

OAT SILAGE IN MILK PRODUCTION SYSTEMS IN THE WESTERN CAPE

By

N. M. Bangani

**Thesis submitted in partial fulfilment of the
requirements for the degree of Masters
(Agricultural Sciences)**

The crest of the University of Stellenbosch is centered behind the thesis submission text. It features a shield with various symbols, topped by a crown and a banner with the motto "Pietate subornant cultus recti".

Supervisor: Professor C.W. Cruywagen
Department of Animal Sciences
Faculty of Agricultural and Forestry Sciences
University of Stellenbosch

March 2002

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my 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

Oat silage in milk production systems in the Western Cape

by

Noluvuyo Bangani

Supervisor: Professor C.W. Cruywagen

Department: Animal Sciences

Faculty: Agricultural and Forestry Sciences

University of Stellenbosch

Degree: M.Sc. (Agric.)

The objectives of this study were to determine the effects of supplementing oat silage (OS) with lucerne (LH) and oat hay (OH) on the production performance of lactating Jersey cows, as well as comparing the ruminal degradability of LH, OH and OS in Holstein and Jersey cows receiving a high forage diet and a high concentrate diet.

In the first trial, five diets containing different combinations of OS and LH together with concentrate mixtures providing 26, 23, 20, 17 and 14% crude protein (CP) were fed to lactating Jersey cows. Lucerne hay was fed at 0, 2, 4, 6, and 8 kg DM/day while OS was fed *ad libitum*. Cows receiving only OS as a forage source had a lower ($P<0.05$) dry matter (DM) intake and produced less milk protein ($P<0.05$). Milk and fat yields as well as milk urea nitrogen (MUN) levels did not differ ($P>0.05$) between treatments.

In the second trial, OS was fed with OH and a concentrate mixture containing 26% CP to lactating Jersey cows. Oat hay was fed at 0, 2, 4, 6, and 8 kg DM/day while OS was fed *ad libitum*. Cows that received OS together with 4 and 6kg OH, respectively had higher ($P<0.05$) DM intakes. Milk, fat, and protein yields as well as MUN levels did not differ

($P>0.05$) between treatments.

The ruminal degradability of LH, OH and OS in Holstein and Jersey cows receiving (i) a high forage and (ii) a high concentrate diet was determined. The two breeds were also compared in terms of rumen pH levels, volatile fatty acids (VFA) and rumen ammonia nitrogen ($\text{NH}_3\text{-N}$) concentrations as affected by time after feeding. The ruminal degradability of freeze dried (FD), oven dried (OD) and fresh oat silage (FS) in Jersey cows receiving a high forage diet was also determined.

The ruminal DM, CP and NDF degradability of LH was higher ($P<0.05$) than that of OH and OS in both Holstein and Jersey cows when they were fed either a high forage or a high concentrate diet. When cows were fed a high forage diet, the effective DM degradability of OS was higher ($P<0.05$) in Holsteins although the CP degradation rates of LH and OH were higher ($P<0.05$) in Jerseys. When they were fed a high concentrate diet, Jerseys had higher ($P<0.05$) effective DM and NDF degradabilities and higher ($P<0.05$) DM and NDF degradation rates in LH while Holsteins had higher ($P<0.05$) effective CP degradability levels than Jerseys in OS.

After feeding a high forage diet, pH levels declined while VFA and $\text{NH}_3\text{-N}$ concentrations increased ($P<0.05$) in both breeds. Jerseys had higher rumen pH, lower ($P<0.05$) VFA and lower $\text{NH}_3\text{-N}$ concentrations than Holsteins throughout the study. When cows were fed a high concentrate diet, Jerseys had higher ($P<0.05$) pH than Holsteins. A post-feeding decline ($P<0.05$) in pH was observed in both breeds.

Fresh oat silage had a lower ($P<0.05$) effective degradability and degradation rates for DM, CP and NDF in comparison to FD and OD oat silage. The DM, CP and NDF degradation rates, as well as effective NDF degradability were higher ($P<0.05$) for FD silage, but effective DM and CP degradabilities were higher ($P<0.05$) for OD oat silage.

It was concluded that on an oat silage diet, lactating Jersey cows should receive a minimum of 2kg LH or 4 to 6kg oat hay together with *ad libitum* OS to improve DM

intake. When cows were fed a high concentrate diet, the ruminal degradability appeared to be superior in Jerseys than Holsteins. Jerseys also had higher rumen pH levels lower VFA and $\text{NH}_3\text{-N}$ concentrations than Holsteins. Feeding interval affects the rumen environment, pH declines while VFA and $\text{NH}_3\text{-N}$ concentrations increased.

SAMEVATTING

Hawerkuilvoer in melkproduksiestelsels in die Wes-Kaap

deur

Noluvuyo Bangani

Studieleier: Professor C.W. Cruywagen

Department: Veekundige Wetenskappe

Fakulteit: Landbou en Bosbou Wetenskappe

Universiteit van Stellenbosch

Graad: M.Sc. (Agric.)

Die doel van hierdie studie was om die effek van die aanvulling van hawerkuilvoer met lusernhooi (LH) en hawerhooi (HH) op die melkproduksie van Jerseykoeie te bepaal. Hiermee saam is die rumen degradeerbaarheid van hawerkuilvoer en lusernhooi ondersoek in Jersey en Holsteinkoeie wat 'n hoë-ruvoer en 'n hoë-kragvoer gebaseerde dieet ontvang het.

In die eerste proef is vyf diëte met verskillende peile van hawerkuilvoer en lusernhooi saam met kragvoere van verskillende ruproteïenpeile (26, 23, 20, 17 en 14% RP) aan 10 lakterende Jerseykoeie gevoer. Hawerkuilvoer is *ad libitum* voorsien en lusernhooi is teen vlakke van 0, 2, 4, 6 en 8kg droëmateriaal (DM) per dag gevoer. Die DM-inname en melkproteïenproduksie van koeie wat hawerkuilvoer as die enigste ruvoerbron ontvang het, was laer ($P < 0.05$) as ander ruvoerkombinasies. Die melk- en vetproduksie, asook melk-ureumstikstofpeile het nie tussen behandelings verskil nie ($P > 0.05$).

In die tweede proef is hawerkuilvoer saam met hawerhooi (soortgelyk as Proef 1) gevoer. Die kragvoercomponent van al die ruvoerkombinasies het 26% RP bevat. Die koeie wat

hawerkuilvoer en 4 of 6kg hawerhooi as ruvoere ontvang het, het hoër ($P<0.05$) droëmateriaalinname gehad. Melk, vet en proteïenproduksie asook melk-ureumstikstofpeile het nie tussen ruvoerkombinasies verskil nie ($P>0.05$).

Die rumendegradeerbaarheid van lusern hooi, hawerhooi en hawerkuilvoer is bepaal in Holstein en Jerseykoeie wat (i) 'n hoë ruvoer- en (ii) 'n hoë kragvoerdieet ontvang het. Die rumen pH, vlugtige vetsuur en rumen-ammoniakkonsentrasies, soos beïnvloed deur tyd na voeding, is ook tussen rasse vergelyk. Die rumendegradeerbaarheid van vars, oondgedroogde en vriesgedroogde hawerkuilvoer is ook bepaal.

Die rumen DM, RP en NDF degradeerbaarhede van lusern hooi was hoër ($P<0.05$) as by hawerhooi en hawerkuilvoer in beide Holstein en Jerseykoeie wat (i) 'n hoë ruvoer- en (ii) 'n hoë kragvoerdieet ontvang het. Op 'n hoë ruvoerdieet, was effektiewe DM degradeerbaarheid van hawerkuilvoer by Holsteins hoër ($P<0.05$) as by Jerseys. Jerseykoeie het egter 'n hoër ($P<0.05$) RP degradeerbaarheidstempo van lusern hooi en hawerhooi gehad.

Jerseykoeie op 'n hoë kragvoerdieet, het hoër ($P<0.05$) effektiewe DM en NDF degradeerbaarhede getoon. Hulle het egter 'n laer ($P<0.05$) effektiewe ruproteïen (RP) degradeerbaarheid by hawerkuilvoer as Friese gehad. Jerseykoeie op lusern hooi het ook 'n hoër ($P<0.05$) DM en NDF degradeerbaarheidstempo getoon.

Jerseykoeie wat 'n hoë ruvoerdieet ontvang het, het 'n hoër ($P<0.05$) rumen- pH en laer ($P<0.05$) vlugtige vetsuur- en rumen-ammoniak konsentrasies as Holsteinkoeie gehad. Jerseykoeie wat 'n hoë kragvoerdieet ontvang het, het ook 'n hoër ($P<0.05$) rumen- pH as Holsteinkoeie gehad. By al die koeie is gevind dat rumen- pH na voeding afgeneem het ($P<0.05$). Vlugtige vetsuur- en rumen-ammoniakkonsentrasies was laag voor voeding en het daarna toegeneem ($P<0.05$).

Vars hawerkuilvoer het laer ($P<0.05$) effektiewe DM, RP en NDF degradeerbaarhede en degradeerbaarheidstempo's as oond- en vriesgedroogde hawerkuilvoer gehad. Die

vriesgedroogde kuilvoer het hoër ($P<0.05$) DM, RP en NDF degradeerbaarheidstempo's sowel as effektiewe NDF degradeerbaarhede gehad. Oondgedroogde kuilvoer het daarteen hoër ($P<0.05$) effektiewe DM en RP degradeerbaarhede gehad.

Die gevolgtrekking is gemaak dat lakterende Jerseykoeie ten minste 2kg lusernhooi of 4 – 6kg hawerhooi per dag moet ontvang wanneer hulle hawerkuilvoer as ruvoerbron ontvang. Op 'n hoë kragvoerdieet, het dit gebleik dat die rumendegradeerbaarheid van vesel by Jerseys beter is as by Holsteins. Die rumen- pH is hoog voor voeding, maar dit neem af nadat die koeie gevreet het. Die rumen- pH van Jerseys was hoër as by Holsteins. Die vlugtige vetsure en rumen-ammoniakkonsentrasies blyk laag te wees voor voeding en neem daarna toe. Konsentrasies was hoër by Holstein as by Jerseys.

ACKNOWLEDGEMENTS

I thank **my Heavenly Father** for the strength that He has given me to finish this study. “I can do all things through Christ who strengthens me” (Philippians 4: 13).

This research was done under the **Young Professional Persons Programme**, which was the initiative of the Western Cape Chief Directorate of Agriculture in Elsenburg. I therefore wish to thank the **Department of Economic Affairs, Agriculture and Tourism of the Western Cape** for all the support and the permission they granted me to use the data in this study.

The **Animal Production Division** for allowing me to use their facilities, with special thanks to **Mr T. T. de Villiers Deputy Director and Dr P. King**, former head of the Animal Production Division for the opportunity to do this research.

The **Steenberg Trust Fund** for financial support to make the research possible.

The **Cannon Collins Educational Trust for Southern Africa** is also gratefully acknowledged for financial support.

A word of special acknowledgement goes to the following persons:

Mr C. J. C Muller, Specialist Scientist (Dairy Science) at the Animal Production Division of the Department of Agriculture: Western Cape, Elsenburg for directing me and for his understanding and support which led to the completion of this study.

Mr J. A. Botha for his excellent technical support.

Mr J. Tshaya, Mr J. Wenn, Mr J. Minnies and Mr K. J. Claassen for feeding, milking and caring for experimental animals.

Mr S. W. P. Cloete for his help with data analysis and interpretation.

The **researchers and personnel** in the Animal Production division who shared their knowledge and offered assistance in some of the technical work.

Prof. C. W. Cruywagen, my supervisor for his valuable inputs.

Mr W. J. Burger for assisting with chemical analysis.

Mrs J. Collier for laboratory analysis of rumen fluid samples.

Mr L. D. Van der Westhuisen for chemical analysis of milk samples.

My mother for investing in my education.

My son **Sonwabile**, for understanding that being away does not mean that I do not love him.

Mr T De Bruyn for the support and confidence in me.

My friends and relatives for their support and friendship.

LIST OF ABBREVIATIONS

ADF	Acid detergent fibre
CP	Crude protein
DM	Dry matter
DMI	Dry matter intake
LH	Lucerne hay
OH	Oat hay
OS	Oat silage
FD	Freeze-dried silage
FS	Fresh oat silage
OD	Oven-dried silage
NH ₃ -N	Rumen ammonia nitrogen
VFA	Volatile fatty acids

Degradability in the text refers to ruminal degradability.

TABLE OF CONTENTS

<i>Declaration</i>	ii
<i>Abstract</i>	iii
<i>Samevatting</i>	vi
<i>Acknowledgements</i>	ix
<i>List of abbreviations</i>	xii
<i>Table of contents</i>	xiii

CHAPTER I

General introduction

1.1	Problem statement.....	1
1.2	Proper nutrition of dairy cows.....	2
1.3	Importance of forages in dairy cow nutrition.....	4
1.4	Small grain forages.....	5
1.5	Oats.....	7
1.6	Increasing intake and digestibility of oats.....	8
	1.6.1 Supplementing with concentrates.....	9
	1.6.2 Supplementing with lucerne.....	9
1.7	Provision for a constant forage supply.....	10
1.8	Forage conservation.....	11
	1.8.1 Hay.....	11
	1.8.2 Silage.....	11
	1.8.2.1 Characteristics of good quality silage.....	12
	1.8.2.2 Increases in silage use.....	13
	1.8.2.3 Reasons for increased silage utilisation.....	13
	1.8.2.4 Problems related to silage making.....	15
1.9	Objectives of the study.....	15
1.10	References.....	17

CHAPTER 2

The production performance of lactating Jersey cows receiving varying levels of lucerne hay and oat silage as forage sources

Abstract	24
2.1 Introduction	25
2.2 Materials and methods	26
2.2.1 Experimental area.....	26
2.2.2 Experimental animals and experimental design.....	26
2.2.3 Experimental feed.....	27
2.2.4 Management of animals before and during the experiment.....	28
2.2.5 Determining dry matter intake.....	29
2.2.6 Chemical analysis of feeds.....	29
2.2.7 Collection of milk samples.....	29
2.2.8 Evaluating the efficiency of feed conversion.....	30
2.2.9 Data analysis.....	30
2.3 Results and discussion	30
2.3.1 Feed composition.....	30
2.3.2 Feed intake.....	33
2.3.3 Milk production and milk composition.....	35
2.3.4 Efficiency of feed conversion.....	36
2.3.5 Milk Urea Nitrogen.....	36
2.3.6 Economic evaluation.....	37
2.4 Conclusion	37
2.5 References	39

CHAPTER 3

The production performance of lactating Jersey cows receiving varying levels of oat hay and oat silage as forage sources.

Abstract	43
3.1 Introduction	44
3.2 Materials and methods	45
3.3 Results and discussion	46
3.3.1 Feed composition.....	46
3.3.2 Feed intake.....	48
3.3.2 Milk production and milk composition.....	49
3.3.3 Economic evaluation.....	50
3.4 Conclusion	51
3.5 References	52

CHAPTER 4

Comparing ruminal forage degradability between Holsteins and Jersey cows receiving a high forage diet using the in situ technique.

Abstract	55
4.1 Introduction	56
4.2 Materials and methods	57
4.3 Results and discussion	59
4.3.1 Ruminal dry matter degradability.....	59
4.3.2 Ruminal crude protein degradability.....	62
4.4.3 Ruminal neutral detergent fibre degradability.....	65
4.4 Conclusion	67
4.5 References	68

CHAPTER 5

Comparing the dynamics of the rumen environment of Holstein and Jersey cows receiving a high forage diet

	Abstract.....	71
5.1	Introduction.....	72
5.2	Materials and methods.....	74
5.3	Results and discussion.....	75
	5.3.1 Rumen pH.....	75
	5.3.2 Rumen ammonia-nitrogen concentration.....	77
	5.3.3 Volatile fatty acid concentration.....	78
5.4	Conclusion.....	82
5.5	References.....	83

CHAPTER 6

Comparing ruminal forage degradability between Holstein and Jersey cows receiving a high concentrate diet

	Abstract.....	86
6.1	Introduction.....	87
6.2	Materials and methods.....	88
6.3	Results and discussion.....	89
	6.3.1 Rumen pH.....	89
	6.3.2 Ruminal dry matter degradability.....	91
	6.3.3 Ruminal crude protein degradability.....	94
	6.3.4 Ruminal neutral detergent fibre degradability.....	96
6.4	Conclusion.....	100
6.5	References.....	101

CHAPTER 7

Comparing ruminal degradability of fresh, freeze-dried and oven-dried silage in Jersey cows receiving a high forage diet.

	Abstract	105
7.1	Introduction	106
7.2	Materials and methods	107
7.3	Results and discussion	109
	7.3.1 Ruminal dry matter degradability.....	109
	7.3.2 Ruminal crude protein degradability.....	111
	7.3.3 Ruminal neutral detergent fibre degradability.....	113
7.4	Conclusion	115
7.5	References	116

CHAPTER 8:

General conclusions	118
----------------------------------	-----

CHAPTER 1

1. General introduction

1.1 Problem statement

The availability of high quality forage is one of the major constraints of dairy production in Southern Africa (Smith *et al.*, 1993). Forage quality can be defined as a function of both forage intake and digestibility. All forages are low in rumen-undegradable protein, energy, essential fatty acids, minerals, trace elements and vitamins (Smith *et al.*, 1993). Although additional protein and energy in the concentrate portion of the diet can help compensate for lower quality forage, dry matter (DM) intake and performance are influenced strongly by forage quality (Khorasani *et al.*, 1993).

The lack of a constant supply of quality forage is associated with soil quality and climate (Smith *et al.*, 1993). Most areas in South Africa are characterised by summer rainfall, resulting in sufficient herbage in pastures only during summer and autumn. During this time, cows can graze pastures with little or no supplementation required. In winter, the conditions deteriorate because of insufficient rain. The nutritional value of natural pastures decline with crude protein (CP) content dropping to about 3 - 4% which is well below the maintenance requirements of a dairy cow. For maintenance, dairy cows require a minimum of between 7% and 8% CP, while high producing animals require at least 13 to 14% CP in their diets (Meissner *et al.*, 1999).

The climate in the Western Cape is different from that of other parts of South Africa. It is typically Mediterranean with moist, cool winters and hot, dry summers. Mean annual rainfall varies from 200 to 650ml (Hardy, 1998). Due to these climatic conditions, it is impossible for Western Cape farmers to produce high quality forage crops such as maize and lucerne unless sufficient irrigation is available. They therefore produce mainly small grain cereals. Lucerne hay is often bought from other parts of South Africa. This means that using lucerne as forage

source for dairy cows is expensive as there are transport costs involved. Lucerne is also difficult to obtain while the quality can vary considerably from one year to the next (*Brand et al.*, 1992).

The Western Cape region is one of the major producing areas of small grain cereals in South Africa. Oats, wheat, barley, and triticale are the small grain forages grown in the Western Cape (Brandt, 1998). The major problem with small grain forages is that they are poor in CP, vitamins and some minerals such as calcium (Morrison, 1961), except when used as pasture at a young stage, or harvested early. This indicates that they cannot be used as the only feed for productive stock, needing supplementation with protein-rich forages and/or concentrates to maintain or improve animal performance. The minimum levels at which protein-rich forages or concentrates must be included when feeding small grain forages without impairing the animal performance remains a problem. There is also very little known about the digestibility of small grain forages produced in this area. The trials that were conducted in this study were aimed at determining the digestibility of small grain forages, specifically oats, and the minimum inclusion levels of supplements when feeding oat silage to lactating Jersey cows.

1.2 Proper nutrition of dairy cows

Milk production is controlled by a number of factors, most importantly, genetics and nutrition (Larson, 1999). As herd production levels continue to increase along with the average herd size, it has become more difficult for dairy farmers to feed their cattle adequate nutrients to maintain high production (Grant & Keown, 1990). An effective feeding system allows maximum intake of a nutritionally balanced diet that meets the cow's needs for maintenance, growth, reproduction and lactation (Smith *et al.*, 1993). This indicates that proper feeding of good balanced diets are the cornerstones of a successful dairy operation (Harris, 1992).

Proper nutrition is required early in the lactation especially to prepare the cow's reproductive system for conception and pregnancy (Grant & Keown, 1990). An insufficient DM intake predisposes the cow to a negative energy balance with a reduced fertility (Wilde, 2001). When the cow is in a negative energy balance, the insulin-like growth factor (IGF)

concentrations are reduced. Low IGF concentrations reduce the effectiveness of follicle stimulating hormone (FSH) resulting in fewer and smaller follicles developing (Wilde, 2001). The pulse frequency of the luteinising hormone (LH) is also decreased, and so, maturation of follicles does not occur. Ovulation becomes delayed or it fails and the follicle becomes cystic. This results in cows not becoming pregnant with longer calving intervals and dairy farmers losing money through less milk per year, fewer calves to sell, more services per conception and increased veterinary costs (Wilde, 2001).

Proper nutrition is also important for cattle to ward off infections, such as mastitis and metabolic problems. A well-nourished cow will be in a better physical condition to handle stress and other physical challenges. Therefore, the feeding system must undergo significant modification as production levels increase, not only for the producer to maintain profitable production, but also for the physical well being of dairy cattle (Grant & Keown, 1990).

Dairy cows are used extensively for converting crop residues and animal wastes to milk and other products such as meat and leather (Blaser, 1978). In dairy herds, the amount of milk produced is of major importance as the milk contributes more than 90% of the total dairy income. A Jersey cow weighing about 350 - 400kg can produce about 4500kg milk with an average butterfat content of 4.5% and protein 3.5% every lactation. For the year beginning September 1999 to end August 2000, the South African National Jersey herd (combined registered and unregistered) produced an average of 4690kg milk with average butterfat and protein contents of 4.47% and 3.53%, respectively (National Dairy Cattle Performance Scheme, 2000). In a single lactation, the cow can produce 10-20 times the amount of milk that nature requires for calf rearing (Smith *et al.*, 1993), suggesting that there is little or no competition between humans and calves for cow's milk.

Cow's milk is a good source of calcium, phosphorus and magnesium for the human diet. A half litre of cow's milk supplies 25% energy, 40% protein, 70% calcium and riboflavin, and about 33% of vitamin A and thiamine of a five year old child's daily requirements (Cruywagen, 1998). Milk calcium is highly absorbable in the digestive tract, hence it is an important source of calcium for growing children and women (Cruywagen, 1998). Milk

protein is of high nutritive quality, with a biological value of 85. Cereal proteins on the other hand have biological values varying between 55-65. Milk also contains fat-soluble vitamins, i.e. vitamin A, D, E and K, although vitamin D, E and K are in low quantities. Fermentation and fortified milk products, such as yoghurt, cheese and cultured milk extend the shelf life of the nutrients in milk without loss of nutritive value. Natural sour milk not only prohibits microbial proliferation in milk, but is also a natural way of introducing desirable organisms into the digestive system (Smith *et al.*, 1993).

Milk yield per cow and the cost of feed to produce milk have by far the greatest influence on profitability in a dairy operation (Harris, 1992). If a dairy is to be successful, the dairyman must continually strive to adopt practices that allow the greatest output of milk at the most economical cost (Harris, 1992). Feed costs usually comprise about 65 - 80% of the production costs of milk (Muller & Botha, 1998; Gordijn & Whitehead 1995). Offering alternative feeds which provide the necessary nutrients at lower cost and promote higher nutrient intakes results in higher milk production levels and increased profitability (Racz, 2000).

1.3 Importance of forages in dairy cow nutrition

Historically, forages have been called roughages because they contain more fibre than concentrate feeds (Rayburn, 1997). Dairy cows fed high-quality forage produce more milk with less supplemental concentrate than cows fed lower-quality forage (Weiss *et al.*, 2001). Diets containing high levels of concentrates are expensive and result in poor profits in the dairy enterprise. Forages account for up to 65% of the feed for dairy cattle (Muller & Botha, 1996), thus forage quality is an important determinant of cattle performance. A general rule of thumb is that the forage quantity of a diet for dairy cows should be at least 35-40% (Dugmore, 1995). According to Grant (1990), 40-50% of the DM in a diet should be forage to avoid low milk fat test. Diets too high in fibre limit milk protein production because not enough energy is consumed (Grant 1990).

Minimum acid detergent fibre (ADF) levels required in the feed DM are 19-21%. Neutral detergent fibre (NDF) should not fall below 26-28%. When diets have lower levels than these,

cows risk a low milk fat test, acidosis, lameness, chronic feed intake fluctuations, and poor body condition, especially in early lactation (Grant, 1990).

In addition to the nutrient contribution of forages, they are required in the diets to maintain animal health by sustaining a stable rumen environment (Allen, 1995). They provide a buffering capacity in the rumen and improve the fermentation efficiency of starchy grains. Fibre also stimulates rumination (cud chewing), salivation, and maintaining normal milk fat and protein composition (Grant, 1990). Insufficient forage intake leads to acidosis, inefficient rumen fermentation and reduced productive life of the cows. High quality forages combine high nutrient intake potential with the beneficial effects of fibre on health (Racz, 2000).

1.4 Small grain forages

Small grains are important forage crops and can be used either as hay, pasture or silage (Klingman, 1958). Many producers consider harvesting small grains for forage rather than for grain (Weiss, 2000) and store it as hay or, more popularly as silage (Marx, 1983). This is because harvesting small grain as a forage crop results in less risk of losing the grain crop to rain, wind and hail (Marx, 1983). Moreover, when harvested at the right stage, small grain silage can provide high quality forage (Shaver, 1996). Early summer harvest of small grain crops allows double cropping with another annual for emergency stored forage or fall pasture (Marten, 1982). Small grains are also one of the easiest crops to grow under primitive methods. In some parts of the world, people still prepare the soil for small grains with the most old-fashioned ploughs, seed by hand and cut with a sickle (Klingman, 1958).

All small grains (oats, barley, wheat, rye, and triticale) make acceptable forages for dairy cows when they are harvested at the right stage of maturity (Weiss, 2000). When harvested at similar stages of maturity, the nutrient composition of the different small grains is similar, i.e., maturity affects composition more than does species (Robinson, 1998). The nutritional value of small grain forage declines rapidly with increasing maturity. Small grain forage harvested in the pre-boot stage has about 20% CP (varies with the amount of nitrogen fertiliser applied), 40% NDF, 30% ADF and *in vitro* digestibility of about 80% (Robinson, 1998). At the milk

stage, CP averages 12%, NDF 48%, ADF 35% and *in vitro* digestibility averages 62% (Weiss, 2000).

Harvesting small grain forage at the right stage of maturity is critical when the forage is to be fed to lactating dairy cows. Rye should be harvested no later than the boot stage and triticale in the boot stage. Oats, wheat, and barley can be harvested in the boot to milk stage. When small grain forage is to be fed exclusively to dry cows and heifers, rye should be harvested in the boot stage, triticale in the milk stage, and oats, wheat and barley in the dough stage. The quality of forages is not as critical for dry cows and heifers while delaying harvest increases DM yields (Robinson, 1998).

Small grain hay is difficult to make because of the long curing time necessary. This therefore means that chopping small grains and ensiling plant material is the preferred method of harvesting these crops (Weiss, 2000). Although small grain hay or silage is satisfactory as forage for dairy cattle, it should be fed along with legume hay or silage as it has a low protein content.

Wheat is produced for bread and barley for the malting industry. It is only the lower quality wheat and barley that is available for animal feed. Barley that is often available to the feeding industry is usually an overflow from the malting industry either due to high a percentage of screenings, a high protein content and fungus infected or damaged kernels (Brandt, 1998). Barley is used without restrictions in the diets of growing and finishing cattle and also for lactating dairy cattle. Wheat, due to its highly fermentable nature, is often limited in diets for ruminants and is primarily used for feeding monogastric animals (Campbell *et al.*, 1995).

Better quality hay is made from oats or barley in comparison to wheat (Morrison, 1961). Oat forage may be better utilised by cattle than barley (NRC, 1984). If ensiled in the early dough stage, small grain forages make fair to good silage. It is advisable to add molasses and/or use some other preservative. The cut forage must also be compacted well in the silo to force air out of the hollow stems and to get rapid fermentation (Morrison, 1961).

