measured during September 2007 was higher for all three treatments than the ME allowable milk predicted by the model, which indicates that the model under-predicts ME allowable milk from pasture systems. The MP allowable milk predicted by the model was higher than the actual milk production for the italian and westerwold ryegrass treatments, but lower for the perennial ryegrass treatment. The higher MP could indicate that protein was over-supplied. Kolver *et al* (1998) found that the milk production predicted using the CNCPS model was sensitive to changes in pasture lignin content, effective fibre, rate of fibre digestion, and the amino acid composition of the ruminal microbes. All three pasture treatments had higher lignin contents than GrssP24Cp40Ndf6Lndf in the CPM feed library, and was higher than the 6% used by Kolver *et al* (1998), which could have limited the ME allowable milk predicted by the model. Effective fibre was not measured in this trial and was assumed to be 50% for all three pasture treatments. Although ruminal pH was not measured during September 2007, the ruminal pH predicted by the CPM model was within the acceptable range (section 2.10.1). The model predicted that the cows that grazed the three pasture treatments were in a negative energy balance, using body reserves and losing condition, especially the cows that grazed the perennial ryegrass treatment, which had fewer DIM than the cows that grazed the italian and westerwold ryegrass treatments. This agrees with the results in Figure 3.6 and 3.7.

It thus appears that the CPM-dairy under-predicts the supply of ME from a pasture-based system. However, if the pastures were analysed for all the nutrients needed as inputs in the feed library, accuracy of prediction would be increased.

CHAPTER 4

EFFECT OF TWO CONCENTRATE LEVELS ON THE RUMEN PH OF COWS GRAZING KIKUYU OVER-SOWN WITH PERENNIAL OR WESTERWOLD RYEGRASS

CHAPTER 4

EFFECT OF TWO CONCENTRATE LEVELS ON THE RUMEN PH OF COWS GRAZING KIKUYU OVER-SOWN WITH PERENNIAL OR WESTERWOLD RYEGRASS

4. Introduction

The rumen study (this chapter) and the production study (see Chapter 3), were done simultaneously utilising the same pastures. The rumen cannulated cows in this study grazed the same pastures as the production study cows. As the pasture stocking rates were sufficiently high at the time, the production study was not affected.

4.1 Materials & Methods

4.1.1 Location, climate, and soil

See Chapter 3 for details.

4.1.2 Duration of the trial

The camp layout can be found in Chapter 3, Figure 3.1. The study consisted of two phases because of the variation in the nutritive value of the pasture over time (referred to as phase 1 & 2). Phase 1 took place from 29 September 2007, when the cows started the adaptation period to 16 November 2007. Phase 2 took place from 01 March 2008 until 29 March 2008. The second experimental period was shorter because the westerwold ryegrass treatment had to be replanted in March 2008, therefore the data had to be collected before the end of March 2008.

4.1.3 Cows, feeding, management, and experimental design

Twelve lactating rumen cannulated cows were randomly allocated to four groups. Two of the four groups were randomly allocated to perennial ryegrass pastures and the remaining two groups were allocated to westerwold ryegrass pastures. It was decided not to use the italian ryegrass treatment as well, as no differences were expected between the westerwold and italian ryegrass pasture treatments in terms of rumen parameters. This decision was based on previous trials carried out on the Outeniqua Research Farm. The groups were balanced for milk production, DIM, and lactation number. The cannulated cows strip grazed the same pastures as the cows in the production study. Within each pasture treatment, one group received 4kg of concentrate per day (2 kg per milking) and the other group received 8kg of concentrate per day (4 kg per milking). Four kilograms was chosen as the control concentrate level, as this is the level of concentrate supplementation that is fed to the herd on the Outeniqua Research Farm, while eight kilograms per cow per day was chosen as the high level of concentrate supplementation because no difference was expected if a lower level was used, and a higher level might have had serious health repercussions for the cows. Cows had access to fresh, clean water *ad libitum* throughout the trial. The composition of the concentrate supplement (supplied by Nova Feeds) fed during phase 1 and 2 is presented in Table 4.1.

Table 4.1: Composition of the concentrate supplement fed to the cows that grazed westerwold and perennial ryegrass over-sown into kikuyu during phase 1 and 2, on a DM basis

Fraction	Phase 1	Phase 2
CP	12.99	14.53
UDP (as % of CP)	47.13	51.5
ME (MJ/kg DM)	12.99	12.6
NSC	65.86	53.5
NDF	8.74	7.16
ADF	2.64	2.4
Fat	3.56	6.8
Ash	6.90	6.1
Ca	1.32	1.6
P	0.34	0.3

CP = crude protein

UDP = undegradable digestible protein

ME = metabolisable energy

NSC = non structural carbohydrates

NDF = neutral detergent fibre

ADF = acid detergent fibre

Ca = calcium

P = phosphorous

The cannulated cows were milked with the cows on the production study, so as to facilitate their separation into the separate pasture groups, the cannulated cows also wore coloured tags attached to a chain around their necks.

Pasture was allocated at 9kg DM per cow per day (above 30mm). The cows received a fresh strip of pasture after every milking. The stocking rate of each camp was calculated in the same way as described in the previous chapter. If the carrying capacity of the pasture was too low to carry the production study cows and the rumen cannulated cows, production study cows were removed and placed on similar pastures. The cows were adapted to the pasture and concentrate supplementation levels for ten days. The adaptation period was kept to 10 days because the cannulated cows were previously supplemented with 6kg concentrate per day and grazed similar pastures. After this, samples and measurements were taken for ten days in experiment 1 and six days in phase 2. After the six or ten day collection period, the two groups within each treatment switched concentrate levels and were once again adapted for ten days before the second collection period commenced.

During phase 1, the cannulated cows were weighed and body condition scored at the beginning of each run. During phase 2, the cannulated cows were weighed at the beginning and at the end of the phase. The cannulated cows were not weighed at the beginning of each run in phase 2 because the whole experimental period only lasted one month. The cannulated cows were body condition scored using the 5 point system as in Chapter 3. The condition scoring was done by the herd manager, Mr. Gerrit van der Merwe during both phases.

4.1.4 Data collection and pH logging system

Data was collected during a 10 day period. During this period rumen pH data was logged twice for every cow on the trial. The loggers were put on the cows on Monday, Tuesday rumen samples were collected at 08:00 and 20:00. Wednesday the rumen pH loggers were switched from the first group of cows to the second. On Thursday rumen samples were collected at 14:00 and 02:00. Friday the loggers were removed, and the *in sacco* bags were inserted at 14:00 and removed the next morning at 02:00. The next week the pH loggers were put on the cows again, however no rumen samples were collected. Different pH logging systems were used for phase 1 & 2 thus each phase is explained separately.

4.1.4.1 Phase 1

After the cannulated cows were adapted for ten days, pH loggers (WTW pH340i pH meter/ data logger with a WTW Sentix 41 pH electrode) were used to gather information on rumen pH and temperature. The temperature is used to indicate if and when the connection between the electrode and the logger is broken. This pH logging system was equipped with an external logger that was attached to the animal via a harness which was fitted just behind the shoulders. A blanket was double folded and placed between the cow and the harness to help avoid the harness hurting the animal. We didn’t want to put the harness on too tight, so to avoid the possibility of the harness slipping and breaking the cable that goes to the electrode, a rope was attached to the harness and the cannula plug. This prevented the belt from slipping and allowed the harnesses to be fitted less tightly that would have otherwise been possible.

The logger was set to log a pH measurement every 10 minutes. The pH values were then averaged to a pH value for every half hour period. There were six logging systems available, therefore only one group was used for pH measurement at a time. Data was logged per group for two days (48 hours) after which the loggers were removed, data downloaded, the electrodes recalibrated using buffer solutions of pH 4 & 7, and the loggers fitted onto the next group. This was repeated resulting in each cow being logged twice during each measurement period. These two graphs were combined to give one graph per cow per run. These graphs were then combined according to the concentrate level and the pasture treatment that the cow received to give four graphs for phase 1. Time below 6.0 and 5.8 was calculated for each cow and averaged for each treatment.

Figure 4.1: Cannulated cow with probe and logger on. The orange rope is to stop the belt from slipping forward. This also enables the belt to be kept looser than would normally be possible

4.1.4.2 Phase 2

In phase 2, a different logging system was used, namely the pH-HR pH/temperature logging systems (www.intech.co.nz). With this system, both the electrode and the logger are placed in the rumen of the cow, so the possibility of a broken connection between the logger and the electrode is significantly reduced. The cannulated cows are also more comfortable without the harnesses. However, the user is not able to check whether the logger is still working as was possible with the previous system. The new system logged an average pH value every 10 minutes. For calculating the average, the logger records a reading every 10 seconds. Six logging systems were available, therefore the data was collected in the same way as explained above. These loggers were also removed after 48 hours; data downloaded, recalibrated using buffer solutions of pH 4 & 7, and fitted onto the next group. However, in this experiment each cow was logged only once in every run. This is because there wasn't enough time to repeat the process, because the westerwold pastures had to be replanted before the end of March.

At the end of the phase, every cow had two data sets, one for each concentrate level. These data sets were combined according to concentrate level and pasture treatment to give four graphs for the second phase. Time below 6.0 and 5.8 was also calculated as explained above.

4.1.5 Rumen samples

Rumen samples were collected to determine the VFA and rumen NH_3-N concentrations. Each of the twelve rumen cannulated cows were sampled four times during the six or ten day data collection period of each sampling period. Samples were collected at 08:00, 14:00, 20:00, and 02:00. Forty-eight samples were collected in total in each run for rumen ammonia and volatile fatty acid determinations. Thus 96 samples were collected for rumen ammonia determination, and the same number was collected for VFA determination during each experiment. The rumen samples were collected by using a drain pump. The pH of the samples was determined immediately after withdrawal and recorded along with the name of the cow and the time. The pH was determined using manual recording with the pH logging systems used in phase 1.

The rumen samples were strained through four layers of cheese cloth to remove feed particles from the rumen liquor. For the rumen ammonia determination, 15ml of rumen fluid was mixed with 2.5ml of a 50% H_2SO_4 solution in a 20ml plastic bottle and frozen immediately. For the volatile fatty acid determination, 18 ml of strained rumen fluid was mixed with 2ml of a 25% H_3PO_4 solution in a 20ml plastic bottle and frozen immediately.

All the bottles were labelled with the type of sample (NH_3-N or VFA), the cow number, the time the sample was collected (08:00, 14:00, 20:00, or 02:00) and the date of collection. All the samples were stored in a freezer fro later analysis at Nutrilab, University of Pretoria.

Figure 4.2: The new logging system being inserted through the cannula. Both the logger and the probe go into the rumen of the cow

Figure 4.3: Drawing a rumen liquor sample from a cannulated jersey cow

Figure 4.4: Measurement of the rumen liquor pH before straining and adding preservatives to the respective samples

4.1.6 *In sacco* NDF disappearance of westerwold and perennial ryegrass

An *in sacco* study was conducted to determine the NDF disappearance of the two grasses over twelve hours when two different concentrate levels were fed. These values were assumed to be indicators of NDF degradability to establish relative differences in NDF degradability between the two grass species and the effect of concentrate level. Three kilograms of wet material was collected from each pasture treatment, cut at 30mm stubble height. The samples were then dried at 60ºC for 72 hours (Botha *et al*., 2007). After the samples were dried, they were weighed and allowed to equilibrate with the environment. The samples were cut into 5-10mm pieces (Taweel, *et al*., 2004) using a herb cutter in the first experiment and a paper guillotine in the second. The instrument used to cut the grass was changed for the second experiment because it was time consuming and labour intensive using a herb cutter. After the samples were cut, they were mixed again (westerwold with westerwold, and perennial ryegrass with perennial ryegrass) to obtain homogenous samples.

Dacron bags with pore size of 53 microns and dimensions of 10cm by 20cm in size were used for the incubation. The Dacron bags were weighed, and then 5g of dried grass was placed into each bag and weighed again. The bags were closed using cable ties and weighed again. Six zero time bags were made up for each incubation series (three containing westerwold ryegrass and three containing perennial ryegrass). Four bags were placed in the rumen of each cannulated cow. The bags were placed in a stocking with a glass marble at the bottom to act as a weight and prevent the bags from floating on top of the rumen contents. The bags were placed in the rumen at 14:00 and removed at 02:00. The bags were incubated for twelve hours. The bags were only incubated for twelve hours because of the possibility that the differences between the treatments might be less pronounced with longer incubation. Furthermore, this is the period when the rumen pH is most likely to drop below 6.0.

Cruywagen (2006) wrote e technical note describing a method to facilitate the removal of *in sacco* bags from the rumen. With this method the Dacron bags are placed in nylon stockings and knotted in between every bag to separate them. The stocking is then attached to the cannula plug by the use of a catcher which also that can hold several legs containing the Dacron bags. This method also permits the removal of bags without exposing the remaining bags to air. A large glass marble is placed in the bottom of the stocking leg and acts as a weight to prevent the bags from floating on top of the rumen contents. A tight knot is made behind the marble to keep in place. Cruywagen (2006) also suggests that depending on the length of the stocking leg, approximately 5 bags can be placed in the stocking in tandem. It is imperative that high quality stockings be used as low quality stocking can stretch out quite a lot in the rumen and make the removal of the bags very difficult. Low quality stocking also break more easily which can cause the loss of bags in the rumen.

After incubation, the bags were removed and washed by hand in the first experiment and a washing machine was used in the second phase. The reason for the difference in the washing procedure between the two experiments is that a washing machine wasn't available for the first experiment. During the first phase the bags were washed under running cold tap water until the water ran clear (Kitessa *et al*., 1999). During the second phase the bags were washed in the washing machine set to a 5 minute cycle using cold water. The bags were washed for five consecutive cycles, and then spun to remove excess water. The bags were then dried at 60ºC for 72 hours, taken out of the oven, five at a time, and weighed immediately (Osuji *et al*., 1993). The zero time bags were not incubated, but also washed and dried in the same manner as the other bags. They were used to determine the DM loss at time zero. Because the grass was exposed to humidity, three 5g samples of each grass type was weighed out and dried during each experimental period to determine the DM content of the pasture samples. The residue left over in the four bags incubated in each cow was combined to give six replications per treatment for each phase. The pooled *in sacco* residues and the pasture samples were analysed for NDF as described in Chapter 3.

Figure 4.5: The pasture samples were cut with a paper cutter during the second phase.

Figure 4.6: *In sacco* bags packed in nylon stockings ready to be inserted into the cannulated cows. The stocking leg is attached to the cannula plug using a clip

Figure 4.7: Inserting the bags into the cannulated cows at two in the afternoon

4.1.7 Statistical analysis

The rumen study had a switch over design, with cows on switching concentrate levels. An analysis of variance using the GLM model (Statistical Analysis Systems, 2008) was used to determine the significance between different levels of treatments and periods for the balanced data of the volatile fatty acid concentrations, rumen NH_3-N concentrations, and the pH data. Means and standard errors (SE) were calculated. The significance of difference (5%) between means was determined by using Fischer's test (Samuels, 1989).

4.2 Results & Discussion

4.2.1 Climatic conditions

The mean minimum, maximum, and average daily temperatures for the two trial periods, as well as the mean monthly rainfall are presented in Table 4.2. The mean temperatures for both the trial periods were within the ranges expected for the specified months. The mean rainfall for the two trial periods was acceptable. The excessive rain that fell during November 2007 occurred after the trial period had ended.

Table 4.2: Mean minimum, maximum and daily temperatures (in ºC), and mean monthly rainfall (mm) for the George area, the duration of the two trial periods

Month	Mean minimum T	Mean maximum T	Mean daily T	Total rainfall (mm)
September	8.8	18.8	12.9	34.3
October	10.4	20.5	15.3	43.6
November	11.9	21.3	16.4	491.4
March	14.1	23.9	18.5	61.9

T = temperature

4.2.2 Phase 1

4.2.2.1 Chemical composition of the experimental diets

Table 4.3 contains the total diet composition of the diets fed to the four groups cows during the first experimental period as the nutritive composition of the diets fed to the four groups of cows is vital in understanding the differences in ruminal pH results. The nutritive composition of the diet was calculated according to the intake estimated using the NDF intake method described in Chapter 3. The calculation is described later on in this chapter, as well as in section 3.2.2.4.

