THE NUTRITIVE VALUE OF FABA BEAN SILAGE FOR LACTATING DAIRY COWS

by

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date:

Abstract

Title	:	The nutritive value of faba bean silage for lactating dairy cows.
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The dry matter (DM) production and chemical composition of whole crop faba beans (*Vicia faba*) and oats (*Avena sativa*) were determined according to fresh material harvested at weekly intervals. From 75 to 166 days after planting whole plants of faba beans and oats were harvested at a height of *ca*. 10 cm above the ground on five randomly selected areas of 0.25 m² each. The freshly harvested material was weighed "as is" and oven-dried to determine the DM content of each sample. The fresh and DM forage production per hectare was then calculated. The crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), nitrogen free extract (NFE), fat (EE), calcium (Ca) and phosphorus (P) contents were determined according to standard laboratory techniques. The change in chemical composition of fresh whole crop material was regressed on days after planting using simple linear regressions. The fresh and DM production of whole crop faba beans and oats increased with advancing growth stage. During the 2002 production year fresh yield production of both whole crop faba beans and oats peaked at 131 days (44.7±6.9 and 28.4±7.1 ton/ha respectively). DM yield peaked at 159 and 152 days for whole crop faba beans and oats being 9.4±1.3 and 8.8±0.7 tons DM/ha respectively. The chemical composition of both forage crops decreased with advancing growth stage. The CP content of whole crop faba beans decreased (P<0.05) from 25.3% at 82 days after planting to 18.4 % at 166 days after planting in the 2002 production year, while during the 2003 production year the CP content of whole crop faba beans decreased (P<0.05) from 28.2 to 19.5 % from 75 to 159 days after planting. During 2002 the CF % of faba beans increased from 20.2 to 22.6%, while during 2003 CF % similarly increased from 21.8 to 26.5%. The CF % for oats during 2003 increased from 25.6 to 36.9%. During the same time the EE, Ca and P contents also decreased (P<0.05), while the NDF, CF and ADF contents increased (P<0.05).

Two milk production studies were conducted to compare the feed intake, milk yield and milk composition of Holstein cows receiving either whole plant faba bean silage or oats as a hay or silage. Faba bean (*Vicia faba*) silage (FBS) was compared to that of cows receiving either oat (*Avena sativa*) hay (OH) or oat silage (OS) and in a 50:50 combination with FBS. Faba beans (*cv*. Ascot) and oats (*cv*. Sederberg) were planted on a Glenrosa soil. Whole crop faba beans were ensiled 145 days after planting in an above ground concrete bunker using a commercial bacterial inoculant after being wilted for one day.

In the first experiment, total mixed rations (TMR) containing FBS, OH or a 50:50 mixture of FBS and OH as forage, together with a concentrate, were fed to three groups of seven lactating Holstein cows each. The experiment was conducted according to a randomized block design. Cows were on average 112±44 days post calving producing 24.0±6.2 kg milk/day. Milk production parameters of cows receiving diets containing

different forages were compared by analysis of variance. The DM intake and milk yield of cows receiving TMR's containing FBS, OH or a mixture of 50:50 FBS and OH as forages did not differ (P>0.05), milk yields being 18.9±1.9, 20.6±1.3 and 20.5±1.4 kg/cow/day respectively. With the exception of MUN, milk composition parameters did not differ among treatments (P>0.10). Cows fed OH as roughage source had a higher (P=0.06) MUN level in the milk. Results from this study indicate that FBS could effectively replace OH in lactating dairy cow diets.

In the second experiment, total mixed rations (TMR) containing FBS, oat silage (OS) or a 50:50 mixture of FBS and OS as forages, together with a concentrate, were fed to six Holstein cows according to a double 3 x 3 Latin Square cross-over experimental design. Each cow received 13 kg DM either FBS, OS or a 50:50 mixture of FBS and OS were fed as forages, together with three different concentrates at nine kg "as is" each, to each cow. Cows were on average 108±30 days post calving producing 22.0±2.0 kg milk/day. DM intake, body weight, milk yield and milk composition parameters of cows receiving diets containing different forages were compared statistically. The DM intake and body weight of cows receiving TMR's containing FBS, OH or a mixture of 50:50 FBS and OS as forages did not differ (P>0.10), although body weight changes differed significantly (P<0.10), i.e. 4.0±3.2, 8.8±3.2 and -6.0±3.2 kg respectively. The milk yield of cows receiving TMR's containing FBS, OS or a mixture of 50:50 FBS and OS as forages did not differ (P>0.10), milk yields being 22.8±0.4, 21.4±0.4 and 21.9±0.4 kg/cow/day respectively. Of the milk composition parameters, the milk CP(%) of cows fed TMR's containing FBS differed (P<0.05) from the cows fed the 50:50 mixture of FBS and OS, as well as cows fed the OS, being 2.82±0.02, 2.93±0.02 and 2.96±0.02% respectively. Results from this study indicate that FBS could effectively replace OS in lactating dairy cow diets.