1.5 Oats

Oats is the forage crop under investigation in this study. It has a high fibre fraction, making it a good feed for ruminants. In the south-eastern countries of America, oats is entirely grown for livestock feed (Klingman, 1958). Oats can be preserved either as hay or silage for feeding cows. It is only planted for silage or hay production in the Mediterranean regions. For this reason, there is little information available on the use of oat forage as a feed for ruminants. Because of the importance of oats as a forage feed for dairy cows in the Western Cape, extensive research needs to be done to improve its production and utilisation.

Oats is among the most popular dairy feeds because it is palatable and bulky (Morrison, 1961). The ADF value of oat silage ranges between 30.8% and 45.7%, with the average being 38.1% (Muller *et al.*, 2000). The NDF content of oat silage ranges between 50.0% and 69.2% with the average being 59.7%, total digestible nutrient (TDN) value ranging between 58.5% and 75.7% with an average of 69.1% and CP ranging between 4.7% and 11.3%, with the average being 7.6% (Muller *et al.*, 2000). Oats, just like other cereals is low in calcium and only fair in phosphorus. It lacks carotene and vitamin D and is low in riboflavin and niacin (Morrison, 1961).

Despite its low nutritive value, oats has certain advantages over other winter crop cereals:

- It is capable of better performance than either wheat or barley where seedbed preparation is limited (Brown, 1975).
- When sown in a moisture deficient seedbed, oats is less liable to moulding.
- Oats fits well in the pasture improvement programmes, and provides valuable winter grazing when other pastures are dormant. After the period of pasture improvement, they use the nitrogen built up in the soil more effectively than any other winter cereals.
- Oats has the ability to produce green feed under comparatively low temperature regimes. There is no part of the wheat belt where oats cannot be grown successfully, including the driest regions.
- Oats has the highest distribution of all the cereals grown in the Mediterranean rainfall region, mainly because it is hardy and better adapted to withstand wet conditions than any

other winter crops.

- It is valuable for conservation of fodder whether as hay, silage or grain. There are fewer feeding problems with oats than with other grains.
- Oats can be used as an excellent rotation crop to combat the spread of wheat diseases such as Flag Smut and the various strains of Foot-Rot and Rot-Rot diseases built up by wheat, barley and barley grasses, oats is also immune to such diseases (Brown, 1975).

1.6 Increasing intake and digestibility of oats

Poor-quality forages are often unable to support rumen conditions that are conducive to optimal microbial activity because of their deficiency in total nitrogen, true protein, readily fermentable carbohydrates and minerals (Ndlovu & Buchanan-Smith, 1985). Proper supplementation is seen as an alternative approach to increase utilisation of poor-quality forages. Supplementation increases acceptability of poor quality forage, even though its chemical and physical properties are not altered. The increased acceptability is related to improved digestibility of the material when fed with a nitrogen source (Meissner *et al.*, 1999).

For best results, the feeder should correct the nutritive deficiencies of the cereal forage, regardless of whether they are fed for fattening, growing or milk production (Ensminger, 1977). It is well established that increasing the protein concentration in the supplement increases milk yield with cows given grass silage-based diets (Chamberlain *et al.*, 1989; Huhtanen *et al.*, 1995). A simple reduction in the amount of concentrates that dairy cows are fed will lead to a protein deficiency in the total diet (Muller & Botha, 1998).

Where CP levels in forages are insufficient to meet the animal's requirements, protein needs to be supplemented using either non-protein nitrogen e.g. urea licks, protein concentrates or conserved forages high in protein (Meissner *et al.*, 1999). In the trials conducted in this study, protein concentrates and lucerne were used as supplements.

1.6.1 Supplementing with concentrates

Concentrates are feeds that have a low fibre content. They can be classified as either carbonaceous or nitrogenous feeds (Ensminger, 1977). Carbonaceous concentrates are those that are high in energy whereas nitrogenous concentrates are high in protein. They are often used as supplements to counteract deficiencies of either protein or energy in ruminant feeds.

Supplementing with concentrates improves animal performance but care must be taken not to overfeed. The forage quantity of a diet for dairy cows should not be less than 35- 40% (Dugmore, 1995). Concentrates have a faster fermentation rate which results in the accumulation of volatile fatty acids and therefore a reduced ruminal pH (Russell & Wilson, 1996). If the pH drops too low, disorders such as rumen acidosis and rumenitis are more likely to occur, leading to reduction in milk production. Herds on high grain diets are also usually more susceptible to mastitis (Miller, 1979).

Laminitis and foot rot are also related to over-feeding of grain. Laminitis is a common secondary factor following acute rumen acidosis or extended periods of heavy grain consumption. The foot problems and injuries that follow are common reasons why cows are culled from the herd (Goings & Sniffen, 1992).

1.6.2 Supplementing with lucerne

Supplementing oats and other cereal forage crops with lucerne hay results in improved animal performance. Positive associative effects between lucerne hay and poor-quality forages were identified by a number of researchers. These include an increase in intake (Soofi *et al.*, 1982), digestibility (Hunt *et al.*, 1985), daily weight gain (Brandt & Klopfenstein, 1986a), volatile fatty acids (VFA) and rumen ammonia nitrogen ($\text{NH}_3\text{-N}$) levels and *in sacco* rate of dry matter fibre digestion (Ndlovu & Buchanan-Smith, 1985). Ndlovu & Buchanan-Smith (1985) attributed the improvements in rates of disappearance from nylon bags when cows were supplemented with lucerne to stimulation of microbial activity due to increased nitrogen and / or easily digestible cell wall from lucerne.

Leng (1982) postulated that there is a strong possibility that a small supplement of lucerne hay may have a beneficial effect on microbial growth. Lucerne increases ammonia levels in the rumen resulting in maximal microbial protein synthesis and this stimulates fibre digestion (Ndlovu & Buchanan-Smith, 1985).

Lucerne has a high protein content and efficiency of protein utilisation is increased when fed with low-protein high-energy feeds (Smith *et al.*, 1993). It has a lower NDF content than grasses and livestock eat more of it than grass hay or silage (Rayburn, 1997).

Lucerne is the most important hay crop in South Africa. This is because it is able to withstand the brackish soils of the semi-arid regions of South Africa under which very few crops thrive. Above all, lucerne hay is palatable, it has high protein, calcium and vitamin levels (Van der Merwe, 1983). In the Western Cape, oats, preserved either as hay or silage, is often used in combination with lucerne hay in the feeding of dairy cows (Muller & Botha, 1998). In the current study, oat silage was used in combination with lucerne hay and concentrate mixtures of varying protein levels.

1.7 Provision for a constant forage supply

In many regions in the world, the climate is not suitable to grow forages during much of the year. A few exceptions include countries like New Zealand where 100% grazing is practised as a form of feeding management for dairy cows. In South Africa, some farmers make use of irrigated pastures. This provides for a constant supply of high quality forage throughout the year allowing for the production of milk at a lower cost (Van der Merwe, 1983). In Europe, where there are high quality pastures, milk production increases in summer with little or no concentrate feeding. Contrary to the all pasture feeding programme practised in New Zealand, cows in the Western Cape are kept mainly under intensive conditions (Van der Merwe, 1983). This increases the cost of milk production. Constant forage supply in these areas is met by the utilisation of conserved forages (Smith *et al.*, 1993).

1.8 Forage conservation

Fodder supply during the dry season is an important factor limiting livestock productivity (Viet *et al.*, 2000). Effective planning of a fodder flow system provides a constant supply of feed during the year (Smith *et al.*, 1993). In many cases, the forage produced during the growing period is more than the amount required by the livestock on a specific farm at that time. This surplus provides for the main supply of forage to be conserved for feeding during periods of shortage (Raymond *et al.*, 1986). Sometimes, forage is grown solely for conservation. Two main processes are used to conserve forage, i.e. hay and silage production (Rotz & Muck, 1994). The aim of an effective forage conservation process is to stop the destructive processes which occur after cutting rapidly and completely so as to preserve as much as possible of the yield and feeding value of the original crop (Raymond *et al.*, 1986). The hay or silage produced must support high levels of animal performance as the producer is paid for performance, be it milk or beef (Keady, 1998).

1.8.1 Hay

Hay crops are normally dried in the field to a moisture content of less than 20% (Rotz & Muck, 1994). The crop may also be dried by high temperature dehydration to a stage at which both chemical and microbial actions cease (Raymond *et al.*, 1986). It is then baled in bales of various sizes, shapes and densities (Rotz & Muck, 1994) and stored in a cool dry place. Harvesting the crop at the proper stage of maturity is the most important aspect of hay production. Factors such as the type of crop, fertilisation, stage of maturity, weather conditions and degree of foliage loss during haymaking, transport or storage affect hay quality. Grinding or pelleting poor quality hay improves intake and limits wasting (Smith *et al.*, 1993)

1.8.2 Silage

Silage represents the harvesting of plant material at a succulent, yet high yielding growth stage (Boyazoglu, 1997). Forage is normally wilted in the field to a moisture content of 50 -65%. It

is then ensiled and stored in either tower or bunker silos, above ground stacks, bags or wrapped large bales (Rotz & Muck, 1994). The silos must be sealed to prevent air moving in and through the cut forage and causing heating from secondary fermentation. The sealing also provides an oxygen-free environment which is essential for effective preservation. To prevent further microbial activities, the crop may be acidified by adding acids such as mixtures of sulphuric and hydrochloric acids, or phosphoric acid before ensiling (Raymond *et al.*, 1982). The sugar in the crop ferments to lactic acid and the pH decreases from 6.8 to reach a normal pH range for silage of 3.8 to 4.2. Moulds and putrefying organisms are inactivated as the forage becomes more acidic. The lactobacilli also become less active at lower pH values (Rotz & Muck, 1994).

1.8.2.1 Characteristics of good quality silage

Good quality silage is determined by the following factors:

- **Smell and taste:** Both smell and taste of silage are due to acid (Morkel, 1921). Silage of first class quality should have an aromatic, vinous or fruity smell and an acidic taste. The taste is pleasing, not bitter or sharp, and the smell is clean, not foul or objectionable (Ensminger, 1956). Where silage is spoiled, it will be found to be alkaline to litmus and permeated by threads of mould (Morkel, 1921).
- **Colour:** Generally, green or brownish silage is good. Tobacco brown or dark brown silage indicates excessive heat. Black silage is rotten and should therefore not be fed to animals (Ensminger, 1956). A pale green colour is indicative of a high degree of acidity (Morkel, 1921).
- **Succulence and palatability:** A very high moisture content at ensiling is likely to cause a sour, strong smelling unpalatable silage. A moisture content below 40% leads to incomplete fermentation, the feed may not pack tightly enough and cattle may not eat as much as they normally would. Stage of maturity also affects succulence and feeding value of silage (Marx, 1982).

1.8.2.2 Increases in silage use

As a form of conserved forage universally, silage is gaining more popularity over hay (Woolford, 1990), despite its being prone to poor intake characteristics (Browne *et al.*, 1995). The most marked change from haymaking to silage was observed in the United Kingdom between 1970 and the mid-1980s. In 1970, only about 10% of forage conserved in the United Kingdom was in the form of silage. By the mid-1980s, this form of forage conservation had risen to over 70%, with the most marked change to silage being on dairy farms (Raymond *et al.*, 1986). In many parts of Ireland and the United Kingdom, silage is, and will remain the basic forage for the majority of dairy and beef cattle during the winter period (Keady, 1998).

In Southern Africa, many dairy farmers are changing from hay to silage because of weather and labour factors (Smith *et al.*, 1993). In the Western Cape, Baard (1989), found that 23.4% of dairy farmers use silage as a forage source for dairy cattle. According to Meeske (2001, personal communication, Outeniqua Experimental Farm, George), about 70% of dairy farmers in the Western Cape use silage as a forage source for dairy cattle during periods of feed shortages. Conserving forage as silage by these farmers is related to difficult haymaking conditions during winter and the unavailability of storage facilities for hay (Meeske, 2001, personal communication).

1.8.2.3 Reasons for increased silage utilisation

Factors that have increased the popularity of silage over hay are the following:

- Silage can be made with less dependence on good weather. Making good quality hay is usually a problem as untimely rains often occur during the drying period resulting in a decline in feeding value of the hay. Fields may also be too wet for heavy baling machines. Harvested forage that has been rained on has to be left in the field for longer periods before baling, resulting in a greater drop in nutritional value. This problem of deterioration in nutritional value of hay due to rain was once experienced in Britain in 1985. Large areas of hay were left to deteriorate for weeks in the field because the hay was too wet to bale (Raymond *et al.*, 1986).

- With silage making, there is no necessity to harvest crops at a mature stage of growth when feed value tends to be least (Woolford, 1990). Waiting to cut the forage at a later stage when the risk of haymaking is smaller results in poorer quality hay because of the lignification of plant cell walls.
- Converting a crop into silage clears the land earlier and this allows for double cropping with another annual crop (Ensminger, 1977).
- Silage makes for less waste, the entire plant being eaten with relish (Ensminger, 1977). With hay making, physical and leaching losses in the field can occur during the drying process. Too often many of the nutritious leaves are shattered and lost and much of the carotene and other nutrients are leached or bleached away (Ensminger, 1956). These losses can exceed 30% of the dry matter in bad conditions. Also, unless the hay is fully dried, there can be further losses, both of dry matter and of nutritive value resulting from continued respiration and microbial activity that can occur in the stacks. It is estimated that over 80% of hay made in the wetter parts of the country is either moulded or overheated. Mouldiness causes the hay to be unpalatable while also creating health problems to animals consuming it (Raymond *et al.*, 1986).
- Unlike hay, there is no danger of fire hazard related to the storage of silage (Ensminger, 1977). This is because the forage is ensiled whilst still moist and stored in that condition. Hay, however it has to be dried first and thereafter, kept in a dry place. This increases the susceptibility of hay to fire hazard.
- Furthermore, silage, like hay, when properly made can reduce dependence on expensive imported feed concentrates, a crucial factor in these days of diminishing returns in agriculture and of prime importance for obvious reasons in the developing countries (Woolford, 1990).

1.8.2.4 Problems related to silage making

There are also some disadvantages related to silage making, such as mouldiness and use of expensive equipments for ensiling, but these are all outweighed by the advantages. The most marked disadvantage of silage is its depressing effect on voluntary feed intake relative to other methods of preservation such as drying, but it has a small effect on digestibility and utilisation of digested feed (NRC, 1984). This statement has been based on the fact that in practise, cows grazing outdoors have higher intakes and consequently higher milk yields than those receiving silage, but this is not a valid comparison. The lower DM intake is related to high moisture content of silage resulting in quick rumen fill with little DM intake per kilogram feed given (Van der Merwe, 1983).

Recent studies by Keady & Murphy (1998), clearly show that when cows are offered herbage either as fresh grass, zero grazed, or grass conserved as silage using a good ensiling technique, silage did not affect intake but decreased milk yield and protein concentration. This reduction in animal performance is assumed to be due to the conversion of water-soluble carbohydrates to lactic and volatile fatty acids, which are poor energy sources for rumen microbes. The fermentation process also results in a reduction in microbial protein synthesis (Keady, 1998). Chopping the forage to about 20mm before ensiling results in greater intakes than that of unchopped material (NRC, 1984).

1.9 Objectives of the current study:

The current study was conducted to:

- Promote the use of home-produced forages and hence reduce dependence on imported feeds.
- Determine whether oat silage can be used successfully as the only forage source for lactating dairy cows in the Western Cape Province.
- Determine the maximum level of oat silage incorporation in the diet of dairy cows without impairing their performance.
- Determine the performance of dairy cows receiving varying levels of oat silage and

lucerne hay or oat hay as forage sources. The amount of milk produced, protein and fat content of the milk were the parameters used to evaluate the cow's performance.

- To determine the ruminal degradability of oat silage, oat hay and lucerne hay.
- To distinguish differences between Holsteins and Jerseys in relation to dry matter, protein and fibre degradability.

To achieve the above objectives, five trials were conducted: two feeding trials and three ruminal degradability trials.

- A feeding trial, where five diets with varying amounts of oat silage and lucerne hay, plus concentrates of varying CP contents were fed to lactating Jersey cows. The cow's performance was evaluated by determining the amount of milk produced, as well as butterfat and protein contents of milk.
- Another feeding trial, where five diets with varying amounts of oat silage and oat hay, plus concentrates of similar crude protein content were also fed to lactating Jersey cows.
- The *in sacco* technique was performed in cows on a high forage diet to determine ruminal degradability of oats, both hay and silage, plus lucerne. Samples of the rumen liquor were also collected to determine rumen pH, ammonia nitrogen and VFA.
- The *in sacco* technique was performed in cows on a high concentrate diet to determine ruminal degradability of oats, both hay and silage plus lucerne. Samples of the rumen liquor were also collected to determine rumen pH.
- The *in sacco* technique to determine the differences in ruminal degradability of fresh, freeze dried and oven dried silages. This study was performed only in Jersey cows.

1.10 References

- Allen, M. S., 1996. Relationship between fermentation acid production in the rumen and the requirements for physically effective fibre. *J. Dairy Sci.* 80: 1447.
- Baard, J. A. J., 1989. Verslag: Situasiebepaling oor melkbeesboerderye in die Winterreënstreek, Swartland Substreek. Department Landbou - Ontwikkeling. Elsenburg
- Blaser, R. E., 1978. Looking to the future in forage-animal production. *Proceedings of the 35th Southern Pasture and Forage Improvement Conference*. Sarasota, Florida: 75.
- Boyazoglu, P. A., 1997. Animal Nutrition, Concepts and application, 2nd edition. J. L. van Schalk Publishers, Pretoria. 145.
- Brand, T.S., Franck, F., & Cloete, S.W.P., 1992. Substitution of lucerne hay by untreated , urea-enriched and urea-ammoniated wheat straw in diets for sheep. *S. A. J. Anim. Sci.* 22 (6) 185.
- Brandt, R. T., & Klopfenstein, T. J., 1986. Evaluation of alfalfa-corn cob associative action. 1. Interaction between alfalfa hay and ruminal escape protein on growth of lambs and steers. *J. Anim. Sci.* 63: 894.
- Brandt, D. A., 1998. Nutritional evaluation of alternative protein and energy sources in the Western Cape. *M.Sc. Thesis*, University of Stellenbosch. 83.
- Brown, W. C., 1975. Oats. In: Australian Field Crops. Volume 1. Wheat and other temperate cereals. Edited by: Lazenby, A. and Matheson, E. M., Angus and Robertson Publishers, Australia.
- Browne I., Allen D.; Phipps, R. & Sutton J., 1995. Mixed forage diets for dairy cows. Summary of a MMB Sponsored Research Project, Cedar, U.K.

- Campbell, L. D., Biola, R. J. & Stothers, S. C., 1995. Variation in chemical composition and test weight of barley and wheat grain grown at selected locations throughout Manitoba. *Can. J. Anim. Sci.* 75: 239.
- Chamberlain, D. G., Martin, P.A. & Robertson, S., 1989. Optimising compound feed use in dairy cows with high intakes of silage. *Rec. Adv. Anim. Nut.* 175.
- Cruywagen, C. W., 1998. Suiwelbestuurtegnologie en melkwinning. Klasnotas, Departement Veekundige Wetenskappe, Universiteit van Stellenbosch.
- Dugmore, T. J., 1995. Rearing dairy replacement heifers. Dairying in Kwa-Zulu Natal, Kwa-Zulu Natal Department of Agriculture, Pietermaritzburg.
- Ensminger, M. E., 1977. Animal Science. 7th ed. The Interstate Printers and Publishers, Danville, Illinois.
- Ensminger, M. E., 1956. The stockman's handbook. 4th ed. The Interstate Printers and Publishers, Danville, Illinois.
- Goings, R. & Sniffen, C., 1992. What makes some cows last longer, *SA Jersey*. 41(3): 59.
- Gordijn, R. J. & Whitehead, E. N. C., 1995. Dairy Business Management. Dairying in Kwa-Zulu Natal. Kwa-Zulu Natal Department of Agriculture, Pietermaritzburg.
- Grant, R. J., 1997. Feeding to maximise milk solids. NebGuide Publication <http://www.ianr.unl.edu/pubs/dairy/g1320.htm>
- Grant, R. J., 1990. Maximising feed intake for maximum milk production. NebGuide Publication. <http://www.ianr.unl.edu/pubs/dairy/g1003.htm>
- Grant, R. J., & Keown, J. F., 1990. Nutritional management of the high producing cow in the 1990's. www.ianresearch.unl.edu/pubs/dairy/g999.htm.

Hardy, M., 1998. Towards sustainable crop production in the Swartland: a short review. *Elsenburg Journal*, 2: 42.

Harris, B. Jr., 1992. Nutrient requirements of dairy cattle.

http://edis.ifas.ufl.edu/scripts/htmlgen.exe?DOCUMENT_DS087

Huhtanen, P., Jaakkola, S. & Saarisalo, E., 1995. The effects of concentrate energy source on the milk production of dairy cows given a grass silage-based diet. *Anim. Sci.* 60: 31

Hunt C. W., Paterson, J. A., & Williams, J. E., 1985. Intake and digestibility of alfalfa-tall fescue combination diets for lambs. *J. Anim. Sci.* 60: 301.

Keady, T. W. J., 1998. The production of high value grass silage and the choice of compound feed type to maximise animal performance. In: European, Middle Eastern & African Lecture Tour, Alltech.

Keady, T. W. J. & Murphy, J. J., 1996. Effect of inoculant treatment on silage fermentation, digestibility, rumen fermentation, intake and performance of lactating dairy cattle. *Grass Forage Sci.* 64: 17.

Khorasani, G. R., Okine, E. K.; Kennelly, J. J. & Helm, J. H., 1993. Effect of whole crop cereal grain silage substituted for alfalfa silage on performance of lactating dairy cows. *J. Dairy Sci.* 76: 3536.

Klingman, G. C., 1958. Crop production in the South. Southern Farm Series. John Wiley & Sons, New York, USA.

Larson, R. L., 1999. Another perspective on milk production.

http://www.angus.org/journal/99_01jan/vetcall.htm.

Leng, R. A., 1982. A theoretical discussion on the factors limiting production in cattle fed basal diets of straw. *Proc. 3rd Bangladesh Conference on Straw utilisation*. 79. Bangladesh Agricultural University, Mynensinh, Bangladesh.

Marten, G., August, 10, 1982. Barley tops oats as a forage for dairy cattle. *Hoards Dairyman*: 1005.

Marx, G. D., January 10, 1983. Consider small grain forage when you are short of feed. *Hoards Dairyman*. 128(1):56

Meissner, H. H., Zacharias, P. J. K. & O'Reagain, P. J., 1999. Forage quality (Feed value). In: *Veld Management in South Africa*. Edited by Tainton, N., University of Natal Press, Pietermaritzburg, South Africa.

Miller, W. J., 1979. Dairy cattle feeding and nutrition. Academic Press Publishers, New York. 358.

Morkel, W. A. K., 1921. Silage and silos. *The Farmers' Advocate*: 835.

Morrison, F. B., 1961. Feeds and Feeding. 9th ed. The Morrison Publishing Company, Canada.

Muller, C. J. C. & Botha, J. A., 1996. Soetlupienkuilvoer of hawerhooi as ruvoer vir lakterende Jerseykoeie. *Elsenburg Journal*. 2: 38.

Muller, C. J. C. & Botha, J. A., 1998. The comparative performance of primiparous Holstein-Friesland and Jersey cows on complete diets during summer in a temperate climate. *S. A. J. Anim. Sci.* 28: 161.

Muller, C. J. C., Botha, J. A., Engelbrecht, A. M., & D'Hangest D'Yvoy, E. D., 2000. The chemical composition of silages produced in a Mediterranean climate. *South African Society of Animal Science 38th Congress Programme and Summaries*. KwaZulu-Natal: 47.

National Research Council, 1984. Nutrient Requirements of Domestic Animals. 6th ed. National Academy Press, Washington, DC.

National Dairy Cattle Performance Testing Scheme, 1 September 1999 - 31 August 2000. Breed & Herd Averages, Volume 19. Animal Improvement Institute, Irene, Republic of South Africa.

Ndlovu, L. R., and Buchanan-Smith, 1985. Utilisation of poor quality roughages by sheep: Effects of alfalfa supplementaion on ruminal parameters, fibre digestion and rate of passage from the rumen. *Can. J. Anim. Sci.* 65: 693.

Racz, V. J., 2000. Forages, key feed ingredients. Animal and Poultry Science, University Saskatchewan. www.usask.ca/research.html

Rayburn, B. E., 1997. Forage Quality - Fibre and Energy. www.caf.wvu.edu/~forage/5012.htm

Raymond, F., Redman, P. & Waltham, R., 1986. Forage conservation and feeding. Farming Press LTD, Suffolk.

Raymond, F., Shepperson, G. & Waltham, R., 1982. Forage conservation and feeding. Farming Press LTD, Suffolk.

Robinson, P. H., 1998. Profitable feeding strategies for dairy cows. General guidelines to utilise low quality forage. www.dairy.biz.com/archive/nutrition-18.htm

Rotz, C. A. & Muck R. E., 1994. Changes in forage quality during harvest and storage. In: Forage quality, evaluation, and utilisation. Edited by Fahey, C. G. Jr., Mertens, D. R., Collins, M. & Moser, L. E., 1994. Madison, USA: 828

Russell, J. B. & Wilson, D. B., 1996. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? *J. Dairy Sci.* 79: 1503.

Shaver, R. D., April 25, 1986. Need an alternative forage? Consider small grain silage. *Hoards Dairyman*: 425.

Smith, W. A., Cruywagen, C. W., & Maree, C., 1993. Dairy production systems. In: Livestock production systems, principles and practice. Edited by Maree, C. & Casey, N. H., 1993. Agri Development Foundation. 222

Soofi, R., Fahey, G. C., JR., Berger, L. L., & Hinds, F. C., 1982. Digestibilities and nutrient intake by sheep fed mixtures of soybean stover and alfalfa. *J. Anim. Sci.* 54: 841.

Van der Merwe, F. J., 1983. Diervoeding, 3rd edition. Kosmo-Uitgewery EDMS BPK, Stellenbosch.

Van der Merwe, F. J. & Smith, W. A., 1991. Diervoeding. Animal Science (Pty) Ltd., Pinelands, South Africa.

Viet, T. Q., Kien, D. D., & Ly, L. V., 2000. Chemical composition and in sacco and in vitro fermentation of dried rice straw-chicken litter and urea-treated rice straw. In: Workshop-seminar "Making better use of local feed resources" SAREC-UAF, January , 2000. National Institute of Animal Husbandry, Hanoi.

<http://www.uta.edu.kh/sarpro/viet.htm#Back%20to%20contents>

Weiss, B., 2000. Small grain forages for dairy cattle. Department of Animal Sciences, OARD/OSU, Wooster. www.scas.cornell.edu/forage/comments/grain.html

Weiss W. P., Eastridge, M. L. & Underwood, J. F., 2001. Forages for Dairy Cattle. Ohio State University Extension. Ohio State University Fact Sheet
<http://ohioline.osu.edu/as-fact/0002.html>

Wilde, D, 2001. Nutritional management of the transition cow: Effects on reproduction and production. Frank Wright Ltd, Derbyshire, United Kingdom
http://www.agri24.com/Mini_Web_AFMA/Images/20010402143305paper19.htm

Woolford, M.K., 1990. Silage: Rethinking Silage Fermentation. What Happens? Is it Necessary? Can we Change it to Control Effluent and Make it More Suitable for Rumen Fermentation? Oxford Biological Consultancy, Great Britain.

CHAPTER 2

The production performance of lactating Jersey cows receiving varying levels of lucerne hay and oat silage as forage sources.

Abstract

Ten multiparous lactating Jersey cows, 8 weeks post-calving were allocated to five diets according to a cross-over experimental design. The five diets contained combinations of oat silage (OS) and lucerne hay (LH) plus concentrate mixtures containing 26, 23, 20, 17 and 14% crude protein (CP). Lucerne hay was fed at varying levels of 0, 2, 4, 6, and 8 kg DM/cow/day while oat silage was fed ad libitum. The concentrate mixtures containing different CP levels were fed at a flat rate of 6.5kg per cow per day. Each feeding period consisted of a 2-week adaptation and a 3-week experimental period. During the experimental period, the following parameters were measured: dry matter intake (DMI), milk production, milk composition and milk urea nitrogen (MUN). The DM intake of cows receiving only ad libitum OS as a forage source was lower ($P<0.05$) than other forage combinations. Milk yield, milk fat and MUN did not differ ($P>0.05$) between treatments. Kilogram protein production of cows receiving only ad libitum OS as a forage source was lower ($P<0.05$) than that of cows receiving other forage combinations.

