BREED DIFFERENCES IN RUMINAL DIGESTIBILITY OF FORAGES IN DAIRY COWS RECEIVING HIGH CONCENTRATE DIETS

by

NICKY RETIEF

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Supervisor: Prof. S.J. Schoeman
Co-supervisor: Dr. C.W. Cruywagen
Department of Animal Sciences
University of Stellenbosch

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Stellenbosch

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

SIGNATURE

DATE

ABSTRACT

BREED DIFFERENCES IN RUMINAL DIGESTIBILITY OF FORAGES IN DAIRY COWS RECEIVING HIGH CONCENTRATE DIETS

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Nicky Retief

Supervisor: Prof. S. J. Schoeman

Co-Supervisor: Dr. C.W. Cruywagen

Department: Animal Sciences

Faculty: Agricultural Sciences

University of Stellenbosch

Degree: M.Sc. (Agric.)

Statistical analysis was conducted on data from two Elsenburg herds, containing 105 Jersey and 232 Holstein cows. The data was examined for external factors which may affect milk yield and milk composition. The data consisted of 337 first lactation records, taken over a 20 year time period. Breed of cow had an effect on milk yield, butterfat and protein production, as did the year in which the cows were born and the age of the heifer at first calving. There was a significant interaction between the breed and year of birth. There are other external factors, which are difficult to quantify, which may have an effect on production. In the following trials, eight ruminally cannulated dairy cows (four Jerseys and four Holsteins) were used to determine the effect of breed on forage digestibility in the rumen. All cows received a high concentrate mixed ration, with supplementary wheat straw. An *in situ* rumen degradability trial was conducted with three different forages, *viz.* lucerne, wheat straw and NaOH-treated wheat straw. The bags were incubated in the rumen for time intervals of 2, 4, 8, 12, 16, 20, 24, 36, 48, 72 and 96 hours and samples were analysed for dry matter (DM) and neutral-detergent fibre (NDF). Higher rumen degradability values ($P<0.01$) of DM and NDF were observed in Jerseys for all three forages. Differences were more apparent for wheat straw and treated wheat straw than for lucerne. The rate of passage of digesta from the rumen was measured in both breeds by a chromium mordanted wheat straw marker. The Holsteins manifested a higher rate of passage ($P<0.05$) than the Jerseys, while daily feed intakes were

also higher ($P<0.01$) for the Holsteins than for the Jerseys. Daily feed intake, expressed as percentage of body weight was, however, slightly higher for the Jerseys than for the Holsteins. The pH value of the rumen fluid was measured at 0, 4, 8, 10 and 12 hours post-feeding. The only significant difference ($P<0.01$) in pH between the breeds was at 4 hours post-feeding, when the ruminal pH dropped more rapidly in the Holsteins than in the Jerseys. The pH in the Holsteins dropped below 6.2, which may have inhibited fibrolytic microbe activity in the rumen, resulting in a lower effective degradability of forages. Total volatile fatty acids were higher in Holsteins from four to 10 hours after feeding, but no differences were observed in acetic acid:propionic acid ratios. It was concluded that Jerseys appear to utilize forages more efficiently than Holsteins and that the differences are more apparent in low quality forages than in high quality forages.

SAMEVATTING

RASVERSKILLE IN RUMENVERTEERBAARHEID VAN RUVOERE BY MELKKOEIE WAT HOË-KRAGVOERDIËTE ONTVANG

deur

Nicky Retief

Studieleier: Prof. S. J. Schoeman
Mede-studieleier: Dr. C.W. Cruywagen
Departement: Veekundige Wetenskappe
Universiteit van Stellenbosch
Graad: M.Sc. (Agric.)

Statistiese analises is op data van twee kuddes te Elsenburg uitgevoer, bestaande uit 105 Jersey- en 232 Holsteinkoeie. Die data is ondersoek vir eksterne faktore wat melkproduksie en melksamestelling kan beïnvloed. Die data het uit 337 eerste-laktasierekords bestaan, wat oor 'n periode van 20 jaar ingesamel is. Ras van die koei, sowel as die jaar van geboorte en ouderdom met eerste kalwing het 'n invloed op melkproduksie, bottervet- en proteïen-opbrengs gehad. 'n Betekenisvolle interaksie is tussen ras en jaar van geboorte waargeneem. Ander moeilik kwantifiseerbare faktore mag ook 'n invloed op melkproduksie hê. In daaropvolgende proewe is agt rumen-gekannuleerde melkkoeie (vier Jerseys en vier Holsteins) gebruik om die invloed van ras op ruvoerverteerbaarheid in die rumen te bepaal. Al die koeie het 'n hoë-kragvoerdieet ontvang, aangevul met koringstrooi. 'n *In situ* rumendegradeerbaarheidstudie is met drie verskillende ruvoere, naamlik lusernhooi, koringstrooi en NaOH-behandelde koringstrooi uitgevoer. Die ruvoere is vir tye van 2, 4, 8, 12, 16, 20, 24, 36, 48, 72 en 96 ure in die rumen geïnkubeer en monsters is ontleed vir droëmateriaal (DM) en neutraal-bestande vesel (NDF). Hoër rumen-degradeerbaarheids-waardes ($P<0.01$) van DM en NDF is in Jerseys waargeneem as in Holsteins vir al drie ruvoere. Verskille was meer opvallend vir koringstrooi en NaOH-behandelde koringstrooi as vir lusern. Uitvloeitempo van digesta uit die rumen is in beide rasse met behulp van chroomgemerkte koringstrooi bepaal. Hoër uitvloeitempo's is in die Holsteins waargeneem as in die Jerseys, terwyl daaglikse voerinnames ook hoër was ($P<0.05$) by die Holsteins as by

die Jerseys. Daaglikse voerinname, uitgedruk as persentasie van liggaamsmassa, was egter effens hoër ($P<0.01$) by die Jerseys as by die Holsteins. Die pH van die rumenvloeistof is op 0, 4, 8, 10 en 12 ure na voeding gemeet. Die enigste betekenisvolle verskil ($P<0.01$) in pH tussen die rasse het op 4 ure na voeding voorgekom toe die pH van die rumeninhoud vinniger in die Holsteins as in die Jerseys gedaal het. Die pH in die Holsteins het onder 6.2 gedaal, wat moontlik fibrolitiese mikrobe-aktiwiteit in die rumen kon inhibeer, met 'n gevolglike daling in effektiewe degradeerbaarheid van die ruvoere. Vanaf 10 ure na voeding was die totale vlugtige vetsuurkonsentrasies hoër in die Holsteins, maar geen verskille in asynsuur:propionsuurverhoudings is waargeneem nie. Die gevolgtrekking is gemaak dat Jerseys skynbaar meer doeltreffend is om ruvoere te benut as Holsteins en dat die verskil tussen rasse meer opvallend is vir lae kwaliteit ruvoere as vir hoë kwaliteit ruvoere.

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ABBREVIATIONS

ADF	Acid-detergent fibre
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
CF	Crude fibre
CP	Crude protein
Cr_2O_3	Chromium oxide
Df	Degrees of freedom
DM	Dry matter
DMI	Dry matter intake
g	Gram
kg	Kilogram
KJ	Kilojoule
K_r	Fractional outflow rates
LSD	Least significant difference
ME	Metabolizable energy
MJ	Megajoules
MS	Mean square
N	Nitrogen
NaOH	Sodium hydroxide
NDF	Neutral-detergent fibre
NFE	Nitrogen-free extractives
NPN	Non protein nitrogen
NRC	National Research Council
OM	Organic matter
P	Probability
RUP	Rumen undegradable protein
RDP	Rumen degradable protein
SAS	Statistical analysis system
SEm	Standard error of mean
TMR	Total mixed ration
UDP	Undegradable protein
VFA	Volatile fatty acids

CONTENTS

Chapter 1

GENERAL INTRODUCTION

At the end of the day, the aim of any milk producer is to make money. This requires an economical balance of what is spent on feed, equipment, health management and other costs and money received from the milk sales. It is generally accepted (Gordijn & Whitehead, 1995) that feed costs comprise about 60% of the total costs in a dairy enterprise. In South Africa, as in most countries, the price received for milk is dependent on the protein and butterfat content of the milk (Muller & Botha, 1998). Thus, it is important to consider the type of feed being offered to the cows and both the quantity and composition of the milk being produced.

There are many factors that influence milk production, some are due to variations between farms, herds and individual cows. Other factors, such as the age of the cow, the stage of lactation and the breed of the cow are easy to quantify and the effect that they will have on milk production can be predicted (Stewart, 1995). Some of these factors and their effect on milk production parameters were considered in the current study.

Milk production and milk composition vary widely between different breeds of cattle. There is a vast difference between beef cattle and dairy cattle, but significant variation also occurs within the different dairy cattle breeds. It is generally accepted that Holsteins produce the greatest quantity of milk, as they are the largest of the dairy breeds, whereas other breeds, such as Jerseys and Guernsey's, produce a larger percentage of milk solids. In the Western Cape, the two main breeds of dairy cows are Holsteins and Jerseys at 59% and 27% respectively (Muller & Botha, 1998). It could therefore be of interest to consider these two breeds in terms of the differences in milk production and milk composition, and the possible differences in feed digestibility.

In the current study, different forages were used in *in situ* digestibility trials with Holstein and Jersey cows, to determine if breed affects ruminal digestibility. The following sources of fibre were used: lucerne, which is a good quality forage as it has a high

nutritive content, NaOH-treated wheat straw and wheat straw which has a low nutritive value. Further trials were carried out to establish whether the rate of passage of digesta, the DM intake or ruminal pH, differed between Holstein and Jersey cows.

1.1 THE EFFECT OF NUTRITION ON MILK YIELD

Lactation in the dairy cow involves the conversion of nutrients, obtained from the feed, into milk (Sutton, 1989). The lactating dairy cow has definite nutritional requirements in order for milk to be produced. It is important to understand these requirements, and the effects of nutrition on milk yield for efficient production levels to be reached. It is not necessarily the most economical option to feed the cows for maximum production yields.

When feeding a lactating dairy cow, milk production is not the only factor that has a demand on available nutrients. In order to effectively feed the producing cow so that milk yield is not negatively affected, the other nutritional needs of the cow need to be met, and the nutritional requirements of the whole cow assessed (McDonald *et al.,* 1988).

Other factors that need to be considered in order to accurately assess the lactating dairy cow's nutritional requirements are: stage of lactation, age of the cow, live mass, body condition, butterfat yield and stage of pregnancy (Stewart *et al.*, 1995). In other words, nutrition must be adequate so that other factors do not limit the availability of nutrients for milk yield.

The Effect of Dry Matter Intake on Milk Yield

The first nutritional limitation to milk yield is the dry matter intake of the cow. If cows could consume an infinite amount of food, there would be no limiting nutrition and milk yield would be a function of the biological capacity of the cow (McDonald *et al.*, 1988). However, the DMI capacity of the dairy cow is limited by various factors.

DMI has been reported to be a function of the calorimic density of the diet (Allen, 1997). There are thought to be two mechanisms controlling intake, namely the physiological

mechanism and the physical mechanism (Allen, 1997). The theory of the physiological mechanism is that the animal eats to meet its energy requirements. The mechanisms of this are not well understood (Baile, 1986; Forbes, 1988).