Table 4.3 The total diet composition (grass plus concentrate) (as a % of DM) of the diets fed to the cows that grazed westerwold and perennial ryegrass over-sown into kikuyu, and received either 4 kg or 8 kg of a concentrate supplement per day, for the duration of the first experimental period

	Treatments			
	WR 4	**WR 8**	**PR 4**	**PR 8**
DM	36.35	50.31	35.27	49.52
Ash	10.51	9.63	10.89	9.91
CP	19.08	17.80	18.96	17.71
ME	10.87	11.36	11.38	11.73
EE	2.75	2.76	3.11	3.02
NDF	40.44	32.65	39.32	31.83
ADF	22.36	17.49	22.46	17.56
NFC	31.32	37.17	27.71	35.98
Ca	0.65	0.80	0.64	0.80
P	0.36	0.35	0.37	0.36

WR4 = westerwold ryegrass, 4 kg concentrate

WR8 = westerwold ryegrass, 8kg concentrate

PR4 = perennial ryegrass, 4kg concentrate

PR8 = perennial ryegrass, 8 kg concentrate

DM = dry matter

CP = crude protein

ME = metabolisable energy

EE = ether extract

NDF = neutral detergent fibre

ADF = acid detergent fibre

NFC = non-fibrous carbohydrates

Ca = calcium

P = phosphorous

4.2.2.2 Ruminal pH

4.2.2.2.1 Results from using pH data loggers

The data loggers recorded the ruminal pH every 10 minutes for a total of four days per cow. The mean pH for every half hour was then calculated. This was done by averaging the reading before, at, and after the specific time. For example, if the reading for 8:00 am needed to be calculated, the average for the readings taken at 7:50, 8:00, and 8:10 was used. The same principle was applied to all the times. The mean for the four days was then calculated.

Because concentrate levels were exchanged and data recorded again, there was a total of six cows on each treatment. The mean of each treatment was then calculated from the pH results from the six cows. The results for the cows that grazed the perennial ryegrass treatment and received four or eight kilograms of concentrate per day are shown in Figure 4.8, while the results for the cows that grazed the westerwold ryegrass treatment and received four or eight kilograms of concentrate per day are shown in Figure 4.9. Each point on the graph is a mean of 72 readings (three readings per time, four days per cow, and six cows per treatment).

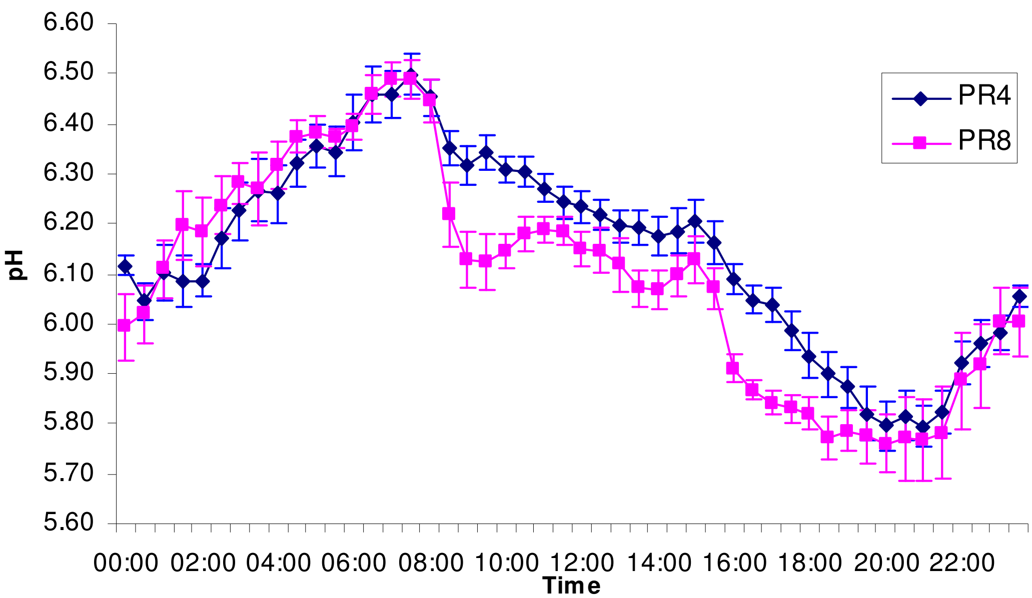

Figure 4.8 The mean pH results of the cows that grazed the perennial ryegrass treatment and received either four or eight kilograms of concentrate per day, with standard error bars. PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The cows that grazed the perennial ryegrass treatment and received 8 kg of concentrate per cow per day had a numerically lower ruminal pH during the day when compared to the cows that received 4 kg of concentrate per cow per day (Figure 4.8). In general, the ruminal pH of cows on both concentrate levels followed the same pattern throughout the day. The highest ruminal pH for both groups occurred before the concentrate supplement was fed (pH 6.50 & 6.49 for PR4 & PR8 respectively at 07:30; and 6.21 & 6.13 for PR4 & PR8 respectively at 15:00). The cows that received 8kg of concentrate per day had a more severe drop in ruminal pH (pH 6.44 – 6.13 between 08:00 and 09:00; and pH 6.13 – 5.91 between 15:00 and 16:00) directly after concentrate supplementation compared to the cows that received 4kg of concentrate per day (pH 6.44 – 6.32 between 08:00 and 09:00; and pH 6.21 – 6.09 between 15:00 and 16:00). This is in similar to the findings of Cajarville *et al* (2006), who observed that the minimum mean ruminal pH occurred 4 hours post-supplementation (section 2.10.1). The results also agree with the findings of Bargo *et al* (2002) who reported that the highest ruminal pH occurred before concentrate feeding, and the lowest ruminal pH after concentrate feeding (section 2.10.1).

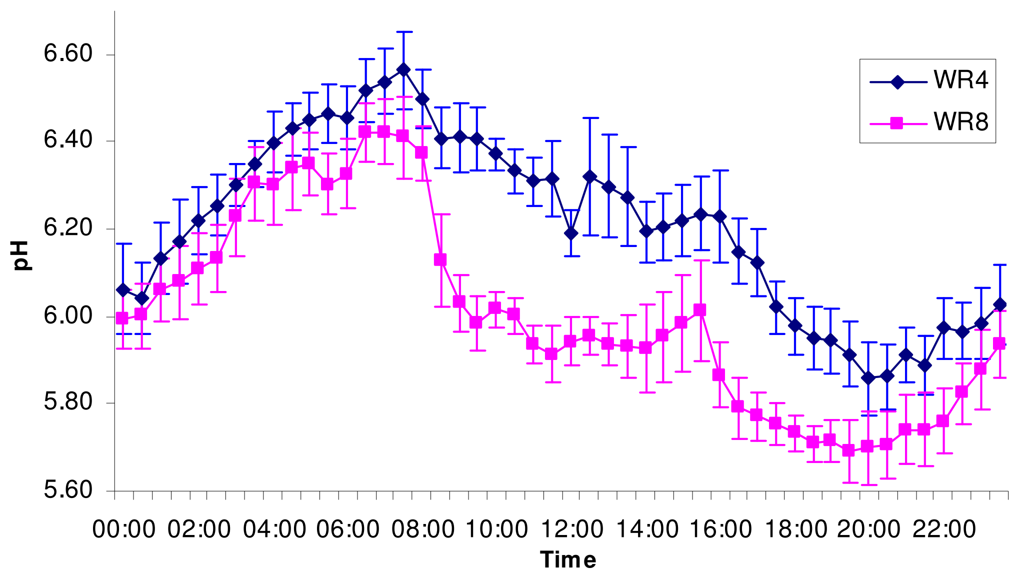

Figure 4.9 The mean pH results of the cows that grazed the westerwold ryegrass treatment and received either four or eight kilograms of concentrate per day, with standard error bars. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate

The cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate per cow per day had a numerically lower ruminal pH than the cows that received 4 kg of concentrate per day (Figure 4.9). This could be due to the fact that the total diet consumed by the cows that received 8 kg of concentrate per day had a lower NDF and higher starch content, which means that the buffering capacity was lower. Both groups of cows showed a drop in ruminal pH after the concentrate supplement was fed. The highest ruminal pH was recorded just before the morning milking for both groups (6.56 for WR4 and 6.41 for WR8 at 07:30; and 6.24 for WR4 and 6.01 for WR8 at 15:30), and the lowest ruminal pH was recorded about four hours after the evening milking (5.91 for WR4 and 5.69 for WR8 at 19:30). This pattern is similar to the perennial ryegrass pasture treatment results, and agree with the findings of Cajarville *et al* (2006), and Bargo *et al* (2002).

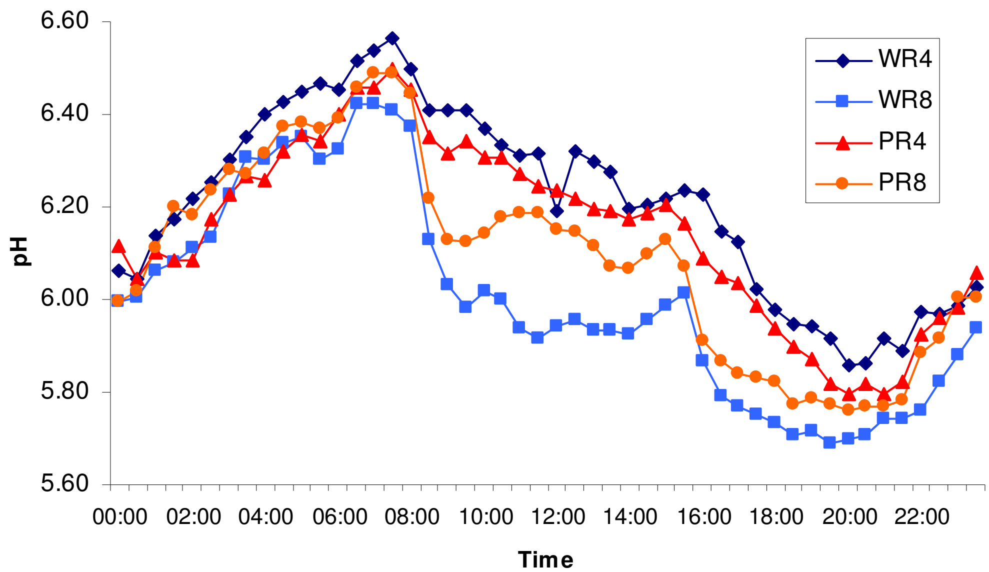

Figure 4.10 Ruminal pH results for the cows that grazed westerwold and perennial ryegrass over-sown into kikuyu, and received either four of eight kilograms of concentrate per day, for the first experimental period. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

Figure 4.10 contains the ruminal pH results of all four treatments. As can be seen from the graph, the cows that grazed the westerwold ryegrass treatment and received 4 kg of concentrate per day had a numerically higher ruminal pH than the cows that grazed the perennial ryegrass treatment and received 4 kg of concentrate supplementation per day. However, the cows that grazed the perennial ryegrass treatment and received 8 kg of concentrate supplementation per day had a higher ruminal pH than the cows that grazed the westerwold ryegrass treatment and received 8 kg of concentrate per day. There was a bigger difference in ruminal pH between the two groups that grazed the westerwold ryegrass treatment (WR4 & WR8), compared to the two groups that grazed the perennial ryegrass treatment (PR4 & PR8).

Bargo *et al* (2003a) stated that the interaction between the amount and type of concentrate, and the pasture intake and quality may play a key role in the effect of concentrate supplementation on ruminal pH. The same concentrate supplement was fed to all the cows participating in the trial. When comparing the diet compositions fed to the four groups (Table 4.3), the relative difference within the groups is not sufficient to explain why WR8 had a more severe pH drop when compared to WR4, than PR8 compared to PR4, as PR8 had a lower NDF content than WR8. The difference in the total diet NDF content between WR4 and WR8 is about 7%, compared to PR4 and PR8 which is about 6%. The difference in ME concentration between the low and high concentrate groups that grazed the westerwold ryegrass treatment is 0.41 MJ ME/kg DM, and the difference between the low and high concentrate groups that grazed the perennial ryegrass treatment was 0.29 MJ ME/kg DM. This is a relatively small difference and is unlikely to have contributed. It seems that the difference in ruminal pH between WR4 and WR8 compared to PR4 and PR8 could be caused by a difference in pasture intake. As pasture intake was not directly measured, this cannot be proved conclusively. To estimate whether there was a difference in pasture intake, pasture intake was estimated for WR8 and PR8 using the NDF intake method (section 2.4.1). The average body weights of the cows were taken as indicated in section 3.2.2.4. When NDF intake was calculated as a percentage of body weight, the NDF intake for the two westerwold ryegrass groups was 4.8kg and the NDF intake for the two perennial ryegrass groups was 4.7kg. The amount of concentrate supplement fed to WR8 and PR8 on a dry matter basis was 7.08 kg per day, with a NDF% of 11.55%. Thus the NDF intake from the concentrate supplement was 0.8kg for both WR8 and PR8. Thus the NDF intake from pasture was 4kg per day for WR8 and 3.9kg per day for PR8. The pasture NDF% for the duration of the trial was

52.24% for the westerwold ryegrass treatment, and 50.76% for the perennial ryegrass treatment. Thus the pasture intake was 7.65kg/day for WR8 and 7.67kg/day for PR8. The pasture intake for WR4 and PR4 was calculated in the same way as described above and was 8.40kg/day for WR4 and 8.46kg/day for PR4. Thus the pasture intake, together with the lower NDF percentage and ME concentration could have contributed to the more severe pH drop between WR4 and WR8, compared to PR4 and PR8.

Table 4.4 shows the average time (in minutes) during a 24 hour period that the ruminal pH of the four groups dropped below pH 6.00, and pH 5.80. The ruminal pH of the cows that grazed the westerwold ryegrass treatment and received 8kg of concentrate per day was below pH 6.00 for more than double the time (765 minutes) of the cows that grazed the same pasture treatment and received 4kg of concentrate per day (330 minutes) ($P < 0.05$). There was no difference in the amount of time the pH dropped below pH 6.00 for the cows that received a high or low level of concentrate supplementation and grazed the perennial ryegrass treatment (360 minutes for PR4; and 480 minutes for PR8) ($P > 0.10$). The average ruminal pH of WR8 was also under pH 5.80 for a longer period of time than that of WR4 (80 minutes for WR4; and 375 minutes for WR8) ($P < 0.05$). There was again no statistical difference in the time the ruminal pH dropped below pH 5.80 for the two groups that grazed the perennial ryegrass treatment (75 minutes for PR4; and 175 minutes for PR8). This indicates that the perennial ryegrass pastures had a better buffering capacity than the westerwold ryegrass pastures. The cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate supplementation per day had a higher mean pH (6.21) than the cows that grazed the same pasture treatment and received 8kg of concentrate supplementation per day (6.00), ($P < 0.05$). There was also a difference between the cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate supplementation per day and the cows that grazed the perennial ryegrass pasture treatment and received 4 kg of concentrate supplementation per day ($P < 0.10$), however there was no difference between the two groups that grazed the perennial ryegrass pasture treatment ($P > 0.10$).

Table 4.4 The average time (in minutes) during a twenty-four hour period that the average ruminal pH was below 6.00, and 5.80, as well as the overall mean ruminal pH for the cows that grazed westerwold and perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

Treatment	**Time below pH 6**	**Time below pH 5.8**	**Overall mean**
Westerwold 4kg	330^{a}	80^{a}	6.21^{a}
Westerwold 8kg	765^{b}	375^{b}	6.00^{bc}
Perennial 4kg	360^{a}	75^{a}	6.15^{ad}
Perennial 8kg	480^{a}	175^{ab}	6.09^{ab}
SEM	107.4	86.3	0.051
P – value	0.674	0.738	0.055

SEM = standard error of means

ab means in the same row with different superscripts differ ($P < 0.05$)

cd means in the same column with different subscript differ ($P < 0.10$)

There were no treatment × time interactions ($P > 0.10$).