Key words: lactating Jersey cows, oat silage, lucerne, dry matter intake, concentrates, milk yield, milk composition.

2.1 Introduction

Although the unit cost of oat silage is lower than that of most alternative feeds, it is seldom used as the only feed for productive stock. This is because of its deficiency in crude protein (CP), vitamins and some minerals (Morrison, 1961). Silages are characterised by a high moisture content resulting in a quick rumen fill at a low dry matter (DM) intake. Intake in ruminants depends on the capacity of their digestive tracts, especially the rumen. When rumen fill is achieved, the ruminant stops eating (Meissner *et al.*, 1999).

The aim of the dairy farmer is to maximise income from the sale of milk and calves. To accomplish this goal, maximisation of DM intake must be a priority (Wilde, 2001). When feeding oat silage, the aim is to include as much of it in the total diet without reducing the level of animal production (Raymond *et al.*, 1982).

Feeding oat silage with forages such as lucerne hay, results in improved animal performance. Positive associative effects between lucerne hay and poor-quality forages have been identified by a number of researchers. These include increased intake (Soofi *et al.*, 1982), digestibility (Hunt *et al.*, 1985), daily gain (Brandt & Klopfenstein, 1986a), VFA and $\text{NH}_3\text{-N}$ levels and *in sacco* rate of fibre digestion (Ndlovu & Buchanan-Smith, 1985). Leng (1982) postulated that there is a strong possibility that a small supplement of lucerne hay may have a beneficial effect on microbial growth in the rumen by providing essential co-factors.

Lucerne hay has a high protein content and efficiency of protein utilisation is increased when fed with low-protein high-energy feeds (Smith *et al.*, 1983). It has a lower NDF content than grasses and livestock eat more of it than grass hay (Rayburn, 1997). Lucerne is the most important hay crop in South Africa. This is because of its ability to withstand the brackish soils of the semi-arid South Africa under which very few crops thrive. Above all, lucerne hay is palatable, it has a high protein and calcium contents and is also high in vitamins (Smith *et al.*, 1983).

In the Western Cape, oat silage is often fed with lucerne hay (Muller, 2001, personal communication). Western Cape dairy farmers buy lucerne hay from other parts of South Africa. This causes lucerne to be an expensive forage source in the Western Cape as there are transport costs involved. Lucerne is also sometimes difficult to obtain in some years (Brand *et al.*, 1992). There is little information available on the minimum levels at which lucerne hay should be included when fed with oat silage to dairy cows without impairing their performance.

The objective of this study was therefore to determine the minimum amount of lucerne hay that can be fed with oat silage to maximise intake and production by lactating Jersey cows.

2.2 Materials and methods

2.2.1 Experimental area

The study was conducted at the Elsenburg Experimental Station in the Western Cape Province of South Africa. Elsenburg is situated 12km north-west of Stellenbosch at an altitude of 177m, latitude 33° 51'S and longitude 18° 50'E (Anonymous, 1989). Elsenburg is in the winter rainfall region which makes it possible to grow small grain forages. The average rainfall is 605mm per annum with the highest precipitation occurring between May and August. The rainfall during these winter months ranges between 85.8 to 93.6mm per month, whereas during the summer months it ranges between 15.2 and 23.1mm per month (Anonymous, 1989).

2.2.2 Experimental animals and experimental design

Ten multiparous lactating Jersey cows were used in the experiment. All cows started with the first treatment approximately 8 weeks post-calving. The cows were allocated to five diets according to a cross-over experimental design.

2.2.3 Experimental feeds

Oats was planted at Elsenburg after the first winter rains and harvested at the soft dough stage. It was then ensiled in a pit silo for a period of 6 weeks to ferment after which it was ready for use in the experiment. Lucerne hay (LH) was obtained from Upington in the Northern Cape Province of South Africa. Using the two forages at varying levels, five diets were formulated using De Kock's model (1999). Lucerne hay was fed at levels of 0, 2, 4, 6, and 8 kg DM/cow/day together with *ad libitum* oat silage (OS). These forage combinations were supplemented with a concentrate mixture to ensure a total diet containing 14% CP. Concentrates therefore had CP levels of 26, 23, 20, 17 and 14% and were fed at a flat rate of 6.5kg DM/cow/day. The feed ingredients of the concentrate mixtures are shown in Table 1.

Table 1: Composition of the concentrate mixtures supplying different CP levels per 1000kg feed using De Kock's model (1999).

CP contents of concentrates (%)	Ingredients of concentrates				
	26	23	20	17	14
Feed ingredients		kg			
Wheat	100	100	100	100	100
Barley	100	100	100	100	100
Wheat bran	82	84	86	88	90
Cottonseed oilcake meal	200	172.5	145	117.5	90
Maize	280	323.5	367	410.5	454
Soybean oilcake meal	150	125	100	75	50
Fishmeal	14	13	12	11	10
Molasses	40	40	40	40	40
Urea	16	12	8	4	0
Limestone	13	12.5	12	11.5	11
Salt	5	5	5	5	5
Wheat straw	0	12.5	25	37.5	50

The concentrate mixture containing 26% CP was fed with a 100% OS diet whereas the 14% CP concentrate was fed with a 100% LH diet. The allocation of experimental feeds is shown in Table 2.

Table 2. Allocation of experimental feeds within treatments

Experimental feeds	Treatments				
	A	B	C	D	E
OS (kg DM/cow/day)	<i>Ad lib</i>	<i>Ad lib</i>	<i>Ad lib</i>	<i>Ad lib</i>	0
LH (kg DM/cow/day)	0	2	4	6	8
Concentrate mixture (%CP)	26	23	20	17	14

OS = oat silage, LH = lucerne hay

2.2.4 Management of animals before and during the experiment

Cows were kept in individual stalls to determine forage intakes. Separate feed troughs were used to determine the intake of individual forages.

Each feeding period consisted of a 2-week adaptation and a 3-week experimental period. During the first four days of adaptation, cows were fed OS, concentrates, LH and a total mixed ration (TMR). At Elsenburg, the TMR is normally fed to lactating cows in the first two months of lactation. Before the start of the experiment, all the cows received the same TMR. It was fed at 8kg on the first day of adaptation, and this was decreased by 2kg each day until the 5th day when cows received no TMR. Each decrease in TMR provided was accompanied by an increase in the amount of OS given. In the second week of adaptation, cows received the treatment diet according to the experimental design.

During the experimental period, weighed amounts of fresh forages (LH and OS, fed separately) were provided to the cows every afternoon. Refusals from the previous feeding were removed and weighed before providing fresh feed. Fresh drinking water was available

ad libitum inside each stall. Cows were machine-milked twice a day at 05H00 and 15H30 and the milk yield of each cow recorded. The total milk yield per day was calculated as the sum of the morning and afternoon milk.

2.2.5 Determining dry matter intake

Dry matter intake of each individual cow was determined twice a week. Feed provided and refusals before giving fresh feed were weighed. Small samples from both refusals and fresh feed were collected, weighed and dried in separate pans in an oven at a temperature of 65⁰C for 48 hours for DM analysis. The percentage feed DM was calculated as kilogram feed after drying per kilogram feed before drying. Dry matter intake was expressed as the difference between amount DM given and consumed.

2.2.6 Chemical analysis of the feed

The oat silage pH was determined once a week. This was done by extracting juice from the silage and taking the reading from the extracted silage juice using the portable pH meter. Dried material of both OS and LH was subjected to laboratory analysis for CP and crude fibre contents according to the methods of the AOAC (1990). The TDN content was determined according to the method of Engels & van der Merwe (1967).

2.2.7 Collection of milk samples

Milk samples were collected twice a week from morning and afternoon milk and mixed. The combined daily sample was analysed for fat, protein and lactose content using a Milko-Scan Infrared Analyser. The samples were also analysed for milk urea nitrogen (MUN) content. The 4% fat corrected milk (FCM) yield was calculated using the following equation:

$$4\% \text{ FCM} = (15 * \text{kg fat yield}) + (0.4 * \text{milk yield})$$

2.2.8 Evaluating the efficiency of feed conversion (EFC)

The efficiency at which the ingested feed was converted into milk was determined. EFC was calculated as the amount of milk produced per cow per kilogram feed consumed.

2.2.9 Data analysis

Production and feed intake data were analysed according to a Multi-factor analysis of variance using the Statgraphics programme (Statgraphics, 1991). Significant differences were declared at $P < 0.05$.

2.3 Results and discussion

2.3.1 Feed composition

The chemical composition of feeds used in the study is presented in Table 3.

Table 3. Chemical composition of feeds (values on DM basis)

	Forages		Concentrates (CP %)				
	LH	OS	26	23	20	17	14
CP	17.42	7.54	26.5	23.6	20.8	17.9	14.6
NDF	45.31	61.32					
ADF	38.14	38.26					
TDN	56.4	64.2	78.8	77.5	79.2	79.1	80.2
pH		3.8					

LH = lucerne hay, OS = oat silage, CP = crude protein, NDF = neutral detergent fibre,
ADF = Acid detergent fibre, TDN = total digestible nutrients

The CP, NDF, ADF and TDN contents of the OS were similar to those observed by Muller *et al.*, (2000). The silage pH was within the 3.8 to 4.2 range suggested by Rotz & Muck (1994).

The crude protein content of LH is within the range of 12% - 20%, and TDN 53 – 60 (late harvested and early harvested, respectively) observed by Van der Merwe, (1983).

The percentage CP and RDP contents of feedstuffs used in the experiment are presented in Table 4. The degradability values of the feedstuffs ranged between 36 and 100%, with urea and molasses having a 100% ruminal degradability. Forages and forage by-products show higher rumen degradability than animal products, such as fishmeal.

Table 4. Crude protein and RDP contents of feedstuffs used in the experiment

Feedstuffs	CP (%)	RDP (%)
Barley	11	71
Wheat	14	86
Wheat bran	17	84
Cottonseed oilcake meal	40	54
Maize	9	53
Soybean oilcake meal	44	61
Fishmeal	71	36
Urea	288	100
Molasses	6	100
Wheat straw ^a	4.8	65
Lucerne	16.1	79
Oats	12.3	92

Erasmus (1992); ^a NRC (2001)

RDP = Rumen degradable protein, CP = Crude Protein

The diets formulated for the experiment contained more than 50% forage. This agrees with the guidelines by Dugmore (1995) that 35-40% of the dairy cow's diet must be forage. The CP content of the feed was also above 14%. According to Grant (1991), CP should make up 14 to 19% of the total feed DM in dairy cow. The CP and RDP contents of the concentrate mixtures supplying different CP levels per 1000kg feed are presented in Table 5.

Table 5. Calculated crude protein and RDP values of the concentrate mixtures supplying different CP levels per 1000kg feed.

Feed ingred.(g)	Protein content of concentrates (kg)					
	26%		23%		20%	
	CP	RDP	CP	RDP	CP	RDP
Barley	1.1	0.781	1.1	0.781	1.1	0.781
Wheat	1.4	1.204	1.4	1.204	1.4	1.204
Wheat bran	1.4	1.17	1.4	1.20	1.5	1.230
COM	8	4.32	6.9	3.73	5.8	3.13
Maize	2.5	1.34	2.9	1.54	3.3	1.75
SOB	6.6	4.03	5.5	3.36	4.4	2.68
Fishmeal	1.0	0.35	0.9	0.33	0.9	0.31
Urea	4.6	4.61	3.5	3.46	2.3	2.30
Molasses	0.24	0.24	0.24	0.24	0.24	0.24
Wheat straw	0	0	0.1	0.039	0.1	0.078
Total	26.8	18.05	23.9	15.92	21.0	13.46
% conc. RDP		67.23		66.40		65.54
% conc. RUP		32.77		33.6		34.46

RDP = Rumen degradable protein, RUP = Rumen undegradable protein, CP = Crude Protein, SOB = Soybean oilcake meal, COM = Cottonseed oilcake meal

2.3.2 Feed intake

The feed intake of cows is presented in Table 6. As expected, DM intakes of the two forages differed significantly ($P < 0.01$) between treatments. This is because the diets were formulated such that a decrease in LH offered to cows should be accompanied by an increase in OS consumed.

Table 6. Forage and concentrate intake of Jersey cows receiving *ad libitum* oat silage and varying amounts of lucerne hay

	Treatments					P
	A	B	C	D	E	
Lucerne	0.00 ^a	1.54 ^b	2.71 ^c	4.24 ^d	7.75 ^e	0.01
Silage	6.9 ^a	6.13 ^b	5.19 ^c	4.33 ^d	0.00 ^e	0.01
Concentrates	6.2	6.25	6.25	6.29	6.29	0.21
Total DMI	13.1 ^a	13.92 ^{ab}	14.15 ^b	14.85 ^b	14.05 ^{ab}	0.03
Total CP intake	16.37	15.79	15.29	14.72	16.15	C
% RDP intake	80.28	79.06	77.58	76.28	71.21	C
% RUP intake	19.72	20.94	22.42	23.72	28.79	C
TDN intake	71.12	69.31	69.35	68.94	66.98	C

DMI = Dry matter intake, CP = crude protein, TDN = total digestible nutrient, C = calculated values, P = significance level, ^{a,b,c} Means within rows with different superscripts, differed significantly.

However, cows did not eat all of the LH allocated to them. This can probably be related to individual cow preferences. However, the total DM intake of cows was still within the NRC guidelines that producing cows should receive 2 to 4% of body weight (NRC, 2001).

Cows receiving only OS as a forage source had a lower ($P < 0.05$) DM-intakes than cows receiving varying amounts of LH plus OS or LH alone (Table 6). This is probably because of the high moisture content of silage which results in quick rumen fill with little DM intake. These results accord with those of Browne *et al.* (1995), who found higher mean DM-intakes

by replacing one third, or more, of a grass silage with an alternative forage. Keenan (2001) suggested that addition of chopped straw in a silage-based diet reduces the acid load in the rumen and tends to dry out the diet giving it a more open and fluffy texture that increases the palatability.

The higher DM intake when LH was added to the diet can also be assumed to be result of increased microbial activity causing an increased ruminal digestibility. Leng (1982) postulated that there is a strong possibility that a small supplement of lucerne hay may have a beneficial effect on microbial growth by providing essential co-factors. This results in increased digestibility of low quality forages and therefore intake. According to these authors, increased feed intakes from such forage mixtures usually results in higher milk yields and gross income. However, Keady & Murphy (1998), found that feeding forage, conserved as silage using a good ensiling technique did not affect intake.

Protein intakes of all the cows were above 14%. The minimum requirement for small breed cows (i.e., cows less than 454kg liveweight) producing less than 20kg is 14.1% (NRC, 2001). Dietary protein is separated into ruminally degraded (RDP) and undegraded (RUP) protein (Erasmus *et al.*, 1990), which have separate functions. Ruminally degraded CP provides a mixture of peptides, free amino acids and ammonia for microbial growth and synthesis of microbial protein, while RUP provides absorbable amino acids to the host animal (NRC, 2001).

The percentage RUP intake was calculated as: $100 - \% \text{ RDP}$. All diets seemed to have RUP values of below 30%. The cows used in this trial, classified under small breeds by the NRC (2001) require 30% RUP. Excess RDP results in an inefficient utilisation of nitrogen. To prevent this, the RDP: UDP ratio system of the NRC (1989) must be used when formulating the cow feed as it has an advantage when compared to the CP system. Use of this system results in less protein needed because of efficient utilisation (Erasmus, 1992).

2.3.3 Milk production and milk composition

The milk yield and milk composition of Jersey cows receiving *ad libitum* OS and varying amounts of LH are represented in Table 7. There was no significant difference ($P>0.05$) in milk production between treatments. Contrary to these findings, Keady and Murphy (1998), found decreased milk yield in cows that were fed grass silage diet compared to cows that were offered fresh herbage. Keady (1998) assumed reduction in animal performance to be due to the conversion of water-soluble carbohydrates to lactic and volatile fatty acids which are not good energy sources for rumen microbes.

Table 7. The production parameters of Jersey cows receiving *ad libitum* oat silage and varying amounts of lucerne hay

Production parameters	Treatments					
	A	B	C	D	E	P
Milk (kg/day)	16.3	17.0	16.9	17.2	17.2	0.18
Fat (%)	4.72	4.53 ¹	4.63	4.69	4.63	0.48
Fat (kg)	0.76	0.76	0.77	0.79	0.78	0.52
FCM (kg)	17.88	18.17	18.25	18.74	18.60	0.36
Protein (%)	3.46	3.50	3.46	3.54	3.53	0.55
Protein (kg)	0.55 ^a	0.59 ^b	0.57 ^{ab}	0.59 ^b	0.60 ^b	0.04
EFC (kg milk/kg feed)	1.24	1.22	1.19	1.16	1.24	0.18
MUN (mg/dl)	20.93	21.24	20.59	20.53	23.05	0.17

^{a,b,c} Means with different superscripts, within rows, differed significantly.

FCM = fat corrected milk; EFC = efficiency of feed conversion; MUN = milk urea nitrogen

With regard to milk composition, there were, with the exception of protein production, no significant differences ($P>0.05$) in production parameters for cows receiving different levels of

LH and *ad libitum* OS. Cows receiving only OS had a lower ($P<0.04$) protein yield than cows receiving a combination of OS and LH. This agrees with the findings of Keady (1998) who found decreased milk protein concentrations when silage was fed to lactating cows. This reduction in milk protein concentration can be associated with an insufficient energy supply to rumen microbes which results in a reduction in microbial protein synthesis.

Nowadays, milk pricing based on percentage protein is becoming more of a standard in the dairy industry. Milk fat is becoming less important due to consumer preference. Consumers prefer low fat milk for health reasons. A higher milk protein content is becoming more in demand for manufacturing dairy products such as cheese (Gustafsson & Palmquist, 1993). Feeding to increase milk protein production increases income in the dairy industry.

2.3.4 Efficiency of feed conversion (EFC)

The efficiency of feed conversion (Table 7) into milk, did not differ significantly ($P>0.05$) between the forage treatments. Muller & Botha (1998) found similar EFC values (1.18kg milk/kg DM consumed) for cows that were fed a TMR.

2.3.5 Milk Urea Nitrogen (MUN)

Milk Urea Nitrogen (Table 7) did not differ ($P>0.05$) between treatments. Although the MUN values observed in this study were fairly high, they were at least below 25mg/dl. The average MUN for the Elsenburg herd at the same time was 19.25mg/dl (Elsenburg herd, 1999). Values below 25mg/dl are considered to be within the acceptable range for individual cows and for the type of forage used. Research at Cornell University and the University of Illinois indicated that the MUN levels of 12 to 18 mg/dl for the herd average and 8 to 25 mg/dl of milk for individual cows be considered as guidelines (Grant, 1997). The results obtained in this trial are therefore in accordance with these guidelines.

MUN analyses can be used as a "red flag", to point out potential problems in a feeding program (Baker & Ferguson, 1999). A high MUN value may indicate a high CP, low rumen

fermentable non-fibre carbohydrate (NFC), or protein and NFC that are not properly combined in the diet. A low MUN value indicates low CP levels in the diets, high rumen fermentable NFC or improper mix of undegradable and degradable protein (Ferguson, 1999; Stallings, 1998). A low MUN can be associated with decreased milk and milk protein production (Grant, 1996). Milk urea is also of economical importance as it is positively correlated to rennet coagulation time in cheese manufacturing (Gustafsson & Palmquist, 1993).

2.3.6 Economic evaluation

The income received from different treatments is presented in Table 8. Feeding 2kg DM of LH together with OS resulted in the highest gross margin above feed cost while feeding LH as the only forage source resulted in the lowest income. This is probably due to higher feed cost. The calculated income from feeding *ad libitum* OS plus 2kg LH was above 5% higher than the gross margin from LH fed alone.

Table 8 Economic evaluation (R/cow/day)

Parameters	Income and expenditure (R/cow/day)				
	A	B	C	D	E
Silage	2.08	1.56	1.04	0.52	0.00
Lucerne	0.00	1.30	2.60	3.90	5.20
Concentrates	6.83	6.50	6.18	5.85	5.53
Milk income	21.19	22.10	21.97	22.36	22.36
GM above feed cost	12.28	12.74	12.15	12.09	11.63

Prices calculated as: milk R1.30/l, oat silage R260.00/ton and lucerne R650/ton, GM = Gross margin
Concentrates: A, 26% = R953, B, 23% = R907, C, 20% = R862, D, 17% = R816, E, 14% = R770/ton

2.4 Conclusion

Feeding silage as the only forage source for lactating cows had a negative effect on both DM intake and milk protein production. Feeds with a high moisture content lead to quick rumen fill. Rumen fill is an important factor affecting the cow's voluntary intake. If a state of satiety is reached, the cow stops eating irrespective of her nutritional requirements being met. To improve total DM intake, daily milk production and income, an inclusion of at least 2kg lucerne hay/cow/day in the diet is recommended.

2.5 References

- Anonymous, 1989. Climate statistics for the winter rainfall region. Compiled by the Agrometeorology Section, Elsenburg, Soil and Irrigation Research Institute, Department of Agriculture and Water Supply.
- Association of Official Analytical Chemists, 1990. *Official Methods of Analysis*. 15th ed. AOAC, Arlington.VA.
- Baker, L., & Ferguson, J., 2001. About MUN; VMD, New Bolton Center, University of Pennsylvania <http://www.dhia.psu.edu/mun.htm>
- Brandt, T.S., Franck, F., & Cloete, S.W.P., 1992. Substitution of lucerne hay by untreated , urea-enriched and urea-ammoniated wheat straw in diets for sheep. *S. A. J. Anim. Sci.* 22 (6) 185.
- Brandt, R. T., & Klopfenstein, T. J., 1986. Evaluation of alfalfa-corn cob associative action. 1. Interaction between alfalfa hay and ruminal escape protein on growth of lambs and steers. *J. Anim. Sci.* 63: 894.
- Browne, I., Allen, D., Phipps, R. & Sutton, J., 1995. Mixed forage diets for dairy cows. Summary of a MMB Sponsored Research Project, Cedar, U.K.
- De Kock, H. C., 1999. Least cost feed formulation programme. Department of Logistics, University of Stellenbosch. Stellenbosch
- Dugmore, T. J., 1995. Rearing dairy replacement heifers. Dairying in Kwa-Zulu Natal, Kwa-Zulu Natal Department of Agriculture, Pietermaritzburg.

Engels, E.A.N. & Van der Merwe, F.J., 1967. Application of an *in vitro* technique to South African forages with special reference to the effect of certain factors on the results. *S. A. J. Agric. Sci.* 10: 983.

Erasmus, L. J., 1992. Nuwe konsepte in die proteien voeding van herkouers 3. Toepassing van RDP: RUP sisteem vir melkkoeie. *AFMA Matrix*, September 1992. Irene Diereproduksie-Instituut: Privaatsak X2, Irene. p14

Erasmus, L. J., Prinsloo, J. & Botha, P. M., 1990. Establishment of a ruminal protein degradation database for dairy cattle using the *in situ* polyester bag technique. 3. Roughages. *S. A. J. Anim. Sci.* 20 (3): 130.

Ferguson J. D., 1999. Milk Urea Nitrogen. http://www.vet.upenn.edu/mun/mun_info.html

Grant, R. J., 1997. Feeding to maximize milk solids. NebGuide Publication
<http://www.ianr.unl.edu/pubs/dairy/g1320.htm>

Grant, R. J., 1996. Milk urea nitrogen testing. NebGuide Publication
<http://www.ianr.unl.edu/pubs/dairy/g1298.htm>

Grant, R. J., & Keown, J. F., 1990. Nutritional management of the high producing cow in the 1990's. www.ianresearch.unl.edu/pubs/dairy/g999.htm.

Gustafsson, A. H., & Palmquist, D. L., 1993. Diurnal variation of rumen ammonia, serum urea, and milk urea in dairy cows at high and low yields. *J. Dairy Sci.* 76: 475.

Hunt C. W., Paterson, J. A., Williams, J. E., 1985. Intake and digestibility of alfalfa-tall fescue combination diets for lambs. *J. Anim. Sci.* 60: 301.

Keady, T. W. J., 1998. The production of high value grass silage and the choice of compound feed type to maximise animal performance. In: European Middle Eastern & African Lecture Tour, Alltech.

Keenan, R., 2001. Coping with poor quality grass silage. Richard Keenan & Co. Ltd.
<http://www.keenantmr.com/>

Leng, R. A., 1982. A theoretical discussion on the factors limiting production in cattle fed basal diets of straw. *Proc. 3rd Bangladesh Conference on Straw utilisation.* 79-104. Bangladesh Agricultural University, Mynensingh, Bangladesh.

Meissner, H. H., Zacharias, P. J. K. & O'Reagain, P. J., 1999. Forage quality (Feed value). In: Veld Management in South Africa. Edited by Tainton, N., University of Natal Press, Pietermaritzburg, South Africa.

Morrison, F. B., 1961. Feeds and Feeding. 9th ed. The Morrison Publishing Company, Canada.

National Research Council, 2001. Nutrient requirements of dairy cattle. 7th ed. National Academy Press, Washington D. C. p44

Ndlovu, L. R., & Buchanan-Smith, 1985. Utilisation of poor quality roughages by sheep: Effects of alfalfa supplementaion on ruminal parameters, fibre digestion and rate of passage from the rumen. *Can. J. Anim. Sci.* 65: 693.

Rayburn, B. E., 1997. Forage quality-fibre and energy. West Virginia Extension Service
<http://www.caf.wvu.edu/~forage/5012.htm>

Rayburn, B. E., 1996. Forage Quality - Protein. West Virginia Extension Service
<http://www.caf.wvu.edu/~forage/5010.htm>

Raymond, F.; Shepperson, G. & Waltham, R., 1982. Forage conservation and feeding. Farming Press Limited, Suffolk. England

Rotz, C. A. & Muck R. E., 1994. Changes in forage quality during harvest and storage. In: Forage quality, evaluation, and utilisation. Edited by Fahey, C. G. Jr., Mertens, D. R., Collins, M. & Moser, L. E., 1994. Madison, USA: p828

Smith, W. A., Cruywagen, C. W., & Maree, C., 1993. Dairy production systems. In: Livestock production systems, principles and practice. Edited by Maree, C. & Casey, N. H., 1993. Agri Development Foundation. p222

Soofi, R., Fahey, G. C., Jr., Berger, L. L., & Hinds, F. C., 1982. Digestibilities and nutrient intake by sheep fed mixtures of soybean stover and alfalfa. *J. Anim. Sci.* 54: 841.

Stallings, C. C., 1998. Milk Urea Nitrogen
http://www.cals.ncsu.edu/an_sci/extension/dairy/cstallings.htm

Statgraphics 5.0., 1991. Statistical Graphic System. Statistical Graphic Corporation Incl., 2115 East Jefferson Street, Rockville, MD, 20852.

Wilde, D, 2001. Nutritional management of the transition cow: Effects on reproduction and production. Frank Wright Ltd, Derbyshire, United Kingdom.
http://www.argi24.com/Mini_Web_AFMA/Images/20010402143305paper19.htm

CHAPTER 3

The production performance of lactating Jersey cows receiving varying levels of oat hay and oat silage as forage sources.

3. Abstract

Ten multiparous lactating Jersey cows, 8 weeks post-calving, from the Elsenburg herd were allocated to five diets according to a cross-over experimental design. Diets contained combinations of oat hay (OH) and oat silage (OS) plus a concentrate mixture containing 26% crude protein (CP). Oat hay was fed at 0, 2, 4, 6, and 8 kg dry matter (DM)/day while OS was fed ad libitum. The concentrate mixture containing 26% CP was fed at a flat rate of 6.5kg per cow per day. Each feeding period consisted of five weeks that were divided into a 2-week adaptation and a 3-week experimental period. During the experimental period, the following parameters were measured: dry matter intake (DMI), milk production, milk composition and milk urea nitrogen (MUN). Cows that were fed only OS, or 2kg OH plus ad libitum oat silage as forage sources had a lower ($P<0.01$) DMI than cows receiving 4kg and 6kg oat hay per day. Also, cows that received only OH as forage source had a lower ($P<0.05$) DMI than cows fed the combination of OS and OH. Concerning milk production, milk fat, milk protein and milk urea nitrogen (MUN), there were no differences ($P>0.05$) between diets.