The physical mechanism theory hypothesizes that intake is limited by the filling properties of the diet. Rumen capacity is a limiting factor to dry matter intake, especially with high roughage diets (Campling & Balch, 1961). Van Soest (1967) found a negative correlation between the fibre content of the diet and DMI, and suggested that fibre could be used as a predictor of DMI. Rumen fill capacity is affected by many factors such as body weight, rumination, rumen motility and rate of passage, as well as an interaction between these factors. However, although rumen capacity has a limiting effect on DMI, satiety is controlled by many different physical, humoral and chemical factors (Forbes, 1988; Grovum, 1987). The greater the DMI of the cow, the more nutrients are available for milk yield. It is not only the amount of nutrients but also the type of nutrient that has an effect on milk yield.

The Effect of Nutritional Energy on Milk Yield

When assessing the effects of nutrition on milk yield, the energy dynamics are of importance. Energy supplying nutrients occur in the greatest quantity in feeds, and it is important that a ration not be deficient in energy. Energy also has the largest effect on production. The cow needs energy for maintenance, growth and production. Production tends to show a continuous response to changes in energy supplied. Energy systems assess the energy values of feeds and relate it to the energy requirements of the animal.

The energy requirements of the animal are relatively easy to assess, via calorimetery. Maintenance energy is calculated in the fasting animal. The quantity of heat produced, measured under fasting conditions, is known as the basal metabolism. Energy required for production can be measured by similar methods. The gross energy value of the milk being produced is calculated and the milk yield is used to estimate the net energy requirements for milk production. The gross energy value of milk can be measured either by bomb calorimetry or by detailed chemical analysis. The ARC (1980) proposed the

following equation for calculating the energy value of milk;

EV (MJ/kg) = 1.509 + 0.0406F where F = fat content of the milk (g/kg)

The efficiency of utilization of food energy for milk production is needed to estimate the amount of food energy required. Estimates of the efficiency of utilization of food energy for milk production (k_l) vary from 0.51 to 0.81 but are mostly around 0.6 (McDonald *et. al.* 1988).

The Effect of Protein on Milk Yield

The protein fraction of cow's milk is dominated by caseins, of which there are five different types. Together they contain approximately 78 % of the total milk nitrogen. Amino acids are absorbed from the blood for protein to be synthesised in the mammary gland. The rest of the proteins in cow's milk are β-lactoglobulins and small amounts of α-lactalbumin, bovine serum, albumin and the immune globulins, pseudo-globulin and euglobin. These are all absorbed directly from the blood (McDonald *et al.*, 1988). Thus it is important that sufficient proteins and amino acids reach the blood stream, for absorption and sufficient protein synthesis in the mammary gland, to ensure that milk yield is not limited.

There are many protein evaluation systems that are currently used. Ruminal modification of nitrogenous material (protein degradation and protein synthesis), as well as post-ruminal degradability have an itergral effect on any protein evaluation system. The extent of protein degradation in the rumen is affected by the rate of digesta passage from the rumen. Various methods to determine protein degradability (e.g. *in situ* dacron bag technique), passage rate and lower intestinal protein digestibility (mobile bag technique) have been documented in the literature. (Ørskov & Mehrez, 1977; Ørskov & McDonald, 1979; Uden *et al.*, 1980; McDonald, 1981; De Boer *et. al.*, 1987).

Prediction models have also been developed, which are based on *in vitro* analyses to estimate duodenal amino acid flow to the duodenum and amino acid composition of duodenal digesta. Regression methods to estimate amounts of individual amino acids flowing to the small intestine were proposed by Hvelplund & Madsen (1989). These

models provide good estimates under restricted experimental conditions.

Due to the degradative and synthetic action of the microbial organisms on feed protein in the rumen, the protein requirement for milk production is generally expressed in terms of rumen degradable protein (RDP) and rumen undegradable protein (RUP). Some sources of protein are susceptible to microbial breakdown in the rumen, the amino acids and nitrogen formed in this degradation is then utilised by the microbes in their growth and multiplication. The microbes eventually pass through the rumen into the digestive tract, providing the ruminant with an alternative form of protein, which is available for milk synthesis in the mammary gland (McDonald *et al.*, 1988). The are, however, some sources of protein which are not degraded in the rumen due to the enhanced structure of the cell wall, which prevents the microbial organisms from attacking it. This protein is then absorbed in the rest of the digestive tract in a more complete form and is a better source of dietary protein than the RDP. As milk yield increases, so does the need for good quality RUP.

Nutrition can affect milk yield in a variety of ways. The producer needs to find the economic optimum between high quality feeds, good nutritional strategies and milk yields. Total milk yield is not the only source of income from milk, milk composition also determines the price of the milk, and nutrition has a large effect on the composition thereof.

1.2 THE EFFECT OF NUTRITION ON MILK COMPOSITION

Nutrition can have a large effect on milk production and milk composition. Researchers and farmers alike are constantly looking for more efficient ways to meet the dairy cow's complex need for nutrients in order to sustain her maximum production potential. The cow's diet is the single most important factor that affects milk production. Nutrition can also change the composition of milk and can be manipulated to ensure that the producer can meet market demands.

Milk Synthesis and Secretion

In order to fully understand how nutrition can affect milk production and composition, it is necessary to look at how milk is synthesized in the mammary gland and the utilization of dietary nutrients for synthesis and secretion. Milk synthesis and secretion are the result of complex interactions involving available nutrients, hormones, physiological and biochemical processes (Sutton, 1988).

The supply of nutrients to the mammary gland is important as the availability of nutrients affects the synthesis of milk. This is dependent on the digestion and absorption of feed nutrients, and is the route whereby dietary manipulations can be used to change the composition of milk. However, it is not a simple relationship, and changing one constituent in the food doesn't result in a similar change in the same constituent in the milk. In general, milk fat concentration can be changed over a wide range, milk protein concentration over a much smaller range and the lactose concentration in milk is relatively constant (Sutton, 1988).

Some constituents of milk are synthesized in the udder, including lactose, casein protein, 75% of the whey protein and 50% of the fatty acids. Others are secreted directly into the milk by diffusion from the bloodstream, already synthesized by extra-mammary tissue. These include some fatty acids, minerals, vitamins and hormones (Fredeen, 1996). Other milk components are the result of the breakdown of products, e.g. gamma-casein and peptease peptones result from the breakdown of beta-casein (Mackle & Bryant, 1996).

Lactose is osmotically active and its rate of secretion regulates the rate of secretion of water, thus, the concentration of lactose in milk remains fairly constant and lactose yield can be used as a measure of milk yield (Sutton, 1988). Changes in milk composition are basically due to changes in the rates of secretion of fat and protein relative to lactose. Glucose is the primary precursor for lactose synthesis.

Milk protein synthesis is similar to the biochemical synthesis of other cellular proteins. Amino acids are used, by RNA, to form protein chains which are transported to the golgi apparatus from which the formed protein is secreted (Thomas & Chamberlain, 1988). In general, there is sufficient uptake of total amino acids for the amino acid N and carbon in milk. However, although the uptake of essential amino acids is adequate, the non-essential amino acids can be in short supply. Some of the essential amino acids are quantitatively transferred to the milk protein but others have a sparing effect on the synthesis of non-essential amino acids. Some amino acids are also used for ATP production. These seem to be modulated by the arterial amino acid supply (Thomas, 1984).

According to Thomas & Chamberlain, (1988) approximately 97% of cow's milk fat are triglycerides, the major fatty acids of 4-18 C-atoms, being mostly even numbered. Acetate is the main precursor of fatty acid synthesis in the mammary gland, the main pathway being the malonyl pathway. Short chain fatty acids are synthesized from acetate and β-hydroxybuterate (Sutton, 1984). This accounts for all the secretion of short-chain fatty acids into milk.

Long chain fatty acids (18-C) are generally taken from the blood plasma triglycerides and low density lipoproteins. This incorporation involves the complete or partial hydrolysis of the plasma triglyceride fatty acids by lipoprotein lipase in the mammary gland (Storry, 1988). Medium chained fatty acids can be derived from either the blood lipids or synthesized in the mammary gland (Thomas & Chamberlain, 1988). Digestive processes that occur in the rumen, and the complex interactions between food ingredients, absorbed nutrients and hormonal control mechanisms, lead to difficulties in predicting the amount of milk fat that will be produced from a diet (Thomas & Chamberlain, 1988). However, the process of lipid digestion in the rumen can be influenced by dietary factors and milk fat can be changed within a fairly wide range (Sutton, 1988). It is important to realize that ultimately, milk secretion is limited by the size of the udder and the metabolic rate of the mammary tissue. In general, milk yield increases with the level of feeding and positive dietary changes, but the curvilinear responses in the yields of fat, protein and

lactose aren't identical, which in itself can lead to changes in milk composition (Thomas & Chamberlain, 1988).

Nutritional Effects on Milk Fat

Since Powell's (1938) observation of the effect of the physical structure of fibre on milk fat concentration, others have examined the characteristics of a roughage which may affect milk fat. An important physical property of a roughage is particle size. Sutton & Morant (1989) suggested that the critical particle size for maintained milk production is ±1cm, which was later revised to 0.6-0.8cm (Sutton, 1988). Thomas (1984) found no conclusive evidence that factors such as digestibility, grazing type and method of storage of conserved forage affected milk fat content.

The amount of roughage in the diet can change the composition of the milk. In general, reducing the forage:concentrate ratio of a diet leads to a decrease in milk fat concentration, but the decrease is variable (Sutton, 1988). Sutton & Morant (1989) showed that the decrease in milk fat concentration is accompanied by an increase in milk yield and milk protein yield. They reasoned that this could be due to the fact that the increase in production of propionic acid with the change in diet could increase the glucose supply, sparing amino acids for milk protein synthesis and providing more precursors for lactose synthesis. The increase in rumen propionic acid stimulates insulin release which increases adipose tissue lipogenesis, thus resulting in decreased milk fat synthesis (Sutton & Morant, 1989).

The source of carbohydrate used in a low roughage diet affects the extent of the decrease. Milk fat is higher when the carbohydrate source is ground maize, fodder beet or fibrous by-products rather than barley (Sutton, 1984). This is possibly due to varying ADF and NDF contents of the carbohydrates, as there seems to be a noticeable relationship between milk fat concentration and dietary ADF concentration. Soluble carbohydrates are generally considered to maintain a higher milk fat concentration than starch (Sutton & Morant, 1989). From a study of various experiments, Sutton (1984) concluded that there was no single value for the amount of forage in the diet or ADF content that can be

used as a guideline to prevent a decrease in milk fat, but suggested that the minimum value is in the range of 450g forage/kg dietary DM and 220g ADF/kg dietary DM.

It is generally accepted that including free lipids in the diet leads to an increase in milk yield. Milk fat concentration is not affected by small amounts of saturated lipids, but when unsaturated lipids or large amounts of any lipids are supplemented, it causes milk fat concentration to decrease (Sutton & Morant, 1989). However, the effects often vary as the lipids or the fat supplements may have various effects on ruminal fermentation. Fat that is not ruminally inert may cause microbial inhibition, reduce fibre digestion and reduce the acetate:propionate ratio, resulting in a depression in milk fat synthesis (Fredeen, 1996). Chilliad (1993, cited by Fredeen, 1996) found that protected tallow had a greater negative effect than other lipid supplements. Conrad (1964, cited by Palmquist & Beaulieu, 1992) suggested that, because gut capacity in relation to milk energy output is more limiting in smaller breeds, Jersey cows are able to utilize higher amounts of dietary fat.