4.2.2.2.2 Manual recording of ruminal pH

The ruminal pH of every cow was recorded every time the rumen samples for VFA and NH_3-N were collected at 8:00, 14:00, 20:00, and 02:00. Figure 4.11 illustrates the variation in ruminal pH from cows on the perennial ryegrass treatment. The ruminal pH of both groups of cows that grazed the perennial ryegrass treatment was below pH 6.00 at 20:00 and 14:00. Although not as refined as Figure 4.8, Figure 4.11 shows the same general trend in ruminal pH changes throughout the day. The standard error bars of the two lines at 20:00 do not overlap, even though there is no significant difference between the two treatments at this time (Table 4.5). At 14:00, the standard error bars do not overlap either; however there is a statistically significant difference between the two treatments at this time (Table 4.5).

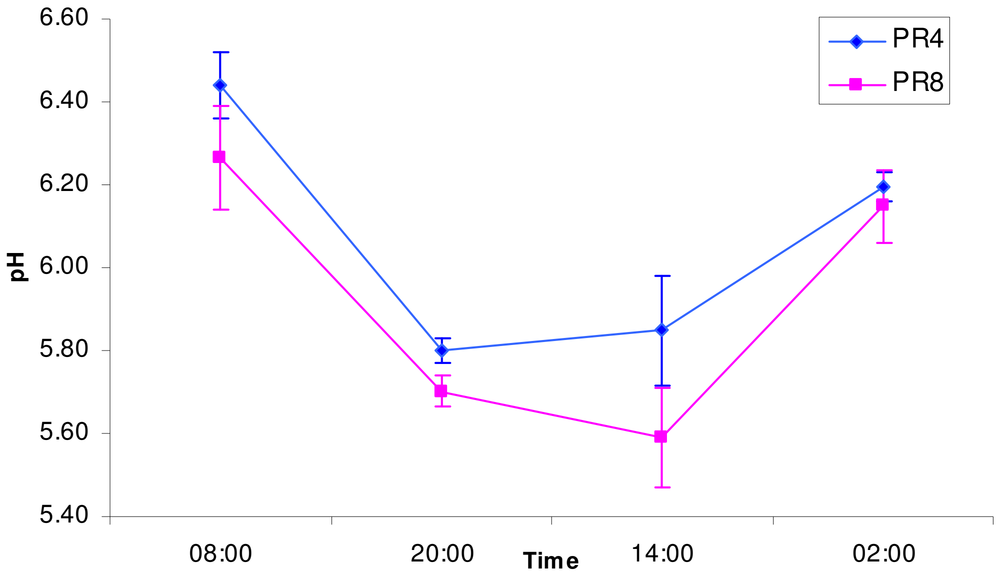

Figure 4.11 Ruminal pH results from the manual recording for the cows that grazed the perennial ryegrass treatment and received either four or eight kilograms of concentrate per day, with standard error bars. PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

In figure 4.12 is illustrated the variation in ruminal pH through manual recording in cows grazed the westerwold ryegrass treatment. Similar to the cows that grazed the perennial ryegrass treatment, both the high and low concentrate supplementation groups had a mean ruminal pH below pH 6.00 at the 20:00 and 14:00 ruminal sampling times. The difference between the two groups in terms of ruminal pH, however, is not as pronounced with the manual recording when compared to the results obtained with the ruminal pH loggers, but Figure 4.12 shows the same general trend in ruminal pH change throughout the day as can be seen in Figure 4.9. However, there was a difference in terms of the pH logged inside the rumen and that logged when the samples were collected. This could be due to fact that the samples were exposed to air for a short while whilst the pH was recorded.

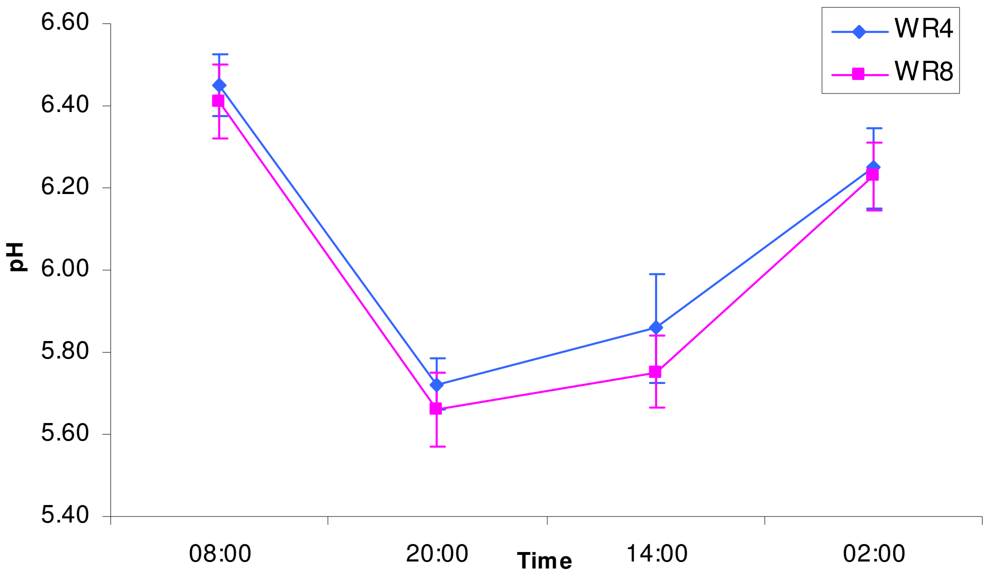

Figure 4.12 Ruminal pH results from the manual recording for the cows that grazed the westerwold ryegrass treatment and received either four or eight kilograms of concentrate per day, with standard error bars. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate

Figure 4.13 illustrates the ruminal pH variation in cows from manual recording for the four times throughout the day for all four the treatments. When this figure is compared to figure 4.10, it shows the same general trend in ruminal pH throughout the day. However, looking at Figure 4.10, the treatment with the lowest ruminal pH was WR8, and looking at Figure 4.13, it was PR8. Each value from the manual recording, as shown in Figures 4.11 – 4.13, is an average of 12 pH readings (6 cows per treatment; two periods), whereas each value in Figure 4.10 is an average of 72 pH readings, which means a significantly low or high reading would have had a more pronounced effect on the average values of Figure 4.13 than they would have had on the average values of Figure 4.10. Thus it is possible for the two figures to differ, and Figure 4.10 will be more accurate than Figure 4.13. This is due to the various factors that can affect the pH value of a sample. The manual samples were exposed to air while the pH reading was taken; these samples were not taken in the same place as the logger was in the rumen, as we were scared of damaging the logger.

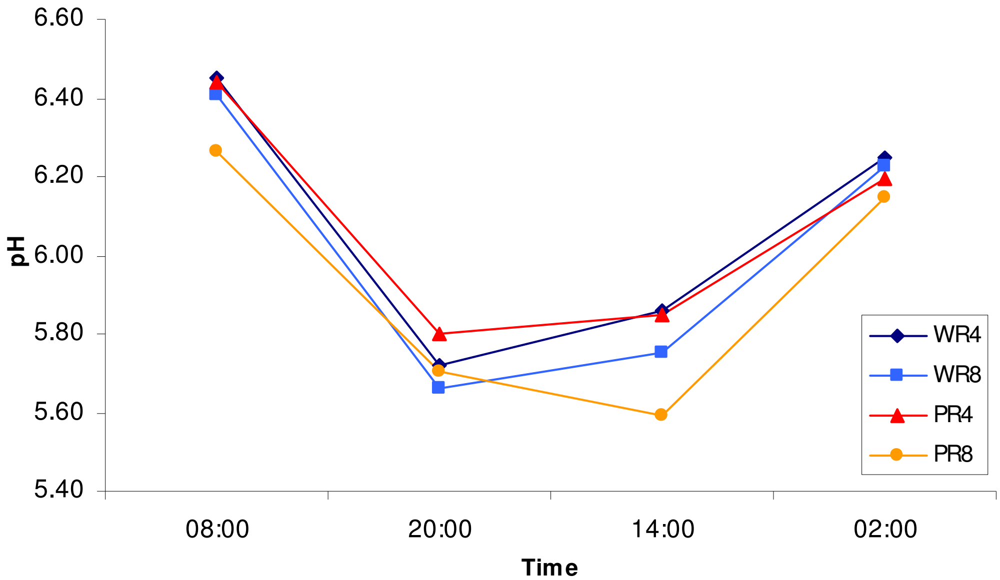

Figure 4.13 Ruminal pH results from the manual recording for the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The results from the manual pH recordings were statistically compared, and are presented in Table 4.5. There was no significant difference in ruminal pH between WR4 and WR8; and PR4 and PR8 at 08:00am ($P > 0.10$). The cows that grazed the perennial ryegrass treatment and received 4kg of concentrate per day had a significantly higher ruminal pH at 14:00 (pH 5.85) than the cows that grazed the same pasture treatment and received 8kg of concentrate per day (pH 5.59) ($P < 0.05$). There was no significant difference in ruminal pH between WR4 and WR8; and PR4 and PR8 at 20:00 and 02:00 ($P > 0.10$). The results presented in this table agree with the results in Figures 4.11 – 4.13.

Table 4.5 The mean ruminal pH measured manually in cows that grazed westerwold or perennial ryegrass pasture treatment and received either four or eight kilograms of concentrate per day, measured when the rumen samples were collected

	Treatments				
Ruminal pH	**WR4**	**WR8**	**PR4**	**PR8**	**SEM**
Ruminal pH measured at:					
08:00	6.45	6.41	6.44	6.27	0.449
14:00	5.85	5.75	5.85^{a}	5.59^{b}	0.748
20:00	5.72	5.66	5.80	5.70	0.332
02:00	6.25	6.23	6.20	6.15	0.874
Overall means	6.07	6.01	6.07	6.02	0.048

SEM = standard error of means

ab means in the same row with different superscripts differ ($P < 0.05$)

4.2.2.3 Ruminal ammonia nitrogen concentrations

The mean ruminal NH_3-N concentrations (mg/dl) for the 6 cows on each treatment were calculated for each of the four times of the day, and are shown in Figure 4.14 and Table 4.6.

At 08:00 there was no difference in ruminal NH_3-N concentration between the low and high concentrate groups of each pasture treatment ($P > 0.10$). However, the cows that grazed the westerwold ryegrass treatment and received 4kg of concentrate per day had a higher ruminal NH_3-N concentration than the cows that grazed the perennial ryegrass treatment and received the same amount of concentrate per day ($P < 0.10$). The cows that grazed the westerwold ryegrass pasture treatment and received either 4 or 8 kg of concentrate supplementation per day had higher ruminal NH_3-N concentrations than the cows that grazed the perennial ryegrass pasture treatment and received 8 kg of concentrate supplementation per day ($P < 0.05$). This indicates that there was more free NH_3-N from proteolysis present in the rumens of the cows on the westerwold ryegrass treatment compared to the cows on the perennial ryegrass treatment, which could indicate that there was more carbohydrate skeletons available for microbial protein synthesis within the rumens of the cows on PR4 compared to WR4. At 20:00, WR4 had a higher ruminal NH_3-N concentration than PR8 ($P < 0.05$). At 14:00, there were no significant differences in ruminal NH_3–N concentration both within and between the pasture treatments ($P > 0.10$).

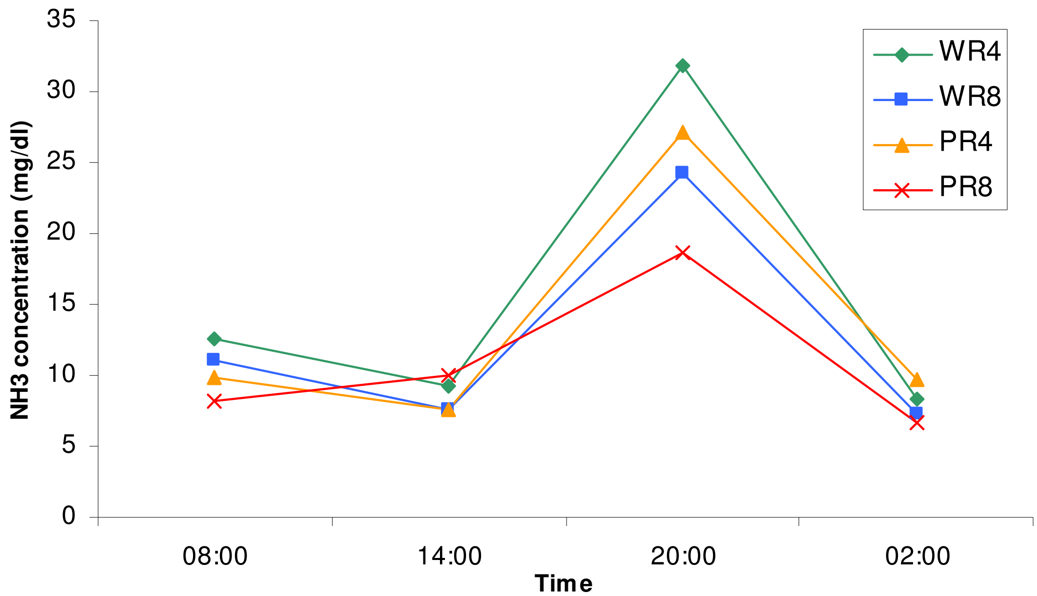

Figure 4.14 Mean ruminal ammonia nitrogen concentration (mg/dl), of the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu and received either four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

At 02:00, the cows that grazed the perennial ryegrass treatment and received 4kg of concentrate per day had a higher ruminal NH_3-N concentration than the cows that grazed the same pasture treatment and received 8kg of concentrate per day ($P < 0.10$). According to McDonald *et al* (2002), the optimal NH_3-N concentration is between 8.5 & 30.0 mg/dl (section 2.10.3). Cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate supplementation per day had an above optimal NH_3-N concentration at 20:00 and a below optimal NH_3-N concentration at 02:00. Cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate supplementation per day had a below optimal NH_3-N concentration at 14:00 and 02:00. Cows that grazed the perennial ryegrass pasture treatment and received 4 kg of concentrate supplementation per day had a below optimal NH_3-N concentration at 14:00, and PR8 had a below optimal NH_3-N concentration at 08:00 and 02:00. Table 4.3 clearly shows that none of the diets fed to the cows were deficient in protein, thus protein resistant to degradation could be the reason. The high NH_3-N concentration observed in WR4 at 20:00 is due to protein degradation exceeding protein synthesis. Both pasture treatments showed that a higher level of concentrate supplementation decreased the ruminal NH_3-N concentration. This was expected, as a higher supply of readily available energy improves the rumen micro organisms' ability to utilise NH_3-N for microbial protein synthesis (Nocek & Russel, 1988) (section 2.10.3). However, all the ruminal NH_3-N concentrations of all four treatments were well above the minimum recommended level for maximum microbial protein synthesis of 5mg/dl (Satter & Slyter, 1974). For most of the sampling times, the NH_3-N concentrations of WR4 and WR8 were higher than that of PR4 & PR8. This could indicate that the protein present in the westerwold ryegrass was more degradable than that of the perennial ryegrass. The results in Table 4.6 are in agreement with those of Bargo *et al* (2003a), who found that the most consistent effect of concentrate supplementation on ruminal fermentation is a decrease in ruminal NH_3-N concentration. The mean ruminal NH_3-N concentration of WR4 was higher than that of both groups of cows that grazed the perennial ryegrass pasture treatment ($P < 0.05$). This indicates that the cows that grazed the perennial ryegrass pasture treatment had more carbohydrate skeleton available for microbial protein synthesis compared to WR4.