Key words: Lactating Jersey cows, oat silage, oat hay, dry matter intake, concentrates, milk yield, milk composition.

3.1 Introduction

Regular increases in the prices of purchased feeds make it difficult for dairy farmers to maintain positive economic gross margins. Feed costs comprise about 60-80% of the total costs in a dairy enterprise (Gordijn & Whitehead, 1995). Reducing feed cost of milk production has always been the aim of a dairy farmer as it results in higher net returns, however, it must not reduce with milk yield. Proper feeding management of the dairy cow is always important as it not only improves the economy of production, but also ensures a healthier cow (Grant, 1997).

Replacing purchased feeds with cheaper home produced forages can bring about a reduction in feed costs (Browne *et al.*, 1995). Conserving home produced forages either as silage or hay for feeding during periods of feed shortage (Ensminger, 1956), also contributes to lowering costs as this prevents buying forage from other parts of the country. In the Western Cape, home produced forages are small grain cereal crops such as oats, barley and wheat.

Oats is the most widely grown forage of all the small grain crops (Wilson, 1959) because of its high adaptability compared to other crops (Brown, 1975). Unlike other small grains, oats is primarily used as a feed for livestock, only a considerable quantity enters into processed food products (Wilson, 1959).

Oats is one of the eight most important cereal crops in the world. Like other cereals, oats has actually increased in total world production since the early 1960s. Results at Minnesota's North-West Experimental station indicate that oat silage can be fed as substitute for conventional forages such as lucerne or maize if harvested at the boot to early heading stage (Marx, 1982). Although the Western Cape is one of the major producers of oat forage, no studies have been done to determine the optimum inclusion level of oat silage when fed to lactating cows together with oat hay. A further aim of this study was to investigate whether oat silage can be used as the only forage source for lactating Jersey cows.

3.2 Materials and methods

The study was conducted at the Elsenburg Experimental station in the Western Cape Province of South Africa. Elsenburg is situated approximately 50km east of Cape Town in the winter rainfall region of South Africa (Anonymous, 1989). Ten multiparous lactating Jersey cows, 8 weeks post-calving, from the Elsenburg herd were used in the experiment. Five diets containing combinations of oat hay (OH) and oat silage (OS) plus a concentrate mixture containing 26% crude protein (CP) were formulated using De Kock's model (1999) and fed to lactating Jersey cows. Oat hay was fed at 0, 2, 4, 6, and 8 kg DM/cow/day while oat silage was fed *ad libitum*. The concentrate mixture containing 26% CP was fed at a flat rate of 6.5kg per cow per day.

Cows were allocated to the five diets according to a cross-over experimental design. They were kept in individual stalls to determine dry matter (DM) intakes. Separate feed troughs were used to determine individual forage intakes.

Each experimental period consisted of five weeks that was divided into a 2-week adaptation and a 3-week experimental period. Cows were fed a total mixed ration (TMR) before the start of the experiment together with oat silage, concentrates and oat hay. Initially, 8kg TMR was offered, reduced by 2kg per day and the other feed increased at the same rate. In the second week of the adaptation period, cows were offered the treatment diet according to the experimental design.

During the experimental period, a weighed amount of fresh forage, (i.e., either oat silage, oat hay or a combination of oat hay and oat silage) was given to the cows every afternoon. Refusals from the previous feeding were collected and weighed before providing fresh feed. Fresh drinking water was available *ad libitum* inside each stall. Dry matter intake of each individual cow was determined twice a week. This was done by taking samples from both refusals and fresh feed. These were weighed and dried in separate pans in an oven at a temperature of 65°C for 48 hours. The percentage feed DM was calculated as kilogram feed after drying per kilogram feed before drying. The dry matter intake was expressed as the

difference between the amount of DM and DM refused.

Cows were machine-milked twice a day at 05H00 and 15H30 and the milk yield of each cow recorded at each milking. Milk samples were collected twice a week, morning and afternoon milk mixed and analysed for milk urea nitrogen (MUN), fat, protein and lactose contents using a Milko-Scan Infrared Analyser.

Samples of the forages and the concentrates were collected once a week during the experimental period and analysed for chemical composition. Dried material was subjected to laboratory analysis for CP and crude fibre contents according to the methods of the AOAC (1990). Oat silage was evaluated weekly for pH and DM content. Production and feed intake data were analysed according to a multi-factor analysis of variance using the Statgraphics programme (1991). Differences between treatments were declared at $P < 0.05$.

3.3 Results and discussion

3.3.1 Feed composition

The chemical composition of the feeds used in this study is presented in Table 1. Oat silage and oat hay differed in CP and NDF contents, with oat hay being lower in CP but higher in NDF than oat silage. This indicates that the oat hay used in this experiment was of poorer quality. The crude protein content of oat silage was within the 4.7% and 11.3% range observed by Muller *et al.* (2000).

The silage pH was within the 3.8 to 4.2 range suggested by Rotz & Muck (1994), indicating that it was well preserved. All diets formulated for the experiment contained more than 50% forage and above 14% CP contents (Table 1). This composition agrees with the guidelines by Dugmore (1995) that 35-40% of the dairy cow's diet must be forage and protein should make up 14 to 19% of the total feed (Grant, 1990).

Crude protein and RDP values of feedstuffs used in the experiment as well as the CP and RDP contribution of each in the diet are shown in Table 2.

Table 1. The chemical composition of feed used in the experiment (values on DM basis)

Parameters	Oat silage	Oat Hay	Concentrates
CP	7.03	5.16	26.38
NDF	62.83	66.67	36.71
pH	3.97		

CP = crude protein, NDF = neutral detergent fibre

Table 2. Crude protein and RDP values of feedstuffs used in the concentrates

Feedstuffs	CP and RDP of feed (%)		Feedstuff contributions (kg)	
	CP	RDP	CP	RDP
Barley	11	71	1.1	0.781
Wheat	14	86	1.4	1.204
Wheat bran	17	84	1.394	1.17
Cottonseed oilcake meal	40	54	8.0	4.32
Maize	9	53	2.52	1.34
Soybean oilcake meal	44	61	6.6	4.03
Fishmeal	71	36	0.994	0.35
Urea	288	100	4.608	4.61
Molasses	6	100	0.24	0.24
Oats	12.3	92		

Crude protein and RDP contents of feed (%) (Erasmus, 1992)

Feedstuffs contributions = calculated values

3.3.2 Feed intake

The total daily intakes by Jersey cows receiving OH and OS as forage sources are presented in Table 3.

Table 3. The daily feed intake of Jersey cows receiving *ad libitum* oat silage and varying levels of oat hay

Parameters	Oat hay provided (kg DM/ day)					P
	0	2	4	6	8	
Oat hay (kg)	0.00 ^a	1.78 ^b	3.31 ^c	4.40 ^d	7.23 ^e	0.00
Oat silage (kg)	6.79 ^a	5.40 ^b	4.29 ^c	3.89 ^d	0.00 ^e	0.00
Concentrates (kg)	6.25	6.25	6.25	6.29	6.29	0.21
Total DMI (kg)	13.14 ^a	13.54 ^a	14.07 ^{ab}	14.69 ^b	13.58 ^a	0.02
Total CP intake (%)	16.07	15.67	15.09	14.71	14.97	C
RDP intake (%)	79.52	79.82	79.56	80.71	80.12	C
RUP intake (%)	20.48	20.18	20.44	19.29	19.88	C

DMI = Dry matter intake, CP = crude protein, C = calculated values, P = significance level, ^{a,b,c} Means within rows with different superscripts, differed significantly.

As expected, OS intake was reduced with increasing levels of OH in the diet. Cows receiving only *ad libitum* OS or 2kg OH plus *ad libitum* OS as forage sources had lower ($P < 0.05$) DM-intakes than cows receiving 4kg and 6kg OH (Table 3). The lower DM intakes can probably be associated with the moisture content of these two diets. High moisture content of feed results in quick rumen fill with little dry matter intake. Keenan (2001) suggested that a simple way to maximise silage intakes would be to include some chopped straw of about 4kg in the diet. This reduces the acid load in the rumen and tends to dry out the diet giving it a more open and fluffy texture that increases the palatability. The additional long fibre also stimulates cud chewing with the release of large amounts of saliva and maintaining a stable pH in the rumen (Keenan, 2001). For best DM intake, the total diets of cows must be kept under 50%

moisture (Howes, 1996). According to this author, the effects may not be all moisture, but can also be related to fermentation products produced during ensiling and the effect of a low pH on rumen microbes.

On the other hand, cows that received only OH also consumed less ($P < 0.05$) feed than cows that were fed 4 – 6kg OH. The reduced DM intake in these cows can probably be related to forage quality. The oat hay used in this study had low CP and high NDF levels. The NDF fraction is considered the primary dietary constituent associated with the fill effect (NRC, 2001). At high NDF concentrations in diets, DM intake is restricted because of feed bulkiness, rumen fill (Dado & Allen, 1995), slow rate of fibre digestion and delayed emptying of the rumen (Ndlovu & Buchanan-Smith 1985). Drier diets also limit DM consumption (Howes, 1996).

Crude protein intakes were above 14% for all the cows. Small breed cows weighing less than 454kg, producing less than 20kg milk require 14.1% CP when they are in mid-lactation (NRC, 2001). The rumen undegradable protein content of the feed (calculated as $100 - \%RDP$) was below 30% (Table 3) which is the required RUP content (NRC, 2001) for the type of cows. A high RDP content of feed results in inefficient utilisation of protein (Erasmus, 1992) as it may increase nitrogen excretion in faeces and urine (St-Pierre & Thraen, 1999).

3.3.2 Milk production and milk composition

Milk production and composition parameters did not differ ($P > 0.05$) between treatments (Table 3). Cows receiving 4 – 6kg OH per day together with *ad libitum* OS were expected to produce more milk. The assumption was based on the fact that higher DM intake results in higher milk yields. This probably suggest that higher milk yield results from higher intake of good quality forage. The efficiency in which the consumed feed was converted into milk also did not differ significantly ($P > 0.05$) between treatments.

There was no significant difference ($P>0.05$) in MUN (Table 3) between treatments. All the MUN values of the cows were between 12 to 18 mg/dl. Research at Cornell University and the University of Illinois indicated that the MUN of 12 to 18 mg/dl for the herd average and 8 to 25 mg/dl of milk for individual cows be considered as guidelines (Grant, 1996). The results obtained in this trial are therefore in accordance with these guidelines.

Table 3. The production parameters of Jersey cows receiving varying amounts of oat hay together with *ad libitum* oat silage.

Production Parameters	Oat hay provided (kg DM/day)					
	A	B	C	D	E	P
Milk (kg/day)	15.07	15.42	15.31	15.55	14.96	0.69
Fat (%)	5.00	5.00	4.93	5.06	4.90	0.68
Fat (kg)	0.75	0.77	0.76	0.77	0.74	0.82
FCM (kg)	17.34	17.66	17.64	17.73	17.07	0.83
Protein (%)	3.74	3.74	3.74	3.79	3.77	0.88
Protein (kg)	0.57	0.58	0.58	0.58	0.57	0.94
EFC (milk/kg feed)	1.15	1.14	1.09	1.06	1.10	0.38
MUN (mg/dl)	15.05	15.68	15.52	15.74	16.12	0.73

FCM = fat corrected milk, EFC = efficiency of feed conversion, MUN = milk urea nitrogen

3.3.3 Economic evaluation

The production costs and profit received when using OS and OH as forage sources are presented in Table 4. It appears that maximum gross margin (GM) would occur when 2 to 6kg OH is included in OS based diets for Jersey cows. The highest profit was obtained when 6kg OH was fed with *ad libitum* OS. The calculated income from feeding *ad libitum* OS plus 6kg OH was about 8% higher than the gross margin from OS fed alone.

Table 4 Economic evaluation (R/cow/day)

	A	B	C	D	E
Oat silage	2.08	1.56	1.04	0.52	0.00
Oat hay	0.00	0.40	0.80	1.20	1.60
Concentrates	6.83	6.83	6.83	6.83	6.83
Milk income	19.59	20.05	19.90	20.22	19.45
GM above feed cost	10.68	11.26	11.23	11.67	11.02

Prices calculated as: milk R1.30/l, oat hay R200.00/ ton and oat silage R260.00/ton.

3.4 Conclusion

Although there were no differences in production parameters of the cows on different forage diets, an amount of 2 to 6kg oat hay per cow per day is recommended when feeding oat silage diets to lactating Jersey cows. Feeding only oat silage as a forage source is not recommended as its high moisture content results in quick rumen fill and reducing DM intake. Addition of hay also reduces the acid load in the rumen and tends to dry out the diet giving it a more open and fluffy texture that increases the palatability. This indicates that adding hay does not only improve profit margins, but also DMI and a healthier cow.

3.5 References

Agricultural Economics and Statistics, 1974. Vol. 23, No 2, FAO, Rome.

Anonymous, 1989. Climate statistics for the winter rainfall region. Compiled by the Agrometeorology Section, Soil and Irrigation Research Institute, Department of Agriculture and Water Supply. Elsenburg.

Association of Official Analytical Chemists, 1990. *Official Methods of Analysis*. 15th ed. AOAC, Arlington.VA.

Brown, W. C., 1975. Oats. In: Australian Field Crops. Volume 1. Wheat and other temperate cereals. Edited by: Lazenby, A. & Matheson, E. M. Angus and Robertson Publishers, Australia.

Browne I., Allen D., Phipps, R. & Sutton, J., 1995. Mixed forage diets for dairy cows. Summary of a MMB Sponsored Research Project, Cedar, U.K.

Dado, R. G & Allen, M. S., 1995. Intake limitations, feeding behaviour and rumen function of cows challenged with rumen fill from dietary fibre of inert bulk. *J. Dairy Sci.* 78: 118

De Kock, H. C., 1999. Least cost feed formulation programme. Department of Logistics, University of Stellenbosch.

Dugmore, T. J., 1995. Rearing dairy replacement heifers. Dairying in Kwa-Zulu Natal, Kwa-Zulu Natal Department of Agriculture, Pietermaritzburg.

Engels, E.A.N. & Van der Merwe, F.J., 1967. Application of an *in vitro* technique to South African forages with special reference to the effect of certain factors on the results. *S.A.J. Agric. Sci.* 10: 983.

Ensminger, M. E., 1956. The stockman's handbook. 4th ed. The Interstate Printers and Publishers, Danville, Illinois. 222

Erasmus, L. J., 1992. Nuwe konsepte in die proteienvoeding van herkouers. 3. Toepassing van RDP: RUP sisteem vir melkkoeie. *AFMA Matrix*, September 1992. Irene Diereproduksie-instituut: Privaatsak X2, Irene. p14

Gordijn, R. J. & Whitehead, E. N. C., 1995. Dairy Business Management. Dairying in Kwa-Zulu Natal. Kwa-Zulu Natal Department of Agriculture, Pietermaritzburg.

Grant, R. J., 1997. Feeding to maximize milk solids. NebGuide Publication
<http://www.ianr.unl.edu/pubs/dairy/g1320.htm>

Grant, R. J., 1996. Milk Urea Nitrogen Testing. NebGuide Publication
<http://www.ianr.unl.edu/pubs/dairy/g1298.htm>

Grant, R. J., 1990. Maximising feed intake for maximum milk production. NebGuide Publication. <http://www.ianr.unl.edu/pubs/dairy/g1003.htm>

Howes, A. D., 1996. Production efficiency for dairy cows. In: Alltech's 1996 European & Southern Africa Lecture Tour. Alltech.

Keenan, R., 2001. Coping with poor quality grass silage. Richard Keenan & Co. Ltd.
<http://www.keenamtmr.com/>

Marx, G. D., 1982. Consider small grain forage when you are short of feed. *Hoard's Dairyman*. 128:56-57(1)

Muller, C. J. C., Botha, J. A., Engelbrecht, A. M., & D'Hangest D'Yvoy, E. D., 2000. The chemical composition of silages produced in a Mediterranean climate. *South African Society of Animal Science 38th Congress Programme and Summaries*. KwaZulu-Natal: 47.

Ndlovu, L. R., & Buchanan-Smith, 1985. Utilisation of poor quality roughages by sheep: Effects of alfalfa supplementaion on ruminal parameters, fibre digestion and rate of passage from the rumen. *Can. J. Anim. Sci.* 65: 693.

National Research Council, 2001. Nutrient requirements of dairy cattle. 7th ed. National Academy Press, Washington D. C. p 44

Rotz, C. A. & Muck R. E., 1994. Changes in forage quality during harvest and storage. In: Forage quality, evaluation, and utilisation. Edited by Fahey, C. G. Jr., Mertens, D. R., Collins, M. & Moser, L. E., 1994. Madison, USA: p828

Statgraphics 5.0., 1991. Statistical Graphic System. Statistical Graphic Corporation Incl., 2115 East Jefferson Street, Rockville, MD, 20852.

St-Pierre, N. R. & Thraen, C. S., 1999. Animal Grouping Strategies, Sources of Variation, and Economic Factors Affecting Nutrient Balance on Dairy Farms. Department of Animal Sciences and Department of Agricultural, Environmental, and Development Economics, The Ohio State University, Columbus, 43210. <http://www.asas.org/JAS/abs/1999/am007.html>

Wilson, H. K., 1959. Grain Crops. 2nd edition. McGraw-Hill Book Company, New York. p34.

CHAPTER 4

Comparing ruminal forage degradability between Holsteins and Jersey cows receiving a high forage diet using the *in situ* technique.

Abstract

Ruminal degradability of lucerne hay (LH), oat hay (OH) and oat silage (OS) was compared between Holstein and Jersey cows using the in sacco technique. These three forages were incubated in the rumen of eleven non-lactating cows (5 Holstein and 6 Jersey cows) for varying time intervals of 96, 72, 48, 36, 24, 12, 8, 4, 2 and 0 hours. Lucerne hay and oat hay were milled through a 2mm sieve before placing in dacron bags, whereas oat silage was cut into 1cm pieces with a sharp pair of scissors. Chemical analyses measured from both post-incubation and original samples included dry matter (DM), crude protein (CP) and neutral detergent fibre (NDF). The fractional disappearance at each incubation time was calculated from the proportion remaining after rumen incubation. Fractional outflow rates (k), of 0.02, 0.05 and 0.08 were used to calculate effective degradability. Holsteins had a higher ($P<0.05$) effective DM and CP degradability for OS and a higher ($P<0.01$) degradation rate for OH. Jerseys had higher ($P<0.05$) CP degradation rates for LH and OH. The NDF degradation rate of LH was also higher ($P<0.05$) in Jersey cows, but effective degradability did not differ between breeds.

Key words: lucerne, oat hay, oat silage, Holstein, Jersey, digestibility, effective degradability, dry matter, crude protein, neutral detergent fibre.

4.1 Introduction

The digestibility of feed is important because the true value of the feed depends on the amount of nutrients that can be utilised by the animal after digestion (Nsahlai & Umunna, 1996). Different feeds bring about changes in rumen environment which influence digestion. These changes include factors within the rumen such as digestion rate of DM, rate of particulate passage, digesta pH and nature of microbial population (Staples *et al.*, 1984). When ruminal digestibility trials are conducted, factors such as diet of the animal, frequency of animal feeding, method of bag placement in the rumen, and degree of bacterial attachment to feed residues remaining in the bag influence nutrient digestion (Stern *et al.*, 1997).

Forages are known to increase ruminal digestibility of feed in ruminants. Rogers & Davis, (1982) found that after 24 hours, the DM disappearance of maize silage was 54.1% and 66.5% in Holstein cows that were fed high grain and high forage diets, respectively. The ability of forage to provide a buffering capacity (Grant, 1990) and sustain a stable environment in the rumen (Allen, 1997) are associated with the increase in feed digestibility in cows on high forage diets. This is because a stable environment and an optimum pH increase the activity of rumen microbes.

Different methods are used to estimate the fermentation process in the rumen (Pienaar *et al.*, 1989). These include, *in vivo*, *in situ* and *in vitro* techniques (Erasmus *et al.*, 1990). The *in vivo* method has been found to be the best way of determining digestibility, but, it is costly, labour-intensive, time consuming (Stern *et al.*, 1997) and unsuitable for screening large numbers of samples (Nsahlai & Umunna, 1996). The *in situ* method is the most preferred method. It provides an advantage over the laboratory methods (*in vitro*) because it involves digestive processes that occur in the rumen of a living animal (Stern *et al.*, 1997). In this trial, the *in situ* technique was the method used. This method involves incubation of feed in nylon bags suspended in the rumen of fistulated animals (Blümmel & Ørskov, 1993) and nutrient disappearance measured at various time intervals (Stern *et al.*, 1997).

With the current trend towards optimising home produced forage utilisation, an understanding of its digestibility and its effects on rumen environment is needed. Although *in vitro* digestibility studies have been conducted since the early 1960's (Tilley & Terry, 1963), little has been done to determine differences between breeds that are fed forage diets. This study was aimed at determining the ruminal degradability of oat and lucerne in cows receiving forage based diets and to compare breeds (Holstein and Jersey) in terms of forage ruminal degradability in the rumen.

4.2 Materials and methods

Eleven non-lactating cows (5 Holstein and 6 Jersey cows), fitted with rumen cannulae, were used in this study. They were housed in individual stalls during the experimental period. Holsteins and Jerseys were fed 4 and 3kg lucerne hay for, respectively at 08H00 in the morning, then oat hay at 17H00 in the evening.

Forage samples were prepared from lucerne hay (LH), oat hay (OH) and oat silage (OS). Samples of LH and OH were ground to pass through a 2mm screen before being put in dacron bags. Oat silage, because of moisture, was cut into 1cm pieces using a sharp pair of scissors. The aim was to preserve as much of the silage juice as possible. Five grams of each of the milled samples, and 10g of OS were put in dacron bags of 230mm x 100mm with a pore size of 53µm to be subjected to ruminal digestion. The bigger amount (10g) was used for OS to compensate for the silage moisture content.

The weighed samples were incubated in the rumen of cannulated cows for varying time intervals of 0, 2, 4, 8, 12, 24, 36, 48, 72 and 96 hours. Three bags for the 96 and 72-hour periods and 2 bags for the 48-hour period were incubated to ensure sufficient quantities of sample residue for chemical analysis. The dacron bags with feed samples were put in orange bags that were divided into 10 compartments. One dacron bag was placed in each compartment to prevent clustering. Separate orange bags for each feed type, that is, LH, OH and OS were used, making a total of 3 orange bags per cow. The orange bags were tied to

nylon strings (ca. 50cm) and suspended in the rumen with the string attached to the cannula. The string allowed free movement of the bags inside the rumen.

The feed samples were put in the rumen in a reverse order starting with the 96-hour bags. The maximum number of dacron bags was limited to not more than 30 bags per cow at a given time so as to allow proper mixing of the rumen fluid with the bag contents. To accomplish this goal, 12 hours after inserting the 72-hour bags, the 12-hour bags, followed consecutively by the 8, 4, and 2-hour bags were inserted. These bags (i.e., 12, 8, 4, and 2-hour bags) were taken out when the 48-hour bags were put in. To prevent the bags from floating in the rumen, weights were secured to them. The bags used for 0-hour digestibility were not incubated in the rumen, but were only subjected to the washing procedure.

At the end of the respective incubation times, bags were removed from the rumen. They were washed under running tap water and placed in ice water to stop the fermentation process. This was then followed by washing the bags in a twin-tub washing machine with cold water. Washing of the bags was done in a gentle cycle of 3 minutes each for 3 times with water changed after every cycle. They were then dried in an oven at 60°C for 48 hours.

Chemical analysis of feed samples, both original and residues was performed after drying the samples. The samples were subjected to laboratory analysis for DM according to the AOAC (1990), NDF according to the Ankom filter bag method (1998) and CP using the Leco method (1996). The fractional disappearance at each incubation time was calculated from the proportion remaining after rumen incubation using the following equation:

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

The degradation rate was fitted to a non-linear model by Ørskov & McDonald (1979):

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

Where p = proportion degraded at time t ,

a = the intercept representing the soluble fraction

b = the insoluble but potentially degradable fraction

c = the degradation rate of the b fraction

$a + b$ represent the maximum extent of degradation or the asymptote of the equation.

The effective degradabilities were calculated by introducing the fractional outflow rates, k , of 0.02, 0.05 and 0.08 as suggested by Erasmus (1990). The following equation was used:

$$P = a + \frac{bc}{c + k} \text{ (Ørskov \& McDonald 1979).}$$

The differences between breeds and treatments were analysed according to a multi-factor analysis of variance using the Statgraphics programme (Statgraphics, 1991). Differences between breeds and treatments were analysed using a multiple range test of the Statgraphics programme. The least significant difference was used to compare means between breeds and between treatments. Differences were declared significant at $P < 0.05$.

4.3 Results and discussion

4.3.1 Ruminal dry matter degradability.

The ruminal DM degradability of LH, OH and OS in Holstein and Jersey cows are presented in Figure 1 and Table 1. For all the forages, the curves are almost overlapping indicating that the percentage DM degradable over time in both breeds was almost similar. For LH and OH, an asymptote was reached at 36 and 48 hours, respectively. The asymptote was assumed to be the endpoint of degradation. Oat silage on the other hand, had not reached the highest point even at 96 hours when the bags were taken out. This indicates that either a longer incubation period was necessary for OS or the model was not able to describe the degradation rate accurately.

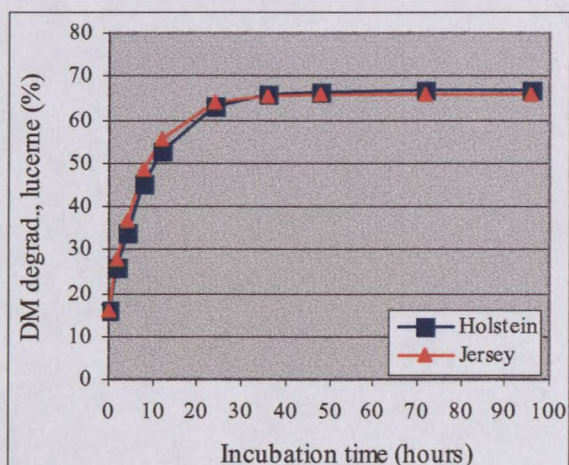


Figure 1(a)

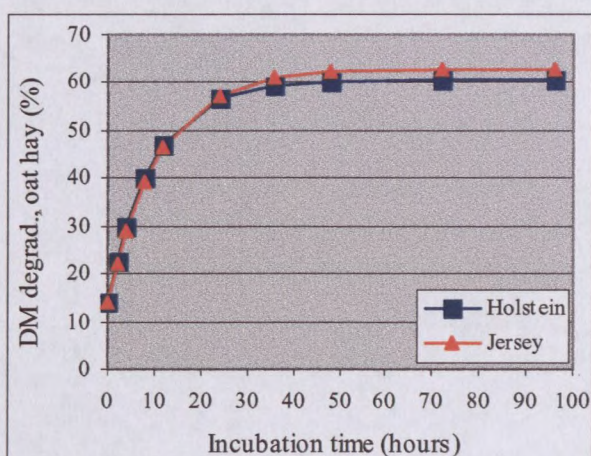


Figure 1(b)

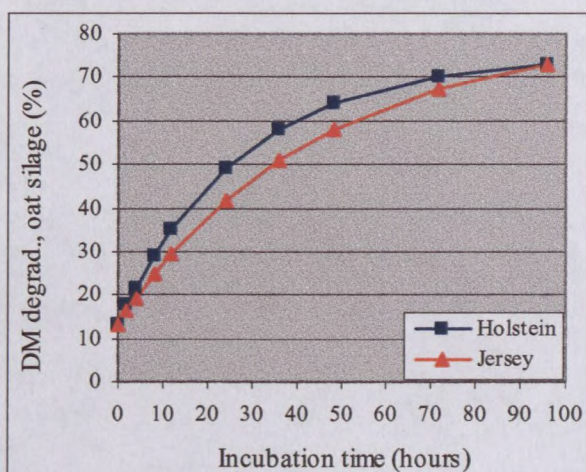


Fig. 1(c)

Figure 1. Ruminal dry matter (DM) degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows receiving a high forage diet.