The level of feed intake is important as results vary with differing levels of DM intake. Broster, *et al.* (1985) found that increasing intake by 30MJ DM/day on a high concentrate diet, reduced the milk fat concentration by 3g/kg. There was no effect on the solids-not-fat (SNF) content of the milk. The composition of the diet was not changed, and the size of the decrease in milk fat concentration was not constant for a specific diet. The effect of increasing the number of concentrate meals given daily in a fixed ration generally has no effect on milk composition, except where milk fat is depressed on low roughage diets, then, increasing the number of meals from 2 to 6 resulted in an increase in milk fat concentration of up to 10g/kg. The size of the increase is related to the severity of the decrease (Sutton & Morant, 1989). This is thought to lessen the increase in insulin and decrease the somatotropin concentration in the blood which are consequences of the low roughage diet and cause the depression in milk fat concentration (Sutton, 1988).

Nutrition has a large effect on the yield and the composition of the milk produced. However, there are many other factors that influence milk yield and milk composition that must also be considered in order to maximize the production potential of the cow.

1.3 FIBRE DEGRADATION

Forage is an important feed source for ruminants, especially in dairy nutrition. A general rule of thumb is that the forage content of a diet for dairy cows should be at least 35-40% of the total DM (Dugmore, 1995). It is important to understand exactly what forage is, what nutrients it supplies, how it is digested and what effect it has on production.

Forages may be classified as feeds which have a certain quantity of cell wall material (Church, 1974). Thus, quantification of the amount of cell wall will give an estimate of the fibre content of the feed. Van Soest (1967) developed the NDF method of forage analysis. Forage is treated with a neutral solution of sodium lauryl sulfate and EDTA which allows recovery of cell wall components (Table 1.).

Table 1. Classification of forage fractions (Van Soest, 1967)

Fraction	Components
Cell contents (soluble in neutral detergent)	Lipids Sugars, organic acids and water-soluble matter Pectin, starch Non-protein N Soluble protein
Cell Wall constituents (fibre insoluble in neutral detergent) 1. Soluble in acid detergent	Hemicelluloses Fibre-bound protein
2. Acid detergent fibre	Cellulose Lignin Lignified N Silica

The NDF method does not account for the physical properties of a fibre and the effectiveness of a fibre in meeting the cows requirements. Mertens (1997) proposed two additional definitions, effective NDF and physically effective NDF. The effective NDF is related to the ability of the feed to maintain milk fat production and physically effective NDF is related to the physical properties of the fibre, its ability to stimulate chewing activity and the establishment of biophasic stratification of ruminal contents which is the floating mat of large particles.

NDF degradability in the rumen can vary widely. The digestibility of the NDF is a function of the potentially degradable fraction, its rate of digestion and its rate of passage (Oba & Allen, 1999). The proportion of lignin is regarded as the main factor limiting fibre digestibility, while crystallinity of cellulose and lignification of polysaccharides also limits digestibility (Escalona *et al.*, 1999). The type of forage will affect the extent of degradation.

Mammals do not produce the enzymes that can degrade cellulose. However, ruminants have a symbiotic relationship with ruminal cellulotic microorganisms that enables them to utilize cellulose and hemicellulose (Russell & Wilson, 1996). The animal provides a suitable environment for microbial growth and the microbes degrade the cellulose, providing the animal with VFA's, which are the end products of fermentation (Russell & Wilson, 1996). In addition, the microbes utilize other nutrients such as N to grow and when they pass through the rumen they are absorbed in the abomasum providing the animal with an invaluable source of protein. In fact the microbial mass synthesized in the rumen can amount to 20% of the absorbed nutrients (McDonald *et al.*, 1988).

The rumen microbial mass consists of bacteria, fungi and ciliate protozoa (Matsui *et al.*, 1998). The protozoa are not that numerous but are fairly large. Only the Oligotrichs can utilize cellulose (McDonald *et al.*, 1988). Fungi constitute about 8% of the microbial mass and have an important role in fibre digestion. They are able to penetrate the cuticle and cell wall of lignified tissue and can degrade more recalcitrant cell walls (Varga & Kolver, 1997). The rumen bacteria are the most proliferant and can number 10^9- 10^{10}/ml

of rumen content. Over 60 species of rumen bacteria have been identified (McDonald *et al.*, 1988). The main species of fibrolytic bacteria are *Fibrobactor succinogenes*, *Ruminococcus flaveraciens*, *Ruminococcus albus*, *Butyrivibro fibrisolvens*, *Clostridium longisparium* and *Clostridium locheadii*. Other species of bacteria that don't degrade cellulose but do have a role in fibre degradation are *Prevotella ruminicola*, *Ruminobacter amylophilus*, *Selenomonas ruminantium*, *Streptococcus bovis, Succimonomas amylolytica* and *Succinivibro dextrinosolvens* (Weimer, 1996).

The total number of bacteria and the populations of individual species vary with the animal's diet. It has been observed (Russell & Wilson, 1996) that when cereal grains were added to the diet, the roughage dry matter digestibility decreased. Cereal grains or more concentrate feeds have faster fermentation rates which results in the build up of VFA's in the rumen, which causes the ruminal pH to decrease (Russell & Wilson, 1996). The ruminal pH is regulated by the balance between fermentation acid production and buffer secretion (Allen, 1997). Buffers, which consist of P and $NaHCO_3$, are secreted in the saliva (McDonald *et al.*, 1988). Chewing stimulates saliva secretion (Allen, 1997), thus by having a diet that is high in concentrates, not only is there faster fermentation acid production, but less saliva secretion, resulting in a lower rumen pH. Russell & Wilson (1996) showed that at pH values less than 6.0, ruminal cellulyosis was totally inhibited. The cellulytic bacteria could not tolerate a pH less than 5.9, although one species, *Butyrivibro fibrisolvens* was able to resist until pH 5.7 but not any lower. Thus, for effective fibre degradation by microbes, it is important that a pH of around 6.6 is maintained in the rumen.

The cell wall shields the nutrients from microbial attack and it has been shown that the digestion of roughages can be improved by modification of the cell wall structure (Chaudhry, 1998). This can be done with sodium hydroxide (NaOH) or calcium oxide (CaO). The addition of yeast culture has been thought to modify ruminal fermentation and fibre digestion (Enjalbert *et al.*, 1999).

The main end products of fermentation are acetic acid, propionic acid, and butyric acid as well as carbon dioxide and methane. Other fatty acids are formed in smaller quantities by the deamination of amino acids in the rumen. The total concentration of VFA's in the rumen varies with the animal's diet and the time from the previous meal (McDonald *et al.*, 1988). Acetic acid is the most dominant acid in the rumen, especially on roughage diets with high cellulose content. The proportion of propionic acid increases and the proportion of acetic acid decreases with increased concentrates in the diet (McDonald *et al.*, 1988).

The dairy cow needs fibre for rumen function and milk production. Fibre provides a more continuous flow of fermentable carbohydrates which improves overall utilization of the diet (Dugmore, 1995). The fibre content of the feed has a large effect on voluntary feed intake of the the animal. This is thought to be due to its degradation characteristics and the time it is retained in the rumen (Fonseca *et al.*, 1998). Oba & Allen (1999) showed that enhanced NDF digestibility of forage significantly increased DM intake and milk yield, although the specific effects are complex and difficult to isolate. Acetic acid, which is the main fermentation product of long fibre, is also an intermediate of milk fat (Dugmore, 1995). Thus, the fibre content of the diet will affect the butterfat content of the milk. Other effects on milk composition have already been discussed.

The effect that fibre has on milk production and milk composition suggests that any differences in fibre digestibility between different breeds of dairy cattle could influence various milk production parameters between the breeds. The aim of this trial was to see whether there were any differences in fibre digestion between Jersey and Holstein cows, and if so, what the reasons for the differences could be.

Chapter 2

GENERAL MATERIALS AND METHODS

This chapter provides a background of the techniques that were used in the trials.

2.1 THE *IN SITU* OR NYLON BAG TECHNIQUE

Various methods are used to assess the nutritive value of a feed. *In vivo* experiments are generally expensive, labour intensive and time consuming (Nocek, 1988). Various *in vitro* techniques to assess the nutritive value of a feed, have been developed. One such technique is the two-stage Tilley and Terry method (Tilley & Terry, 1963). This involves incubating dried forage samples with rumen liquor, followed by acid pepsin. The DM disappearance is then used to calculate digestibility (Tilley & Terry, 1963). Gas production techniques use the association between rumen fermentation and gas production to estimate the digestibility of the feed. This gas production is the result of anaerobic digestion of carbohydrates by the rumen microbial population. Thus, the gas production is measured, and used to study the rate and extent of digestion via various mathematical models (Getachew *et al.*, 1998). Enzymatic digestibility assays use enzymes instead of micro-organisms to evaluate end point digestibility (Getachew *et al.*, 1998), but they have limited validity as they do not experience the interactions in the rumen environment (Stern *et al.*, 1997). Electrophoretic analysis assesses the relationship between fractional protein contents, measured via gel electrophoresis and digestibility (Stern *et al.*, 1997).

A commonly used technique for approximating the *in vivo* fermentation process in the rumen is the *in sacco* or *in situ* method. This method estimates the disappearance of the nutrient under investigation in the rumen using cannulated animals and nylon bags. The nylon bags, containing measured amounts of the feedstuff to be evaluated, are suspended in the rumen of fistulated animals for various time periods. The residual feedstuff, after the bags have been removed from the rumen, is evaluated (Cronje, 1982). Thus, the feed is in contact with the ruminal environment and it is assumed that fermentation and

degradation is similar in the bag as in the rumen. However, the tested feedstuff is not subject to digestion in its entirety as there is no mastication, rumination or passage (Nocek, 1988). The method was first proposed by Quin *et al.* (1938) who placed cylindrical bags of thin silk in sheep via a rumen cannula. McAnally (1942), Balch & Johnson (1950), Erwin & Elliston (1959) and others, further developed the technique. Ørskov & McDonald (1979) developed methods and models to evaluate the time course of degradability. Since then, the *in sacco* method has become widely accepted and commonly used. Various other authors (Nocek, 1988; Pienaar *et al.*, 1989; England *et al.*, 1997; Moss & Givens, 1997) have compared the *in sacco* technique to other methods of estimating digestibility of a feedstuff, and found it to be an acceptable and practical method.

As with any experimental method, it is important to be aware of limitations of the technique and factors that might affect the accuracy of the results. Animal effects are inherent in any experiment done with live animals and should preferably be standardized within a given trial. Some aspects that may have an effect include; species, physiological status, stress, feeding level and regime (Moss & Givens, 1997). According to Huntington & Givens (1995) the following factors may affect the accuracy of the *in situ* technique:

Bag

- Type of material:

There are three types of cloth that are generally used to make the bags, viz. nylon, polyester or dacron. The weave of the material is important as this can have an effect on the pore size. The two types of weaves are multifilamentous or monofilamentous. The latter is heat treated which forms permanent corrugations where the filaments cross, resulting in precisely defined pores that will not distort.

- Pore size:

Pore size is important as it needs to be able to allow the influx of digestion agents and buffers and the removal of degradation end products, but prevent efflux of undegraded sample and influx of rumen digesta, not associated with the test feed. Thus, the pore size is at best a compromise and the suggested range is between 35-60 μm.

Sample preparation

- Drying:

Sample feed is dried to reduce changes in composition due to respiration and enzymatic action. Drying also facilitates milling, especially with wet forages. The nature and content of various constituents of the feed may be influenced by the drying process. The most commonly used method is drying in a force draft oven. Long drying times and low temperature are best to prevent thermochemical degradation of the sample feed. Other methods of drying include freeze and microwave drying.