Table 4.6 The ruminal ammonia nitrogen concentration, in mg/dl, of the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

	Treatments					
	WR4	**WR8**	**PR4**	**PR8**	**SEM**	**P-value**
08:00	12.54^{ac}	11.10^{a}	9.86^{abd}	8.11^{b}	0.857	0.034
20:00	31.80^{a}	24.26^{ab}	27.06^{ab}	18.71^{b}	1.338	0.086
14:00	9.19	7.56	7.57	10.02	1.480	0.425
02:00	8.40^{cd}	7.31^{cd}	9.73^{c}	6.73^{d}	1.067	0.369
Overall mean	16.16^{a}	13.94^{ab}	11.76^{b}	11.08^{b}	1.26	0.549

xy means in the same row with different superscripts differ (P < 0.05)

cd means in the same row with different superscripts differ (P < 0.10)

WR4 = westerwold ryegrass, 4kg of concentrate

WR8 = westerwold ryegrass, 8kg of concentrate

PR4 = perennial ryegrass, 4kg of concentrate

PR8 = perennial ryegrass, 8kg of concentrate

The highest ruminal NH_3-N concentrations were observed at 20:00 for all four treatments. This was ± 5 hours after the evening milking (cows were milked and fed the concentrate supplement at 15:00). Cajarville *et al* (2006) observed maximum ruminal NH_3-N concentrations 8 hours post-supplementation. The 14:00 sample was taken 7½ hours post-supplementation, however, these concentrations were lower then the 08:00 ruminal NH_3-N concentrations. Cajarville *et al* (2006) also found that the maximum ruminal NH_3-N concentrations coincided with the minimum ruminal pH values. The results of this trial agree with this part of his observation, as the maximum ruminal NH_3-N concentrations (31.80, 24.26, 27.06 & 18.71 mg/dl for WR4, WR8, PR4 & PR8 respectively) were recorded at 20:00, and the minimum ruminal pH values were also recorded at 20:00 (pH 5.86, 5.70, 5.80 & 5.76 for WR4, WR8, PR4 & PR8 respectively).

There were treatment × time interactions at 08:00 for PR4; at 20:00 for WR4 and WR8; and at 02:00 for WR4 (P < 0.10).

4.2.2.4 Ruminal volatile fatty acid concentrations

The concentration of the total ruminal volatile fatty acids (mmol/dl), including acetic, propionic, butyric, iso-butyric and valeric acids, averaged for the six cows on each treatment is reported in Table 4.7 & Figure 4.15.

There were no differences in total VFA concentration between the four treatments ($P > 0.10$), which were 11.06 mmol/dl for WR4, 11.88 mmol/dl for WR8, 11.52 mmol/dl for PR4, and 11.44 mmol/dl for PR8. These results are in agreement with the results of Garcia *et al* (2000) and Reis & Combs (2000), who reported that supplementation had no effect on total VFA concentrations, even at a decreased ruminal pH. There were no differences in acetic acid concentrations between the four treatments ($P > 0.10$), which were 7.44, 7.71, 7.70 and 7.45 mmol/dl for WR4, WR8, PR4 and PR8, respectively. There was therefore no clear effect of level of concentrate supplementation on acetic acid concentration. The cows that grazed the westerwold ryegrass treatment and received 8kg of concentrate per day had a significantly higher ($P < 0.10$) ruminal propionate concentration (2.31 mmol/dl), than the cows that grazed the same treatment and received 4kg of concentrate per day (2.05 mmol/dl). This was expected since it is well established that an increased starch intake or higher concentrate: roughage ratio generally leads to an increased ruminal propionate production (Hutjens, 2008). However, there were no significant differences in propionate concentrations between PR4 (2.17 mmol/dl) and PR8 (2.29 mmol/dl) ($P > 0.10$) even though PR8 had a slightly higher numerical ruminal propionate concentration than PR4. The cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate supplementation per day had a lower ruminal propionic acid concentration than the cows that grazed the perennial ryegrass pasture treatment and received 8 kg of concentrate supplementation per day ($P < 0.10$). This indicates that the perennial ryegrass pasture treatment had more available starch than the westerwold ryegrass pasture treatment, as there was no difference between the two groups that grazed the perennial ryegrass pasture treatment ($P > 0.10$). The results on the westerwold ryegrass pasture treatment are in accordance with the results of Bargo *et al* (2002) and Berzaghi *et al* (1996), all of whom found that concentrate supplementation increased ruminal propionate concentration and production. The cows that grazed the westerwold ryegrass treatment and received 8 kg of concentrate per day had a higher (P < 0.05) ruminal butyric acid concentration (1.61 mmol/dl) than the cows that grazed the same treatment and received 4 kg of concentrate per day (1.40 mmol/dl), however there were no significant differences in butyric acid concentrations between the two groups that grazed the perennial ryegrass treatment (P > 0.10), which was 1.44 and 1.47 mmol/dl for PR4 and PR8, respectively. However, PR4 had a lower butyric acid concentration (1.44 mmol/dl) than WR8 (1.61 mmol/dl).

Table 4.7 The total ruminal volatile fatty acid, acetic, propionic and butyric acids concentrations, in mmol/dl, of the cows that grazed westerwold and perennial ryegrass over-sown into kikuyu and received either four or eight kilograms of concentrate per day

	Treatments					
Item	**WR4**	**WR8**	**PR4**	**PR8**	**SEM**	**P-value**
Total concentration	11.06	11.88	11.52	11.44	0.365	0.524
Acetic acid	7.44	7.71	7.70	7.45	0.231	0.561
Propionic acid	2.05^{c}	2.31^{d}	2.17^{cd}	2.29^{d}	0.098	0.010
Butyric acid	1.40^{a}	1.61^{bc}	1.44^{ad}	1.47^{a}	0.063	0.299

ab means in the same row with different superscripts differ (P < 0.05)
cd means the same row with different subscripts differ (P < 0.10)
SEM = standard error of means
WR4 = westerwold ryegrass, 4kg of concentrate
WR8 = westerwold ryegrass, 8kg of concentrate
PR4 = perennial ryegrass, 4kg of concentrate
PR8 = perennial ryegrass, 8kg of concentrate

The proportions of the individual volatile fatty acids that make up the total VFA concentrations of the four treatments are shown in Figure 4.15. The volatile fatty acid proportions of the westerwold ryegrass pasture treatment changed from 67:19:13 for acetic: propionic: butyric to 65:19:14 when the amount of concentrate supplemented was increased from 4 to 8 kg of concentrate per cow per day. The proportion of acetic acid in the rumen decreased from 67% to 65%, while the proportion of butyric acid increased from 13% to 14%. The proportion of propionic acid in the rumen stayed the same at 19%.

These results agree with the results of Khalili & Sairanen (2000), who reported a reduction in acetic acid concentration only in response to increased concentrate supplementation.

The volatile fatty acid proportions of the perennial ryegrass pasture treatment changed from 67:19:12 to 65:20:13 when the amount of concentrate supplemented was increased from 4kg to 8kg of concentrate per cow per day. The proportion of acetic acid in the rumen decreased from 67% to 65%, the proportion of propionic acid increased from 19% to 20%, and that of butyric acid from 12% to 13%. These results agree with the results of Bargo *et al* (2002) who reported a reduction in the acetate/propionate ratio, as well as an increase in butyrate as the amount of concentrate supplemented was increased. These changes, however, were relatively small and of no real biological significance.

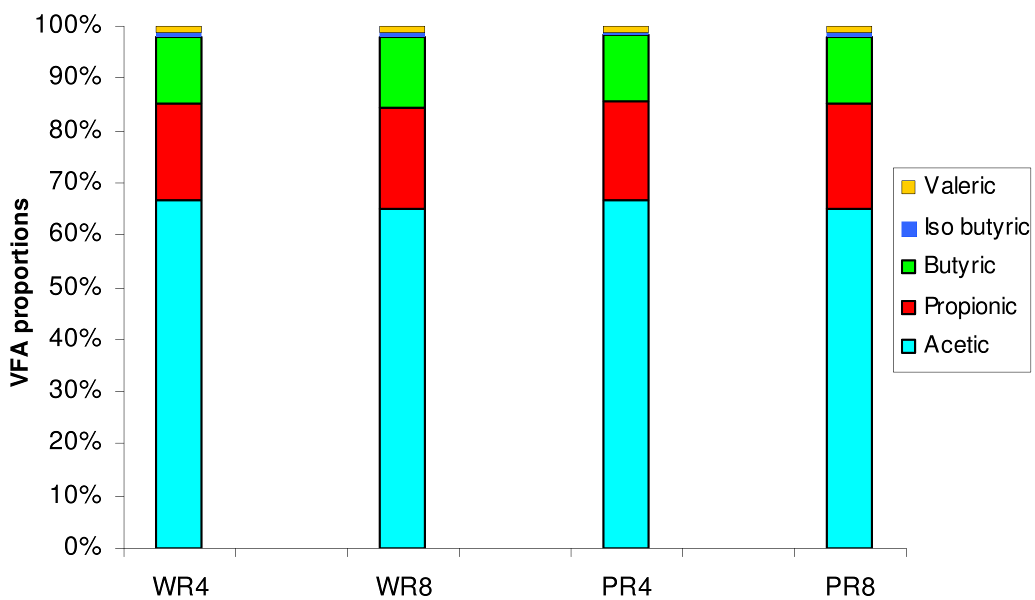

Figure 4.15 The proportions of the individual volatile fatty acids that make up the total volatile fatty acid concentrations of the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

There were treatment × time interactions for WR8 for propionic and butyric acid concentrations.

4.2.2.5 *In sacco* NDF disappearance of pastures

Four bags were incubated in each cow, these bags were pooled per cow, and the residue was analysed for NDF content. Using the obtained NDF disappearance values, the percentage NDF disappearance was calculated for each cow. Table 4.8 contains the mean percentage NDF disappearance for each of the four treatments.

The cows that grazed the westerwold ryegrass treatment and received 4kg of concentrate per day had a higher percentage NDF disappearance (19.34%) than the cows that grazed the same pasture treatment and received 8kg of concentrate per day (13.81%), as well as the cows that grazed the perennial ryegrass pasture treatment and received either 4 (11.48%) or 8 kg (7.71%) of concentrate supplementation per day ($P < 0.05$). There was no difference in the percentage NDF disappearance between the two groups that grazed the perennial ryegrass pasture treatment ($P > 0.10$). The cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate supplementation per day had a higher percentage of NDF disappearance than the cow that grazed the perennial ryegrass pasture treatment and received the same amount of concentrate supplementation ($P < 0.05$). The results of the westerwold ryegrass pasture treatment are in accordance with those of Meissner *et al* (1991) and Bargo *et al* (2002), who found a depression in both the rate and extent of cell wall degradation when ryegrass was supplemented with maize meal. This is due to the readily fermentable components of grain reducing the rate of rumen microbial degradation of fibrous components of forage in the rumen (section 2.9.3). The NDF percentage of the pasture samples that were incubated in the rumens of the cows were 48.41% for the westerwold ryegrass pasture treatment, and 48.92% for the perennial ryegrass pasture treatment, as the samples were cut in early October 2007. Thus both the pasture treatments had NDF percentages well below the 55-60% NDF content where cell wall digestion is severely depressed when concentrate supplementation is increased (Van Soest, 1976, Mertens & Ely, 1979, Meissner *et al*, 1991). The difference between the two ryegrass species could be explained by the findings of Vadiveloo & Holmes (1979) who showed that the severity of the depression in NDF digestion depends on the quality of the forage. Neutral detergent fibre degradation, and thus cell wall degradation, also depends on ruminal pH. When the results of the percentage NDF disappearance were compared with the results in Table 4.4, it can be seen that PR4 had a longer time below pH, than WR4. Even though the difference was not statistically significant, it could have contributed. To explain the difference in NDF disappearance between the two treatments, as according to Varga & Kolver (1997), fibre fermenting bacteria are limited by a ruminal pH below 6.0.

Table 4.8 The percentage NDF disappearance from the *in sacco* bags over a twelve hour period for cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

	Treatments				
Item	**WR4**	**WR8**	**PR4**	**PR8**	**SEM**
NDF disappearance (%) in 12h	19.34[a]	13.81[bd]	11.48[bd]	7.71[bc]	1.838

abcd means in the same column with different superscripts differ (P < 0.05)

WR4 = westerwold ryegrass, 4kg of concentrate

WR8 = westerwold ryegrass, 8kg of concentrate

PR4 = perennial ryegrass, 4kg of concentrate

PR8 = perennial ryegrass, 8kg of concentrate

SEM = standard error of means

NDF = neutral detergent fibre

There was a treatment × time interaction for the WR4 treatment ($P < 0.10$).

4.2.3 Phase 2

4.2.3.1 Chemical composition of the experimental diets

Table 4.9 contains the nutritive composition of the diets fed to the cows on the four treatments during March 2008. When interpreting results from the rumen fermentation study, it is important to relate the results to the total diet composition.

Table 4.9 The nutritive composition of the diets fed to the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day, for the second experimental period (March 2008)

	Treatments			
Item	**WR 4**	**WR 8**	**PR 4**	**PR 8**
DM	35.17	52.22	35.41	52.39
Ash	10.77	9.62	10.65	9.53
CP	20.47	18.53	20.28	18.40
ME	10.57	11.25	10.37	11.10
EE	2.88	3.52	3.27	3.78
NDF	44.42	33.68	43.57	33.08
ADF	21.99	16.20	22.21	16.48
NFC	21.46	34.66	22.24	35.20
Ca	0.76	1.07	0.80	1.10
P	0.36	0.35	0.37	0.35

WR4 = westerwold ryegrass, 4kg of concentrate

WR8 = westerwold ryegrass, 8kg of concentrate

PR4 = perennial ryegrass, 4kg of concentrate

PR8 = perennial ryegrass, 8kg of concentrate

DM = dry matter

CP = crude protein

ME = metabolisable energy

EE = ether extract

NDF = neutral detergent fibre;

ADF = acid detergent fibre

NFC = non-fibrous carbohydrates

Ca = calcium; P = phosphorous

4.2.3.2 Ruminal pH

4.2.3.2.1 Results from using pH data loggers

The ruminal pH results from the two groups that grazed the perennial ryegrass pasture treatment (PR4 and PR8), are presented in Figure 4.16. As can be seen from the graph, the cows that received 8kg of concentrate per day had a numerically lower ruminal pH for most of the 24 hour period. The difference between the two groups was particularly noticeable during 08:00am and 22:30 pm. The highest ruminal pH values for both groups were recorded before the morning feed (6.44 & 6.50 for PR4 and PR8, respectively at 07:30). There was a marked drop in the average ruminal pH values of both groups after the concentrate supplement was fed. This agrees with the results of Bargo *et al* (2002) who found that the highest ruminal pH occurred before concentrate feeding, and the lowest ruminal pH after concentrate supplementation (section 2.10.1).

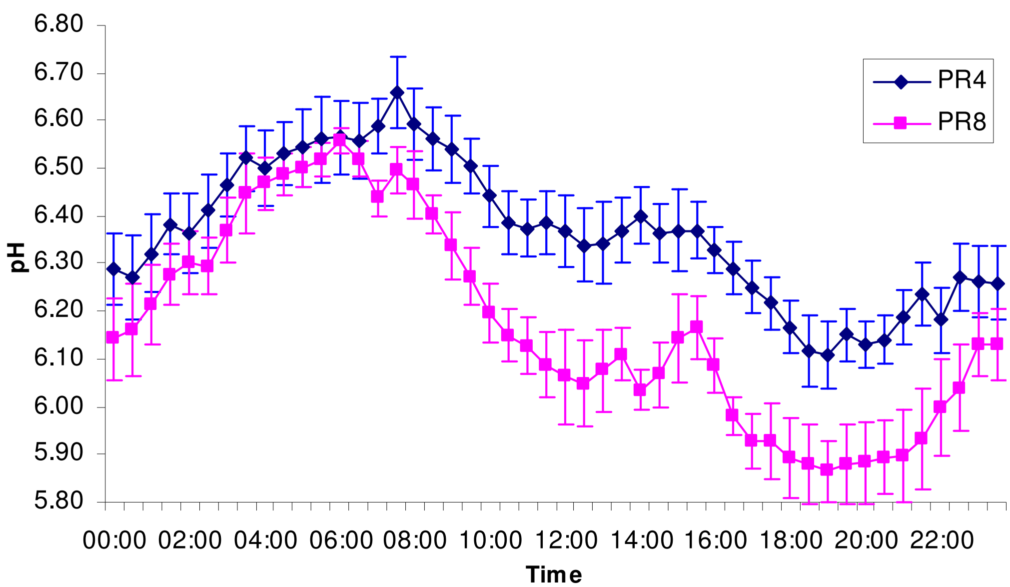

Figure 4.16 The average ruminal pH over a 24 hour period of cows that grazed perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day, with standard error bars. PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The mean ruminal pH of the two groups of cows that grazed the westerwold ryegrass pasture treatment (WR4 and WR8), are presented in Figure 4.17. As can be seen from the graph, the ruminal pH readings of both groups were close to one another throughout the 24 hour recording period, with standard error bars overlapping most of the time. The ruminal pH of the cows that received 8kg of concentrate per day was numerically higher than that of the cows that received 4kg of concentrate per day during 00:00 and 08:00 am. Although the PR8 pH curve was above the PR4 curve from 00:00 to 08:00 and vice versa from 08:00 to 00:00, the mean pH over the 24hr period did differ ($P < 0.10$). The lack of a consistent effect of concentrate supplementation on ruminal pH was also observed by Bargo *et al* (2003a) and they concluded that the relationship between the amount of concentrate supplemented and the resulting ruminal pH is not a simple one. The results from the two groups that grazed the westerwold ryegrass pasture treatment support this statement.