The non-linear parameters (Table 1) describing the soluble fraction (*a*), the potentially degradable fraction (*b*), and rate of degradation (*c*), did not differ between breeds, although parameters differed ($P < 0.01$) between forages (Table 2). The soluble fraction was not expected to differ between breeds as it did not involve the effect of the animal, it was only the function of the feed. The potential degradability of OS was higher ($P < 0.01$) than other forages

in both breeds. The degradation rate of the insoluble fraction was higher ($P < 0.01$) in LH and OH than in OS (Table 2). The difference in degradation rate between OH and OS may be related to both the high moisture content and the large particle size of the silage. High moisture content resulted in difficulty of the rumen fluid containing microbial flora to penetrate the wet silage. Reduced particle size increases surface area for enzymatic attack and results in a higher fermentation rate (Staples *et al.*, 1984).

Table 1. Ruminal dry matter degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows as estimated by the model of Ørskov & McDonald (1979).

	Lucerne			Oat hay			Oat silage		
	Holst	Jersey	P	Holst	Jersey	P	Holst	Jersey	P
Non-linear									
A	16.0	16.0	NS	14.2	14.2	NS	13.3	13.3	NS
B	50.8	50.0	NS	46.4	48.8	NS	61.4	66.8	NS
C	0.108	0.133	NS	0.103	0.090	NS	0.037	0.023	NS
Deff									
0.02	58.7	58.9	NS	51.1	50.4	NS	52.2 ^a	47.0 ^b	<0.05
0.05	50.6	51.51	NS	43.2	41.5	NS	38.6 ^a	33.1 ^b	<0.05
0.08	45.01	46.35	NS	38.3	36.5	NS	32.1 ^a	27.4 ^b	<0.05

Holst = Holstein, Deff = effective degradability, P = probability, NS = not significant, S = significant

Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

The lucerne hay and oat hay effective DM degradabilities did not differ ($P > 0.05$) between breeds but in OS, Jerseys had a lower ($P < 0.05$) effective DM degradability at all fractional outflow rates. This can be attributed to the bigger rumen capacity of the Holsteins resulting in pressure and detrition of the big silage particles by muscular activity of the rumen walls and therefore higher effective degradability.

Despite the high potential DM degradable fraction of OS (Table 2), its effective degradabilities at ruminal turnover rates of 0.05/h and 0.08/h were lower ($P < 0.01$) than that of LH and OH. The lower effective ruminal degradability of OS could possibly be explained by the larger particle size used (10mm) compared to the 2mm screen for LH and OH. Solaiman *et al.*, (1982) showed shorter lag times and less indigestible cell wall for LH and orchard grass ground at 1mm than ground at 8mm screen. An appropriate particle size of form would seem to be one which is masticated and presented to the rumen (Solaiman *et al.*, 1982). The effective DM degradability of LH at a rate of 0.05/h for both breeds is almost similar to that found by Andrighetto *et al.*, (1993) which was 49%. There was no literature available to support or dispute the above findings.

Table 2. Mean values for lucerne hay, oat hay and oat silage DM degradability

Parameters	Lucerne	Oat hay	Oat silage	P
Non-linear				
A	16 ^a	14.2 ^b	13.3 ^c	<0.01
B	50.37 ^a	47.582 ^a	64.02 ^b	<0.01
C	0.20 ^a	0.096 ^b	0.030 ^c	<0.01
Deff				
0.02	58.82 ^a	51.04 ^b	49.69 ^b	<0.01
0.05	51.054 ^a	42.32 ^b	35.87 ^c	<0.01
0.08	45.68 ^a	37.38 ^b	29.75 ^c	<0.01

Deff = effective degradability, P = probability ^{a, b, c} Means with different superscripts differ significantly

4.3.2 Ruminal crude protein degradability

Figure 2 represents the curves comparing ruminal CP degradability of LH, OH and OS between Holstein and Jersey cows. Both breeds reached the highest point of CP degradation at 36 hours with LH and OH. However, with OS asymptote was not reached even at 96 hours when the bags were removed from the rumen. This can possibly be attributed to poor microbial functioning and low fermentation rates observed for OS in DM degradability.

Breed differences (Table 3) were observed in potential degradable CP fraction for OS and degradation rates of LH and OH. Holsteins were more efficient ($P<0.01$) in both parameters. In both breeds, the rate of degradation was lower ($P<0.01$) for OS than for OH (Table 4). This can be explained by reduced rate of DM degradation of this forage, which was assumed to be due to larger particle size and silage moisture content. Contrary to the particle size theory, Ehle *et al.*, (1982) showed that rates of nitrogen digestion for several feed ingredients were not affected by particle size.

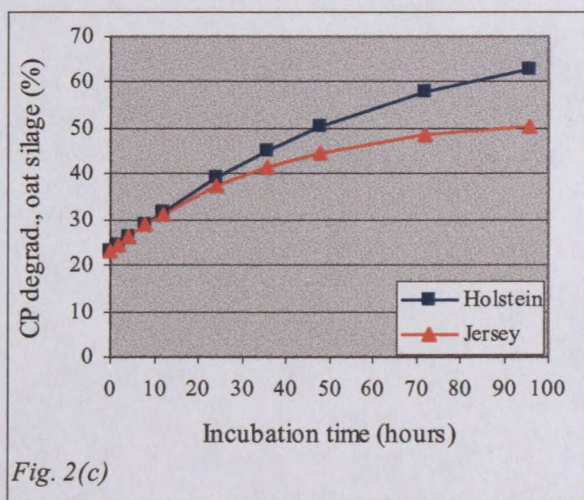
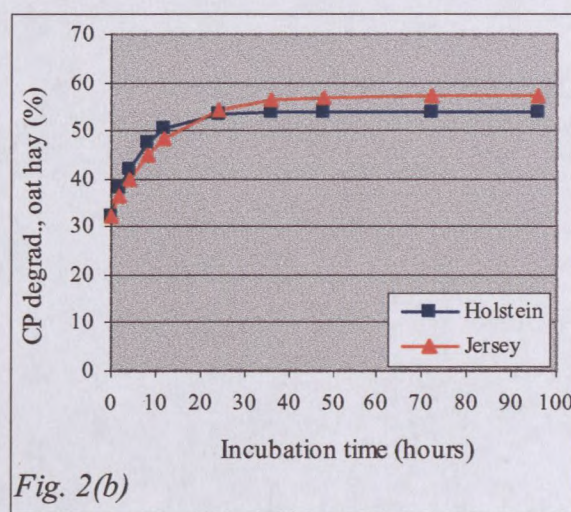
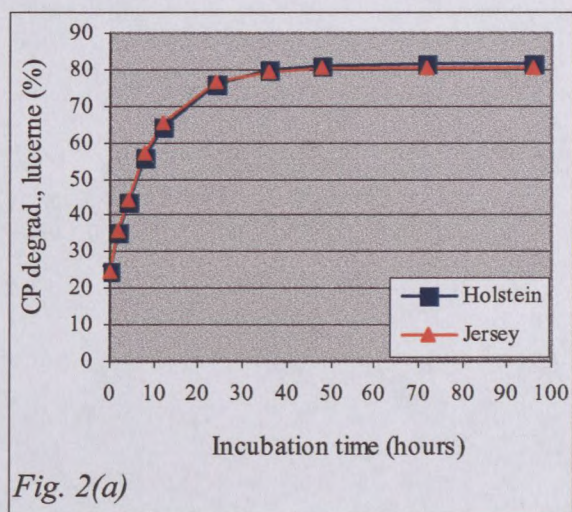


Figure 2. The crude protein degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows receiving a high forage diet.

Table 3. Ruminal crude protein degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows as estimated by the model of Ørskov & McDonald (1979).

	Lucerne			Oat hay			Oat silage		
	Holst	Jersey	P	Holst	Jersey	P	Holst	Jersey	P
Non-linear									
a	24.9	24.9		32.41	32.41		23.0	23.0	
b	56.6	55.8	NS	21.5	21.0	NS	46.7	26.2	<0.05
c	0.132	0.113	<0.02	0.099	0.086	<0.05	0.017	0.028	NS
Deff									
0.02	71.9	71.8	NS	51.1	52.6	NS	44.7	39.6	<0.05
0.05	62.5	62.8	NS	48.0	48.1	NS	34.8	33.1	NS
0.08	56.2	56.7	NS	45.9	45.3	NS	31.1	30.3	NS

Holst = Holstein, Deff = effective degradability, P = probability, NS = not significant, S = significant

Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

Table 4. Mean values for lucerne hay, oat hay and oat silage CP degradability

Parameters	Lucerne	Oat hay	Oat silage	P
Non-linear				
a	24.9 ^a	32.4 ^b	23.0 ^c	<0.01
b	56.21 ^a	23.27 ^a	36.45 ^b	<0.01
c	0.109 ^a	0.106 ^a	0.022 ^b	<0.01
Deff				
0.02	71.87 ^a	51.08 ^b	42.40 ^c	<0.01
0.05	62.63 ^a	48.06 ^b	33.48 ^c	<0.01
0.08	56.44 ^a	45.50 ^b	30.68 ^c	<0.01

Deff = effective degradability, P = probability ^{a, b, c} Means with different superscripts differ significantly

Holsteins also showed a higher ($P<0.05$) effective CP degradability in OS at a fractional outflow rate of 0.02/h, although no significant differences between breeds were found at 0.05 and 0.08/h. This can be related to the higher apparent potential CP degradability of OS by Holsteins.

4.3.3 Neutral detergent fibre degradability

The NDF degradability of LH, OH and OS in Holstein and Jersey cows receiving a high forage diet is presented in Figure 3 and Table 5.

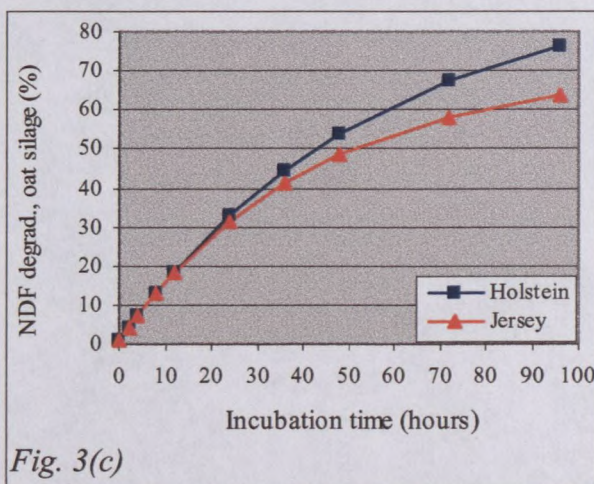
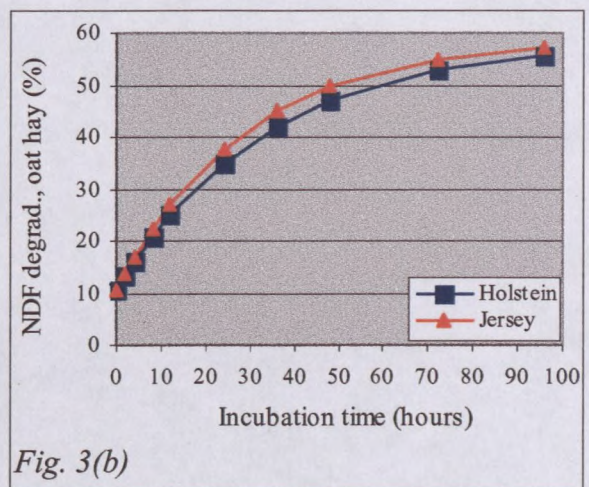
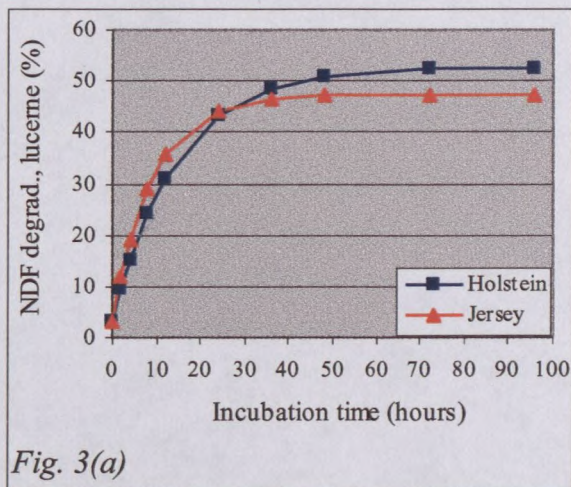


Figure 3. The Neutral detergent fibre (NDF) degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows receiving a high forage diet.

For both breeds, the highest point of LH ruminal NDF degradability was reached at 48 hours, but for OH and OS, asymptote was not obtained even at 96 hours. This is because, for fibre digestion to proceed, micro-organisms often have to penetrate resistant barriers such as epicuticular waxes and the cuticle layer that can resist enzymatic attack (Varga, *et al.*, 1997). This therefore prolongs the lag phase and results in a longer period required for fibre digestion.

Table 5. Ruminal neutral detergent fibre degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows as estimated by the model of Ørskov & McDonald (1979).

	Lucerne			Oat hay			Oat silage		
	Holst	Jersey	P	Holst	Jersey	P	Holst	Jersey	P
Non-linear									
a	3.31	3.31		10.6	10.6		0.81	0.81	
b	49.3	44.1	NS	48.0	48.2	NS	86.9	69.5	<0.05
c	0.069	0.109	<0.05	0.030	0.035	NS	0.018	0.025	NS
Deff									
0.02	41.1	39.9	NS	37.8	38.5	NS	42.6	39.2	NS
0.05	31.5	32.7	NS	27.4	28.3	NS	24.0	23.2	NS
0.08	25.8	27.9	NS	22.8	23.7	NS	16.9	17.3	NS

Holst = Holstein, Deff = effective degradability, P = probability, NS = not significant, S = significant

Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

Holsteins appeared to be more efficient ($P < 0.01$) than Jerseys in degrading the OS insoluble fraction. The degradation rate of lucerne hay was however, higher ($P < 0.05$) in Jersey cows. This is in accordance with the findings of Retief (2000) who found that Jerseys had a faster NDF degradation rate than Holsteins. For all three forages, the effective NDF degradability did not differ ($P > 0.05$) between breeds at all fractional outflow rates. Retief (2000) reported that Jerseys appear to be more efficient in digesting low quality forages than Holsteins. It should be noted that, in the study reported by Retief (2000), cows received a high concentrate basal diet vs. the forage based diet in the current study. According to Ndlovu & Buchanan-

Smith (1985), poor quality forages are characterised by slow rates of fibre digestion and slow rates of evacuation of indigestible material resulting in a poor voluntary feed intake. Particle size did not bring about differences in this parameter.

Table 6. Mean values for lucerne hay, oat hay and oat silage NDF degradability

Parameters	Lucerne	Oat hay	Oat silage	P
Non-linear				
a	3.31 ^a	10.6 ^b	0.81 ^c	<0.01
b	46.70 ^a	48.11 ^a	78.19 ^b	<0.01
c	0.090 ^a	0.032 ^b	0.021 ^c	<0.01
Deff				
0.02	40.50	38.12	40.86	NS
0.05	32.07 ^a	27.85 ^b	23.91 ^c	<0.01
0.08	26.87 ^a	23.26 ^b	17.08 ^c	<0.01

Deff = effective degradability, P = probability ^{a, b, c} Means with different superscripts differ significantly

4.4 Conclusion

Results from the current study suggest that lucerne hay is superior to oat hay and oat silage regarding ruminal crude protein and NDF degradability. Although no final conclusions can be made as far as the breeds are concerned, it would appear that the crude protein in oat silage is degraded at a faster rate in Holsteins than in Jersey cows are on a forage based diet. Regarding NDF, the degradation rate of lucerne was higher in Jerseys, while potential NDF degradability in oat silage was higher in Holsteins. Effective NDF degradability, however, appears to be similar in both breeds for all forages investigated.

References

- Allen, M. S., 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fibre. *J. Dairy Sci.* 80: 1447.
- Andrighetto, I., Bailoni, L., Cozzi, G., Tolosa, H. F., Hartman, B., Hinds, M., & Sapienza, D., 1993. Observation *in situ* degradation on forage cell components in alfalfa and Italian ryegrass. *J. Dairy Sci.* 76: 1774.
- Association of Official Analytical Chemists, 1990. *Official Methods of Analysis*. 15th ed. AOAC, Arlington.VA.
- Blümmel, M., & Ørskov, E. R., 1993. Comparison of *in vitro* gas production and nylon bag degradability of roughages in predicting feed intake in cattle. *Anim. Feed Sci. & Techn.* 40: 109.
- Ehle, F. R., Murphy, M. R., & Clark, J., H., 1982. *In situ* particle size reduction and the effect of particle size on degradation of crude protein and dry matter in the rumen of dairy steers. *J. Dairy Sci.* 65: 963.
- Erasmus, L. J., Prinsloo, J., & Botha, P. M., 1990. Establishment of a ruminal protein degradation data base for dairy cattle using the *in situ* polyester bag technique. 3. Roughages. *S. A. J. Anim. Sci.* 20(3):130.
- Grant, R. J., 1990. Maximising feed intake for maximum milk production. NebGuide Publication. <http://www.ianr.unl.edu/pubs/dairy/g1003.htm>
- Ishler, V., Heinreichs, J & Varga, G., 2001. Background in basic nutrition of dairy cattle (Part1). <http://www3.das.psu.edu/dcn/catnut/422/contents.html>

Kelley, C. L., 1998. Method for determining neutral detergent fibre (aNDF). ANKOM Technology.

Leco Corporation, 1996. Nitrogen and Protein determinator. In: Instrumentation for characterisation of organic / inorganic materials and microstructural analysis. USA.

Ndlovu, L. R., & Buchanan-Smith, 1985. Utilisation of poor quality roughages by sheep: Effects of alfalfa supplementaion on ruminal parameters, fibre digestion and rate of passage from the rumen. *Can. J. Anim. Sci.* 65: 693.

Nsahlai , I. V., & Umunna, N. N., 1996 . Comparison between reconstituted sheep faeces and rumen fluid inocula and between in vitro and *in sacco* digestibility methods as predictors of intake and *in vivo* digestibility. *J. Agric. Sci.* 126: 235.

Ørskov E. R., & McDonald, I., 1979. The estimate of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. *J. Agric. Sci.* (Cambridge). 92: 499.

Pienaar, J. P., Roux, C. Z., & Cronje, P. B., 1989. Comparison of in vivo and in sacco methods to estimate mean retention time of fermentable organic matter in the rumen. *S. A. J. Anim. Sci.* 19(2): 71.

Retief, N., 2000. Breed differences in ruminal digestibility of forages in dairy cows receiving high concentrate diets. *MSc. Thesis.* Stellenbosch University. p32.

Rogers, J. A., & Davis, C. L., 1982. Effects of intraruminal infusions of mineral salts on volatile fatty acid production in steers fed high grain and high roughage diets. *J. Dairy Sci.* 65: 953.

Solaiman, S. G., Marty, F. A., Belyea, R. L. & Weiss, M. F., 1982. Effect of diet composition and forage particle size on cell wall digestion rates of alfalfa and orchardgrass *in situ*. *J. Dairy*

Sci. 65 (Suppl. 1): 144 (Abstr.).

Staples, C. R., Fernando, R. C., Fahey, G. C., Jr., Berger, L. L., & Jaster, E. H., 1984. Effects of intake of a mixed diet by steers on digestion events. *J. Dairy Sci.* 67 (5): 995.

Statgraphics 5.0. 1991. Statistical Graphic System. Statistical Graphic Corporation Incl., 2115 East Jefferson Street, Rockville, MD, 20852.

Stern, M. D., Bach, A., & Calsamiglia, S., 1997. Alternative techniques for measuring nutrient digestion in ruminants. *J. Anim. Sci.* 75: 2256.

Tilley, J. M. A. & Terry, R. A., 1963. A two stage technique for the *in vitro* digestion of forage crops. *J. British Grassl. Soc.* 18: 104.

Varga, G. A. & Kolver, E. S., 1997. Microbial and animal limitations to fibre digestion and utilisation. *J. Nutr.* 127, 819S-823S.

CHAPTER 5

Comparing the dynamics of the rumen environment of Holstein and Jersey cows receiving a high forage diet.

Abstract

The aim of the study was to determine differences in rumen pH, volatile fatty acids (VFA) and rumen ammonia nitrogen (NH₃-N) between Holsteins and Jerseys as affected by time post-feeding. These parameters were measured shortly before feeding, and 2, 6 and 8 hours after feeding. The total mean daily pH for Jerseys was higher ($P<0.01$) than that of Holsteins. Both breeds showed a higher ($P<0.01$) pH before feeding, followed by a decline ($P<0.05$) as hours increased post-feeding. Holsteins had higher ($P<0.01$) NH₃-N and VFA concentrations than Jerseys. Before meals and 8 hours after feeding, Jerseys had a significantly higher ($P<0.01$) acetate production than Holsteins. Concerning propionate, the two breeds differed ($P<0.01$) only before meals with Jerseys having a higher concentration than Holsteins. Holsteins produced more ($P<0.01$) butyrate and valerate concentrations before and 8 hours after feeding than Jerseys.

Key words: pH, volatile fatty acids, rumen ammonia nitrogen, before and post-feeding.

5.1 Introduction

Understanding the rumen environment is vital as changes in it can cause poor health and reduced productivity. The rumen is inhabited by micro-organisms which convert crop residues and animal wastes to food and other products (Blaser, 1978). Feeding should therefore be aimed at meeting both the animal and microbial needs to promote efficient cellulose and hemicellulose digestion (Ishler *et al.*, 2001). Microbial yield depends largely on the availability of nitrogen and carbohydrates in the rumen. Simultaneous availability of these nutrients is required (Russell & Hespell, 1981, Shabi *et.al.*,1998)) as asynchronous supply might reduce the efficiency of microbial growth (Newbold & Rust, 1992).

Soluble protein and dietary non-protein nitrogen serve as significant sources of nitrogen for rumen bacterial growth (Chen *et al.*, 1987). Most ruminal bacteria use ammonia as a source of nitrogen to synthesise microbial protein. Ammonia is derived in the rumen through microbial degradation of dietary protein and nitrogen, from hydrolysis of recycled urea to the rumen, and from degradation of microbial crude protein. The biological value of microbial protein is 66 to 87% (Ishler *et al.*, 2001).

If the diet is deficient in protein, or if the protein resists degradation, the concentration of rumen ammonia will be low and the growth of rumen micro-organisms will be slow, resulting in a retarded breakdown of carbohydrates (Holtshaussen, 2000). The ammonia level of rumen fluid needed for efficient rumen microbial synthesis is only 5-7mg/100ml (NRC, 1976). When conditions are not conducive to rapid utilisation of ammonia by microbes, ammonia is more likely to build up in the rumen fluid. Concentrations above 80mg/100ml are associated with toxicity and is the point at which the ability of the liver to convert ammonia to urea is exceeded (NRC, 1976).

Fermentation of carbohydrates by rumen microbes result in the production of VFA's. The VFA's can provide up to 80% of the energy needs of the animal (Ishler *et al.*, 2001). The three main VFA's are acetate, propionate and butyrate. The total concentration of the VFA's in the rumen liquor varies between 2 and 15 g/l according to the animal's diet and the time that has

lapsed since the previous meal (NRC, 1976). The relative proportion of the acids vary, with acetate being the most predominant (50-60%), followed by propionate (18-20%) then butyrate (12-18) (Ishler *et al.*, 2001). Acetate predominates in forage diets. It is used for fatty acid synthesis and is essential to maintain adequate quantities of milk fat. Propionate reaches its highest concentrations in high grain diets and is used in lactose or milk sugar synthesis. Butyrate provides energy to the rumen wall and is used for fatty acid synthesis in adipose and mammary gland tissues (Ishler *et al.*, 2001).

Continuous removal of VFA's by absorption from the reticulo-rumen is important for maintaining a stable ruminal pH (Allen, 1997). Ruminal pH is one of the most variable factors which influences both the microbial population and feed intake. Two basic groups of bacteria function at various pH's, these are the fibre digesters and the starch digesters. The fibre digesters (cellulolytic and methanogenic bacteria) are most active at a pH of 6.2 to 6.8. and are reduced when the pH begins to fall below 6.0. The starch digesters prefer a more acidic environmental pH of 5.2 to 6.0 (Ishler *et al.*, 2001).

Low ruminal pH has direct negative effects on energy intake and absorbed protein which are primary factors limiting production of high producing cows (Allen, 1997). Decreases in pH result in decreased appetite (Shinozaki, 1959), ruminal motility, microbial yield (Hoover & Stokes, 1991) and fibre digestion (Terry *et al.*, 1969). To accommodate all these needs, normal feeding practices should maintain a pH range between 5.8 to 6.4.

Seeing that the rumen pH, VFA and ammonia concentrations determine microbial functioning and the extent at which feed is digested, it is important to determine to what extent these parameters are influenced by other factors such as breed and feeding intervals. The objective of this study is therefore to relate changes in rumen pH, VFA and $\text{NH}_3\text{-N}$ concentrations as affected by breed and feeding interval.

5.2 Materials and methods

This study was conducted concurrently with the ruminal degradability study (Chapter 4). All cows, that is, 5 Holstein and 6 Jersey cows that were involved in the ruminal degradability study were used for the study. Holsteins and Jerseys were fed 4 and 3kg lucerne hay per day, respectively at 08H00 in the morning, then oat hay at 17H00 in the evening.

In the last two days of the ruminal degradability experiment, rumen fluid samples were collected at 06h00, 10h00, 14h00 and 16h00 to be analysed for pH, volatile fatty acids (VFA) and rumen ammonia ($\text{NH}_3\text{-N}$) concentrations. The pH reading was taken immediately after collection of the rumen fluid samples using a portable pH meter. This is because the pH of the rumen fluid is very unstable, and may decrease rapidly when allowed to stand. To prepare for VFA and $\text{NH}_3\text{-N}$ concentrations, 9ml of the rumen fluid was collected from each cow at each time interval. One millilitre of a 10% sodium hydroxide solution for VFA, and 1ml of a 50% sulphuric acid solution for $\text{NH}_3\text{-N}$ concentrations, was added to each sample as preservative. This was then stored at -20°C until analysed.

Differences between breeds and time elapsed post-feeding were analysed according to a multi-factor analysis of variance using the Statgraphics programme (Statgraphics, 1991). The differences between breeds and treatments were analysed using a multiple range test of the Statgraphics programme. The least significant difference was used to compare means between breeds and between time elapsed after feeding. Significant differences were declared at $P < 0.05$.

5.3 Results and discussion

5.3.1 Ruminal pH

Ruminal pH of Holstein and Jersey cows receiving a high forage diet is presented in Figure 1.

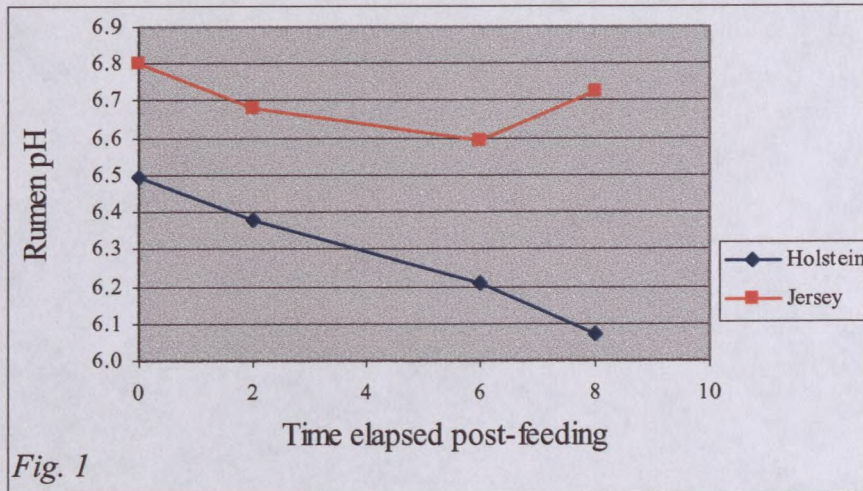


Figure 1 Ruminal pH changes in Holstein and Jersey cows on a high forage diet as affected by time intervals post-feeding.