- Milling and sieving:

Milling the feed sample results in greater homogeneity, reduces the particle size and increases the effective surface area for microbial degradation. Variations in results were decreased and DM and NDF disappearance increased when ground feed was compared with chopped material (Nocek & Kohn, 1988). However, the influence of particle size on disappearance in not certain as results are contradictory (Ehle *et al.*, 1983). Milling also affects particle size distribution. Different plant constituents may shatter differently, resulting in different particle sizes having different nutritive values. Sieving the sample reduces physical losses of very small particles after the sample is weighed. Emanuele & Staples (1988) suggested that the loss of fine particles could affect degradation results. Particle shape is an important factor (Mertens, 1977) in regulating the rate and extent of rumen degradation changes. Mechanical grinding was shown to produce similar particle shapes as chewing and digestion. It must be remembered that the aim of sample preparation is to simulate the digesta post mastication and rumination.

- Weighing of feed samples:

The ratio of sample weight to bag surface area has an effect on the results. It is important to avoid bias when filling the bags. The sample must be as homogeneous as possible and the bags should be filled in random order. There must be enough residue left, after long incubation times, for subsequent chemical analysis (Nocek, 1988). However, it is very important not to over fill the bags, as this may result in delayed bacterial attachment,

increased lag times and an under-estimation of degradability. Erwin & Elliston (1959) first showed that DM degradability decreased linearly as the weight of the sample increased. Subsequently, other researchers have found a negative relationship between sample size and bag surface area. No ideal relationship has been decided on, but a ratio of 16mg/cm^2 is suggested for dry feed samples; fresh feeds may require a larger ratio for sufficient residue post-incubation.

Rumen incubation

- Placement of bags within the rumen:

The aim is to place the bags in the rumen where they have free movement in the rumen liquor and are squeezed during muscular contractions. This aids fluid exchange between the bag and the rumen (Stritzler *et al.*, 1990). The ventral sac seems to be the most common site of incubation as it is more aqueous and thus more able to attack and colonize freshly exposed feed surfaces, whereas micro-flora in the dorsal sac may be more restricted as they are already associated with plant material (Stewart, 1979). The bags are usually attached to a weighted carrier which has a cord attaching it to the cannula. The length of this cord will determine how deep in the rumen the bags will be suspended. The minimum cord length should be from the cannula to the bottom of the rumen.

Post-rumen incubation processing

- Contamination of the bag and its residues:

Microbial contamination of forage residues can lead to substantial underestimation of degradability value. Van Milgen *et al.,* (1992) showed that prolonged incubation resulted in the build up of mineral deposits. Thus, the post-rumen incubation washing procedure is important. Dipping bags in iced water or ethanol solution have been suggested as ways to stop microbial activity. Washing procedures are varied. Hand-washing until the water runs clear was common, but household washing machines give more standardized results. The time and the severity of the program used will affect DM losses from the bag (Hyslop, 1991).

Host diet effects

The diet being fed has a large effect on the rumen environment and the microbial population. As the aim is to get the interior of the bag as similar to the rumen environment as possible, the diet effects on *in situ* degradation must be considered. Some diets affect the rumen muscular contractions, which results in increased fluid exchange between the rumen and the bag interior. Maize diets may result in bacterial slime which blocks the pores of the bag, but this may be prevented by the abrasive action of the fibrous mat and the bag. Long fibre may be a requirement in the basal diet. It is important that the basal diet meets the N and energy requirements of the microflora without being in excess.

Various models have been suggested to estimate the digestibility or degradability of a feedstuff from the *in situ* data. Ørskov & McDonald (1979) developed a model to estimate both potential degradability and effective degradability using time and the rate of passage of digesta through the rumen. Details of the model are given in Chapter 4. Pienaar *et al.* (1989) looked at alternative models of digestion using mean retention time. Cronje (1982) compared the method of Ørskov & McDonald (1979) with another method by Miller (1980, cited by Cronjie, 1982). The different models that are available tend to yield varying results. Huntington & Givens (1995) recommend using the model by Ørskov & McDonald (1979).

2.2 PASSAGE RATE MARKERS

There are two phases of substrate that pass through the GI of the cow, viz. the liquid phase and the solid phase. These are known to have a relatively independent turn-over rate (Uden *et al.*, 1980), and thus are measured independently. In the current study, the fibre fraction of the food was being monitored, therefore only a solid phase marker was used.

A reference compound known as a marker, is often used to monitor the flow of digesta through the GIT (Owens & Hanson, 1992). It is necessary to know the rate of flow of digesta as it is one of the factors that influence the digestion, absorption and utilization of the nutrient by the animal (Colucci *et al.*, 1982).

Owens & Hanson (1992) suggested some requirements of an ideal marker; the marker must not be absorbed, it must not affect the digestive tract nor be changed by the digestive tract or its microbial population, it must flow with the material it is marking or it must be intimately associated with the material, and it must have a specific and sensitive method of estimation. It is also important to be aware of assumptions that are used in marker calculations. These assumptions are that the rumen is always full, and that the flow of digesta is continuous (Owens & Hanson, 1992). Factors to be considered when evaluating a marker would be method of preparation, marker digestion and flow, migration from material to other substrates, recycling of the marker within the rumen (e.g. N), absorption of the marker in the GIT, and the analysis of the marker or material after recovery (Owens & Hanson, 1992). In research, various types of markers have been used. Generally, markers are either inherent or external. An inherent marker is a component of the feedstuff such as acid insoluble ash. External markers are inert compounds which would be in equilibrium with the material such as seeds or metal atoms (Owens & Hanson, 1992).

A marker that is commonly used in marking the liquid phase of digesta is ^{51}Cr-ethylenediaminetetra-acetic acid (Cr-EDTA) which stays in solution (Faichney, 1975), Co-EDTA is another alternative (Uden *et al*,1980). Previously, substances such as glass, charcoal, beads, ball bearings, plastic pieces, seeds, rubber pieces and powdered Brazil nuts have been used as solid markers (Uden *et al.*,1980). Bismuth salts, $BaSO_4$ and Cr_2O_3 have also been used. Their physical properties, however, are not the same as the solid digesta they are to mark, and thus do not yield very accurate results (Uden *et al*,1980). Dyes, especially Anthroquinane Violet, have been used to stain feed (Uden *et al.*,1980). However, it is absorbed from the GIT (Uden *et al.*,1980), limiting its use. Low concentrations of rare earth metals that are absorbed onto feed particles have been used,

but these are not easily recoverable (Uden *et al*,1980). A number of recent studies have used mordant metal atoms as markers (Grovum & Williams, 1973; Colucci *et al*.,1982; Mir *et al*., 1991). These are easier to identify and quantify than organic compounds (Uden *et al*.,1980). Elements with trivalent and tetravalent bonds form strong ligands with plant cell walls, thus providing a bonding that can withstand GIT conditions (Uden *et al*,1980). Chromium (III) forms stable complexes with food ingredients, and has been used in various studies (Grovum & Williams, 1973; Uden *et al*.,1980; Colucci *et al*., 1982; Ehle, 1983; Mir *et al*, 1991; Robinson *et al*.,1996; DeVega & Poppi, 1997; Mir *et al*., 1997).

Uden *et al*.(1980) gives a detailed method for mordanting Cr to fibre. It is important to wash the forage thoroughly to remove any soluble matter that may affect the Cr recovery. The Cr mordants are prepared by the reduction of the hexavalent dichromate complexes. Uden *et al* (1980) tested the Cr- mordant in various situations, *in vivo* and *in vitro*, and concluded that it "furfilled most criteria as a particulate marker." It has since been suggested that the accuracy of the Cr-mordant marker method may be affected by the particle density of the feed (Ehle, 1983) and the type of diet (DeVega & Poppi, 1997). Christian & Coup (1954) provided a method of Cr marker recovery from the faeces. Another type of marker being used is *Bacillus stearothermophilus* spores. The results from using these spores as a marker show good correlation with Cr-mordant marker results (Mir *et al*., 1997).

The Cr-mordant complex was used as a marker in the current study to estimate the solid phase flow of digesta from the rumen.

Chapter 3

FACTORS AFFECTING MILK PRODUCTION

INTRODUCTION

To achieve the most economical production level from dairy cows, it is important to understand the numerous factors that affect the composition and production of milk. Nutrition is an important aspect of production and has a large influence on production and composition. However, there are also other factors that are important and could make a large difference to the overall efficiency of the farm. Muller & Botha (1998) studied the effect of breed on milk production as did Bitman *et al* (1996) and Rodriguez *et al* (1997a). Fisher *et al* (1983) studied the effect of age and weight at calving on first lactation milk yield, while Khan & Shook (1996) found an increase in milk yield as age at first calving increased. Schaeffer & Jamrozik (1996) suggested that milk yield is affected by geographical region, breed, herd management, lactation number, age at calving, month of calving and number of days in lactation. There are other external factors that affect production, but are not easy to identify, such as disease, heat stress and milking parlour management. There are also interactions between the various factors which must be considered.

In order for the farmer to obtain the maximum production potential from his herd, he needs to be aware of those factors, both internal factors specific to the cow, and external factors, which could either limit or improve production. The aim of this study was to identify the amount of variation in milk yield and milk composition that is due to some of these factors.

STATISTICAL ANALYSIS

Data from two Elsenburg herds were analysed to investigate factors which may affect milk yield and milk composition. In the analysis, 337 first lactation records were used,

232 Holsteins and 105 Jerseys. The data was collected over a 20 year period from 1975 to 1995. The effect of breed, age at calving and the year of birth on milk production was analysed. Other factors that may affect milk yield such as season of birth and body condition score were not available in this data set. It is also important to remember that some factors are specific to each farm, such as housing and parlor effects, heat stress, distance walked and height climbed.

The data was analysed using a step-wise regression procedure of SAS (1996).

The analysis model was;

$$y = \mu + breed_i + age_j + year_k + (breed*year)_{ik} + (age*year)_{jk} + e_{ijk}$$

where y = dependent variable

μ = overall mean of y

breed = Jersey or Holstein

age = age of heifer at calving

year = year of birth

e_{ijk} = random residual error

RESULTS AND DISCUSSION

The means, coefficients of variation, R^2 values and the amount of variation accounted for by each effect, are presented in Table 1.

Table 1. The means, coefficient of variation and R^2 values of milk production and the amount of variation accounted for by factors that affect milk production

	Milk (kg)	Butterfat (kg)	Butterfat %	Protein (kg)	Protein %
Mean	4983.9	18.96	38.76	171.8	3.49
CV%	13.22	12.65	7.91	12.52	5.01
R^2%	77.28	72.2	66.1	72.5	72.3
Variation (%) accounted by:					
Breed	22.39	5.33	39.62	11.91	29.79
Year	39.85	3.79	15.86	39.22	3.92
Age	3.89	1.58	NS	5.87	NS
Breed*year	3.04	4.64	4.35	3.93	4.57
Age*year	NS	3.84	NS	NS	3.93

Breed

Breed of cow had a significant effect on milk yield and milk composition. It accounted for 22.4% of the variation in milk yield. Table 2 shows differences in milk production and composition between the Holstein and Jersey breeds. The total milk yield of the Holsteins was 10.3 % higher than the mean, but the Jerseys had higher butterfat (13.04% higher than the mean) and protein (8.16% higher than the mean) percentages.