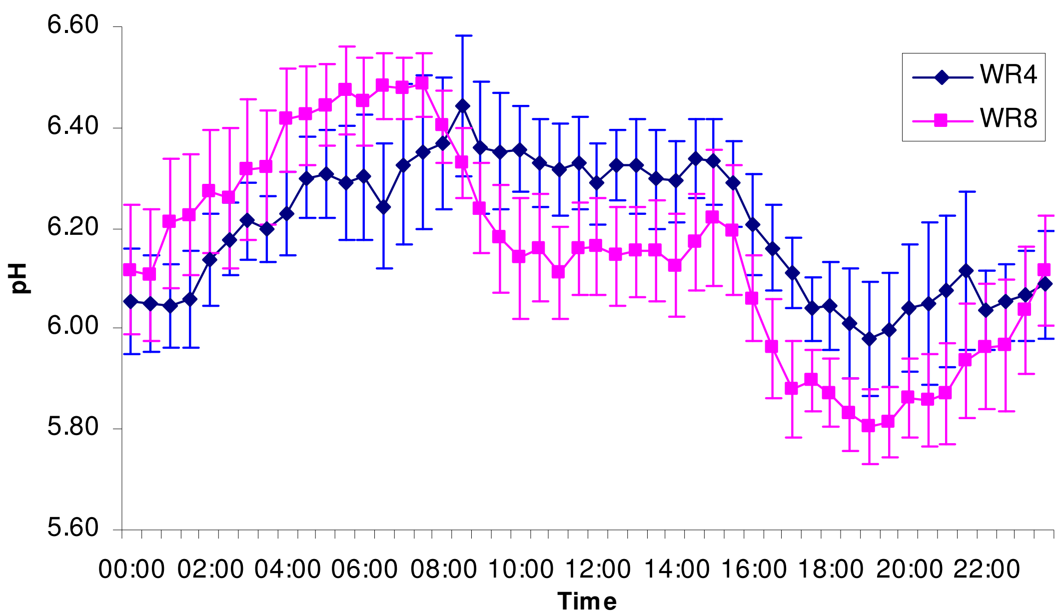

Figure 4.17 The average ruminal pH over a 24 hour period of the two groups of cows that grazed westerwold ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day, with standard error bars. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate

The combined ruminal pH results of the four treatments are presented in Figure 4.18. In this figure, the standard error bars are not shown. The ruminal pH curves of the two groups of cows that received 4 kg of concentrate supplementation (WR4, PR4) were above the two groups of cows that received 8 kg of concentrate supplementation (WR8, PR8) for most of the 24hr period. During phase 2, there was a numerically bigger difference in ruminal pH between the two groups that grazed the perennial ryegrass pasture treatment than between the two groups that grazed the westerwold ryegrass pasture treatment. Again, the difference might lie in the amount of pasture consumed by each group per day. The intakes were estimated as explained in section 4.2.2.1. The pasture intakes of the four groups were: 7.59 kg/d for WR4, 6.98 kg/d for WR8, 7.58 kg/d for PR4, and 6.95 kg/d for PR8. The difference in the estimated pasture intake is not that large, but coupled with the higher energy intake; this could have contributed to the lower ruminal pH.

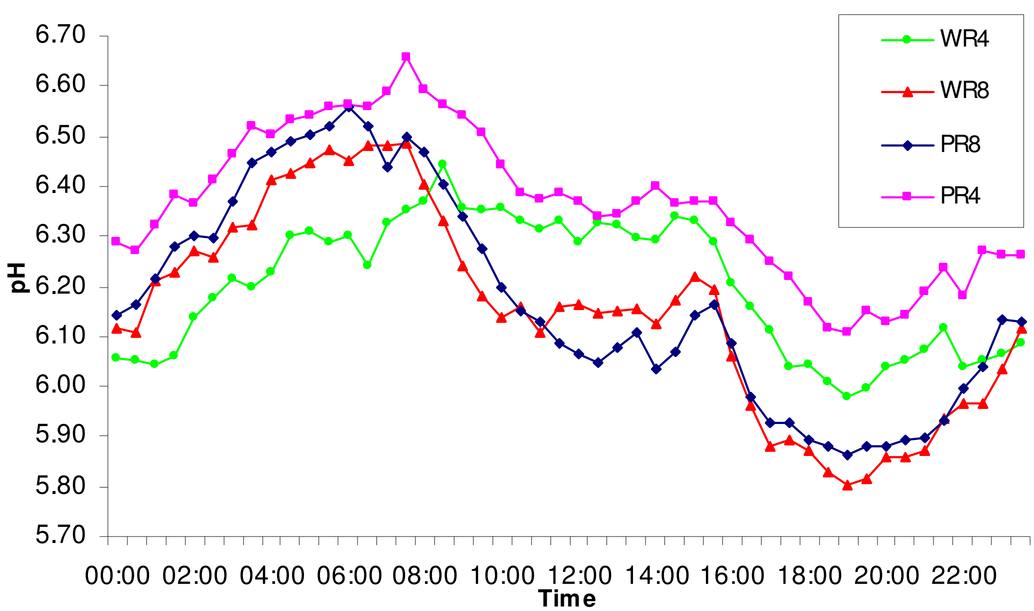

Figure 4.18 The average ruminal pH over a 24 hour period of the cows that razed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The average times during a 24 hour period in which the ruminal pH of the four groups dropped below pH 6.00 and pH 5.80 are shown in Table 4.10. The pH of cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate supplementation per day remained below pH 6.00 and 5.80 for a longer amount of time than that of the cows that grazed the perennial ryegrass pasture treatment and received 4 kg of concentrate supplementation per day ($P < 0.10$). The ruminal pH of PR8 was below 6.00 for 5.75 hours longer than that of PR4. When the overall means were compared, PR4 had a higher mean pH over the 24hr period than PR8 ($P < 0.10$). The cows that grazed the perennial ryegrass pasture treatment and received 4kg of concentrate supplementation per day had a higher mean ruminal pH than WR8 ($P < 0.10$). This indicates that the westerwold ryegrass pasture treatment had a more pronounced buffering effect than the perennial ryegrass pasture treatment.

Table 4.10 The average time during a twenty-four hour period when the ruminal pH is below 6 and 5.8 for the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

Treatment	Time below pH 6	Time below pH 5.8	Mean
Westerwold 4kg	335^{de}	120^{de}	6.20^{cde}
Westerwold 8kg	440^{d}	255^{d}	6.17^{c}
Perennial 4kg	70^{e}	0^{e}	6.36^{de}
Perennial 8kg	415^{de}	100^{de}	6.18^{cde}
SEM	147.5	95.42	0.06
P – value	0.992	0.883	0.170

cde means in the same column with different superscripts differ ($P < 0.10$)

SEM = standard error of means

There were no treatment × time interactions ($P < 0.10$).

4.2.3.2.2 Manual recording of ruminal pH

Figure 4.19 contains the ruminal pH results from the manual recording for the two treatments that grazed the westerwold ryegrass pasture treatment. Although not as refined as Figure 4.17, this graph shows the same general trend in daily ruminal pH change. The biggest difference in ruminal pH was recorded at 14:00 where cows grazing WR4 had a mean pH of 6.11, and cows grazing WR8 had a mean pH of 5.69, a difference of 0.42.

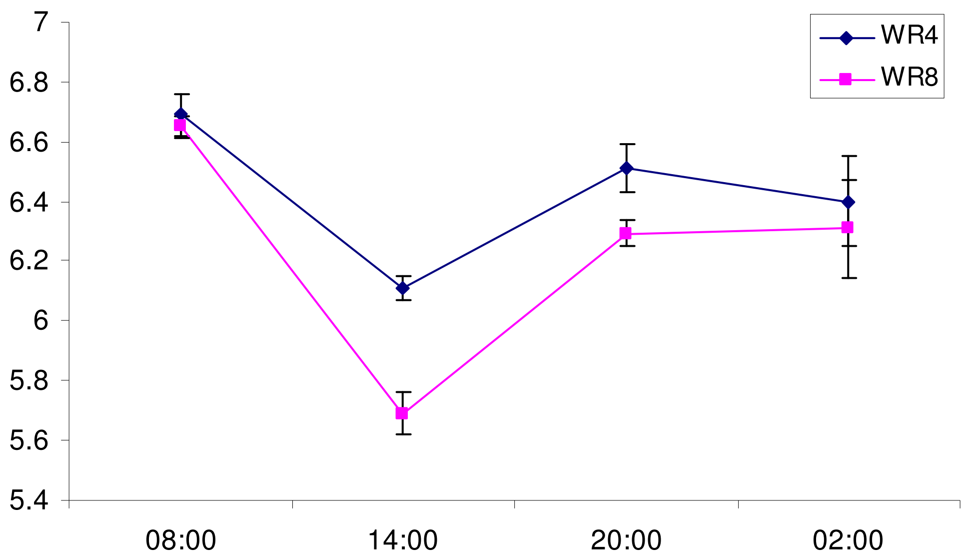

Figure 4.19 The average ruminal pH, recorded via manual pH recording, of the cows that grazed westerwold ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate

Figure 4.20 shows the ruminal pH results from the manual pH recording for the two groups that grazed the perennial ryegrass pasture treatment (PR4 & PR8). The ruminal pH curve of the cows that received 4 kg of concentrate per day was above that of the cows that received 8 kg of concentrate per day. Again, the lowest ruminal pH values for both groups were recorded at 14:00 and were 6.18 for PR4 and 5.86 for PR8. Although not as refined as Figure 4.16, this graph shows the same general trend in daily ruminal pH change throughout the day, for most of the points.

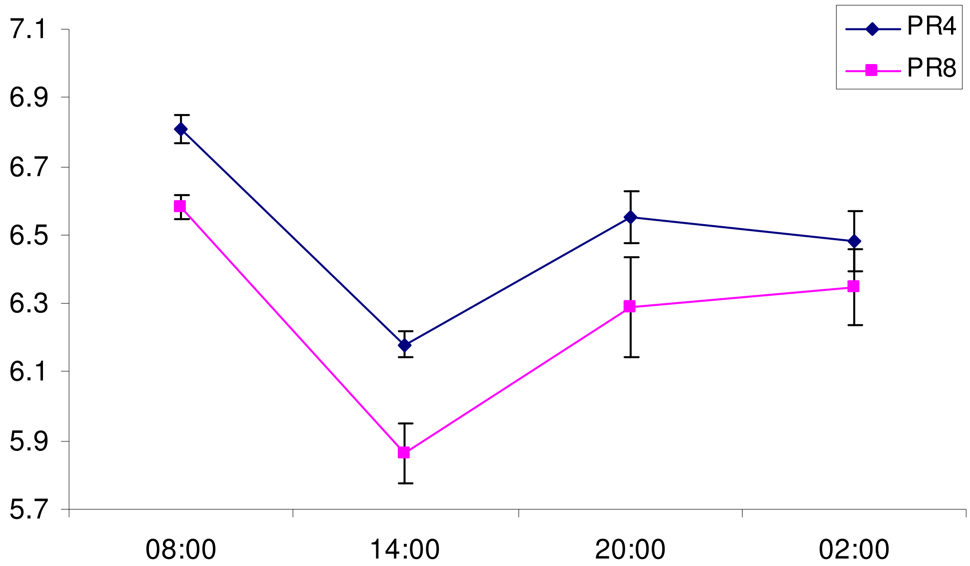

Figure 4.20 The average ruminal pH, recorded via manual pH recording, for the cows that grazed perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day, with standard error bars. PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The ruminal pH results from the manual recording for all four treatments are shown in Figure 4.21. The standard error bars were not included in order to simplify the graph. Again, although not as pronounced as Figure 4.18, this graph shows the same general trend in daily ruminal pH change. The pH values of all four groups are numerically slightly lower than those recorded by the ruminal pH loggers, which could be due to Figure 4.18 being more accurate than the manual recording pH graph, because of the larger data set. The variation could also be due to the fact that the samples were exposed to air while the pH values were recorded, as well as the fact that the samples were not taken next to the loggers as we were afraid of damaging the loggers.

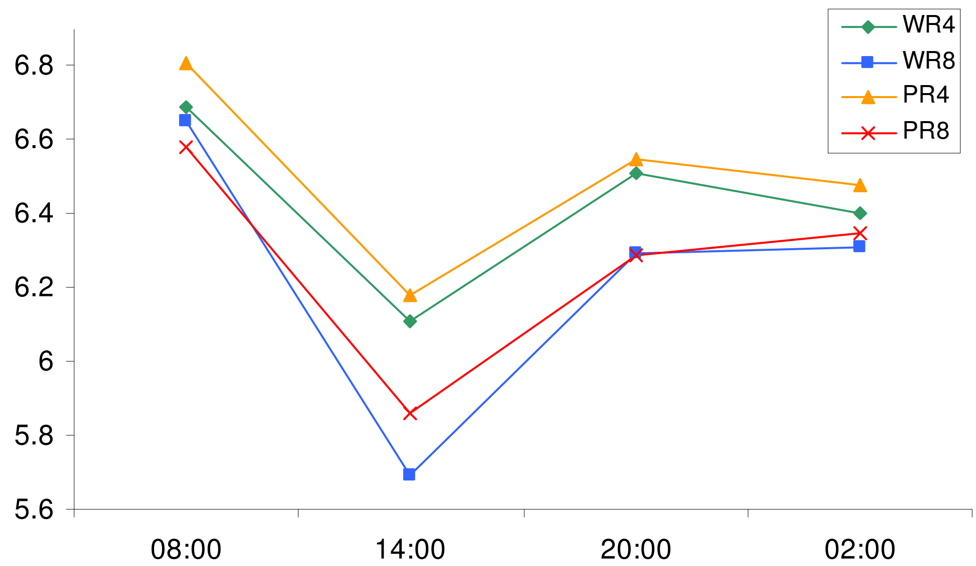

Figure 4.21 The average ruminal pH results from the manual pH recording for the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day, for the second experimental period (March 2008). WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The mean ruminal pH values of the four treatments measured when the rumen samples were collected were statistically compared and are shown in Table 4.11. The cows that grazed the perennial ryegrass pasture treatment and received 4 kg of concentrate per day had a higher ruminal pH (pH 6.81) at 08:00 than the cows that grazed the same pasture treatment and received 8kg of concentrate per day (pH 6.58) ($P < 0.05$). The cows that grazed WR8 had a lower ruminal pH at 08:00 than the cows that grazed PR4 ($P < 0.10$). At 14:00, WR4 had a significantly higher ruminal pH (pH 6.11) than WR8 (pH 5.69) ($P < 0.05$). During the same time, the cows that grazed the perennial ryegrass pasture treatment and received 4 kg of concentrate per day had a higher ruminal pH (pH 6.18) than the cows that grazed the same treatment and receive 8 kg of concentrate per day (pH 5.86) ($P < 0.10$). The cows that grazed PR4 also had a higher ruminal pH than WR8 ($P < 0.05$). At 20:00, the cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate per day had a higher ruminal pH (pH 6.51) than the cows that grazed the same treatment and received 8 kg of concentrate per day (pH 6.29) ($P < 0.10$). At the same sampling time, the cows that grazed the perennial ryegrass treatment and received 4 kg of concentrate per day had a higher ruminal pH (pH 6.55) than the cows that grazed the same treatment and received 8 kg of concentrate per day (pH 6.29) ($P < 0.05$). Again, PR4 had a higher ruminal pH at 20:00 than WR8 ($P < 0.05$). There was no significant difference between the treatments at 02:00 ($P > 0.10$). It is important to note that not too much emphasis should be placed on differences in pH at single time intervals. Rather interpret results based on the broader picture, i.e. time below pH 5.8 over a 24hr period or differences in the mean ruminal pH over a 24hr period. There were no differences in the time below pH 6.0 or 5.8 when the four treatments were compared ($P > 0.10$). Results therefore suggest that the level of supplementation would not be expected to have a significant effect on rumen microbial protein synthesis or fibre digestion. Overall nutrient intake would be expected to have a more pronounced effect on animal performance than differences in ruminal fermentation patterns. The cows that grazed WR4 had a higher overall mean ruminal pH than WR8 and PR8, and the cows that grazed PR4 had a higher overall mean ruminal pH than PR8 and WR8 ($P < 0.05$). This indicates that concentrate supplementation did depress ruminal pH to a statistically significant level.