The total mean daily pH (Table 1) for Jerseys (6.7) was higher ($P < 0.01$) than that of Holsteins (6.3). According to Rodriguez *et al.* (1997), Jerseys are generally inclined to have a higher rumen pH than Holsteins. The mean daily pH of both breeds was suitable for fibre digestion. The optimum pH for fibre digestion has been found by Stewart (1977) and Terry *et al.* (1969) to be between 6.3 and 6.7. According to Varga & Kolver (1997), and Ishler *et al.*, (2001), at a rumen pH of below 6.2 the action of fibrolytic micro-organisms is suppressed and this results in a decreased fibre degradation.

Both breeds showed a high ($P < 0.01$) pH before and 2 hours post-feeding which was followed by a decline ($P < 0.05$) as hours increased post-feeding. Jerseys showed a higher ($P < 0.05$) pH than Holsteins throughout the day. Rodriguez *et al.* (1997) reported that Jerseys are more inclined to have a higher ruminal pH before feeding than Holsteins ($P < 0.05$). Retief (2000), also observed similar findings.

In this study, the contrast between breeds in terms of pH became more apparent at 6 and 8-hours after feeding. The mean pH dropped from 6.49 to 6.21 and from 6.80 to 6.62 in Holsteins and Jerseys, respectively. The decline was more pronounced ($P<0.05$) in Holsteins. Unlike Jerseys, whose pH started to peak up after 6 hours, the Holstein pH continued to decrease (Figure 1).

Table 1. Post-feeding changes in rumen pH of Holstein and Jersey cows on a high forage diet

Time post feeding (h)	Rumen pH		
	Holsteins	Jerseys	Probability
0	6.49	6.80	<0.05
2	6.38	6.68	<0.05
6	6.21	6.62	<0.05
8	6.07	6.72	<0.05
Daily mean	6.29	6.71	<0.01

The sharp contrast between the two breeds can be associated with the meal size and longer eating time as Holsteins received more feed than Jerseys. Holsteins were offered and consumed more feed than Jerseys. According to Allen (1997), there is a negative correlation between meal size and ruminal pH, as meal size increases, the pH decreases. If the percentage organic matter truly digested in the rumen is very high and total fermentation acid production exceeds the buffering capacity of the reticulo-rumen, pH decreases (Allen, 1997). This, however cannot be a valid reason in this instance as the feed was offered to the cows according to their body weights.

The general decline with post-feeding intervals that was found in both breeds is in accordance with the findings by Dado & Allen (1993) and Robinson & McQueen (1993). According to Allen (1997), ruminal pH is responsive to meals and chewing, it decreases following meals and increases during bouts of rumination. Robinson & McQueen (1993) associated the reduction in pH post-feeding with increased availability of fermentable substrate after feeding. The high pH before feeding can be attributed to rumination. Increased salivary flow during bouts of rumination neutralises fermentation acids (Allen, 1997) and results in a higher pH.

5.3.2 Rumen ammonia-nitrogen (NH₃-N) concentrations

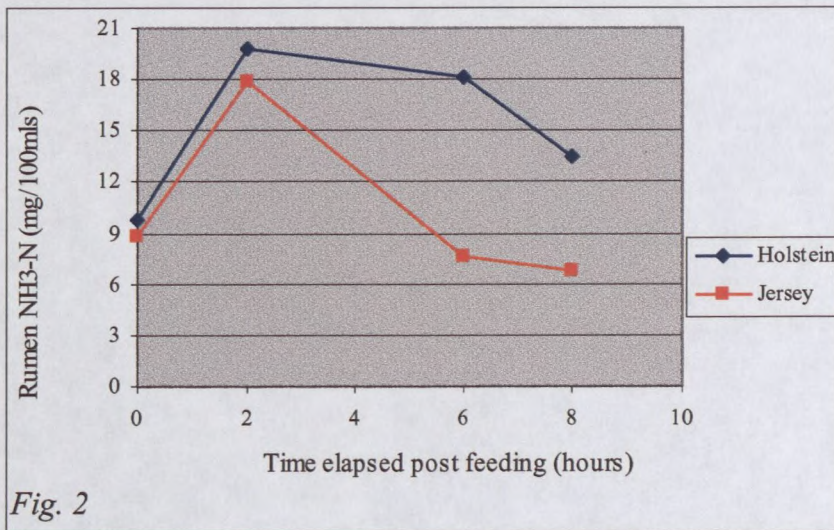


Figure 2 Rumen ammonia nitrogen concentration changes in Holstein and Jersey cows on forage diet as affected by time post-feeding.

In both breeds, a sharp increase in NH₃-N concentrations was observed 2-hours post-feeding. This increase was followed by a decline in NH₃-N concentrations as time increased post-feeding (Figure 2). This is in agreement with Gustafsson & Palmquist (1993) who reported NH₃-N in Holsteins to peak at 1 hour and Jerseys 2 hours after feeding, followed by a baseline 6 hours after feeding. Rodriguez *et al.* (1997) associated the increase in NH₃-N with the availability of fermentable substrate. According to Staples *et al.* (1984), the linear trends before feeding and 2 hours after feeding was the evidence of nitrogen recycling back into the rumen.

The mean total NH₃-N concentrations differed significantly ($P < 0.01$) between breeds with the concentrations being higher ($P < 0.01$) in Holsteins than Jerseys (Table 2). Before feeding, there were no differences between breeds, the two breeds started to differ significantly ($P < 0.01$) after feeding. Holsteins had higher ($P < 0.01$) NH₃-N concentrations throughout after feeding. Higher levels of NH₃-N concentrations maintained by Holsteins can be related to the nitrogen intakes. Holstein and Jerseys received 4kg and 3kg lucerne hay per day, respectively, resulting in more CP degradation in lucerne hay by Holstein and higher ammonia productions.

Table 2. Rumen ammonia-nitrogen concentration of Holstein and Jersey cows on a high forage diet.

Time post-feeding (h)	NH ₃ -N (mg/100ml)		
	Holstein	Jersey	P
0	8.53	8.93	NS
2	20.51	17.71	<0.05
6	18.12	7.75	<0.05
8	12.62	6.61	<0.05
Daily mean	14.94	10.25	<0.05

P = probability, NS = not significant

The total rumen NH₃-N concentrations produced by both breeds was however, in excess of the minimum requirements of 5-8mg/100ml rumen fluid proposed by Satter & Roffler (1977) and the NRC (1976). Higher NH₃-N levels usually reflect a deficiency of readily available energy necessary for bacteria to utilise recycled nitrogen for growth (Staples *et al.*, 1984). Contrary to Satter & Roffler (1977), Kellaway & Leibholz (1980) found optimal levels of NH₃-N for maximum microbial protein synthesis to be 34mg/100ml rumen fluid. In a recent study by Gustaffson & Palmquist (1993), high NH₃-N concentrations indicate that a sufficient amount of protein was degraded to meet microbial requirements. According to the NRC (1976), 80mg/100ml rumen fluid and above is associated with toxicity and is the point at which the ability of the liver to convert ammonia to urea is exceeded.

5.3.3 Volatile fatty acid (VFA) concentration

Differences ($P < 0.01$) in total VFA production over time post-feeding (Table 3) were observed. The VFA production before feeding was low and peaked at 2 hours post-feeding. This response indicated decreased fermentable substrate before feeding followed by an increased fermentable substrate after feeding (Rodriguez *et al.*, 1997). VFA production in Holsteins and Jerseys peaked 6 and 2 hours respectively post-feeding and declined thereafter (Figure 3).

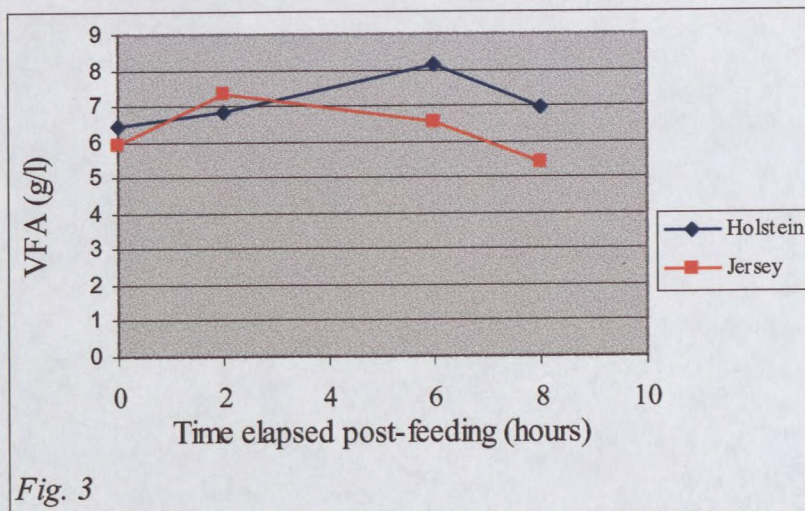


Figure 3 Volatile fatty acid concentration changes in Holstein and Jersey cows on a high forage diet as affected by time intervals post-feeding.

For both breeds, the total VFA concentration (Table 3) varied between 5 and 8g/l of rumen fluid. This is in accordance with the minimum requirements by the NRC (1976) that VFA concentration should be above 2 and below 15g/l of rumen fluid. The total VFA concentration in the rumen liquor varies according to the animal's diet and the time that has elapsed since the previous meal (Miller, 1979). The two breeds differed significantly ($P < 0.05$) in total VFA production, with Holsteins having a higher ($P < 0.05$) production than the Jerseys (7.20g/l vs. 6.42g/l). This is probably the reason why the rumen pH in Jerseys was higher compared to Holsteins. Contrary to this finding, Rodriguez *et al.* (1997) found that total VFA was not affected by breed, except only before feeding when Jerseys had a lower total VFA concentration than Holsteins.

For both breeds, the molar proportion of acetate was above 60% of the total VFA for all times (Table 4). According to the NRC (1976) acetate, being the most predominant should be about 60%. The findings in this study are normal for cows on forage diets. High cellulose diets give rise to mixtures high in acetate (Miller, 1979). Before meals and 8 hours after feeding, Jerseys had a significantly higher ($P < 0.01$) acetate production than Holsteins (Table 4). Holsteins showed no significant differences between time before meals till 6 hours after feeding. A sharp decrease ($P < 0.01$) was observed 8 hours after feeding. Jerseys showed a high ($P < 0.02$)

acetate concentration before the meals followed by a sharp decline 2 hours after feeding. The findings in Jerseys are in accordance with Rodriguez *et al.*, (1997) who found increased acetate concentrations before feeding followed by a decrease after feeding.

Table 3. Volatile fatty acid concentrations of Holstein and Jersey cows on a high forage diet.

Parameters	Amounts (g/l)		Proportion (%)		
	Holstein	Jersey	Holstein	Jersey	P
Acetate	4.57	4.09	63.23	65.25	<0.05
Propionate	1.37	1.28	19.05	19.20	NS
Butyrate	1.05	0.78	14.13	12.29	<0.05
Valerate	0.28	0.22	3.59	3.26	<0.05
Total VFA	7.19	6.42	100	100	<0.01

P = probability, NS = not significant

Table 4. VFA molar proportions as affected by time post-feeding

VFA	Molar proportion post-feeding (%)				
	0	2	6	8	P
Acetate (%)	66.03 ^a	64.24 ^b	65.19 ^{ab}	63.28 ^c	<0.05
Propionate (%)	18.50 ^a	20.30 ^b	19.30 ^c	19.50 ^c	<0.05
Butyrate (%)	13.90 ^a	11.84 ^b	12.53 ^b	15.12 ^c	<0.05
Valerate (%)	2.90 ^a	4.04 ^b	4.18 ^b	3.38 ^c	<0.05

^{a, b, c} Means with different superscripts within rows, differ significantly

The total propionate production remained below 20% for both breeds (Table 3). According to the NRC (1976), propionate concentration should be approximately 20-35%. The lower propionate concentrations are due to higher acetate concentrations. The two breeds differed (P<0.01) only before meals with Jerseys having a greater concentration than Holsteins. At 2 hours after feeding, propionate production increased in both breeds, significant (P<0.01) only

for Holsteins and this was followed by a decline in both breeds. The increase in propionate coincided with a decrease in acetate.

The acetate: propionate ratio did not seem to change much with breed and time (Figure 4). This is in agreement with the results of Retief (2000) who also did not find a change in acetate: propionate ratio with time. The ratio of acetate: propionate varied between 3.1: 1 and 3.6: 1 for Holsteins, whilst in Jerseys it varied between 3.1: 1 and 3.5: 1. This range is closer to the findings of Brand *et al.* (1992) in sheep that were fed high forage diets.

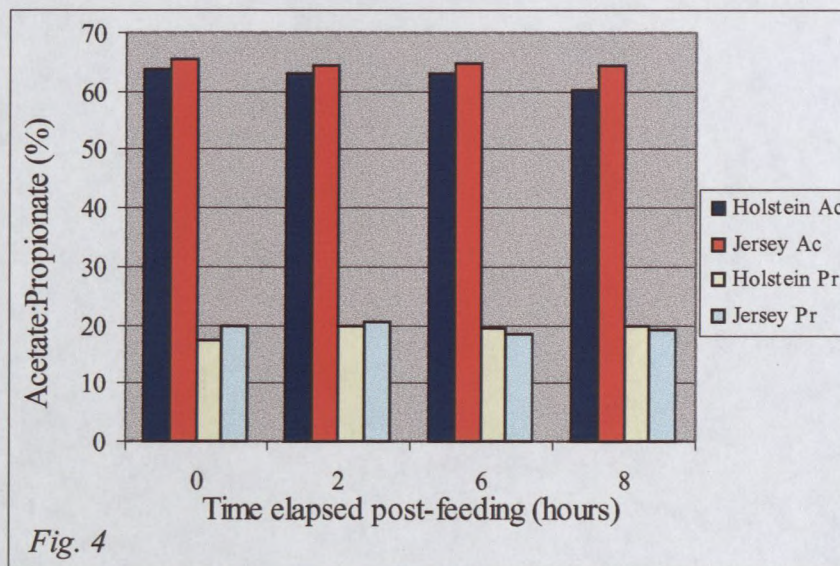


Figure 4. Acetate and propionate percentage changes in Holstein and Jersey cows receiving high forage diet as affected by time interval post-feeding.

The total butyrate production remained between 10-20% for both breeds, which indicates sufficient ruminal fermentation of amino acids. This agrees with the requirements of the NRC (1976). Holsteins produced more ($P < 0.01$) butyrate before and 8 hours after feeding than Jerseys, viz. 15.6 and 16.28% for Holsteins and 12.32 and 13.96% for Jerseys.

Holsteins had a higher ($P < 0.01$) total valerate concentration than Jerseys. Both breeds had lower valerate concentration before meals, which increased 2 hours after feeding. The

increase in Holsteins continued till 6 hours post-feeding, after which it reached a peak and started to decline. Valerate concentration in Jerseys peaked 2 hours after feeding, thereafter, the concentrations declined. The increase in valerate concentration after meals indicates that the diet contained high rumen degradable protein. Rodriguez *et al.* (1997) and Seymour *et al.* (1992) observed reduced concentrations of butyrate and valerate when they fed cows diets high in rumen undegradable protein. These authors associated this with decreased ruminal fermentation of amino acids.

5.4 Conclusion

On forage based diets, Jerseys appear to have higher rumen pH, lower $\text{NH}_3\text{-N}$ and lower VFA concentration than Holsteins. Values are time dependent, before feeding and 8 hours post-feeding, pH was high whereas $\text{NH}_3\text{-N}$ and VFA concentrations were low for both breeds. This indicates a negative relationship between pH and fermentable substrate availability.

References

- Allen, M. S., 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fibre. *J. Dairy Sci.* 80:1447
- Blaser, R. E., 1978. Looking to the future in forage-animal production. *Proceedings of the 35th Southern Pasture and Forage Improvement Conference*. Sarasota, Florida, USA: p 75.
- Brand, T.S., Franck, F., & Cloete, S.W.P., 1992. Substitution of lucerne hay by untreated , urea-enriched and urea-ammoniated wheat straw in diets for sheep. *S. A. J. Anim. Sci.* 22 (6):185.
- Chen, G., Russel, J. B. & Sniffen, C. J., 1987. A procedure for measuring peptides in the rumen fluid and evidence that peptide uptake can be a rate-limiting step in ruminal protein degradation. *J. Dairy Sci.* 70:1211.
- Dado, R. G. & Allen, M. S., 1993. Relationship between eating behaviour and ruminal pH in dairy cows consuming low or high fibre diets. Page 18 in *Abstr. Conf. Rumen function*, Cornell University, Ithaca, NY.
- Gustafsson, A. H., & Palmquist, D. L., 1993. Diurnal variation of rumen ammonia, serum urea, and milk urea in dairy cows at high and low yields. *J. Dairy Sci.* 76: 475.
- Holtshaussen, L., 2000. The effect of different levels of protein degradability in starter and finishing diets on veal calf performance. *MSc Thesis*. University of Stellenbosch
- Hoover, W. H. & Stokes, S. R., 1991. Balancing carbohydrate and protein for optimum rumen microbial yield. *J. Dairy Sci.* 74: 3630.
- Ishler, V., Heinrichs, J & Varga, G., 2001. Background in basic nutrition of dairy cattle (Part1). <http://www3.das.psu.edu/dcn/catnut/422/contents.html>

Kellaway, R. C. & Leibholz, J., 1980. Effect of nitrogen supplements on intake and utilisation of low quality roughages. *Proc. Aust. Soc. Anim. Prod.* 14: 61

Miller, W. J., 1979. Dairy cattle feeding and nutrition. Academic Press Publishers, New York. p 358.

National Research Council, 1976. Nutrient Requirements of Domestic Animals 6th edition, National Academy Press, Washington, DC.

Newbold, J. R. & Rust, S. R., 1992. Effect of asynchronous nitrogen and energy supply on growth of ruminal bacteria in batch culture. *J. Anim. Sci.* 70: 538.

Retief, N., 2000. Breed differences in ruminal digestibility of forages in dairy cows receiving high concentrate diets. *MSc. Thesis*. University of Stellenbosch. 32

Robinson, P. H. & McQueen, R. E., 1994. Influence of supplemental protein source and feeding frequency on rumen fermentation and performance in dairy cows. *J. Dairy Sci.* 77: 1340.

Rodriguez, L. A., Stallings, C. C., Herbein, J. H. & McGilliard, M. L., 1997. Diurnal variation in milk and plasma urea nitrogen in Holstein and Jersey cow in response to degradable dietary protein and added fat. *J. Dairy Sci.* 80: 3368.

Rogers, J. A., & Davis, C. L., 1982. Effects of intraruminal infusions of mineral salts on volatile fatty acid production in steers fed high grain and high roughage diets. *J. Dairy Sci.* 65 : 953.

Russell, J. B. & Hespell, R. B., 1981. Microbial rumen fermentation. *J. Dairy Sci.* 64: 1153.

Satter, L. D. & Roffler, R. E., 1977. Influence of nitrogen and carbohydrate inputs on rumen fermentation. In: *Recent advances in animal nutrition*. Eds: Haresign, W. & Lewis, D.,

London, Butterworths, p 25.

Seymour, W. M., Polan, C. E., & Herbein, J. H., 1992. In vivo degradation of protein in diets formulated for two degradabilities. *J. Dairy Sci.* 75: 2447.

Shabi, Z., Arieli, I., Bruckental, Y., Aharoni, S., Zamwel, S., Bor, A. & Tagari, H., 1998. Effect of synchronisation of the degradation of dietary crude protein and organic matter and feeding frequency on ruminal fermentation and flow of digesta in the abomasum of dairy cows. *J. Dairy Sci.* 81:1991.

Shinozaki, K., 1959. Studies on experimental bloat in ruminants. 5. Effects of various volatile fatty acids introduced into the rumen on the rumen motility. *Tohoku Journal of Agric. Res.* 9: 237.

Staples, C. R., Fernando, R. C., Fahey, G. C. (Jr.), Berger, L. L., & Jaster, E. H., 1984. Effects of intake of a mixed diet by steers on digestion events. *J. Dairy Sci.* 67 (5) :995.

Statgraphics 5.0., 1991. Statistical Graphic System. Statistical Graphic Corporation Incl., 2115 East Jefferson Street, Rockville, MD, 20852.

Stewart, C. S., 1977. Factors affecting the cellulolytic activity of rumen contents. *Appl. Environ. Microbiol.* 33:497.

Terry, R. A., Tilley, J., M., A., & Outen, G. E., 1969. Effect of pH on cellulose digestion under in vitro conditions. *J. Agric. Sci.* 20: 317.

Varga, G. A. & Kolver, E. S., 1997. Microbial and animal limitations to fibre digestion and utilisation. *J. Nut.* 127, 819S.

CHAPTER 6

Comparing ruminal forage degradability between Holstein and Jersey cows receiving a high concentrate diet

Abstract

The in situ technique was used to determine ruminal degradability of lucerne hay (LH), oat hay (OH) and oat silage (OS) in Holstein and Jersey cows receiving a high concentrate diet. Changes in rumen pH, as affected by breed and feeding interval, were also determined. Lucerne hay and oat hay were ground to pass through a 2mm sieve. Oat silage was cut with a pair of scissors to a length of about 1cm before incubation. The bags containing samples were incubated in the rumen of four Holstein and four Jersey cows fitted with rumen cannulae for periods of 0, 2, 4, 8, 16, 24, 48 and 72 hours. Cows received a total mixed ration (TMR) at a rate of about 25kg for Holsteins and 15 to 18kg for Jerseys. Jerseys had a higher ($P<0.05$) mean daily pH than Holsteins. Both breeds had their lowest pH 5 hours after feeding. Except for LH at an outflow rate of 0.02 per hour, Jerseys had higher ($P<0.05$) effective dry matter (DM) and neutral detergent fibre (NDF) degradabilities at all fractional outflow rates in all forages. Regarding crude protein (CP), Jerseys showed a lower ($P<0.05$) effective degradability at all fractional outflow rates in oat silage, but with other forages, the two breeds did not differ.

Key words: digestibility, effective degradability, lucerne, oat hay, oat silage, Holstein, Jersey, pH, dry matter, crude protein, neutral detergent fibre.

6.1 Introduction

In order to establish the amounts and ratios of nutrients necessary for optimum microbial and animal response, one needs to predict the degree to which the nutrients are made available in the rumen from a variety of ingredient sources (Nocek, 1988). High concentrate feeding is usually associated with a depressive effect on forage digestibility. Mertens & Loften (1980) associated the *in vivo* depression of fibre digestion when starch is added to the diet with the reduction of cellulolytic activity by acid conditions associated with rapid starch fermentation. Rapid starch fermentation result in increased VFA productions and hence a lowered pH (Rogers & Davis, 1984). Ruminal cellulolysis is totally inhibited at pH values below 6.0 (Mould *et al.*, 1984) and feed intake may decrease by about 25% (Russell & Wilson, 1996).

Williams *et al.* (1953), found the digestibility of oat hay to decrease by 1 to 2% units when starch was added to sheep diets at 20% of dry matter. Declines in digestibility of lucerne hay by 2 to 5% were also observed by Burroughs *et al.* (1949), when 20% starch was added in the diet of steers. El-Shazyl *et al.*, (1961) proposed the hypothesis that rumen microbes preferentially utilise starch before the population shifts to degradation of more refractory fibrous carbohydrates.

When breed comparison studies were conducted in cows that were fed high concentrate diets, Retief (2000) found the effective DM and NDF degradability of forages to be higher in Jerseys than in Holsteins. This author reported that the differences were more apparent for the lower quality forages, which in this instance were wheat straw and sodium hydroxide treated wheat straw. According to Retief (2000), the above results suggest that Jersey cows are more efficient in utilising lower quality forages than Holstein cows.

Although some experiments have been conducted to distinguish differences in forage digestibility between Jersey and Holstein cows offered high concentrate diets, the literature is still insufficient to validate the obtained results. This therefore means that repeated studies for more accurate assessment need to be carried out. The objective of this study was to distinguish differences in digestibility of oat silage, oat hay and lucerne hay between Jersey

and Holstein cows receiving concentrate diets. Changes in rumen pH, as affected by breed and feeding interval were also determined.

6.2 Materials and methods

The *in situ* technique was used to determine the ruminal degradability of lucerne hay (LH), oat hay (OH) and oat silage (OH). Non-lactating Holstein (n = 4) and Jersey (n = 4) cows, fitted with rumen cannulae were used as experimental animals. Cows were housed in individual stalls and were fed a total mixed ration (TMR). The TMR contained oat hay (20%), lucerne (15%), wheat (33%), maize (5%), oats (10%), cottonseed (15%), urea (0.5%), limestone (1.0%) and salt (0.5%). Holsteins were fed about 25kg and Jerseys 15 to 18kg TMR divided into two meals daily.

In preparing the samples for ruminal degradation, LH and OH were ground to pass through a 2mm sieve. Oat silage was cut with a pair of scissors to a length of about 1cm before incubation. Five grams of the milled samples and 10g of oat silage were weighed into dacron bags of 230mm x 100mm with a pore size of 53µm (Bar Diamond, Idaho). The bags, containing samples, were incubated in the rumen for periods of 2, 4, 8, 16, 24, 48 and 72 hours. They were suspended in the rumen with a nylon line of about 30cm, attached to stainless steel discs. The discs were connected to a hook in the cannula with a 50cm nylon line. Three bags for the 72-hour periods and 2 bags for the 48-hour period were incubated to ensure sufficient quantities of sample residue for chemical analysis. The reverse method, starting with the 72-hour bags was applied on insertion so that an all-out system could be practised upon removal.

On the last day of the experiment, rumen fluid samples for pH were collected at 10h00, 13h00 and 18h00. The pH was measured immediately after collecting the sample.

On completion of the experiment, the bags were removed from the rumen. Immediately after removal, the bags were rinsed in running tap water and placed in ice water to stop the

fermentation process. They were then rinsed in a twin-tub washing machine for 3 cycles running 3 minutes each. The water was changed after every cycle. After rinsing, the bags were dried in an oven at 60°C for 48 hours. Chemical analysis for DM using the AOAC method (1990), NDF using the Ankom method (1998) and crude protein using the Leco method (1996) was done on dried samples. To calculate the fractional disappearance and effective degradability of feeds, the equations in Chapter 4 were used.

Differences between breeds and forages were analysed according to a multi-factor analysis of variance using the Statgraphics programme (Statgraphics, 1991). Differences between breeds and treatments were analysed using a multiple range test of the Statgraphics programme. The least significant difference was used to compare means between breeds and between forages. Significant differences were declared at $P < 0.05$.

6.3 Results and discussion

6.3.1 Rumen pH

Differences related to time post-feeding were observed in rumen pH. For both breeds, pH was higher ($P < 0.05$) 2 hours after feeding. This was followed by a sharp decrease between 2 and 5 hours after feeding (Figure 1). The type of diet fed to experimental animals had a major contributory effect on the sharp decline in post-feeding pH. Higher fermentation rates on diets high in soluble carbohydrates lead to increase in volatile fatty acid (VFA) concentrations (Poore *et al.*, 1993). Increased VFA concentrations have been reported to have a depressing effect on pH (Jay, 1992). A similar reduction in pH after feeding was observed by Robinson & McQueen (1994), and Rodriguez *et al.*, (1997). These authors associated the decrease in pH with increased availability of fermentable substrate after feeding.

An increase in pH was again observed between 5 and 8 hours. This increase might have been due to a reduction in substrates before the next feeding (Rodriguez *et al.*, 1997) or increased salivary flow into the rumen during bouts of rumination (Allen, 1997) which neutralise fermentation acids (Bailey & Balch, 1961).