Table 2. First lactation yield and composition differences between Jerseys and Holsteins

	Jersey	Holstein
Milk (kg)	4194.7 ± 27.97	5497.62 ± 47.96
Butterfat (kg)	182.02 ± 1.19	200.23 ± 2.51
Butterfat (%)	4.3816 ± 2.96	3.6582 ±2.23
Protein (kg)	156.03 ±9.13	182.07 ±1.57
Protein (%)	3.7760 ± 8.73	3.3507 ± 1.8

Bitman *et al.*(1996) studied differences in production between Holsteins and Jersey cows on two different diets. They found that the average milk yield of the Holstein cows was 32.5kg/day while that of the Jersey cows was 20.8kg/day. However, protein, solids-non-fat and fat percentages were all higher for the Jersey cows.

Muller & Botha (1998) measured the production performance of Holstein and Jersey cows in the South African context. They found that Holstein cows produced more ($P<0.01$) milk per day than Jerseys. However, the Holsteins produced milk with 2.97% fat and 3.38% protein, whereas the Jersey cows produced milk with 3.96% fat and 3.90% protein. These are similar to the results found in this analysis. The Holsteins milk had 3.66% butterfat and 3.35% protein while the Jerseys had 4.38% butterfat and 3.77% protein. This seems to be the general trend in most studies as similar results were found by Gibson (1986), L'Huiller *et al.* (1988) Rodriguez *et al.* (1997a), Rodriguez *et al.* (1997b) and Van der Werf *et al.* (1998).

Year

The year that the cows were born accounted for a large part of the variation in production viz. 39.85% of the variation in milk yield, 15.86% of the variation in butterfat % and 3.93% of the variation in protein %. The interaction between year and breed was also significant for all production parameters. However, there was no change in the breed ranking, in other words, the Holsteins still had higher milk yields and the Jerseys had higher butterfat and protein percentages. The interaction of year and age was only significant for butterfat production. The data was taken from first lactation heifers, thus, the year does not allude to the age of the cow or lactation number, but the year in which the cow was born. The years considered in this data set were from 1975 to 1995. The milk yield increased through the years from a least squares mean of 4099.4kgs for the Holsteins in 1975 and 3177.1kg for the Jerseys in 1980 to 7001.1kg and 5512.6kg for the Holsteins and Jerseys, in 1994 respectively. In 1995, the milk yield was slightly lower than in the previous year. Although the butterfat % varied between the years, there was no consistent pattern. The Holsteins had the highest butterfat % namely, 3.85% in 1988 and the lowest namely, 3.21% in 1985. The Jerseys ranged from 3.94% in 1986 to 4.80% in 1984. Similarly, the protein % ranged between the years but there was no set pattern of increase or decrease. The highest protein % for the Holsteins was 3.55% in 1988 and the lowest, 2.98%, in 1992. The highest protein % for the Jerseys was 4.14% in 1981 and the lowest was 3.42% in 1992. The effect of year on milk production is not a direct effect and may be due to many external factors. However, from this data it can be seen that certain years, such as 1988 and 1992, were especially productive and it would be beneficial to look at certain aspects of those years, such as the feeding strategy, the weather, the genetic improvement and others.

Age of heifer

The age of the heifer at first calving was added to the model as a co-variate. The heifers ranged in age from 19 months to 35 months with the mean at 25 months. The age of the cow had a significant effect on the milk yield, butterfat production and protein production. It can be seen from Table 1 that age accounted for 3.895% of the variation in

milk yield. However, there was no significant effect on the percentage of butterfat or protein yield. Fig. 1 shows the regression of age and milk yield where milk yield increased as the age at first calving increased. This was due to the fact that the heifers were still growing and not all the nutrients and energy that could be used for milk production were being used for growth. At about 36 months, growth slowed down and the effect of age at first calving should reach a plateau. Unfortunately this cannot be seen in Fig. 1 as 30 months was the oldest age at first calving in the given data set. Khan & Shook (1996) found an increase in milk yield as age at first calving increased. They found that as the lactation number increased, the effect of age at first calving decreased. Dugmore (1995) suggested that heifers should not calve before 23 months of age. In heifers calving at younger ages, there is a decline in the first lactation milk yield as energy is being used for growth.

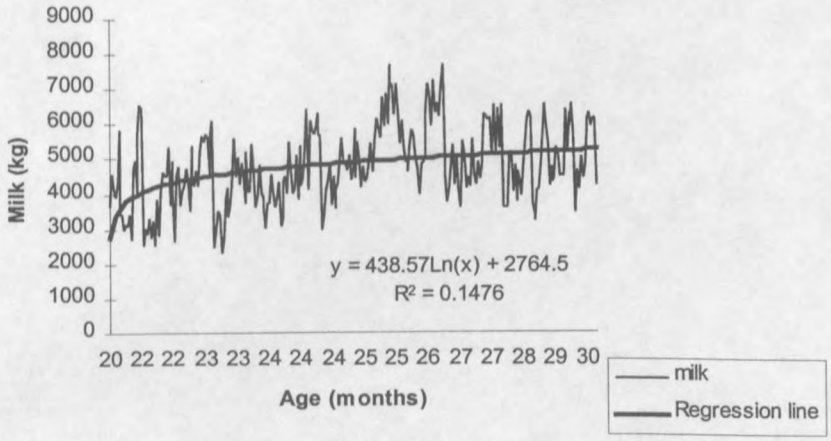

Fig. 1. The regression of milk yield on age of the heifer at calving.

External Factors

Many factors are inherent to the farm and are difficult to assess between specific farm situations. The method of housing cows is such a factor, whether they are kept on pasture or housed in a feedlot. Another factor related to housing is the ambient temperature and the amount of shade and water available for the cows. High temperatures have a negative

impact on production (Muller & Botha, 1998) and water is essential, not only to help keep the cows cool, but it is a vital part of milk synthesis. It has been shown that the distance cows walk and the height that they climb going to and from the milking parlor affects milk production. They are using energy that could be used for production consequently they produce less milk, they are more susceptible to heat stress and time that could be spent eating, is being wasted. For each 3km walked and 5m climbed an additional amount of 3MJ ME is required (Stewart *et al.* 1995). The milking parlor and milking routine can also have an effect on milk production. If cattle are nervous due to bad handling or excessive noise, milk let-down can be inefficient. Milk let-down stimuli are important. The parlor must be effective so that cows are milked quickly and do not have to wait long in the heat or in muddy conditions that may breed diseases (Evans, 1995).

Disease, especially mastitis, will affect milk production and energy is being used to fight the infection. The body condition score of the cow can effect milk production, especially at calving as body fat reserves are used to produce milk. Domecq *et al.*(1997) showed that a one point increase in body condition score between drying off and calving could result in 545.5kg more milk during the lactation. The season in which a cow is born affects yield (Barash *et al.*, 1995); milk yield is lowest in cows born in early spring and highest in cows born in late autumn. The stage of lactation and pregnancy also influences production as milk yield follows a general lactation curve which peaks at 6-8 weeks after partition and then gradually declines. At 4-5 months of pregnancy, more energy is used for fetal growth and milk yield decreases (Scott *et al.*, 1996).

The genetic potential of the cow can also have a large impact on the milk yield of the individual cow. Breeding and genetics have become important to the farmer. Although it can be expensive, it is possible to breed genetically superior cows far easier now that artificial insemination is a common practice in dairy farming and top quality semen and imported semen can be readily obtained. There are six selection criteria that are often considered, viz. milk yield, fat and protein yield, feet and legs, udder capacity and "dairyness" (Boulle, 1995). Feet and legs are important in the often tough and extensive

South African conditions. Cows walk a lot and good conformation prevents walking difficulty and infections. Udders should be well attached and should have even central teat placement for effective milking. Body capacity is associated with rumen function and nutrient utilization. Dairyness is a subjective evaluation of certain characteristics such as the shape of the cow and her angularness, her temperament and the shape of her tail, which are thought to be evident in high producing cows (Boulle, 1995).

CONCLUSIONS

Although it is not easy to quantify all the factors that have an effect on milk production and milk composition, some of the influences can be assessed. The age of the cow at first calving has a significant effect, as does the year the data was recorded. The breed of the cow has shown to have a significant effect on milk yield and milk composition. It has been found that while Holsteins produce more milk, Jerseys have higher butterfat and milk protein percentages.

Although the Holsteins produce more milk, they also have a higher dry matter intake (Taylor *et al.*, 1986; Muller & Botha, 1998). Oldenbroek (1988) suggested that the intake capacity of the Jerseys was only 82.84% of the larger breeds. Thus, milk yield needs to be considered in terms of efficiency. Muller & Botha (1998) compared the efficiency of Holstein and Jersey cows and found values of 1.38 and 1.18 kg milk/kg DM consumed respectively. It therefore seems that the Holstein breed has a higher feed efficiency in terms of milk production than the Jerseys.

Chapter 4

COMPARISON OF FIBRE DEGRADABILITY IN THE RUMEN OF JERSEY AND HOLSTEIN COWS

INTRODUCTION

Jersey and Holstein cows have often been compared in terms of maintenance efficiency (Taylor *et al.*, 1986), energetic efficiency (Solis *et al.*, 1988) and their response to added dietary fat and its effect on milk yield and composition (Palmquist & Beaulieu, 1992, Rodriguez *et al.*, 1997a). Oldenbroek (1988) explored the differences between the two breeds on two diets, viz. a complete roughage diet and a 50% concentrate diet. He found significant breed x diet interaction for fat concentration and differences in biological efficiency between both the breeds and the diets. However, research documentation on the differences in fibre degradability in the rumen between Jersey and Holstein breeds is very limited. Fibre affects both milk yield and milk composition (Sutton & Morant, 1989) and the quality of the fibre also has an effect on both parameters (Solis *et al.*, 1988). As there are differences in milk production between Jersey and Holsteins, it would be of interest to discover whether there are differences in fibre digestion between the breeds.

Some factors that influence the rate and extent of digestion are level of feed intake (Escalona *et al.*, 1999) and the time available for digestion to occur (Russell & Wilson, 1996). Owens & Hanson (1992) showed that increased feed degradation in the rumen is associated with a lower DM intake and longer rumen retention time. The aim of the study was therefore to compare rate and extent of fibre digestion in the rumen, the passage rate of digesta from the rumen, and the daily DM intake between Holstein and Jersey cows.

MATERIALS AND METHODS

Animals and diets

Initially, the trial was to be conducted with four Holstein cows and four Jersey cows. However, one of the Holstein cows was diagnosed as having anaplasmosis and had to be

removed from the trial. The cows were all non-lactating and fitted with rumen cannulae. They were housed in a semi-open barn with feeding troughs and sand filled sleeping stalls, separated by a center aisle that was flushed twice a day. The cows were fed a lactating cow total mixed ration (TMR) at levels of 12 kg/day for the Holsteins and 9 kg/day for the Jerseys with supplementary wheat straw *ad libitum*. This was a high energy and high protein diet as would be fed to lactating dairy cows. The cows were adapted to the diet for two weeks before the trial started. For the passage rate trial, the cows were given measured amounts of the feed, and the orts were collected and recorded daily.

In Situ Trial

Three forages, viz. lucerne, wheat straw and wheat straw treated with 0.02% NaOH were tested in each cannulated cow. Samples were dried and ground in a Wiley mill through a 1mm mesh. They were then sieved to remove dust and fine particles that might give an over-estimation of digestibility. White, monofilament polyester bags, 10x20 cm in size with a pore size of 53 micron (±10) were used (Bar Diamond, Inc., Parma ID). Five grams of each forage sample (the recommended sample size for the given bag size) was accurately weighed, transferred into bags and sealed. The filled bags were dried and weighed again. It was determined that, for longer incubation times, 5g of sample would not leave enough residues for subsequent chemical analysis. Duplicate bags were therefore prepared for incubation times longer than 24 hours.