Table 4.11 The average ruminal pH of the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day, measured when the rumen samples were collected

	Treatments					
	WR4	**WR8**	**PR4**	**PR8**	**SEM**	**P-value**
Ruminal pH measured at:						
08:00	6.69^{c}	6.65^{dc}	6.81^{aec}	6.58^{bc}	0.052	0.083
14:00	6.11^{acd}	5.69^{b}	6.18^{acd}	5.86^{ce}	0.106	0.671
20:00	6.51^{d}	6.29^{ae}	6.55^{b}	6.29^{ae}	0.069	0.750
02:00	6.40	6.31	6.48	6.35	0.106	0.842
Overall mean	6.43^{a}	6.24^{b}	6.51^{a}	6.27^{b}	0.047	0.593

abc means in the same column with different superscripts differ ($P < 0.05$)

de means in the same column with different subscripts differ ($P < 0.10$)

SEM = standard error of means

4.2.3.3 Ruminal ammonia nitrogen concentrations

The mean ruminal NH_3-N (mg/dl) values for the six cows on each treatment was averaged and are shown in Figure 4.22 and Table 4.12. There was no difference between the four treatments in terms of NH_3-N concentration at 08:00 am and 20:00 pm ($P > 0.10$). At 14:00, the cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate per day had a higher ruminal NH_3-N concentration (10.70 mg/dl) than the cows that grazed the same treatment and received 8 kg of concentrate per day (6.36 mg/dl) ($P < 0.05$). At the same time, the cows on PR4 had a higher ruminal NH_3-N concentration (10.57 mg/dl) than the cows on PR8 (8.50 mg/dl) ($P < 0.10$). These results are in agreement with the findings of Bargo *et al* (2003a), who found that the most consistent effect of concentrate supplementation on ruminal fermentation was a reduction in ruminal NH_3-N concentration (section 2.10.3). There was also a difference in ruminal NH_3-N concentration at 14:00 between the two groups that received 8 kg of concentrate per day (WR8 & PR8), where PR8 had a higher ruminal NH_3-N concentration than WR8 ($P < 0.10$). This could be explained by the higher CP and lower ME concentration of WR8 compared to PR8 (Table 4.9), as a higher supply of readily available energy in the rumen increases the rumen microorganisms ability to utilise NH_3-N and thus decreases the ruminal NH_3-N concentration (Nocek & Russel, 1988; Taweel *et al*, 2004b). At 02:00 the cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate per day had a higher ruminal pH than the cows that grazed the perennial ryegrass pasture treatments and received the same amount of concentrate ($P < 0.05$).

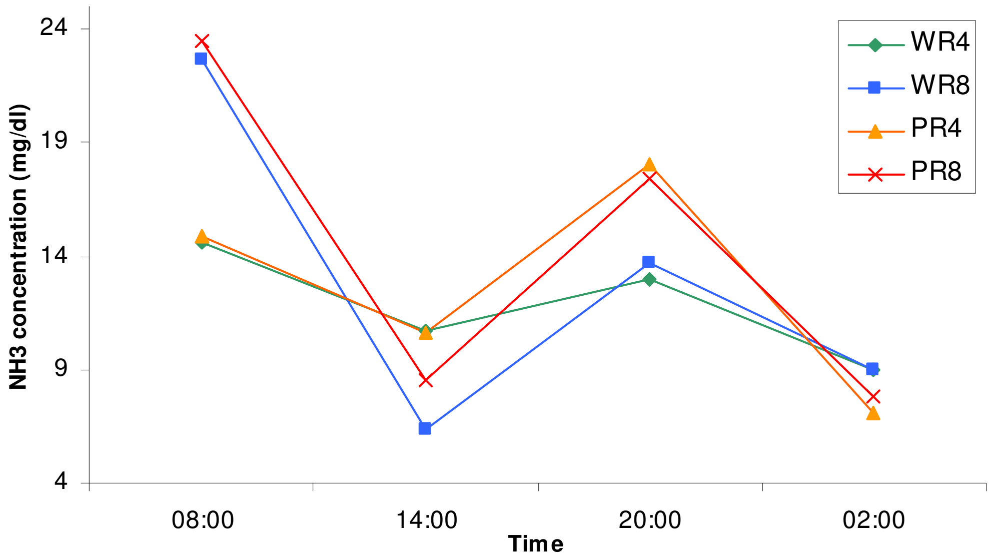

Figure 4.22 The mean ruminal NH_3-N concentration, in mg/dl, of the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kg of concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

The mean NH_3-N concentrations of the cows that grazed the westerwold ryegrass pasture treatment and received 4 kg of concentrate per day were within the optimal range of 8.5 to 30.0 mg/dl that was described by McDonald *et al* (2002), for all four of the sampling times. The cows that grazed WR8 treatment had an NH_3-N concentration below the optimal range (6.36 mg/dl) at the 14:00 sampling time. Both groups of cows that grazed the perennial ryegrass pasture treatment had ruminal NH_3-N concentrations below the optimal range at the 02:00 sampling time. However, all the treatments had NH_3-N concentrations above the minimum recommended level for maximum microbial protein synthesis at all the sampling times. Even WR8, which had a NH_3-N concentration of 6.36 mg/dl at the 14:00 sampling time, was above the minimum recommended level of 5mg/dl (Satter & Slyter, 1974). It is therefore clear that at no time was the amount of available NH_3-N a limiting factor in terms of microbial protein synthesis (Taweel *et al*., 2004b).

Table 4.12 The mean ruminal NH_3-N concentrations (mg/dl) of cows that grazed the westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

	Treatments					
	WR4	**WR8**	**PR4**	**PR8**	**SEM**	**P-value**
08:00	14.59	22.61	14.82	23.43	4.068	0.801
20:00	12.97	13.71	18.04	17.37	2.123	0.361
14:00	10.70^{ad}	6.36^{bd}	10.57^{ad}	8.50^{e}	0.792	0.365
02:00	8.95^{a}	8.96^{a}	7.05^{b}	7.82^{ab}	0.577	0.014
Overall mean	11.80	12.91	12.62	14.28	1.129	0.811

ab means in the same row with different superscripts differ (P < 0.05)
de means in the same row with different superscripts differ (P < 0.05)
SEM = standard error of means
WR4 = westerwold ryegrass, 4kg of concentrate
WR8 = westerwold ryegrass = 8kg of concentrate
PR4 = perennial ryegrass, 4kg of concentrate
PR8 = perennial ryegrass, 4kg of concentrate

The highest ruminal NH_3-N concentrations were observed at 08:00 for WR4, WR8, and PR8, and at 20:00 for PR4, while the lowest pH values were observed at 19:00 for all four treatments. The lowest ruminal NH_3-N concentrations were observed at 02:00 for WR4, PR4, and PR8, and at 14:00 for WR8, while the highest pH values were recorded between 06:00 and 08:30 for all four treatments. These results do not agree with the findings of Cajarville *et al* (2006) who found that the highest pH values coincided with the lowest ruminal NH_3-N concentration (section 2.10.3). Interpretation of ruminal NH_3-N values at specific time intervals and trying to relate those to nutrient intake or diet composition, however, should be done with caution. Interpretation and resulting conclusions should rather be based on mean values obtained over consecutive days with numerous measuring points per 24h day.

There were treatment × time interactions at 20:00 for WR8, PR4, and PR8, as well as at 02:00 for WR8 ($P < 0.10$).

4.2.3.4 Ruminal volatile fatty acid concentrations

The mean concentrations of total volatile fatty acids (mmol/dl), including acetic, propionic, butyric, isobutyric, and valeric acids, for the six cows on each treatment is reported in Table 4.13 and Figure 4.23.

The cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate per day (WR8), had a higher total VFA concentration (12.61 mmol/dl) than the cows that grazed the same treatment and received 4 kg of concentrate per day (10.97 mmol/dl) ($P < 0.10$). The total VFA concentration of cows that grazed PR8 did not differ from the ruminal VFA concentrations of the cows that grazed PR4. The increase in total VFA concentration that was observed when concentrate supplementation was increased is in agreement with the results of Bargo *et al* (2003a). The cows that grazed PR4 had a higher total VFA concentration compared to the cows that grazed WR8 ($P < 0.05$). There were no significant differences in acetic acid concentrations between the two groups of cows on each pasture treatment ($P > 0.10$). However, WR8 had a higher acetic acid concentration than PR8 ($P < 0.10$). the cows that grazed PR4 had a lower acetic acid concentration than the cows that grazed WR8 ($P < 0.05$) The cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate per day had a higher propionic acid concentration (2.77 mmol/dl) than the cows that grazed the same treatment and received 4 kg of concentrate per day (2.19 mmol/dl) ($P < 0.05$). The cows that grazed the perennial ryegrass pasture treatment and received 8 kg of concentrate per day also had a higher propionic acid concentration (2.46 mmol/dl) than the cows that grazed the same pasture treatment and received 4 kg of concentrate per day (2.01 mmol/dl) ($P < 0.10$). The cows that grazed WR8 also had a higher Propionic acid concentration than the cows that grazed PR4 ($P < 0.05$). The results of both pasture treatments agree with the results of Bargo *et al* (2002) and Berzaghi *et al* (1996), all of whom found that propionate concentration increased with concentrate supplementation. The cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate per day had a higher butyric acid concentration (1.49 mmol/dl) than the cows that grazed the same pasture treatment and received 4 kg of concentrate per day (1.20 mmol/dl) ($P < 0.05$). The cows that grazed the perennial ryegrass pasture treatment and received 8 kg of concentrate per day had a higher butyric acid concentration (1.36 mmol/dl) than the cows that grazed the same treatment and received 4 kg of concentrate per day (1.17 mmol/dl) ($P < 0.10$). The cows that grazed WR8 had a higher butyric acid concentration than the cows that grazed PR4 ($P < 0.05$). These results are in agreement with those of Bargo *et al* (2002), who also found that the butyric acid concentration increased with concentrate supplementation.

Table 4.13 The total volatile fatty acid, acetic, propionic and butyric acids concentrations, in mmol/dl, of the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

	Treatments					
	WR4	**WR8**	**PR4**	**PR8**	**SEM**	**P-value**
Total concentration	10.97^{d}	12.61^{ae}	10.34^{bd}	11.28^{d}	0.552	0.321
Acetic acid	7.38^{abde}	8.11^{ad}	6.97^{be}	7.25^{be}	0.334	0.157
Propionic acid	2.19^{a}	2.77^{b}	2.01^{ad}	2.46^{abe}	0.174	0.812
Butyric acid	1.20^{a}	1.49^{b}	1.17^{ad}	1.36^{ae}	0.069	0.103

ab means in the same row with different superscripts differ ($P < 0.05$)
de means in the same row with different superscripts differ ($P < 0.10$)
12 means in the same row with different subscripts differ ($P < 0.10$)
SEM = standard error of means
WR4 = westerwold ryegrass, 4kg of concentrate
WR8 = westerwold ryegrass, 8kg of concentrate
PR4 = perennial ryegrass, 4kg of concentrate
PR8 = perennial ryegrass, 8kg of concentrate

Figure 4.23 contains the proportions of the individual volatile fatty acids that make up the total VFA concentration in the rumen for each of the four treatments. With an increase in the amount of concentrate supplemented to the cows that graze the westerwold ryegrass pasture treatment, the mean molar proportions of acetate: propionate: butyrate changed from 67:20:11 for cows supplemented with 4 kg of concentrate, to 64:22:12 for cows supplemented with 8 kg of concentrate. These results agree with the findings of Bargo *et al* (2002) who found that the acetate/propionate ratio decreased and the butyrate concentration increased when concentrate supplementation increased.

In cows that grazed the perennial ryegrass pasture treatments, the molar proportions of volatile fatty acids in the rumen changed from 67:19:11 to 65:21:12 when the amount of concentrate supplemented was increased from 4 kg to 8 kg of concentrate per cow per day. Similarly, these results are also in agreement with those of Bargo *et al* (2002).

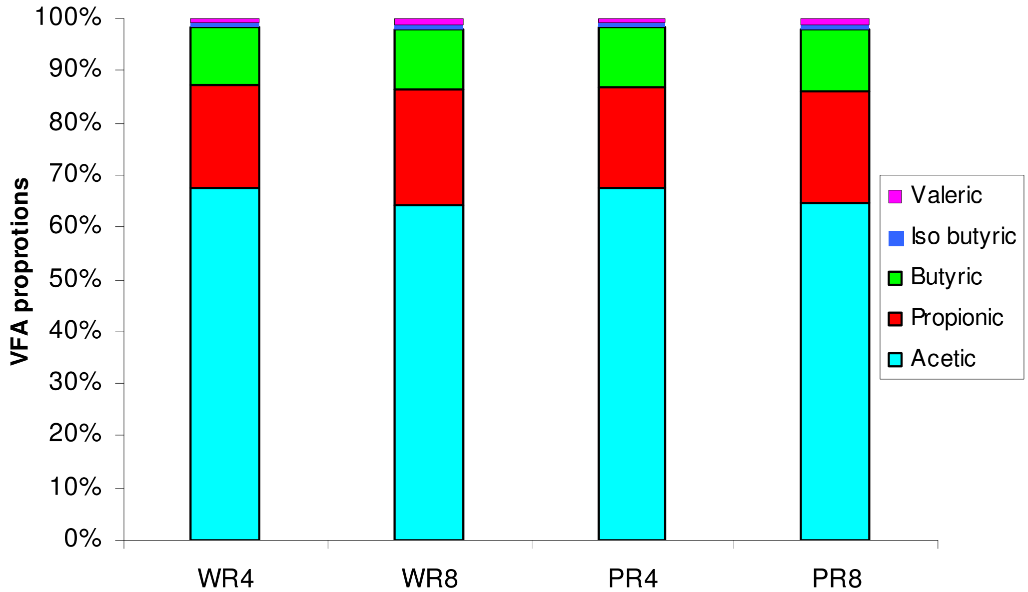

Figure 4.23 The proportions of the individual volatile fatty acids that make up the total volatile fatty acid concentrations for the cows that grazed westerwold and perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day. WR4 = westerwold ryegrass, 4kg of concentrate; WR8 = westerwold ryegrass, 8kgof concentrate; PR4 = perennial ryegrass, 4kg of concentrate; PR8 = perennial ryegrass, 8kg of concentrate

There were treatment × time interactions for the WR4 treatment for total VFA ($P < 0.10$) and acetic acid ($P < 0.05$) concentrations, as well as for the PR4 treatment for butyric acid concentration ($P < 0.05$).