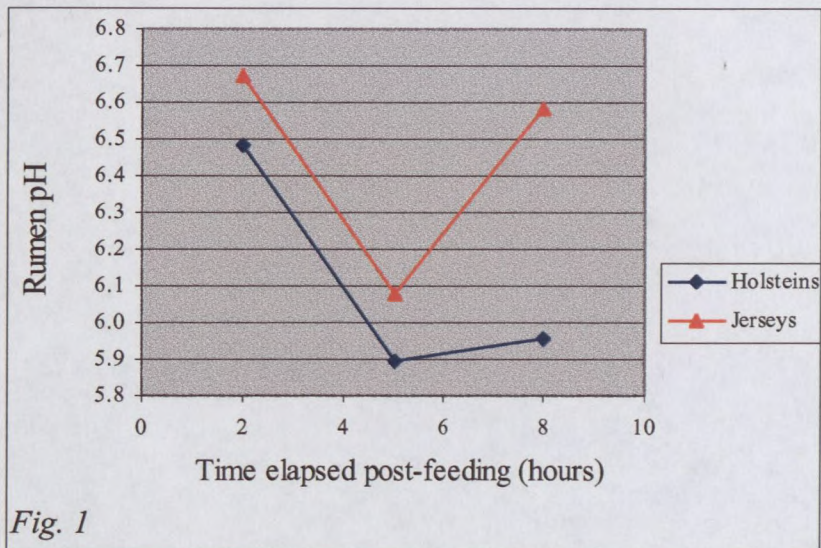


Fig. 1

Fig. 1 Ruminal pH changes in Holstein and Jersey cows on high concentrate diet as affected by time intervals post-feeding.

Although Jerseys appeared to have a higher pH between 2 – 5 hours after feeding, the two breeds did not differ statistically (Table 1). They only differed significantly ($P < 0.05$) between 5 and 8 hours after feeding with the rumen pH in Jersey increasing rapidly from 6.08 to 6.59. The increase in Holstein rumen pH was very low, i.e. from 5.90 to 5.93. Retief (2000) found Holsteins to have a significantly lower pH ($P < 0.05$) than Jerseys 4 hours after feeding but found no differences ($P > 0.05$) after 8 hours. For the mean daily ruminal pH, Jerseys also had a higher pH ($P < 0.05$) than Holsteins (Table 1). According to Rodriguez *et al.* (1997a), Jerseys are generally inclined to have a higher ruminal pH than Holsteins.

Table 1 Post-feeding changes in rumen pH of Holstein and Jersey cows on concentrate diet

Time post-feeding	Holsteins	Jerseys	P
2	6.49	6.67	NS
5	5.90	6.08	NS
8	5.93	6.59	<0.05
Daily mean	6.10	6.45	<0.05

P = probability, NS = not significant, S = significant

Diets should be balanced to maintain adequate ruminal pH, because lower ruminal pH decreases ruminal motility (Shinozaki *et al.*, 1959), microbial yield and fibre digestion (Hoover & Stokes, 1991). Results by McCullough (1968) indicated that low ruminal pH decreased the activity, or number of cellulolytic micro-organisms, or both *in vivo*.

6.3.2 Ruminal dry matter degradability

The curves comparing the ruminal DM degradability of lucerne hay, oat hay and oat silage between Holstein and Jersey cows are shown in Figure 2.

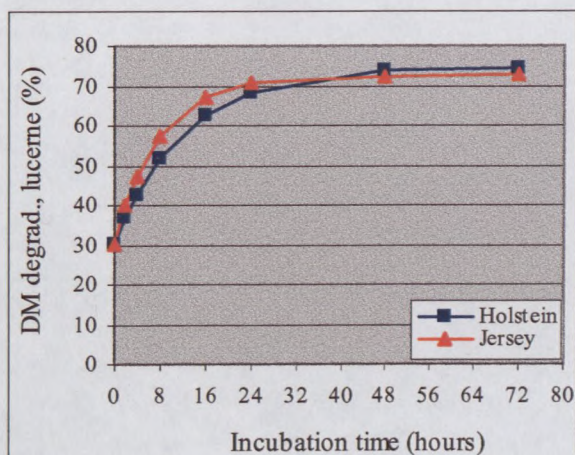


Fig. 2(a)

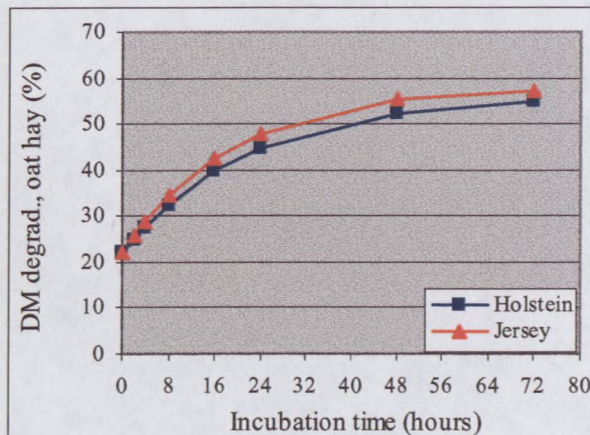


Fig. 2(b)

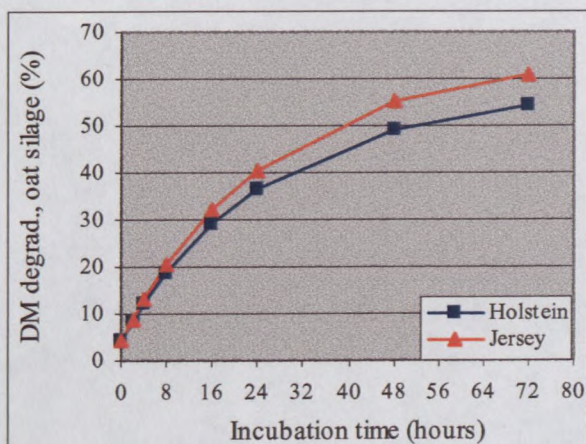


Fig.2(c)

Figure 2. The ruminal DM degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows receiving a high concentrate diet.

With DM degradability for LH, an overlapping is observed between breeds in the first two hours, but after 4 hours, the Jersey curve peaks up reaching the highest degradability point at 24 hours and Holsteins at 48 hours. This indicates a faster degradability rate of LH in Jerseys. For oat hay and oat silage, DM degradability of both breeds did not reach asymptote, indicating that the ruminal degradability of the two forages was still continuing when bags were removed. For both oat hay and oat silage, the DM degradability curve for the Jerseys was slightly higher, and this was more apparent with OS.

The soluble fraction did not differ between breeds as it was only the function of the feed. Jerseys showed a higher ($P<0.05$) potential DM degradability for OS (Table 2) and a high ($P<0.05$) degradation rate for LH compared to Holsteins. Retief (2000) did not find differences in degradation rates of LH between the two breeds.

Table 2. Ruminal dry matter degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows as estimated by the model of Ørskov & McDonald (1979).

	Lucerne			Oat hay			Oat silage		
	Holst	Jersey	P	Holst	Jersey	P	Holst	Jersey	P
Non-linear									
a	30.3	30.3		22.0	22.0		4.3	4.3	
b	44.4	42.3	NS	34.5	35.9	NS	53.1	60.6	<0.05
c	0.082	0.128	<0.05	0.045	0.053	NS	0.039	0.038	NS
Deff									
0.02	65.7	66.9	NS	45.5	48.1	<0.05	37.6	43.8	<0.05
0.05	57.7	60.9	<0.05	38.0	46.6	<0.05	26.0	30.4	<0.05
0.08	52.5	56.3	<0.05	34.1	36.4	NS	20.4	23.8	<0.05

Holst = Holstein, Deff = effective degradability, P = probability, NS = not significant

Non-linear parameters: a = soluble fraction, b = the potentially degradable fraction, and c = rate of degradation

This study did not reveal differences between breeds ($P>0.05$) in degradation rates of OS and OH. Retief (2000) found Jerseys to have a higher ($P<0.01$) rate in digesting poor- quality

Table 4. Mean values for lucerne hay, oat hay and oat silage DM degradability

Parameters	Lucerne	Oat hay	Oat silage	P
Non-linear				
A	30.3 ^a	22.0 ^b	4.3 ^c	<0.01
B	43.33 ^a	35.22 ^a	56.81 ^b	<0.01
C	0.1050 ^a	0.049 ^b	0.039 ^c	<0.01
Deff				
0.02	66.29 ^a	46.79 ^b	40.71 ^c	<0.01
0.05	59.13 ^a	39.25 ^b	28.18 ^c	<0.01
0.08	54.39 ^a	35.26 ^b	22.10 ^c	<0.01

^{a, b, c} Means with different superscripts within rows, differ significantly

forages (in this instance, wheat straw) than Holsteins. Between treatments (Table 3), the potential DM degradability of OS was higher ($P<0.05$) than that of both OH and LH, while that of LH was higher ($P<0.05$) than OH.

With the exception of LH at a fractional outflow rate of 0.02 and OH at a fractional outflow rate of 0.08, Jersey cows had higher ($P<0.05$) effective DM degradabilities at all fractional outflow rates in all the forages.

The above results suggest that Jerseys appear to be more efficient in digesting forages than Holsteins. The decreased effective degradability in Holsteins can be associated with the reduced ruminal pH that was observed in this breed. For most of the time in this study, ruminal pH for Holsteins was below 6.0. Low ruminal pH result in low microbial yield (Hoover, 1986). The fibre digesters (cellulolytic and methanogenic bacteria) are most active at a pH of 6.2 to 6.8, and can be reduced when the pH begins to fall below 6.0 (Ishler *et al.*, 2001).

6.3.3 Ruminal crude protein degradability

The extent of CP degradability is presented in Figure 3. An overlapping of the curves is observed in LH, with both breeds reaching the highest point at 24 hours. For OH, Jerseys reached an asymptote at 24 hours while the fractional disappearance continued in Holsteins till 48 hours. For OS, CP degradability in Jerseys seemed not to reach asymptote, indicating that digestion was still continuing at 72 hours while Holsteins reached the highest point at 48 hours.

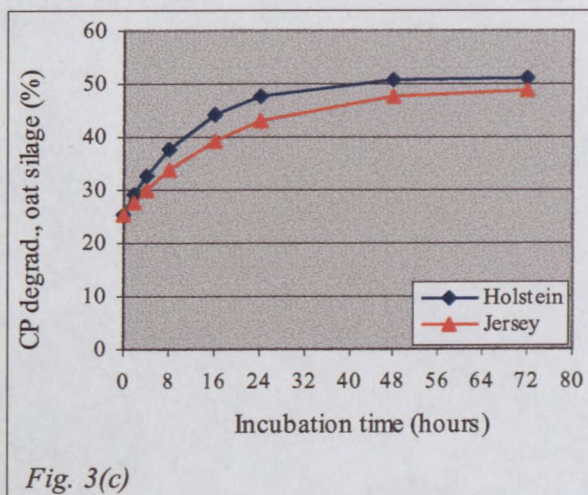
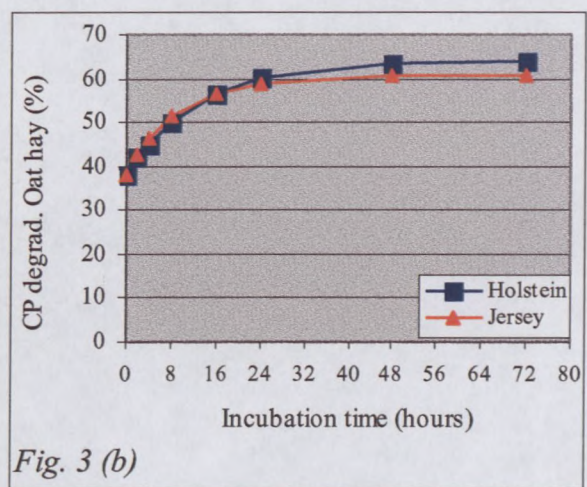
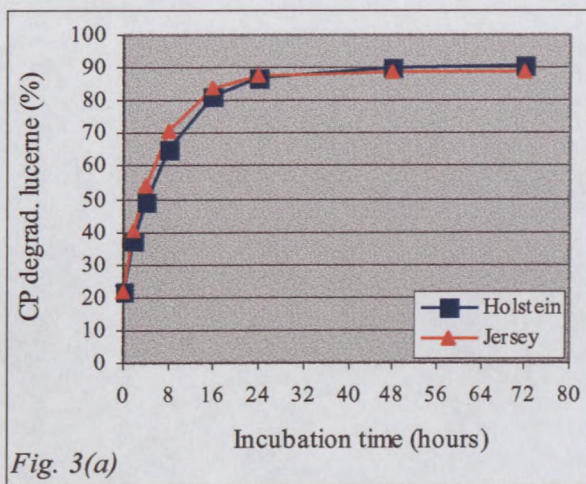


Figure 3. The ruminal crude protein degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows receiving a high concentrate diet.

For all forages, the potential degradability (Table 4) seemed to be higher in Holsteins but the two breeds did not differ significantly ($P>0.05$). Jerseys appeared to have a lower degradation rate for oat silage, higher for lucerne hay and oat hay but the differences were not significant ($P>0.05$). The degradation rate for lucerne hay observed in this study (0.125 Holsteins and 0.162 Jerseys vs. 0.21) is lower than that found by Erasmus *et al.* (1990).

For lucerne hay, Holsteins and Jerseys did not differ at 0.02 and 0.05 fractional outflow rate per hour but Jerseys had a higher ($P<0.05$) effective CP degradability at 0.08/hour outflow rate. The extent of ruminal CP degradation for lucerne hay at a fractional outflow rate of 0.02/h found in this study was almost similar to the 83.5% found by Erasmus *et al.* (1990). Jerseys had a lower ($P<0.05$) effective CP degradability for oat silage at all fractional outflow rates.

Table 3. The ruminal crude protein degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows as estimated by the model of Ørskov & McDonald (1979).

	Lucerne			Oat hay			Oat silage		
	Holst	Jersey	P	Holst	Jersey	P	Holst	Jersey	P
Non-linear									
a	22.0	22.0		38.2	38.2		25.3	25.3	
b	68.4	66.7	NS	25.8	22.4	NS	25.9	23.9	NS
c	0.125	0.162	NS	0.079	0.109	NS	0.084	0.055	NS
Deff									
0.02	80.9	81.4	NS	58.5	55.6	NS	45.5	40.9	<0.05
0.05	70.7	73.0	NS	53.6	51.9	NS	40.4	36.0	<0.05
0.08	63.6	66.7	<0.05	50.7	49.2	NS	37.6	33.5	<0.05

Holst = Holstein, Deff = effective degradability, P = probability, NS = not significant, Non-linear parameters:

a = soluble fraction, b = the potentially degradable fraction, and c = rate of degradation

Table 5. Mean values for lucerne hay, oat hay and oat silage CP degradability

Parameters	Lucerne	Oat hay	Oat silage	P
Non-linear				
a	22.0 ^a	38.20 ^b	25.3 ^c	<0.01
b	67.56 ^a	24.08 ^b	24.91 ^b	<0.01
c	0.143 ^a	0.094 ^b	0.070 ^c	<0.01
Deff				
0.02	81.16 ^a	57.02 ^b	43.05 ^c	<0.01
0.05	71.88 ^a	52.60 ^b	38.20 ^c	<0.01
0.08	65.14 ^a	49.95 ^b	35.57 ^c	<0.01

^{a, b, c} Means with different superscripts within rows, differ significantly

6.3.4 Ruminant neutral detergent fibre degradability

The percentage of ruminal NDF degradation for OS in this study showed negative degradability values up to 12 hours of incubation. The excess NDF in the post-incubation residues was assumed to be of microbial origin. This would suggest a prolonged lag phase for OS, possibly related to penetration ability of microbes on OS. Attachment, which occurs through the process of adhesion via protein complexes of ruminal micro-organisms to their substrate is a prerequisite for the digestion of forage in the rumen (Varga & Kolver, 1997). Adhesion is followed by successive microbial colonisation within the adherent population until the digestive consortia are formed and nutrients are released from substrate digestion (Cheng *et al.*, 1991). It should also be kept in mind that the oat silage used in this study was not milled, but cut into 1cm pieces, while the other forages were milled through a 2mm sieve. Milling would enhance contact of microbes to the substrate, and would affect the duration of the lag phase.

Negi *et al.* (1988) also reported negative degradability values, although in ruminal nitrogen degradability for wheat straw up to 12 hours, and for rice straw up to 24 hours of incubation.

Janicki & Stalling (1988) observed nitrogen degradability values after 1 or 2 hours of incubation that were less than at 0 hour of incubation for orchard grass hay, wheat straw and rice straw. Similar findings were reported by Erasmus *et al.* (1990) for Smuts finger grass, pearl millet hay and Midmar ryegrass. According to Erasmus *et al.* (1990), ruminal bacteria had adhered to forage particles and were not removed by washing and rinsing. Nocek & Grant (1987) suggested that estimation of bacterial contamination should be considered when establishing ruminal degradability values for low protein forages.

The extent of ruminal NDF degradability of LH, OH and OS in Holstein and Jersey cows is presented in Figure 4.

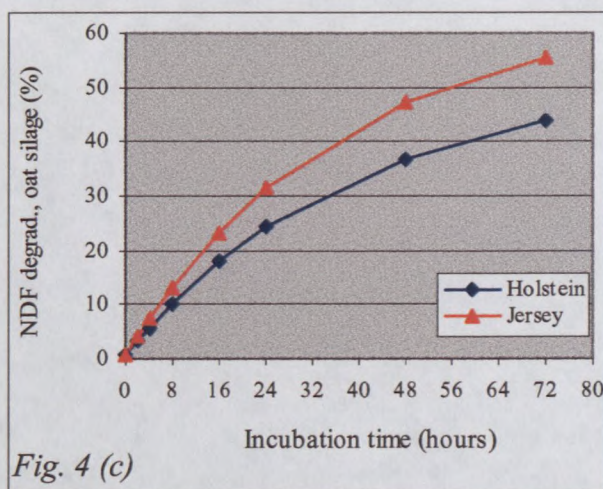
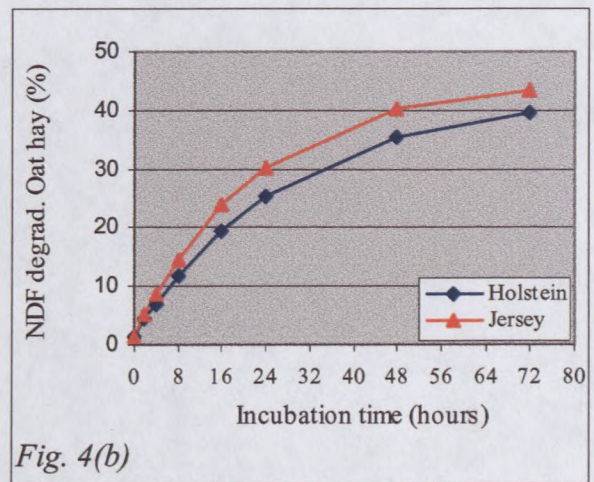
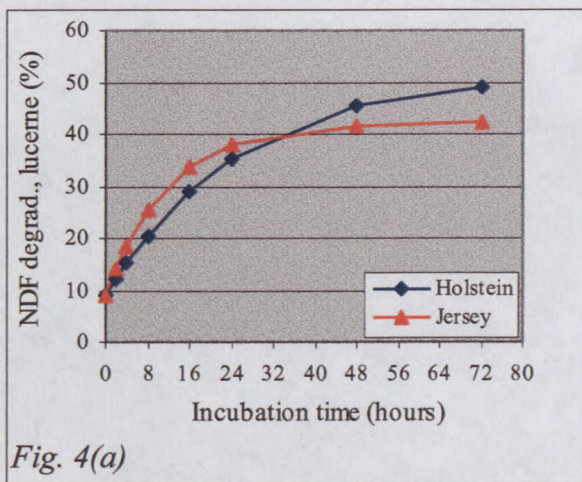


Figure 4. The neutral detergent fibre (NDF) digestibility of lucerne hay, oat hay and oat silage in Holstein and Jersey cows receiving a high concentrate diet.

In all forages, both breeds did not reach an asymptote, indicating that NDF degradation was still continuing when the bags were taken out or that the model was not capable of describing disappearance values accurately.

The potential NDF degradability of LH (Table 6) was higher ($P < 0.05$) in Holsteins but the breeds did not differ ($P > 0.05$) in OH. For OS, Jerseys had a higher ($P < 0.05$) potential NDF degradability than Holsteins. Retief (2000) did not find differences between breeds in potential NDF degradability in both lucerne and wheat straw. Although the NDF degradation rates for OH and OS in the current study appeared to be higher in Jerseys, there were no significant differences ($P > 0.05$) between breeds. Holsteins and Jerseys differed significantly only in the NDF degradation rate of LH, with Jerseys having a higher ($P < 0.05$) rate. Higher rates of NDF degradation are important as DM intake is limited by the amount of ruminal undigested NDF (Mertens, 1987). Retief (2000) did not find differences ($P > 0.05$) between the two breeds in terms of NDF degradation rate.

Table 6. The neutral detergent fibre degradability of lucerne hay, oat hay and oat silage in Holstein and Jersey cows as estimated by the model of Ørskov & McDonald (1979).

	Lucerne			Oat hay			Oat silage		
	Holst	Jersey	P	Holst	Jersey	P	Holst	Jersey	P
Non-linear									
a	8.9	8.9		1.5	1.5		0.81	0.81	
b	42.6	33.4	<0.05	40.9	43.8	NS	50.9	63.6	<0.05
c	0.040	0.087	<0.05	0.037	0.045	NS	0.025	0.027	NS
Deff									
0.02	35.1	35.9	NS	27.5	31.5	<0.05	28.5	37.1	<0.05
0.05	26.0	29.9	<0.05	18.5	22.0	<0.05	17.3	23.0	<0.05
0.08	21.7	26.0	<0.05	14.1	17.0	<0.05	12.5	16.8	<0.05

Holst = Holstein, Deff = effective degradability, P = probability, NS = not significant, S = significant

Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

Table 7. Mean values for lucerne hay, oat hay and oat silage NDF degradability

Parameters	Lucerne	Oat hay	Oat silage	P
Non-linear				
a	8.9 ^a	1.5 ^b	0.81 ^c	<0.01
b	38.03 ^a	42.328 ^b	57.22 ^b	<0.01
c	0.064 ^a	0.041 ^b	0.0260 ^c	<0.01
Deff				
0.02	35.49 ^a	29.52 ^b	32.8 ^c	<0.01
0.05	27.93 ^a	20.21 ^b	20.14 ^b	<0.01
0.08	23.88 ^a	15.56 ^b	14.67 ^b	<0.01

^{a, b, c} Means with different superscripts within rows, differ significantly

Except for lucerne hay at an outflow rate of 0.02 per hour, the effective NDF degradabilities between the two breeds differed significantly ($P < 0.05$) in all three forages at all fractional outflow rates, with Jerseys having higher ($P < 0.05$) effective NDF degradability values. This would suggest that Jerseys appear to be more efficient in digesting fibre than Holsteins. Retief (2000) made the same conclusion. The efficiency observed in Jerseys can be attributed to their higher ruminal pH. The ruminal pH in Jerseys was above 6.0 for most of the time. The fibre digesters are most active at a pH of 6.2 to 6.8, and can be reduced when the pH begins to fall below 6.0 (Ishler *et al.*, 2001). Ruminal cellulolysis is totally inhibited at pH values below 6.0 (Mould *et al.*, 1984). Mertens & Loften (1980) associated the *in vivo* depression of fibre digestion when starch is added to the diet with the reduction of cellulolytic activity by acid conditions associated with rapid starch fermentation.

Lucerne hay had the highest ($P < 0.01$) effective NDF degradability, followed by OH, then OS (Table 7). The higher effective NDF degradability in lucerne hay can possibly be attributed to the higher soluble DM fraction.

6.4 Conclusion

The results obtained in this study suggest that Jerseys appear to be more likely to have a higher rumen pH than Holsteins when receiving a high concentrate diet. This therefore makes them to be more efficient in digesting forage than Holsteins, especially the low quality forages. Jerseys in this study had higher effective degradability in all forages and almost in all nutrients except for CP in oat silage where Holsteins showed efficiency in digesting it. This indicates that pH below 6.0 results in decreased cellulolytic activity. The low ruminal pH, commonly observed in Holsteins led to decreased cellulolytic activity and low digestibility.

6.5 References

- Allen, M. S., 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fibre. *J. Dairy Sci.* 80:1447.
- Association of Official Analytical Chemists, 1990. *Official Methods of Analysis*. 15th ed. AOAC, Arlington.VA.
- Bailey, C. B. & Balch, C. C., 1961. Saliva secretion and its relation to feeding in cattle. 2. The composition and rate of secretion of mixed saliva in the cow during rest. *Brit. J. Nut.* 15:383.
- Burroughs, W., Gerlaugh, P., Edgington, B. H., & Bethke, R. M., 1949. The influence of corn starch upon roughage digestion in cattle. *J. Anim. Sci.* 8: 271
- Cheng, K. J., Forsberg, C. W., Minato, H & Costerton, J. W., 1991. Microbial ecology and physiology of feed degradation within the rumen. In: Physiological aspects of digestion and metabolism in ruminants. Editors: Tsuda, T., Sasaki, Y. & Kawashima R. Academic Press, Toronto. p 595.
- El-Shazyl, K., Dehority, B. A., & Johnson, R. R., 1961. Effects of starch on the digestion of cellulose in vitro and in vivo by rumen microorganisms. *J. Anim. Sci.* 20: 268
- Erasmus, L. J., Prinsloo, J., & Botha, P. M., 1990. Establishment of a ruminal protein degradation data base for dairy cattle using the *in situ* polyester bag technique. 3. Roughages. *S. A. J. Anim. Sci.* 20(3): 130.
- Hoover, W. H. & Stokes, S. R., 1991. Balancing carbohydrate and protein for optimum rumen microbial yield. *J. Dairy Sci.* 74: 3630.

Ishler, V., Heinrichs, J. & Varga, G., 2001. Background in basic nutrition of dairy cattle (Part1). <http://www3.das.psu.edu/dcn/catnut/422/contents.html>

Janicki, F. J. & Stallings, C. C., 1988. Degradation of crude protein in forages determined by in vitro and in situ procedures. *J. Dairy Sci.* 71: 2440.

Jay, J. M., 1992. Food preservation with chemicals. In: Modern food microbiology 4th ed. Van Nostrand Reinhold Co. New York. p 269.

Kelley, C. L., 1998. Method for determining neutral detergent fibre (aNDF). ANKOM Technology.

Leco Corporation, 1996. Nitrogen and Protein determinator. In: Instrumentation for characterisation of organic / inorganic materials and Microstructural analysis. USA.

McCullough, M. E., 1986. Feeding dairy cows. In: The how and why of feed programming. W. D. Hoards & Sons Company, Fort Atkinson, Wisconsin. p 85.

Mertens, D. R., 1987. Predicting intake and digestibility using mathematical models of ruminal function. *J. Anim. Sci.* 64: 1548.

Mertens, D. R., & Lofton, J. R., 1980. The effect of starch on forage fibre digestion kinetics *in vitro*. *J. Dairy Sci.* 63 : 1437.

Mould, F. L., Orskov, E. R. & Mann, S. O., 1984. Associative effects of mixed feeds. 1. Effects of type and level of supplementation and the influence of rumen fluid pH on cellulolysis in vivo and dry matter digestion of various roughages. *Anim. Feed Sci. Tech.* 10:15

Negi, S. S., Singh, B. & Makkar, H. P. S., 1988. Rumen degradability of nitrogen in typical cultivated grasses and leguminous fodders. *Anim. Feed Sci. Tech.* 22,79

Nocek, J. E., 1988. *In situ* and other methods to estimate ruminal protein and energy digestibility: A review. *J. Dairy Sci.* 71: 2051.

Nocek, J. E. & Grant, A. L., 1987. Characterisation of *in situ* nitrogen and fibre digestion and bacterial nitrogen contamination of hay crops forages preserved at different dry matter percentages. *J. Anim. Sci.* 64: 552.