The sealed bags were placed in a 250 x 600mm bag made of nylon netting, which was weighed and inserted into the rumen. The perforated bag was fastened to the cannula plug via a nylon cord of ±50cm. Bags were incubated in the rumen for 2, 4, 8, 12, 16, 20, 24, 36, 48, 72 and 96 hours (England *et al.*, 1997), inserted in reverse order. In other words, the bags to be incubated for 96 hours were inserted into the rumen first, at 08h00 on the first day of the trial. Over the following days, the bags were inserted at the relevant times, and all the bags were removed on the 5th day at 08h00. Nocek (1988) compared the two sequences of bag insertion and removal and found better degradation results with reverse order incubation. This could be because there is no interruption of

the digestive process, improved standardization of the washing procedure and the effect of the insertion time in relation to feeding time (Huntington & Givens, 1995).

On removal from the rumen, the bags were immediately placed in ice water and then rinsed under cold running water to inhibit microbial activity. They were then washed in a twin-tub washing machine in cold water on the gentle cycle for 10 min. A bag containing feed samples but which had not been incubated in the rumen was washed along with the others to determine the soluble fraction. The bags were dried in a force draught oven at 60^0 C for 24h, and cooled in a desiccator before weighing.

Samples of the initial feed and residues from the bags were analyzed for DM and NDF (AOAC, 1998).

The fractional disappearance of DM and NDF over time was calculated by the following equation:

$$\text{Fractional disappearance} = \left(\frac{g\ \ before\ \ incubation - g\ \ after\ \ incubation}{g\ \ after\ \ incubation}\right)*100$$

DM and NDF disappearance was fitted to the following non-linear model of Ørskov and McDonald (1979):

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

Where p is the fractional disappearance and a, b and c are non-linear parameters fitted by an iterative least squares procedure. Parameter a represents the immediately soluble fraction, b is the potentially degradable fraction and c is the rate at which b is degraded.

The effective degradabilities were calculated from the equation:

$$P = a + \frac{bc}{c+k}$$ (Ørskov and McDonald, 1979)

Where P is the effective degradability and k is the flow rate of digesta through the rumen. Flow rates of 0.02, 0.05 and 0.08 per hour were used as suggested by Erasmus *et al.* (1990).

Data was analyzed by a one-way analysis of variance (ANOVA) to obtain least square means and LSD comparisons were used to detect differences between breeds.

Passage Rate Trial

Wheat straw was washed to remove soluble matter and then mordanted with Cr according to the method of Uden *et al* (1980). A solution of $Na_2Cr_2O_7$ was used with a Cr equivalent of 10% of the fibre weight.

The marker (mordanted wheat straw) was inserted into the rumen in a single-pulse dose and was well mixed with the rumen contents. An initial sample was taken and designated as 0h. Rumen samples and faecal grab samples were taken at 3, 6, 9, 12, 15, 18, 24, 30, 36, 48, 54, 60, 79, 84, 96 and 120 hours post-dosing. The rumen contents were thoroughly mixed before samples were taken. Three nylon bags containing the Cr mordanted wheat straw were suspended in the rumen for 24 hour to test the stability of the marker (Uden *et al.*, 1980). Recovered samples were dried and analyzed for Cr concentration (AOAC, 1998).

From the marker trial, the rate of passage of rumen digesta was estimated as the regression coefficients of the natural log of the Cr concentration versus time, using regression analysis (Ørskov and McDonald, 1979). A one-way analysis of variance was used to detect any significant differences between the breeds.

RESULTS AND DISCUSSION

The extent of ruminal DM and NDF degradation of lucerne, wheat straw and NaOH-treated wheat straw at various fractional outflow rates is presented in Table 1 and the disappearance curves of DM and NDF are presented in Fig. 1, 2 and 3.

Table 1. Effective degradability of DM and NDF at fractional outflow rates of 0.02, 0.05 and 0.08/h.

Item	Lucerne			Wheat straw			NaOH-treated wheat straw		
DM	0.02/h	0.05/h	0.08/h	0.02/h	0.05/h	0.08/h	0.02/h	0.05/h	0.08/h
Holstein	28.8	25.1	22.8	19.2	12.8	10.3	28.0	21.9	18.8
Jersey	31.7	28.5	26.2	26.3	19.2	15.5	35.1	28.0	23.9
P	0.01	0.02	0.03	0.0003	0.0005	0.0007	0.003	0.001	0.001
NDF									
Holstein	22.0	18.3	16.0	15.2	9.7	7.6	19.8	12.3	9.9
Jersey	25.0	21.5	19.1	20.7	14.3	11.2	25.2	17.1	13.7
P	0.01	0.03	0.04	0.004	0.003	0.004	0.0009	0.001	0.001

The effective DM degradability and NDF degradability was higher for Jersey cows at all flow rates, for all the forages. The difference appears to be more apparent for the lower quality forages, viz. wheat straw and NaOH treated wheat straw. These results suggest that Jersey cows appear to be more efficient in utilizing lower quality forages than Holstein cows. No literature could be found to support these findings.

Effective NDF degradability values for lucerne hay found by Andrighetto *et al.* (1993) corresponded closely to the values found for the Holstein cows in this study. Similar values for effective DM degradability for lucerne were found by Julier *et al.* (1999), using a filter bag *in vitro* technique and by Iantcheva *et al.* (1999) using gas production estimates.

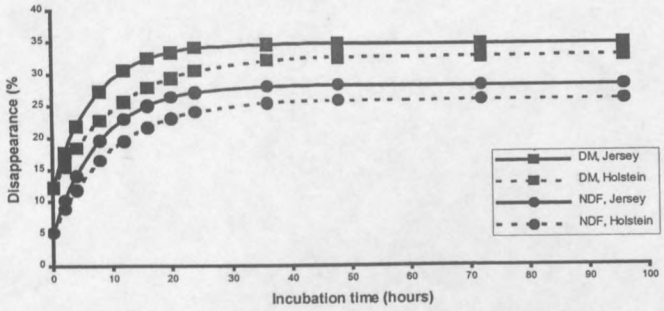

Fig. 1 Ruminal disappearance of lucerne DM and NDF in Holstein and Jersey cows.

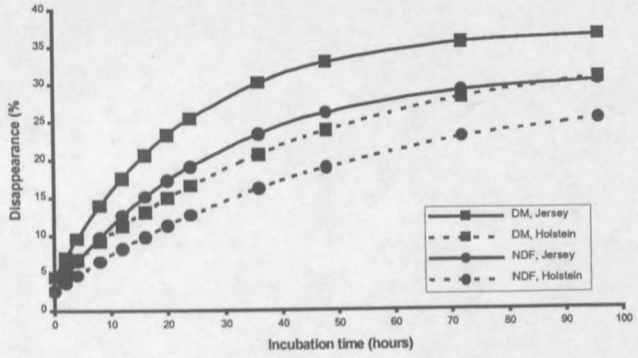

Fig. 2 Ruminal disappearance of wheat straw DM and NDF in Holstein and Jersey cows.

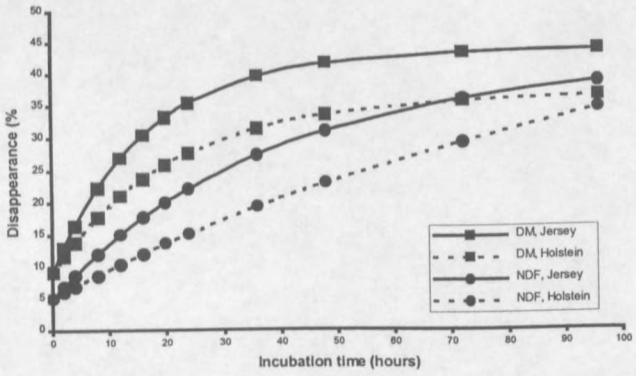

Fig. 3 Ruminal disappearance of NaOH-treated wheat straw DM and NDF in Holstein and Jersey cows.

There is limited literature on DM and NDF degradability in the Jersey cow. Ingvartsen & Weisbjerg (1993) suggested that Jersey cows digest food faster than Holsteins, as although they found no difference in OM digestibility, they found that Jersey cows had a faster rate of passage than Holsteins.

The non-linear parameters, *a, b* and *c* are presented in Table 2.

Table 2. The effect of breed on the non-linear parameters a, b and c for DM- and NDF- disappearance of different forages from the rumen.

	Lucerne			Wheat straw			NaOH wheat straw		
DM	a	b	c	a	b	c	a	b	c
Holstein	12.18	20.70	0.087	4.33	30.62	0.021	9.03	27.87	0.046
Jersey	12.28	22.57	0.138	4.33	32.66	0.043	9.03	34.98	0.059
P	-	0.06	0.11	-	0.45	0.01	-	0.03	0.09
NDF									
Holstein	5.20	20.89	0.097	2.63	27.10	0.019	4.98	51.50	0.009
Jersey	5.20	23.15	0.122	2.63	28.80	0.035	4.98	37.00	0.026
P	-	0.06	0.30	-	0.56	0.04	-	0.09	0.01

a = soluble fraction

b = potentially degradable fraction

c = rate of degradation

The *a* value represents the immediately soluble fraction of the feed and should be similar to the value (t_0) obtained when the bags were washed but not incubated in the rumen. The *a* value is similar for both breeds as it is a function of the feed and not influenced by other factors. The *b* and *c* values are derived functions of feed and microbial interactions.

It appears as if breed had no effect on potential degradability values of DM and NDF in the case of wheat straw. For lucerne, however, potential DM and NDF degradability (b-values) tended to be higher for Jerseys than for Holsteins, while potential DM degradability of NaOH treated wheat straw was significantly higher in Jerseys. For Holsteins, potential NDF degradability of NaOH wheat straw tended to be higher than for Jerseys.

The *c* value represents the rate of degradation of the slowly degraded fraction represented by *b*. The *c* value for wheat straw degradability was significantly higher in Jerseys than in Holsteins for both DM (P=0.01) and NDF (P=0.04). For NaOH treated wheat straw, the rate of NDF degradation (*c*) was significantly (P=0.03) higher for Jerseys than for Holsteins, while DM degradability only tended to be higher in Jerseys (P=0.09). The *c* value for lucerne digestibility was not significantly different between the breeds. For lucernce, it therefore appears that the potential degradable fraction (*b*-values) is the only parameter differing between breeds. For the lower quality forages, however, both potential degradability and rate of degradation appears to have an effect on the difference observed between breeds regarding effective degradability. This can have important implications where forages are presented in various physical forms that can affect passage rate, e.g. ground vs course.

Estimates of the fractional rate at which rumen digesta pass through the rumen (or rate constant, k), as measured from rumen and faecal data, are presented in Table 3.

Table 3. Rate constants for digesta flow from the rumen of Holstein and Jersey cows, as determined from feacal and rumen samples.

Item	Feacal samples	Rumen samples
Holstein	0.018	0.022
Jersey	0.012	0.018
P	0.084	0.025

The rate of passage is generally proportional to the rate of digestion (Colucci *et al.*, 1982). Thus, it could be expect that, as Jersey cows had higher digestibility values, they would have had a slower rate of passage.