4.2.3.5 *In sacco* NDF disappearance of pastures

The average percentage NDF disappearance of the two pasture treatments incubated in the rumens of cows receiving either 4 or 8 kg of concentrate supplementation is shown in Table 4.14. There was no significant difference in NDF disappearance between the two groups that grazed the westerwold ryegrass pasture treatment, which were 5.41% and 3.15% for WR4 and WR8, respectively. The cows that grazed the perennial ryegrass pasture treatment and received 4 kg of concentrate per day had a significantly higher NDF disappearance (8.45%) during the twelve hour incubation period than the cows that grazed the same treatment and received 8 kg of concentrate per day (4.51%), ($P < 0.05$). The results obtained on the perennial ryegrass pasture treatment agree with the results of Meissner *et al* (1991), who showed that supplementation significantly decreased NDF disappearance when cows grazed kikuyu pastures.

The lack of a significant difference in NDF disappearance for the westerwold ryegrass pasture treatment could be partially explained by the amount of time that the pH dropped below pH 6.00. For the perennial ryegrass pasture treatment, there was a difference of 345 minutes between PR4 and PR8, whereas the westerwold ryegrass pasture treatment had a difference of 105 minutes between WR4 and WR8. As fibre digesting bacteria are limited by a ruminal pH of less than 6 (Varga & Kolver, 1997), the longer period of time that the pH was under 6 for PR8 compared to WR8 could partly explain the lack of a significant difference in NDF disappearance between WR4 and WR8.

Both pasture treatments had relatively high NDF contents (westerwold ryegrass treatment = 58.59%, and perennial ryegrass treatment = 57.39%). Meissner *et al* (1991) stated that even when supplementation was disregarded, digestion of the cell wall is particularly slow / depressed when NDF content is above 55-60%. When the results from the first experiment are compared to those of the second experiment, it can be seen that the NDF disappearance decreased. However, these results were not statistically compared, as they occurred under different environmental conditions.

Table 4.14 The percentage NDF disappearance from the *in sacco* bags over a twelve hour period for the cows that grazed westerwold or perennial ryegrass over-sown into kikuyu, and received either four or eight kilograms of concentrate per day

	Treatments				
Item	**WR4**	**WR8**	**PR4**	**PR8**	**SEM**
NDF disappearance (%) in 12h	5.41^{ab}	3.15^{a}	8.45^{b}	4.51^{a}	1.297

ab means in the same row with different superscript differ ($P < 0.05$)

SEM = standard error of means

NDF = neutral detergent fibre

WR4 = westerwold ryegrass, 4kg of concentrate

WR8 = westerwold ryegrass, 8kg of concentrate

PR4 = perennial ryegrass, 4kg of concentrate

PR8 = perennial ryegrass, 8kg of concentrate

Treatment × time interactions were present for the WR8 treatment ($P < 0.10$), and the PR4 treatment ($P < 0.05$).

CHAPTERR 5

ECONOMIC EVALUATION OF THREE PASTURE SYSTEMS: ITALIAN, WESTERWOLD, OR PERENNIAL RYEGRASS OVER-SOWN INTO KIKUYU

CHAPTER 5

ECONOMIC EVALUATION OF THREE PASTURE SYSTEMS: ITALIAN, WESTERWOLD, OR PERENNIAL RYEGRASS OVER-SOWN INTO KIKUYU

For the economic evaluation, a 50 ha farmlet was assumed for each of the three treatments, in order to obtain a milk price from Nestle, in May 2008, which is presented in Table 5.1. The rest of the economical evaluation was done on a per hectare basis.

Table 5.1 The milk price (as supplied by Nestle), calculated according to the fat and protein percentages, for italian, westerwold, and perennial ryegrass over-sown into kikuyu

	Treatments		
Item	**Italian ryegrass**	**Westerwold ryegrass**	**Perennial ryegrass**
kg milk produced/ha	30446	29761	32288
Milk fat%	4.94	4.97	4.63
Milk protein%	3.84	3.75	3.64
Milk price(R)	3.63	3.56	3.44

R = South African rand

Dry cows were assumed to graze dry land pastures, and were not taken into account in the calculations. The milk production per hectare of cows grazing the three treatments was used to calculate the margin over specified costs per hectare for each of the three pasture treatments. The amount of concentrate consumed was calculated for each treatment, and the concentrate cost per ton was supplied by Nova in May 2008. For the calculation of the pasture costs, the seed costs were calculated according to the seed prices in May 2008, which were R20.40 for the italian ryegrass; R19.00 for the westerwold ryegrass; and R32.32 for the perennial ryegrass, while the cost of electricity, irrigation, machinery, and fertilization was taken from the average data as provided by the farmer study group of the Outeniqua Research Farm. The fertilizer costs according to this data was R3,777.00 per hectare, thus making the fertilizer cost per treatment R11,331.00. The machinery costs were calculated according to the depreciation of the machinery used to establish each treatment. Depreciation was calculated according to the utilisation method (The Standard Bank of South Africa, 2005). Allocated and fixed costs were calculated according to the cents per kg of milk produced per hectare, with the price provided by the farmer study group.

Table 5.2 The economic evaluation to determine margin over specified costs for Italian, westerwold and perennial ryegrass over-sown into kikuyu. All prices are on a per hectare basis

Item	Treatments		
	Italian ryegrass	**Westerwold ryegrass**	**Perennial ryegrass**
INCOME			
Milk price(R/ litre)	3.63	3.56	3.44
Kg milk produced per ha	30446	29761	32288
Total income per hectare	110518.98	105949.16	111070.72
TOTAL FEED COST			
Concentrate purchased			
Ration 1 (R/ha)	10902.67	10341.50	9379.50
Ration 2 (R/ha)	20457.33	19653.33	20814.67
Ration 3 (R/ha)	17801.23	22223.90	21007.67
Pasture produced			
Seed costs (R/ha)	581.40	541.50	736.90
Irrigation (R/ha)	745.00	745.00	745.00
Electricity (R/ha)	686.00	686.00	686.00
Fertilizer costs (R/ha)	3777.00	3777.00	3777.00
Machinery (R/ha)	1735.00	1735.00	1735.00
Total	56685.63	59703.23	58881.74
Margin over feed costs per hectare	**53833.35**	**46245.93**	**52188.98**
ALLOCATED COSTS			
Medical and Veterinary (R/ha)	2131.22	2083.27	2260.16
Artificial insemination (R/ha)	1217.84	1190.44	1291.52
Miscellaneous (R/ha)	2131.22	2083.27	2260.16
Total	5480.28	5356.98	5811.84
Gross margin per hectare	**48353.07**	**40888.95**	**46377.14**
FIXED COSTS			
Depreciation of machinery (R/ha)	6089.20	5952.20	6457.60
Labour (R/ha)	218.56	111.68	218.56
Miscellaneous (R/ha)	5480.28	5356.98	5811.84
Total	11788.04	11420.86	12488.00
Margin over specified costs per hectare	**36565.03**	**29468.09**	**33889.14**

R = South African rand

Table 5.2 contains the economical evaluation results of the three pasture treatments. Cows that grazed the italian ryegrass pasture treatment had the highest milk price due to the high fat and protein content, while cows that grazed the perennial ryegrass pasture treatment provided the lowest milk price due to the low fat and protein content of the milk compared to the other two pasture treatments. When the milk production per hectare was multiplied by the milk price (R) of each treatment, the perennial ryegrass pasture treatment had the highest income from milk production (R 111,070.16), followed by the italian ryegrass pasture treatment (R 110,518.98) and the westerwold ryegrass pasture treatment (R 105,949.16). When the total feed costs were subtracted, the italian ryegrass pasture treatment resulted in the highest margin over feed costs. The perennial ryegrass pasture treatment had a higher total feed cost due to the higher concentrate intake per hectare, which was due to a higher stocking rate, as well as the higher seed price. When the allocated costs and fixed costs were subtracted, the italian ryegrass pasture treatment had the highest margin over specified costs (R 36,565.03), followed by the perennial ryegrass pasture treatment (R 33,889.14), and the westerwold ryegrass pasture treatment (R 29,468.09).

If the milk fat and protein content of the perennial ryegrass pasture treatment were to increase, the perennial ryegrass pasture treatment would probably have the highest margin over specified costs. Even with its higher milk price, the westerwold ryegrass pasture treatment still had a lower margin over specified costs than the perennial ryegrass pasture treatment, due to its lower milk production per hectare.

In conclusion, the economical evaluation from this study showed that the italian ryegrass pasture treatment had the best return per hectare. However, if the milk prices for all three pasture treatments were equal, the perennial ryegrass pasture treatment would have shown the best return.

CHAPTER 6

CONCLUSIONS

CHAPTER 6
CONCLUSIONS

6.1 Production study

All three pasture treatments had relatively similar chemical compositions, and all three pasture treatments provided high quality roughage for the cows that grazed them. High producing Jersey cows grazing perennial ryegrass over-sown into kikuyu pastures and receiving 4 kilograms of concentrate per day produced more milk per hectare (32288 kg/ha) than cows grazing italian (30446 kg/ha) or westerwold (29761 kg/ha) ryegrass over-sown in to kikuyu pastures. The perennial ryegrass pasture treatment also had a higher stocking rate than the two annual ryegrass pasture treatments (6.93 vs. 6.44 & 6.49). However, due to the lower milk protein and milk fat percentages of cows that grazed the perennial ryegrass pasture treatment, as well as the higher concentrate intake per hectare of the cows that grazed the perennial ryegrass pasture treatment (8200 kg/ha), compared to the cows that grazed the annual ryegrass pasture treatments (7808 and 7881 kg/ha for the italian and westerwold ryegrass pasture treatments, respectively), the italian ryegrass pasture treatment provided a higher return (R/ha) than the perennial ryegrass pasture treatment.

It appears that with the higher milk protein percentage and margin over specified costs, italian ryegrass over-sown into kikuyu is the best choice for a kikuyu based pasture system in the South Cape region of South Africa. However, if the milk protein percentage of the cows grazing perennial ryegrass over-sown into kikuyu pastures can be increased, such a system would be a better choice, as the carrying capacity would be higher than a system based on italian ryegrass over-sown into kikuyu. The best option for a dairy farmer in the Southern Cape might be to utilise both the italian and perennial ryegrass pasture systems on the farm, and then based on his experience, decide which system suits his conditions the best.

Future studies should look at a way of over-sowing both italian and perennial ryegrass into a kikuyu based pasture. The combination of these two ryegrass species could potentially solve some of the fodder flow problems experienced in the Southern Cape region of South Africa.

6.2 Rumen study

Feeding a higher level of concentrate supplementation to high producing dairy cows grazing westerwold or perennial ryegrass over-sown into kikuyu pastures decreased the ruminal pH of the cows and keeps it below pH 6.00 for a longer period of time. A high level of concentrate supplementation decreased the mean ruminal pH of the cows that grazed both the westerwold and perennial ryegrass pasture treatments ($P < 0.05$) during phase 1 of the trial, but had no effect of mean ruminal pH during the second phase of the trial ($P > 0.10$). The mean rumen ammonia concentration decreased when a high level of concentrate was supplemented on both pasture treatments during phase 1 of the trial ($P < 0.05$), but concentrate supplementation had no effect on rumen ammonia nitrogen concentration during the second phase ($P > 0.10$). During both phases of the trial, a high level of concentrate supplementation had no effect on the rumen acetic acid concentration, however cows that grazed the westerwold ryegrass pasture treatment and received 8 kg of concentrate supplementation had a higher acetic acid concentration compared to cows that grazed the perennial ryegrass pasture treatment and received the same amount of concentrate supplementation. A high level of concentrate supplementation increased rumen propionate and butyrate concentrations of cows grazing both pasture treatments during both phases of the trial. Neutral detergent fibre disappearance decreased when a high level of concentrate was supplemented for both pasture treatments during phase 1 of the trial, but only affected the perennial ryegrass pasture treatment during the second phase.

It appears that feeding a moderate level of concentrate supplementation (4 kilograms per cow per day) has a better effect on the ruminal environment, maintaining the ruminal pH above the critical point for fibre digestion of 6.00 for most of the day, as well as decreasing the possibility of sub-clinical ruminal acidosis when cows grazed ryegrass dominant pastures, but had a less pronounced effect when the dominant pasture specie was kikuyu.

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CHAPTER 7

CRITICAL REVIEW

CHAPTER 7
CRITICAL EVALUATION

7.1 Production Study

Planting dates: The italian and westerwold ryegrass pasture treatments were planted one month earlier than the perennial ryegrass pasture treatment, because the established kikuyu pastures need to be growing less aggressive in order for the perennial ryegrass to establish itself, as perennial ryegrass is harder to establish than the two annual ryegrasses. This meant that the climate, rainfall, and temperatures that the cows grazing the annual ryegrass pasture treatments were exposed to for the first month of lactation differed from the conditions that the cows grazing the perennial ryegrass pasture treatment were exposed to. Another difference is the better autumn growth of the italian and westerwold ryegrass pasture treatments compared to the perennial ryegrass pasture treatment due to their earlier planting dates. The planting dates for the annual ryegrasses were not delayed because we wanted good winter grazing.

Another reason why the two annual ryegrasses were planted earlier than the perennial ryegrass is because this trial was more from a practical point of view, in other words the treatments were planted like a farmer would have planted the grasses. In retrospect, from a scientific point of view, it would have made sense to make a compromise in terms of planting dates, in other words we could have planted all three treatments during late March or early April. This would have

The time span in which the cows entered the trial could have been shorter. However, because the cows on the Outeniqua Research Farm calve throughout the year, this was impossible.

Put-and-take compared to fixed stocking rates: If a fixed stocking rate was applied the pasture measurements would have been different. There would also have been a problem in terms of the number of cows necessary to graze down the pasture. In July and August the stocking rates were quite low so the cows had to graze down the pastures at a faster rate to consume sufficient dry matter. In October and November camps would have had to be removed from the system due to the high pasture growth rate. These camps could have been used to make silage which could have been supplemented in the months when the pasture could not carry the fixed amount of cows. If silage was made with low quality kikuyu in January and February and fed out in July and August, it would have lowered the milk production of the cows, because kikuyu results in low quality silage. There might also be an effect of concentrate supplementation on milk production due to the put-and-take system, because the higher the stocking rates, the higher the amount of concentrate supplemented per hectare.

Variation in the milk composition analysis: The first possible source of variation is the sampling technique. The same sampling technique was used throughout the trial. The samples collected through milking were mixed (the bottles removed were not shaken) and then a fixed amount was measured and poured into the sample bottle. There might have been variation in the amount of mixing of each sample. The other source of variation could be the infrared analysis. If the machine is not checked regularly for accuracy, the results could be faulty.

The use of the rising plate meter to estimate the intake of cows: We suspect that this technique is inaccurate. If intake was the focus point of the study, we would have used a marker technique to determine intake. However, the rising plate meter is a useful tool for estimating the amount of dry matter produced and for calculating the stocking rate of the pasture at farm level. This is evident in this study when you look at the amount of milk produced per hectare, the weight gain of the cows and the stocking rates that were used. If the stocking rate had been too high it would have had a negative impact on the regrowth of the pasture and the pasture would have had a lower carrying capacity in the next cycle.

Grazing of pastures: The cows grazing the pastures in this trial had an extra day to back graze. This could have been avoided by cordoning off the grazing area with electrical wire. However, this would have created a logistical problem because the water point in each camp was fixed. The fact that the cows could back graze had the advantage that if the pasture wasn't properly utilized the previous day, they could graze it again along with that days' allocated grazing. This also helped to achieve good post-grazing pasture heights.

Replacement of cows: The fact that the cows grazed the same treatment for the whole lactation makes the data more representative of what would happen on a farm.

Most system trials replace the trial cows after three months so that the cows grazing the treatments are always early in the lactation cycle.

Extremes in age and body weight: It would have been better to avoid extremes in body weight and age in the separate groups, as this increases variation and decreased the probability of detecting a significant difference between the groups. The groups allocated to each of the three pasture treatments were balanced for lactation number. The problem with older cows is they might not last the whole lactation. We were fortunate that none of the production study cows used in this trial died during the trial. One cow did however hurt her back and this drastically lowered her milk production compared to the previous lactation. The other problem with older cows is they walk slower than the rest of the group which means that they arrived on the pasture later than the rest of the cows because we didn't force them to walk faster than their own comfortable pace.