Ørskov E. R., & McDonald, I., 1979. The estimate of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. *J. Agric. Sci. (Cambridge)*. 92: 499.

Poore, M. H., Moore, J. A., Swingle, R. S., Eck, T. P. & Brown, W. H., 1993. Response of lactating cows to diets varying in fibre source and ruminal starch degradability. *J. Dairy Sci.* 76: 2235.

Retief, N., 2000. Breed differences in ruminal digestibility of forages in dairy cows receiving high concentrate diets. *MSc. Thesis*. University of Stellenbosch. p 32.

Robinson, P. H. & McQueen, R. E., 1994. Influence of supplemental protein source and feeding frequency on rumen fermentation and performance in dairy cows. *J. Dairy Sci.* 77:1340.

Rodriguez, L. A., Stallings, C. C., Herbein, J. H. & McGilliard, M. L., 1997. Diurnal variation in milk and plasma urea nitrogen in Holstein and Jersey cow in response to degradable dietary protein and added fat. *J. Dairy Sci.* 80: 3368.

Rogers, J. A., & Davis, C. L., 1982. Effects of intraruminal infusions of mineral salts on volatile fatty acid production in steers fed high grain and high roughage diets. *J. Dairy Sci.* 65: 953

Russell, J. B. & Wilson, D. B., 1996. Why are ruminal cellulolytic bacteria unable to digest cellulose at low pH? *J. Dairy Sci.* 79, 1503

Shinozaki, K., 1959. Studies on experimental bloat in ruminants. 5. Effects of various volatile fatty acids introduced into the rumen on the rumen motility. *Tohoku J. of Agric. Res.* 9: 237.

Statgraphics 5.0. 1991. Statistical Graphic System. Statistical Graphic Corporation Incl., 2115 East Jefferson Street, Rockville, MD, 20852.

Varga, G. A. & Kolver, E. S., 1997. Microbial and animal limitations to fibre digestion and utilisation. *J. Nut.* 127, 819S.

Williams, V. J., Rottle, M. C., Moir, R. J., & Underwood, E. J., 1953. The influence of varying dietary levels of protein and starch upon digestibility, nitrogen retention and the free micro-organisms of the rumen. *Austr. J. Biol. Sci.* 6: 142

CHAPTER 7

Comparing ruminal degradability of fresh, freeze-dried and oven-dried oat silage in Jersey cows receiving a high forage diet.

Abstract

The difference in dry matter (DM), crude protein (CP) and neutral detergent fibre (NDF) degradability between fresh (FS), freeze-dried (FD) and oven dried (OD) oat silage, in Jersey cows receiving a high forage diet were determined using the in situ technique. Freeze-dried and oven-dried silage were milled to pass through a 2mm sieve and fresh silage was cut into 1cm pieces using a sharp pair of scissors. The weighed samples of these forages were incubated in the rumens of cannulated cows for 2, 4, 8, 12, 24, 36, 48, 72, and 96 hours. The dry matter (DM), crude protein (CP) and neutral detergent fibre (NDF) degradation rate and effective degradabilities of FS were lower ($P<0.05$) than that of FD and OD silage. Freeze-dried silage had higher ($P<0.05$) CP and NDF degradation rates but DM degradation rate did not differ ($P>0.05$) from that of OD silage. The effective DM and CP degradability was higher ($P<0.05$) in OD silage while the effective NDF degradability was higher in FD silage.

Key words: degradability, effective degradability, wet silage, freeze dried silage, oven-dried silage, dry matter, crude protein , neutral detergent fibre.

7.1 Introduction

The method of sample preparation for degradability studies influences the rate and extent of its degradability. Particle size is the major factor influencing the digestive process (Mertens & Ely, 1982). The high moisture content of silage makes it impossible to be milled before being used in ruminal degradability experiments, and samples need to be dried before milling. Drying is required to preserve product quality while reducing the moisture content and avoiding thermal or mechanical degradation (Shaw, 2001). Selection of the right drying system requires a thorough knowledge of the properties of the feed material as well as the desired characteristics of the final product (Shaw, 2001). Two methods of drying can be used, viz., freeze-drying and oven drying.

Oven drying is the simplest way of drying and it needs almost no special equipment. It involves heating the feed sample in an oven at a temperature of 60°C for 48 hours. The problem commonly experienced is that heating can alter the chemical structure of some proteins, rendering it bound to undegradable material and therefore making it unavailable for degradation. Heating forms cross-linkages in proteins that reduce the rate of protein digestion by preventing enzyme penetration or by masking the sites of enzyme attachment (Hendriks *et al.*, 2001). This can lead to an underestimation of rumen degradable protein of the unheated raw material.

Freeze-drying is the process of dehydrating frozen foods under vacuum so that the moisture content changes directly from a solid to a gaseous form without having to undergo the intermediate liquid state through sublimation (Shaw, 2001). Freeze-drying appears to be more advantageous than oven-drying because the product maintains its original size and shape. Also, when placed in water, the feed reconstitutes to its original state (Horvath, 2001). The problem with freeze-drying is that the ice particles formed when freezing the feed before drying can lead to minimum cell rupture (Freeze-Dry Foods Limited, 2001). Freeze drying is also extremely expensive (Horvath, 2001).

With both drying methods, the moisture in silage evaporates, resulting in a failure to subject the silage to digestion in its original state. To reduce the particle size of silage, it could be cut with either a knife or a pair of scissors to smaller pieces of about one centimetre. The cutting method can be seen as the best method as it simulates the as fed moisture content and particle size. The moisture in silage is preserved and the cut pieces are of the same size as those that are found in the rumen. Since the cut samples are hand-made, they however, lack the homogeneity that exists with machine milled samples. Also, the cut silage pieces can be too big resulting to a reduced surface area for enzymatic attack. According to Staples *et al.* (1984), increased mastication reduces particle size and increase surface area for enzymatic attack.

This trial was conducted to determine differences in ruminal degradability between freeze-dried, oven-dried and fresh oat silage in Jersey cows receiving a high forage diet.

7.3 Materials and methods

The *in situ* method was used to determine ruminal degradability of oven-dried (OD), freeze-dried (FD) and fresh (FS) oat silage. Five non-lactating Jersey cows fitted with rumen cannulae were used in the experiment. The cows were housed in individual stalls and fed 3kg lucerne hay per day and *ad libitum* oat hay. Fresh water was also available *ad libitum*.

Oven-dried and freeze-dried silages were milled to pass through a 2mm sieve. To preserve the moisture in fresh silage, it was cut with a sharp pair of scissors to pieces of about 1cm in length. Five grams of OD and FD silage samples were weighed into dacron bags of 230mm x 100mm with a pore size of 53µm (Bar Diamond, Idaho). For FS, 10g were weighed into dacron bags to compensate for the moisture content of the silage. The weighed samples were incubated in the rumen of cannulated cows for periods of 0, 2, 4, 8, 12, 24, 36, 48, 72 and 96 hours. Three bags for 96 and 72-hour periods and two bags for 48-hour periods were prepared to provide for enough residues for NDF and CP analysis.

The dacron bags with weighed feed samples were put in orange bags that were designed to have 10 compartments, with one dacron bag accommodated in each compartment. Three orange bags with OD, FD and FS samples in separate bags were prepared for each cow. The orange bags were suspended with nylon strings of about 50cm attached to the rumen cannula with a hook. The string allowed for free movement of the bags inside the rumen.

Feed samples were put in the rumen in the reverse order starting with the 96-hour bags so that the all-out system could be practised upon removal. The number of dacron bags was limited to a maximum of 30 bags per cow at a given time to allow proper mixing of the rumen fluid with the bag contents. This number was maintained by inserting the 12-hour bags, followed consecutively by 8, 4, and 2-hour bags when the 72-hour bags were inserted. The 4 sets of bags were taken out when the 48-hour bags were put in. To prevent the bags from floating in the rumen, they were weighed down with weights. The bags used to determine 0-hour ruminal degradability were not incubated in the rumen, but were only subjected to the washing procedure.

On removal, bags were washed in running tap water and then placed immediately in ice water to stop the fermentation process. Bags were then washed in a twin tub washing machine for three cycles lasting three minutes each. Washing water was changed after every cycle. They were then dried in an oven at 60°C for 48 hours.

Dried samples were analysed for NDF using the Ankom method (1998), DM according to the methods of the AOAC (1990) and CP according to the Leco method (1996). To calculate the fractional disappearance and effective degradability of feedstuffs, the equations in Chapter 4 were used.

Differences between forages were analysed according to a one-way analysis of variance using the Statgraphics programme (Statgraphics, 1991). Differences between treatments were analysed using a multiple range test of the Statgraphics programme. The least significant difference was used to compare means between forages. Significant differences were declared at $P < 0.05$.

7.3 Results and discussion

7.3.1 Ruminal dry matter degradability

The ruminal DM degradability of fresh, freeze-dried and oven-dried oat silage are presented in Figure 1. The DM degradability increased with time but asymptote, which was assumed to be the highest point of degradability, was not reached even after 96 hours. An overlapping in the freeze-dried and oven-dried silage curves was observed while the fresh silage curve was below the other two curves throughout.

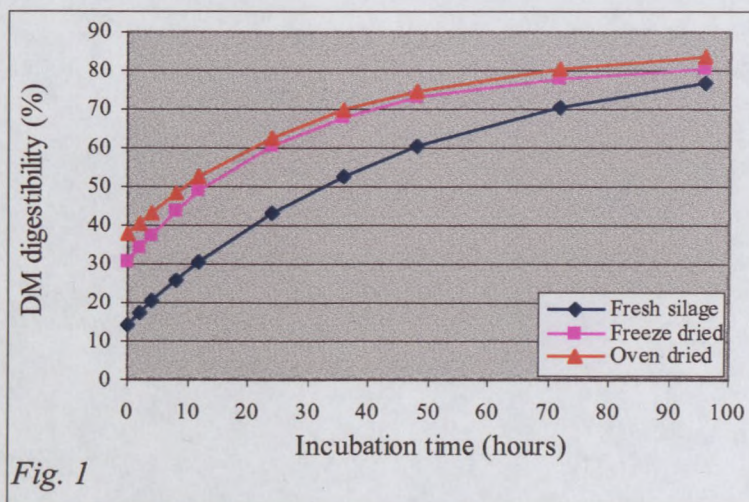


Figure 1. The ruminal dry matter (DM) degradability of fresh, freeze-dried and oven-dried oat silage in Jersey cows a high receiving a forage diet.

The ruminal DM degradability of fresh, freeze-dried and oven-dried silage in Jersey cows, calculated according to the model of Ørskov & McDonald (1979), is presented in Table 1. The soluble fraction was the function of the feed only. Oven-dried silage had the highest ($P<0.05$) soluble fraction, followed by freeze-dried, then fresh silage. The fresh silage was expected to have a lower soluble DM fraction because of the larger particle size. The potential degradability of fresh silage was higher ($P<0.05$) than that of both freeze-dried and oven-dried silage, but the freeze-dried and oven-dried silage did not differ ($P>0.05$). Despite the higher potential DM degradability observed in fresh silage, it had a lower ($P<0.05$) DM degradation

rate than freeze-dried and oven-dried silages. The lower degradation rate of fresh silage may be attributed to both the high moisture content and the large particle size of this silage.

High moisture content results in difficulty of the rumen fluid containing microbial flora to penetrate the fresh silage. The larger particle size of fresh silage in this study decreased surface area for enzymatic attack, and this was assumed to be the most probable reason for lower fermentation rates. Reducing the particle size increases surface area for enzymatic attack and results in higher fermentation rates (Staples *et al.* 1984). Weakly *et al.* (1977), indicated that dry matter and nitrogen degradation is lower with coarse compared to fine particles. Particle breakdown occurs through chewing during eating and rumination, microbial fermentation and through detrition by muscular activity of the rumen walls (Moseley & Jones, 1984; and Murphy & Nicoletti, 1984). Microbial action plays a minor role in particle breakdown, chewing is the main factor (Moseley & Jones, 1984).

Table 1. The ruminal DM degradability of oven-dried, freeze-dried and fresh oat silage in Jersey cows as estimated by the model of Ørskov & McDonald (1979).

Parameters	Fresh silage	Freeze-dried	Oven-dried	P
Non-linear				
a	14.5 ^a	30.5 ^b	37.7 ^c	<0.01
b	71.37 ^a	51.12 ^b	48.50 ^b	<0.01
c	0.02178 ^a	0.03459 ^b	0.03046 ^b	<0.01
Deff				
0.02	51.37 ^a	62.88 ^b	66.67 ^c	<0.01
0.05	35.94 ^a	51.43 ^b	55.82 ^c	<0.01
0.08	29.61 ^a	45.97 ^b	50.89 ^c	<0.01

Deff = effective degradability, P = probability, ^{abc} means within rows with different superscripts differ significantly. Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

At all fractional outflow rates, the effective DM degradability of fresh silage was lower ($P<0.05$) than that of both freeze-dried and oven-dried silage, while freeze-dried effective DM degradability was also lower ($P<0.05$) than that of oven-dried. This can be attributed to the high soluble fraction of this silage compared to others.

7.3.2 Ruminal crude protein degradability

The ruminal CP degradability of fresh silage, freeze-dried and oven-dried silages is presented in Figure 2 and Table 2. Asymptote, which was assumed to be the highest point of degradation, was reached at 8, 24 and 36 hours for freeze-dried, oven-dried and fresh oat silage, respectively.

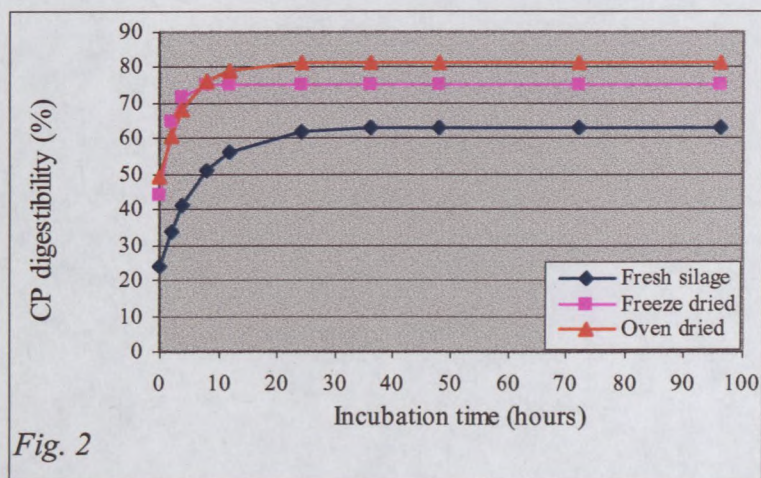


Figure 2. The ruminal crude protein (CP) degradability of fresh silage, freeze-dried and oven-dried oat silage in Jersey cows receiving forage diet.

Oven-dried oat silage had the highest ($P<0.05$) soluble CP fraction, followed by freeze-dried, then fresh oat silage. The higher soluble CP fraction in-oven dried silage can possibly be attributed to the higher soluble DM fraction. However, the potential degradability of oven-dried and freeze-dried oat silage did not differ, but were lower ($P<0.05$) than that of fresh silage. Freeze-dried silage had a higher ($P<0.05$) rate of degradation, and was followed by oven-dried, then fresh silage ($P<0.05$). This can also be seen in Figure 2, as the highest point

of degradability was reached already after 8, 24 and 36 hours for freeze-dried, oven-dried and fresh oat silage, respectively.

At 0.02 and 0.05 fractional outflow rates per hour, oven-dried silage had the highest effective CP degradability, followed by freeze-dried, then fresh silage ($P < 0.05$), but at 0.08 fractional outflow rate per hour, the effective CP degradability did not differ ($P > 0.05$) between freeze-dried and oven-dried silages. The higher effective CP degradability of oven-dried silage can be attributed to its higher soluble fraction.

Table 2. The crude protein degradability of oven-dried, freeze-dried and fresh oat silage in Jersey cows as estimated by the model of Ørskov & McDonald (1979).

Parameters	Fresh silage	Freeze dried	Oven dried	P
Non-linear				
a	24.3 ^a	44.0 ^b	49.5 ^c	<0.01
b	38.8400 ^a	31.229 ^b	31.986 ^b	0.03
c	0.06138 ^a	0.55823 ^b	0.21970 ^c	<0.01
Deff				
0.02	54.954 ^a	74.045 ^b	78.827 ^c	<0.01
0.05	48.059 ^a	72.456 ^b	75.539 ^c	<0.01
0.08	43.962 ^a	71.037 ^b	73.519 ^b	<0.01

Deff = effective degradability, P = probability, NS = not significant, S = significant

Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

It was assumed that the effective CP degradability of oven-dried silage would be lower than that of freeze-dried silage at all fractional outflow rates. This assumption was based on the fact that heating can alter the chemical structure of some proteins, rendering them bound to undegradable material and therefore unavailable for degradation. According to Hendriks *et al.* (2001), heating results in formation of cross-linkages in proteins which reduce the rate of protein digestion by preventing enzyme penetration or by masking the sites of enzyme attachment.

7.3.3 Ruminal neutral detergent fibre degradability

The ruminal neutral detergent fibre degradability of fresh silage, freeze-dried and oven-dried oat silage is presented in Figure 3. None of the curves reached asymptote, indicating that fibre digestion was still continuing when the bags were removed from the rumen after 96 hours.

The soluble NDF fraction (Table 3) of the silages differed significantly, with freeze-dried silage having the highest ($P<0.05$) soluble fraction. The potential NDF degradable fraction of fresh silage was higher ($P<0.05$) than that of both the freeze-dried and oven-dried silages. The oven-dried silage had a higher ($P<0.05$) potential NDF degradable fraction than freeze-dried silage. Despite the lower potential NDF degradability of freeze-dried silage, it had the highest ($P<0.05$) degradation rate. Slow rates of fibre digestion result in slow rates of evacuation of indigestible material resulting in poor voluntary intake (Ndlovu & Buchanan-Smith 1985).

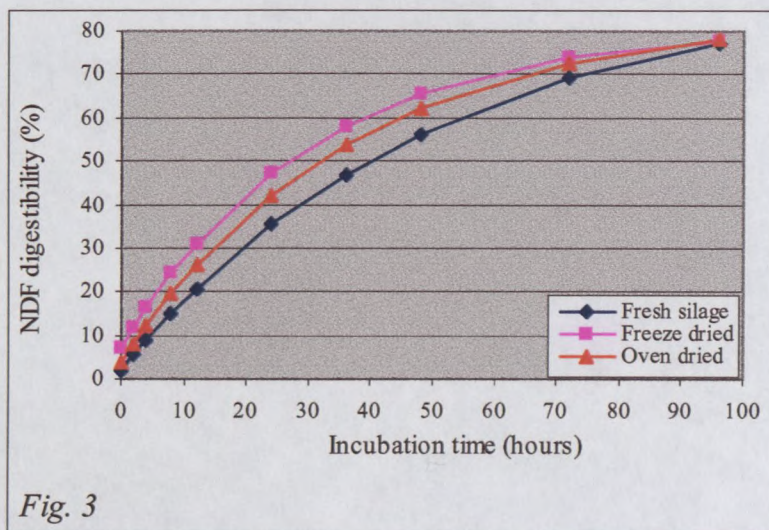


Fig. 3

Figure 3. The ruminal neutral detergent fibre (NDF) degradability of fresh silage, freeze-dried and oven-dried oat silage in Jersey cows receiving a high forage diet.

Table 3 represents the neutral detergent fibre degradability of fresh, freeze-dried and oven-dried silages in Jersey cows as estimated by the model of Ørskov & McDonald (1979).

The effective NDF degradability of freeze-dried silage was higher than that of the other two

forages at all fractional outflow rates. This can be attributed to both the higher soluble fraction and higher degradation rate of this feed. The fresh silage had the lowest effective NDF degradability values at all fractional outflow rates. This can be associated with lower DM degradability that has been observed with this feed.

Table 3. The ruminal neutral detergent fibre degradability of oven-dried, freeze-dried and fresh oat silage in Jersey cows as estimated by the model of Ørskov & McDonald (1979).

Parameters	Fresh silage	Freeze-dried	Oven-dried	P
Non-linear				
a	2.1	7.1	3.8	<0.01
b	86.949 ^a	73.485 ^b	78.318 ^c	<0.01
c	0.01955 ^a	0.03292 ^b	0.02704 ^c	<0.01
Deff				
0.02	45.829 ^a	52.659 ^b	49.540 ^b	<0.01
0.05	26.949 ^a	36.181 ^b	31.711 ^c	<0.01
0.08	19.457 ^a	28.471 ^b	23.900 ^c	<0.01

Deff = effective degradability, P = probability, NS = not significant, S = significant

Non-linear parameters: *a* = soluble fraction, *b* = the potentially degradable fraction, and *c* = rate of degradation

7.4 Conclusion

Fresh oat silage had lower DM, CP and NDF degradabilities ($P < 0.05$) in comparison to freeze-dried and oven-dried silages. The moisture content and particle size were assumed to be the major causes of the lower degradability of fresh silage. Freeze-dried silage had a higher DM, CP and NDF degradation rate than fresh and oven-dried silages. The effective NDF degradability was also higher with freeze-dried, but the effective DM and CP degradability was higher in oven-dried silage. The implication of this is that fresh silage samples would give lower degradability values than other methods of sample preparation. Further studies are necessary to compare the different drying methods with fresh silage using samples of similar particle size. The most representative particle size of oat silage in rumen of dairy cows after mastication needs further investigation to improve the accuracy of the *in situ* method.

7.5 References

- Association of Official Analytical Chemists, 1990. *Official Methods of Analysis*. 15th ed. AOAC, Arlington.VA.
- Freeze-Dry Foods Limited, 2001. Introduction to Freeze-Drying Technology. 579 Speers Road, Oakville, Ontario Canada, L6K 2G4. <http://www.freeze-dry.com/tech/tech.html>.
- Hendriks, W. H., Emmens, M. M. A., Trass, B., & Pluske, J. R., 2001. Effect of heat processing of protein & mineral. Massey University, New Zealand.
<http://www.ighawaii.com/naturally/newsletter/heatprotein.html>
- Horvath, L., 2001. Freeze drying. <http://www.freeze-dry.com/tech/tech.html>.
- Kelley, C. L., 1998. Method for Determining Neutral Detergent Fibre (aNDF). ANKOM Technology.
- Leco Corporation, 1996. Nitrogen and Protein determinator. In: Instrumentation for characterisation of organic / inorganic materials and Microstructural analysis. USA.
- Mertens, D. R. & Ely, L. O., 1982. Relationship of rate and extent of digestion of forage utilisation – a dynamic model evaluation. *J. Anim. Sci.* 54: 895.
- Moseley, G. & Jones, J. R., 1984. The physical digestion of perenial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) in the foregut of sheep. *Br. J. Nutr.* 52: 381.
- Murphy, M. R. & Nicoletti, J. M., 1984. Potential reduction of forage and rumen digesta particle size by microbial action. *J. Dairy Sci.* 67: 1221.
- Ndlovu, L. R., & Buchanan-Smith, 1985. Utilisation of poor quality roughages by sheep: Effects of alfalfa supplementaion on ruminal parameters, fibre digestion and rate of passage

from the rumen. *Can. J. Anim. Sci.* 65: 693.

Ørskov E. R., & McDonald, I., 1979. The estimate of protein degradability in the rumen from incubation measurements weighted according to the rate of passage. *J. Agric. Sci. (Cambridge)*. 92 : 499.

Shaw, V. F., 2001. Fresh options in drying (Niro Inc.)

<http://www.gea-niro.com.mx/chemarticles/fresh.html>

Staples, C. R., Fernando, R. C., Fahey, G. C. (Jr.), Berger, L. L., & Jaster, E. H., 1984. Effects of intake of a mixed diet by steers on digestion events. *J. Dairy Sci.* 67 (5): 995.

Statgraphics 5.0. 1991. Statistical Graphic System. Statistical Graphic Corporation Incl., 2115 East Jefferson Street, Rockville, MD, 20852.

CHAPTER 8

GENERAL CONCLUSIONS

Feed cost, which comprises about 65 - 80% of the total milk production costs is the most important factor that affects profitability in a dairy enterprise. If a dairy is to be successful, the dairy farmer must continually adopt practices that allow the greatest output of milk at the most economical cost. Offering home produced forages, which provide the necessary nutrients at a lower cost and promote higher nutrient intakes results in higher milk production levels and increased profitability. Conserving the home produced forages either in silage or hay form brings about a constant forage supply during the periods of feed scarcity.

Since the Western Cape is one of the major producers of small grain forages in South Africa, an understanding of their nutrient composition is important to farmers. This will help them to determine the levels of supplementation needed when feeding small grain forages to their productive stock. In the studies conducted here, oats, which is a small grain forage, was observed to be low in crude protein. It is also low in vitamins and some minerals such, as calcium. Understanding the minimum supplements one can give when feeding oats without impairing the production performance of the cow result in increased dry matter intake, higher milk yields and therefore increased profitability. Two kg of lucerne hay was found to be the minimum amount that should be provided to lactating Jersey cows receiving oat silage.

Feeding oat silage as the only forage source resulted in a lower DM intake and reduced protein content in milk. The lower DM intake was associated with the high moisture content causing quick rumen fill. It is therefore advisable that silage should always be fed with hay. Hay reduces the acid load in the rumen while drying out the diet giving it a more open and fluffy texture that increases palatability.

Knowledge of feed degradability, and changes in the rumen environment because of feed type and time elapsed after feeding is important. This is because changes in the rumen environment bring about changes in feed degradability, the health of the cow and productivity.

Understanding breed differences in feed degradability gives a broader understanding of the efficiency at which a certain type of feed is utilised by the cow.

Feed digestibility is of great importance as the true value of the feed depends on the amount of nutrients that can be utilised by the animal after digestion. As expected, cows digested high quality forages more efficiently than lower quality ones. When the cows were fed forage diets, very little differences were observed between breeds. It was therefore concluded that breed does not affect ruminal degradability when the cows are receiving forage diets. Differences however, became more apparent when the cows were fed high a concentrate diet. Jerseys appeared to be more efficient at digesting forage than Holsteins when they were fed a high concentrate diet. This was associated with their rumen pH as it was almost always above 6.0, whereas that of Holsteins was always below 6.0, which is the minimum pH required by cellulolytic microbes.

Particle size is the major factor influencing the digestive process. Because of the high moisture content of silage it has to be dried before milling for use in digestibility experiments. The drying process, however, can cause thermal or mechanical degradation. In a study that was conducted with Jersey cows, fresh silage had lower DM, CP and NDF degradability values than freeze-and oven-dried silages. Freeze-dried silage had higher degradation rates and effective NDF degradability. The oven-dried silage had higher effective DM and CP degradability. The method in which silage samples must be prepared before insertion in the rumen for digestion is still a problem that needs further investigation.

The rumen environment is the major factor that influence feed digestibility. This study has shown that forages are important in ruminant feeding as they provide a buffering capacity and sustain a stable environment in the rumen. This helps to improve the fermentation efficiency. The cows that received a high forage diet had a pH higher than 6.0, with volatile fatty acid (VFA) concentration above 2 and below 15g/l, and the rumen ammonia (NH₃-N) levels below 80mg /100mls rumen fluid. NH₃-N concentrations above 80mg /100mls are associated with toxicity.

Feeding a high concentrate diets to cows resulted in lower rumen pH values, especially for the Holsteins. Ruminal pH dropped to levels below 6.0. Inefficient fibre digestion was observed. Oat silage NDF degradation did not take place in the first 12 hours of incubation. Low pH also causes disorders such as rumen acidosis and rumenitis, leading to reduction in milk production. Although cows in this study did not reach the stage of acidosis and rumenitis as they were fed concentrates for a very short period, this is important to note as it is one of the reasons why dairy cows are culled from the herd.

The rumen environment differed significantly between Holsteins and Jerseys. Jerseys had higher rumen pH, lower VFA and $\text{NH}_3\text{-N}$ concentrations than Holsteins. The difference in pH was observed in both forage and high concentrate feeding. Time elapsed after feeding also differed significantly. Before feeding, cows had higher pH, lower VFA and $\text{NH}_3\text{-N}$ concentrations but after feeding, it was the vice versa. It was therefore concluded that substrate availability and eating behaviour influence the rumen environment.