Results from faecal samples were not significantly different (P=0.084), but flow rate tended to be higher for Holsteins. According to the literature (Wylie *et al.*, 2000) the

one-component model for the decay curve of Cr, $C=C_0^{-kt}$ can be criticized for faecal samples because of different dilution rates in the various digestive compartments.

Estimations obtained from rumen samples differ significantly between the breeds (P=0.025). Because influx and efflux from the rumen is interdependent (i.e. the continuous competition between intake and outflow, when the relevancy of the rumen fill concept is accepted), the one-compartment model is appropriate in the case of rumen samples, and the decay curve for Cr can be expected to accurately describe the rate of passage of digesta from the rumen. Rumen samples were taken until 120h after introducing Cr- mordanted cell walls to the rumen. The regression of LN [Cr] at different time intervals (0-60h, 0-72h, 0-84h, 0-96h and 0-120h) on time, was examined. With the exception of 0-120h, equations obtained from all the time-[Cr] regressions described similar passage rates. Cr-concentration values (LN [Cr]) were inconsistent at 120h. It is assumed that the [Cr] would be so low at 120h as to make analysis inaccurate. The 120h values were therefore discarded, and regressions estimated until 96h.

The passage rate results explain the differences between the breeds regarding rumen degradabilities, because with the higher flow rates observed in the Holsteins, one would expect shorter retention times, therefore lower digestibilities. The same would apply for Jerseys, with slower flow rates indicating longer retention times, and thus a higher rate of digestibility.

The results of this study were contradictory to those of Ingvartsen & Weisbjerg (1993), who measured the rate of passage in 7 Jersey and 7 Friesian cows. The basal diet was a complete mixed ration. They found that Jersey cows had a 21% higher rate of passage than the Friesian cows. The difference could be due to the difference in rations, as in the current trial, the cows had access to wheat straw, in addition to the concentrate ration. Unfortunately, there is not sufficient literature to validate these results and repeatability studies should be carried out for a more accurate assessment. There are many factors that may affect the accuracy of passage rate trials using markers, viz. migration, incomplete recovery and kinetic assumptions (Owens & Hanson, 1992).

When the actual rate constants obtained from this study are used to estimate effective DM and NDF degradabilities, the differences between Holsteins and Jerseys became even more pronounced, as indicated in Table 4.

Table 4. Effective degradability of DM and NDF as calculated from actual flow rates obtained in the current study (0.022 for Holsteins and 0.018 for Jerseys).

Item	Lucerne	Wheat straw	NaOH-treated wheat straw
DM			
Holstein	28.8	19.3	27.9
Jersey	32.3	27.4	35.8
P	0.01	0.0003	0.003
NDF			
Holstein	22.3	15.2	19.9
Jersey	25.4	21.7	26.8
P	0.01	0.003	0.008

The digestibility of a feed and the rate of passage are related to feed intake (Colucci *et al.*, 1982). The daily dry matter intake and daily water intake are presented in Table 5.

Table 5. Daily feed and water intake (kg) of Holstein and Jersey cows.

Item	Feed	Water
Holstein	14.6	56.8
Jersey	11.0	37.6
P	0.0012	0.0009

The Holstein cows had a significantly higher DMI than the Jersey cows ($P<0.01$). This is to be expected as the Holsteins are a bigger breed and have a larger rumen. Oldenbroek (1988) suggested that the intake capacity of the Jerseys was only 82.84% of the larger breeds. Using this assumption on the data from this study would give an intake of only 1kg DM per day more for the Holstein than for the Jerseys. Muller & Botha (1998)

measured the DM and water intake of Holstein and Jersey cows in South Africa. They found that Holsteins had both a higher ($P<0.001$) DM and water intake. They also found that the average body weight of Holsteins was higher ($P<0.0001$) than those of Jerseys. When they estimated intake as a percentage of body weight, they found that Jerseys had a higher DM and water intake than the Holsteins. Taylor *et al.* (1986) also suggested that the best way to compare DMI was as a percentage of body weight.

The average weights of the Holsteins was 614.5 kg and those of the Jerseys 399.3 kg. Expressed as a percentage of body weight (BW), feed intake was 2.37% of BW for Holsteins and 2.76% of BW for Jerseys. Similar results were observed by Muller & Botha (1998) who reported feed intakes of 3.13% of BW and 2.84% of BW for Jerseys and Holsteins, respectively. This would suggest that the higher feed intake of Holsteins in kilograms per day alone does not explain the higher passage rate of digesta and lower digestibility values observed in the Holsteins.

CONCLUSIONS

Results from this study indicated that the rate of ruminal degradation of dry matter and NDF from wheat straw and NaOH-treated wheat straw (lower quality forages) was generally higher in Jersey cows than in Holsteins. The potential degradability, but not the rate, of lucerne dry matter and NDF (high quality forage) was also higher in Jerseys than in Holsteins. The net result was that the effective degradability of dry matter and NDF for all the forages investigated was higher in Jersey cows than in Holsteins. Higher effective degradabilities were accompanied by lower passage rates of digesta observed from the rumen of Jersey cows. It therefore appears that Jerseys are more efficient utilisers of low quality forages than Holsteins. Differences between breeds were more apparent for the lower quality forages. This may have practical implications, especially in areas where high quality forages are difficult to obtain. The reason for the differences observed between the breeds are not clear and warrants further research.

Chapter 5

DIFFERENCES IN RUMEN pH AND VOLATILE FATTY ACID CONCENTRATION BETWEEN JERSEY AND HOLSTEIN COWS

INTRODUCTION

The key to understanding the digestive processes which occur in the rumen is to look at the rumen environment. The uniqueness of the rumen is due to the symbiotic relationship between the host animal and the microbial organisms that live in the rumen. It is this relationship that enables the ruminant to utilize cellulose and hemicellulose (Russell & Wilson, 1996). The microorganisms in the rumen degrade the cellulose in the feed. The end products of this fermentation are volatile fatty acids (VFA's) which are utilized by the animal primarily as sources of energy (Varga & Kolver, 1997).

Different food types are degraded at different rates in the rumen. Soluble carbohydrates, such as starch, degrade very rapidly which results in a build up of VFA's in the rumen (Russell & Wilson, 1996). Forage feeds do not ferment as rapidly. As the VFA concentration affects the pH, the accumulation of VFA's due to a high starch diet would cause the pH in the rumen to decrease, whereas with a more fibrous diet, the pH remains neutral (Allen, 1997). Weimer (1996) identified specific species of bacteria which specifically degrade cellulose and hemicellulose in fibre. They are collectively known as the fibrolytic microbes. Russell & Wilson (1996) observed that fibrolytic microbes are especially sensitive to pH and that a small decline in ruminal pH can severely inhibit fibre digestion.

In the *in situ* trial, it was found that Jersey cows were more effective in degrading NDF in the rumen than Holsteins. The basal diet was a high concentrate diet. In the current study, the rumen environment of Jersey and Holstein cows, was examined in terms of pH profile and VFA concentrations, to see if there were any notable differences that could explain the differences observed in rumen degradability.

MATERIALS AND METHODS

This trial was conducted simultaneously to the passage rate study. Three Holstein cows and four Jersey cows, all non-lactating and fitted with rumen cannulae, were used. All the cows received a lactating cow total mixed ration (TMR) at 08h00 daily and supplementary wheat straw was available *ad lib*. The cows were adapted to the diet for two weeks before the trial started. The daily dry matter intake and water consumption was recorded.

Samples of the rumen fluid were taken at 08h00, 12h00, 16h00,18h00 and 20h00 on the first day of the trial, representing 0, 4, 8, 10 and 12 hours post-feeding. The pH of the fluid was measured immediately with the aid of a portable pH meter, where after the samples were frozen. Ruminal VFA concentrations were determined by gas chromatography (AOAC, 1998).

Statistical analysis of the results was done using Statgraghics (1998). The data was analysed by a one-way analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Table 1 and Fig. 1 present pH values observed in the rumen for Jersey and Holsteins at different times after feeding.

Table 1. The pH value of rumen fluid in Jersey and Holstein cows at different times post-feeding.

Item	0h	4h	8h	10h	12h
Holstein	7.48	6.08	6.18	6.25	6.4
Jersey	7.72	6.62	6.2	6.31	6.43
P	0.12	0.002	0.82	0.56	0.743
SEm	0.09	0.046	0.053	0.049	0.046

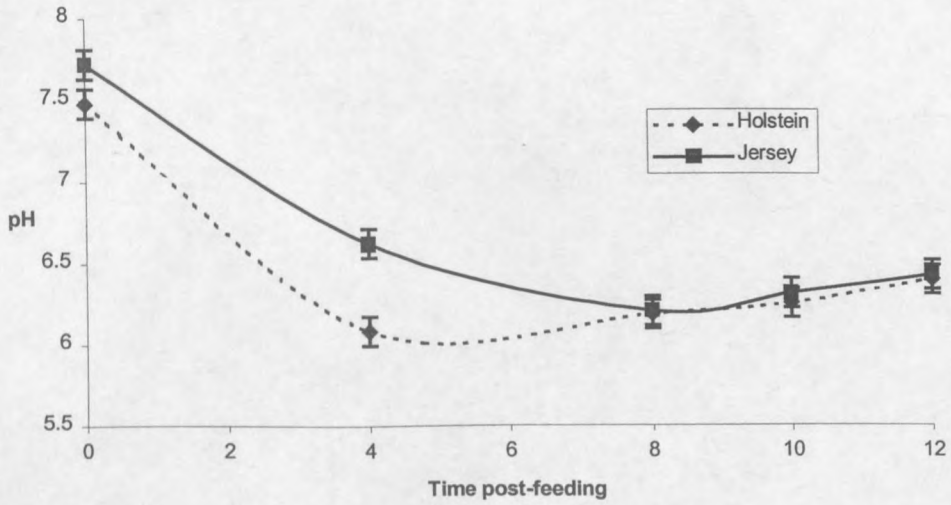

Fig. 1. Post-feeding changes in rumen pH over time in Jersey and Holstein cows.

A sharp decrease in rumen pH was observed in the Holstein cows between 0 and 4 hours post-feeding, followed by a gradual increase after 4 hours. The initial decrease was probably due to the high concentrate content of the TMR. Although wheat straw was available *ad lib*., cows finished the TMR before eating any of the wheat straw. Arieli *et al.* (1996) also found that the ruminal pH decreased post-feeding. Allen (1997) found similar results and reported that the rate of decline of the pH is faster as the meal size increases and as the dietary NDF concentration decreases. As the ruminal fermentation rate increases, which is a characteristic of soluble carbohydrate feeding, the ruminal pH declines (Russell & Wilson, 1996). The ruminal pH of the Holsteins dropped faster, and significantly lower ($P<0.01$) than in the Jerseys during the first 4 hours. This was probably due to the observation that the Holsteins finished their TMR by 4 hours after feeding, while the Jerseys took much longer to finish theirs. Rodriguez *et al.* (1997b) found that Jerseys were generally inclined to a higher ruminal pH than Holsteins. Rodriguez *et al.* (1997a), however, found no differences between Jerseys and Holsteins regarding ruminal pH on a total mixed ration with supplementary fat. A low rumen pH (less than 6.2) suppresses the action of the fibrolytic micro-organisms, which results in a decrease in fibre degradation (Varga & Kolver, 1997). Therefore, the lower pH of the

Holsteins observed for at least 8 hours during the day may be one of the reasons why they showed lower degradability values in the *in situ* trial. The pH of the Holstein cows dropped to 6.08 whereas that of the Jersey cows only dreased to 6.63 at 4 hours post-feeding. Fibre degradation is suppressed at low pH levels and is inhibited at a pH below 6.0 due to the inability of the fibrolytic micro-organisms to function at a low pH (Russell & Wilson, 1996).