Planting time: Perennial ryegrass is only replanted in April. When perennial ryegrass is replanted into pastures that already contain perennial ryegrass, the pastures are then mulched at a higher level compared to the annual ryegrasses. This means that the growth rate of kikuyu has to be even lower than for the annual ryegrasses, because it will not be set back to a sufficient extent to allow the newly planted perennial ryegrass to grow if the pastures are replanted in March.

Collection of pasture samples for CNCPS analysis: It was decided to collect the pasture samples for CNCPS analysis during September. The reason for this was that this period gave a good representation of the grazing in spring. If the samples were taken earlier, the pasture samples would have had a very low fibre content, and if the pastures were sampled later on in the trial, the samples would have had a very high fibre content.

7.1 Rumen Study

pH data loggers: I would use the same pH logging system in both of the phases of the trial. I would want at least two systems as a back-up at all times. This was not a problem with the old system where we had one assembled and calibrated back-up at all times. The assembly of the old system was also quite easy so if more than one back-up was required it could be built and calibrated in less than 10 minutes, however building a logger with the new system was more difficult as everything had to be sealed properly due to the fact that the whole system was placed inside the rumen. Calibration of the old system was also easier, as it was done manually rather than via a computer link. I would have liked to test the new system before use. An experiment was conducted to test the old system against the new system and they compared well. However, the manufacturers sent a different electrode with the new loggers ordered early 2008 which they claimed to be easier to use. It turned out to be quite the opposite, however the loggers did work and we were able to log reliable pH data.

Washing procedure: I would have liked to use a washing machine in both experiments, but the research farm didn't own one in 2007 so there was no alternative.

Number of replications: The number of cannulated cows used on the rumen study could be a restriction. Six cows were used per pasture treatment, therefore with the exchange of concentrate levels, there were six cows on each of the four treatments in each experiment. It might have been more accurate to use twelve cows per treatment, but then the pasture treatments would not have been able to carry the rumen study cows along with the production study cows. This made the use of more cannulated cows impossible. The variation between cows is also a problem. This variation was reduced by the exchange of concentrate levels. It might have been beneficial to exchange the pasture treatments as well.

Length of incubation period: With the *in sacco* procedure it might have been beneficial to have another incubation period that was longer than twelve hours. The incubation was done over the time when the rumen pH is at its lowest to maximize the chance of observing differences between the treatments. It was thought that with a longer incubation the rumen pH would reach its maximum value decreasing the differences between treatments.

Rumen sampling time schedule: With the rumen sampling, only four times were chosen for sampling because in previous trials more sampling times were used without significantly contributing to making different conclusions compared to when only four time points were used. We were not trying to establish a trend in volatile fatty acid concentrations and ruminal ammonia nitrogen levels, only to determine the levels at certain times of the day. The ruminal pH of the cannula cows on the rumen study trial was at its lowest at 20:00 pm. The *in sacco* incubation commenced at 14:00 pm and the bags were removed at 02:00 am the next morning.

Perception on rumen fill: There is a perception amongst some that the cow's rumen isn't full enough when grazing pastures. This assumption comes from the fact that the faeces was quite loose. This is the opposite of what we found. In the first rumen study experiment, the 8:00 am rumen fluid collection was quite difficult because the rumens of the cows were very full and contained a lot of fibrous material which clogged up the tube. In the second experiment this problem was reduced but still present on the kikuyu. Figure 4.1 is a photo of a cows' rumen taken during the second experiment (March 2008). In our work it was clear that just because the faeces are loose doesn't mean that the cow is not ingesting enough roughage.

Data collection period for phase 2: I would have liked to extend the sample and data collection period for the second experiment in the rumen study. Before the second experiment, another MSc student was doing his rumen study. His study had to be extended due to the problems with the new logging system. This meant that I only received the cannulated cows on the 1st of March 2008. My collection period could not be extended beyond 31 March 2008, because the Italian and westerwold pastures had to be replanted in March 2008. The pastures were replanted as soon as the cows finished grazing a paddock, therefore by the end of March 2008, there were no more westerwold pastures left. The planting date for the westerwold ryegrass could not be delayed. The soil temperatures are perfect for planting westerwold and Italian in March 2008, the DM production of kikuyu decreases during March, it grows less aggressively, which also makes March the perfect time for replanting the annual ryegrasses. The final reason for planting the annual ryegrasses in March is fodder flow. If the annual ryegrasses are not replanted in march, there won't be sufficient grazing available in June and July to meet the demands of the cows.

From the abovementioned it is clear that planning of dairy cattle production or rumen fermentation studies are far more complicated than when conducting experiments with TMR's. There are far more factors that are out of the control of the researcher when conducting pasture studies.

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APPENDIX A

NUTRIENT REQUIREMENTS OF THE LACTATING DAIRY COW

Table A1 contains the nutrient requirements of the lactating dairy cow as stated in Erasmus *et al* (2000). This information was used to determine whether the diets fed to the cows during the trial contained sufficient nutrients to satisfy the cows' requirements throughout the lactation.

Table A1 The nutrient requirements of the lactating dairy cow as stated in Erasmus *et al* (2000)

	Early lactation	**Mid – late lactation**
CP (%)	16-18	13-16
Sol CP, % of CP	30-35	30-40
RUP, % of CP	34-40	34-38
ME (MJ/kg DM)	11.5	10.5
ADF (%), min	19	19
NDF (%), min	28-32	28-25
Effective NDF (%)	20-24	23-27
NSC (%)	35-40	35-40
Fat (%)	5-7	4-6
Ca (%)	0.8-1.0	0.7-0.8
P (%)	0.24-0.38	0.34-0.38

CP = crude protein
Sol CP = soluble crude protein
RUP = rumen undegradable protein
ME = metabolisable energy
ADF = acid detergent fibre
NDF = neutral detergent fibre
NSC = non-structural carbohydrates
Ca = calcium
P = phosphorous

APPENDIX B
SELECTION OF TRIAL COWS

Production Study:

All the dry cows in the herd at the Outeniqua Research Farm were reviewed for selection for use in the trial. All the cows that would calve for the first time, cows that were not functionally sound (only three working teats, etc.), and cows that had behavioural problems (refuse to stand still in the crush; storm humans; etc.) were excluded. The 4% fat-corrected milk production of the previous lactation, lactation number, and calving date were used as criteria for blocking. Cows that calved too early or too late were excluded. Cows with extremely high milk productions (above 8000 litres fat-corrected milk per lactation) were also excluded. Fifteen blocks were selected. All the cows were then ranked according to block number. Cows within blocks were randomly allocated to the three different pasture treatments (15 cows per treatment) from June to July 2007. Tables B1 to B3 contain the three groups that grazed the italian, westerwold, and perennial ryegrass pasture treatments.

Table B1 The blocked cows that grazed italian ryegrass over-sown into kikuyu, note that cow one from the italian ryegrass groups was blocked with cow one from the westerwold, as well as the perennial group

No.	Name	Lact no.	Expected calving date	Calving date	Milk production (305d)	BF%	Protein%	FCM 305d
1	Bella 120	3	29 Apr 07	29 Apr 07	5175	4.88	3.42	5858.1
2	Elize 80	1	29 Apr 07	29 Apr 07	4563	4.81	3.79	5117.4
3	Marta 135	3	29 Apr 07	13 May 07	5022	4.48	3.32	5383.6
4	Alet 84	6	15 May 07	22 May 07	5817	4.56	3.45	6305.6
5	Etna	5	29 Apr 07	29 Apr 07	5536	5.53	3.95	6806.5
6	Japonica 64	2	26 May 07	24 May 07	4476	5.20	3.64	5281.7
7	Dora 101	4	28 May 07	22 May 07	4928	5.53	4.09	6059.0
8	Japonica 67	3	27 May 07	24 May 07	4670	4.99	3.59	5363.5
9	Berta 3	6	12 Jun 07	02 Jun 07	6313	4.88	3.50	7146.32
10	Japonica 65	2	11 Jun 07	13 Jun 07	4799	5.33	3.70	5756.5
11	Ida 33	5	20 Jun 07	22 Jun 07	5590	5.10	3.52	6512.4
12	Blondie 62	1	14 Jun 07	03 Jun 07	4270	5.19	3.67	5032.2
13	Amsa 7	3	09 Jun 07	01 Jun 07	5952	4.10	3.58	6934.1
14	Dora 92	5	15 Apr 07	15 Apr 07	5852	4.99	3.42	6721.0
15	Hes	4	07 Jun 07	03 Jun 07	5884	4.89	3.64	6669.5
AVE					**5256.47**	**5.03**	**3.62**	**6063.2**
SEM					**634.59**	**0.30**	**0.21**	**717.18**

AVE = average

SEM = Standard error of means

Table B2 The blocked cows that grazed westerwold ryegrass over-sown into kikuyu. Note that cows one was blocked with cow one from the westerwold and perennial groups

No.	Name	Lact no.	Expected calving date	Calving date	Milk production (305d)	BF%	Protein%	FCM 305d
1	Loret 34	2	04 May 07	04 May 07	5143	4.98	3.89	5899.0
2	Dora 113	2	08 May 07	08 May 07	4237	4.89	3.62	4802.6
3	Dora 109	2	09 Apr 07	09 Apr 07	4919	4.97	3.51	5634.7
4	Gerlien 14	7	17 May 07	20 May 07	5546	4.91	3.39	6303.0
5	Dora 99	4	05 May 07	06 May 07	6340	5.97	3.66	7262.5
6	Greta 39	1	02 Jun 07	23 May 07	4312	4.23	3.60	5107.6
7	Alta 30	2	26 May 07	24 May 07	5229	4.75	3.40	6373.5
8	Elize 70	5	28 May 07	27 May 07	5036	5.60	3.27	5489.2
9	Berta 5	5	19 May 07	18 May 07	5717	5.31	3.77	6840.4
10	Marta 141	3	30 May 07	31 May 07	4880	4.16	3.75	5729.1
11	Marlize 47	5	29 May 07	31 May 07	5596	5.91	3.74	6359.9
12	Blondie 56	3	13 Jun 07	07 Jun 07	4577	5.15	3.43	5366.5
13	Marta 123	3	13 Jun 07	08 Jun 07	6308	5.03	3.52	7282.6
14	Bella 113	4	22 Jun 07	10 Jun 07	5029	5.40	3.77	6085.1
15	Etna 1	3	16 Jun 07	10 Jun 07	5252	5.83	4.01	6693.7
AVE		**3.40**			**5241.4**	**5.07**	**3.62**	**6081.96**
SEM		**1.59**			**636.55**	**0.30**	**0.20**	**746.56**

BF% = butterfat percentage

FCM 305d = 305 day fat-corrected milk production

AVE = average

SEM = standard error of means

Table B3 The blocked cows that grazed perennial ryegrass over-sown into kikuyu. Note that cow one was blocked with cow one from both the italian and westerwold groups

No.	Name	Lact no.	Expected calving date	Calving date	Milk production (305d)	BF%	Protein%	FCM 305d
1	Firefly 46	5	11 Jul 07	05 Jul 07	5276	5.08	3.54	6130.7
2	Blondie 64	1	07 Jul 07	01 Jul 07	4612	4.64	3.53	5054.8
3	Firefly 47	3	29 Jun 07	26 Jun 07	4909	4.65	3.40	5387.6
4	Dora 94	6	22 Jun 07	28 Jun 07	5898	4.67	3.66	6490.8
5	Susa 5	2	09 Jun 07	07 Jun 07	5663	4.95	3.65	6470.0
6	Dora 119	1	06 Jul 07	11 Jul 07	4562	5.45	3.77	5554.2
7	Symbol 62	3	16 Jul 07	10 Jul 07	5306	5.07	3.62	6157.6
8	Marta 137	3	1 Jul 07	23 Jul 07	4936	4.89	3.65	5595.0
9	Bella 108	6	12 Jul 07	01 Jul 07	5450	5.33	3.66	6537.3
10	Marta 138	2	07 Jul 07	04 Jul 07	4987	4.91	3.73	5667.7
11	Alet 85	6	20 Jul 07	17 Jul 07	5460	5.20	3.43	6442.8
12	Dora 105	3	14 Jul 07	12 Jul 07	4820	4.86	3.43	5441.8
13	Lua 11	2	16 Jul 07	21 Jul 07	5896	4.84	3.41	6638.9
14	Gerlien 16	5	28 Jul 07	23 Jul 07	6063	4.39	3.07	6389.1
15	Mona	4	01 Jul 07	30 Jun 07	5862	4.88	3.69	6635.8
AVE		**3.40**			**5311.53**	**4.92**	**3.55**	**6039.60**
SEM		**1.72**			**491.40**	**0.28**	**0.18**	**533.31**

BF% = butterfat percentage

FCM 305d = 305 day fat-corrected milk production

AVE = average

SEM = standard error of means

Rumen Study:

Phase 1:

The cannulated Jersey cows available for the experimental period were blocked according to average daily milk production of the previous week, days in milk, and lactation number. It was not possible to exclude any of the available cannulated cows as only 12 were at available for the duration of the trial. The groups were balanced for the blocking criteria to make them as comparable as possible. Table B4 contains the two groups of Jersey cows that grazed the westerwold and perennial ryegrass treatments, respectively.

Table B4 The two groups of cannulated Jersey cows that grazed the westerwold and perennial ryegrass pasture treatments, respectively, during October – November 2007

		Westerwold ryegrass treatment		
No.	Name	Ave daily milk production	DIM	Lactation no.
1	Firefly 44	-	1	6
2	Bella 137	10.33	203	2
3	Mara 26	14.45	259	3
4	Marta 107	8.78	172	8
5	Babs 23	22.13	208	3
6	Blondie 35	13.25	258	6
AVE		**14.29**	**183.5**	**5**
		Perennial ryegrass treatment		
1	Greta 18	16.58	17	10
2	Bella 130	14.60	204	3
3	Dora 107	12.85	248	3
4	Marlize 36	12.70	102	9
5	Alet 80	17.80	243	6
6	Greta 34	13.73	278	3
AVE		**14.34**	**182**	**6**

DIM = days in milk

AVE = average

Phase 2:

For this phase it was decided to block the cows differently than in the previous experiment. For this phase the cows that were blocked together were allocated to the same group. In the previous phase the cows in the same block were allocated to different pasture treatments, but the same concentrate treatment. In this phase the cows that were blocked together were allocated to the same pasture treatment, but to different concentrate treatments. Table B5 contains a list of the cows in their respective blocks. Table B6 contains the cows as they were allocated to the two pasture treatments.

Table B5 How the cannulated Jersey cows were blocked according to daily milk production, DIM, and lactation number

No.	Name	Milk production	DIM	Lactation number
1	Firefly 44	15.3	152	6
1	Greta 18	13.9	169	10
2	Dora 107	18.3	52	4
2	Greta 34	20.1	66	4
3	Mara 26	17.3	46	4
3	Blondie 35	15.4	49	7
4	Alet 98	17.1	88	4
4	Marta 133	20.0	78	5
5	Bella 130	12.2	356	3
5	Bella 137	14.5	355	2
6	Marlize 36	14.5	254	9
6	Alet 80	13.2	395	6

DIM = days in milk

Table B6 The two groups of cannulated Jersey cows that graze the westerwold and perennial ryegrass pasture treatments, respectively, during March 2008

Westerwold ryegrass treatment				
No.	Name	Milk production	DIM	Lactation number
6	Alet 80	13.2	395	6
2	Dora 107	18.3	52	4
1	Greta 18	13.9	169	10
6	Marlize 36	14.5	254	9
2	Greta 34	20.1	66	4
1	Firefly 44	15.3	152	6
AVE		**15.88**	**181.6**	**6.5**
Perennial ryegrass treatment				
5	Bella 130	12.2	356	3
4	Alet 98	17.1	88	4
3	Blondie 35	15.4	49	7
5	Bella 137	14.5	355	2
4	Marta 133	20.0	78	5
3	Mara 26	17.3	46	4
AVE		**16.08**	**162**	**4.2**

DIM = days in milk

AVE = average