Total VFA concentration and acetc acid and propionic acid as percentages of total VFA are shown in Table 2 and Fig. 1 & 2.

Table 2. Rumen volatile fatty acid concentration in Holstein and Jersey cows at different time intervals post-feeding.

	0h	4h	8h	10h	12h
Total VFA (mg/l)					
Holstein	5506.9	9710.5	8711.7	7371.53	10227.6
Jersey	3177.5	5053.3	5304.8	5693.95	5049.45
P	0.15	0.001	0.02	0.456	0.138
SEm	671.1	332.0	548.3	1008.78	1452.99
%Acetic acid					
Holstein	59.1	55.9	58.2	55.63	57.31
Jersey	55.3	52.8	52.9	53.54	52.24
P	0.17	0.07	0.20	0.5737	0.476
SEm	1.17	0.65	0.78	1.698	0.9615
%Propionic acid					
Holstein	16.7	21.3	22.6	21.67	21.16
Jersey	20.7	24.5	25.8	24.42	23.69
P	0.14	0.11	0.23	0.3746	0.3015
SEm	1.12	0.79	1.18	1.365	1.253

There was a significant difference in the total VFA concentration at 4 hours post-feeding ($P = 0.001$) which coincided with the difference in rumen pH value (Fig. 1). There was also a difference at 8 hours post-feeding ($P = 0.02$). Allen (1997) found a negative relationship between ruminal pH and VFA concentration ($r^2 = 0.130$). Arieli *et al.* (1996) showed post-feeding VFA concentrations to be higher than the pre-feeding values. Soluble carbohydrates have a faster fermentation rate than roughages (Russell & Wilson,

1996) thus at four hours post-feeding, the elevated VFA concentrations are most likely due to the high concentrate level of the feed.

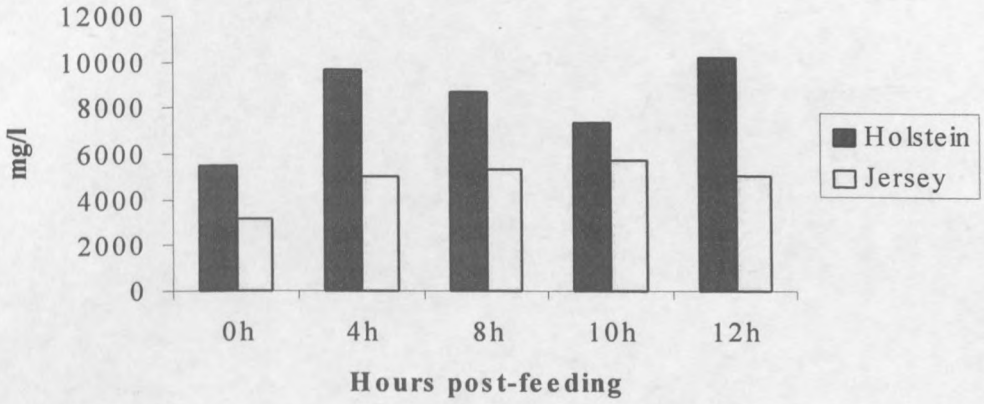

Fig. 2. Total VFA concentration (mg/l) in the rumen of the Holstein and Jersey cows at different times post-feeding.

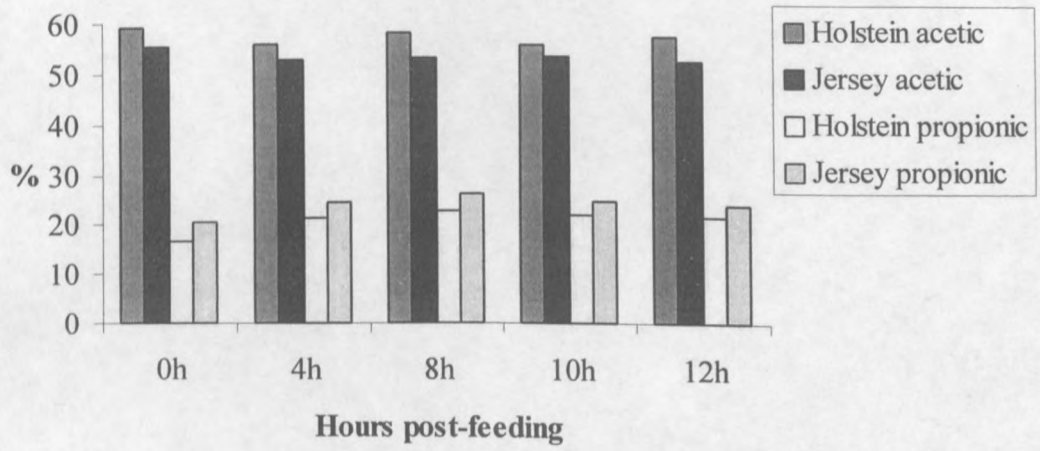

Fig. 3. Acetic and propionic acid as percentages of total VFA in Jersey and Holstein cows at different times post-feeding.

Although the differences between breeds appear marked in Fig. 2, the differences were not statistically significant, due to wide variation and probably the limited number of animals. Fig. 3 indicates the relative changes in proportions of acetic acid and propionic

acid. The proportion of acetic acid is usually greater when a high roughage diet is fed, but with increasing concentrates in the diet there is a shift towards propionic acid (McDonald *et al.*, 1988).

Acetic and propionic acid proportions did not appear to change much over time. Results of the current study are in accordance with those of Rodriguez *et al.* (1997b) who found no differences in the VFA concentrations between breeds, except at feeding when Jerseys had a slightly lower total VFA concentration than Holsteins. Rodriguez *et al.* (1997a) found similar results to those found in this trial, and reported that the only significant difference observed between Jerseys and Holsteins was in total VFA concentrations. There were no differences in the individual VFA proportions. Both these trials were conducted on a high energy diet.

CONCLUSIONS

In the *in situ* trial, no apparent reasons could be found why Holstein cows had lower ruminal degradability values than Jerseys. The higher passage rates of digesta from the rumen in Holsteins have certainly contributed to lower degradabilities, but because these parameters are interdependent, the actual reason for breed differences remained unclear.

The current study compared potential differences in the rumen environment (the pH of rumen fluid and VFA concentrations in the rumen) of Holsteins and Jerseys cows. Jersey cows tended to have a higher rumen pH, which was significant at 4 hours after feeding. A corresponding increase in the VFA concentration was observed at the same time. The increase was significantly higher for the Holsteins than for the Jerseys. This may have contributed to the lower rate of fibre degradation in the Holsteins as fibrolytic activity is suppressed at a low pH. Although the difference in pH only occurred at one time interval, the effect might have lasted long enough to manifest differences in fibre digestibility. The reason for pH differences warrants further research, but it is speculated that differences in eating behaviour was one of the main reasons.

Chapter 6

GENERAL CONCLUSIONS

Due to the ever increasing cost of living, everyone needs to try and make the most of the resources available to them. The dairy farmer is no exception; he needs to optimise production for his situation. This may not necessarily mean maximising production yields, but rather utilising different production methods, feed or animals, to get the best returns.

If a milk producer understands the various factors which affect milk production, he will have a good understanding of effective herd management, and not loose milk yield, and ultimately profit, due to poor management strategies. There are many factors that have been shown to affect milk yield. Some of the factors investigated, were the breed of the cow, the age of the heifer at first calving and the year of birth. These factors had an effect on butterfat and protein production, as well as milk yield. Some of these are important in management decisions to optimise production in respect to resources available.

If a heifer calves too young, her milk yield will be low, as she is still using nutrients for growth. As the age at first calving increases, so does milk yield. The farmer needs to find an optimal age for his herd to calve, so as to optimise lifetime production of the herd.

There are other external management factors which could affect milk yield. The farmer needs to ensure that the cows are housed in good conditions, with adequate shade and water. The distance the cows walk, and any hills which they climb, especially on the way to the milking parlour could influence milk production. There are other management factors such as disease, milking parlour routine and body condition score which the farmer needs to optimise for milk production.

It is known that the breed of cow has an effect on both milk yield and butterfat and protein content. As different breeds of dairy cows are thought to be better suited to

different conditions, a producer should give careful consideration to the breed of cow he has in his herd. As not much research has been done comparing the differences in breeds in various conditions, it is difficult to make conclusions. These trials were based on the assumption that there is a difference in feed utilisation between Jersey and Holstein cows. Knowing if a particular breed is better able to utilise a certain type of feed better than other breeds, would help the producer to be able to effectively utilise the available feed and the breed of cows which he has available.

It is thought that Jerseys are better suited to extensive conditions, and are able to perform better on a lower quality feed than Holsteins. Holsteins are thought to be well suited to intensive production systems, where there is high input, and high milk yields are optimum.

When comparing the effective degradability of NDF and DM of three different types of forage feeds, results were obtained that could give some credibility to these theories. The Jersey cows consistently had higher effective degradability values than the Holsteins. However, the difference in degradability was greater for wheat straw and NaOH-treated wheat straw than for lucerne. This would suggest that Jerseys would be more efficient on low quality forages or where higher quality feed is very expensive.

It was important to investigate some of the factors which influence digestibility, and try to find the reason for the differences observed in effective degradability. When the rate of flow of digesta through the rumen was measured, it was found that the Jerseys had a slower flow rate than the Holsteins. This is consistent with the results which were found in the digestibility trial. A slower rate of flow of digesta through the rumen implies that the digesta is retained in the rumen for a longer period of time, allowing the microbes and enzymes more chance to digest a larger portion of the contents. This would increase the effective degradability values.

A faster rate of passage is often associated with a higher DMI. When considering the daily dry matter intake, the Holsteins ate far more than the Jerseys. However, when the

DMI was compared as a percentage of body weight, the Jerseys had a slightly higher value than the Holsteins (2.76 vs 2.37). It can not be assumed that differences in intake were the reason for the differences in degradability, although it could have had some effect.

As the rumen environment has an effect on feed utilisation, it was necessary to investigate any differences in pH values and the rumen volatile fatty acid concentrations between the breeds. The only time that there was a significant difference in the pH, was 4 hours post-feeding. The Holsteins finished all their TMR feed fairly quickly, and by 4 hours post-feeding, the pH values had dropped significantly to a value of 6.08. The Jerseys ate their feed much slower, and a slower decline in the pH value of the Jersey cows was observed. The pH value of rumin fluid in the Jerseys did not drop below 6.2. At pH levels below 6.2, the fibrolytic microbial organisms are inhibited, which results in less fibre digestion in the rumen. This could be one of the contributing factors for the lower effective degradability values observed in Holsteins.

There were slight differences in the total VFA concentration in the rumen of Jersey and Holstein cows, with the most significant difference at 4 hours post feeding. This was consistent with the pH values measured at the same times, and could once again be associated with the faster rate of concentrate intake in the Holsteins.

In conclusion, it appears as if Jersey cows are more efficient than Holsteins in utilizing forages. The difference is more apparent in poor quality forages such as wheat straw and NaOH-treated wheat straw than in high quality forages such as lucerne hay. Although the rate of feed intake, which has an effect on the rumen pH profile, may partially explain the differences, further research is needed to completely explain differences observed between Holstein and Jersey cows.

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