The South African database on *in situ* protein and fiber degradability values for whole crop faba beans and oats is limited. The chemical composition of whole crop faba beans and oats constantly change as plants mature. For optimal stage of ensiling and feed formulation it would be useful to have CP, NDF and ADF degradability values available for whole crop faba beans and oats harvested at different growth stages. The objective of this study was to determine the ruminal nutrient degradabilities of whole crop faba beans (*Vicia faba*) and oats (*Avena sativa*). Whole crop faba beans and oats were cut at weekly intervals from 75 to 159 days after planting. Effective DM, CP, NDF and ADF degradability values of faba beans and oats harvested at 117, 131, 145 and 159 days after planting were determined by using the *in situ* nylon bag technique. Three non-lactating Holstein cows fitted with ruminal fistulae were used. Plant material put into Dacron bags was incubated in the rumen for 4, 8, 12, 24, 48, 72 and 96 hours. The degradability of DM, CP, NDF and ADF fractions of whole plant faba beans and oats in four different growth stages (117, 131, 145 and 159 days from planting) did not differ (P<0.05) among cows. The degradability of different fractions for both roughages were affected (P<0.05) by growth stage and incubation hours. DM, CP, NDF and ADF disappearance of whole crop faba beans and oats at 117 and 159 days after planting differed (P<0.05) at 4, 8, 12, 24, 48, 72 and 96 hours of incubation time. The DM, CP, NDF and ADF disappearance values were fitted to the non-linear model $p = a + b\ (1- e^{-ct})$. The effective degradabilities (*P*) could be calculated using a fractional outflow rate of k = 0.05. For whole crop faba beans, parameter *b* (potentially degradable fraction) and parameter *c* (the rate at which *b* is degraded) all differed significantly ($P<0.05$) between four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity for CP, NDF and ADF. In oats, parameter b and parameter c did not differ ($P>0.05$) between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity.

Results from this study could make a valuable contribution towards the South African databases on faba bean and oats nutrient values and can be used in dynamic feed formulation. Faba beans cut as fresh crop or silage may in the foreseeable future play an increasingly larger role in the feeding of dairy cattle in the Winter Rainfall Region of South Africa. As in the case of lupin silage, though with much higher protein content, farmers will be able to produce their own quality and high protein roughage. The nutritive properties of faba bean silage holds great promise as a forage in lactating dairy cows.

Opsomming

Titel	:	Die voedingswaarde van fababoonkuilvoer vir lakterende melkkoeie.
Kandidaat	:	Antony William Louw
Studieleier	:	Prof. C.W. Cruywagen
Mede-studieleier	:	Dr. C.J.C. Muller
Graad	:	M.Sc. (Agric.)

Die droëmateriaal (DM) produksie en chemiese samestelling van heelplant fababone (*Vicia faba*) en hawer (*Avena sativa*) is bepaal deur vars plantmateriaal op 'n weeklikse basis te sny. Plantmonsters van beide fababoon en hawerplante is gesny vanaf 75 tot 166 dae na plant op 'n hoogte van *ca*. 10 cm bo die grond. Plantmonsters is weekliks gesny op vyf ewekansige persele met 'n oppervlak van 0.25 m² elk. Die vars gesnyde plantmateriaal is geweeg en daarna ge-oonddroog om die DM inhoud van elke monster te bepaal. Die varsmateriaal en DM opbrengs per hektaar is bereken. Die ruproteïen (RP), ruvesel (RV), neutraal bestande vesel (NBV), suur bestande vesel (SBV), stikstof vrye ekstrak (NVE), eterekstrak (EE), kalsium (Ca) en fosfor (P) inhoud is bepaal volgens standaardlaboratorium metodes. Lineêre regressie is gebruik om die verandering in chemiese samestelling van heelplant fababone en hawer te kwantifiseer. Vars en DM produksie van heelplant fababone en hawer het toegeneem met toename in groeistadium. Gedurende die 2002 produksiejaar het varsmateriaal opbrengs vir beide fababone en hawer gepiek op 131 dae (44.7±6.9 en 28.4±7.1 ton/ha respektiewelik). Heelplant fababoon en hawer DM opbrengs het gepiek op 159 en 152 dae na plant op 9.4±1.3 en 8.8±0.7 ton DM/ha, respektiewelik. Die chemiese samestelling van beide gewasse het afgeneem met toename in groeistadium. Die RP inhoud van heelplant fababone het verminder ($P<0.05$) van 25.3% op 82 dae na plant tot 18.4% op 166 dae na plant vir die 2002 produksiejaar, terwyl gedurende die 2003 produksiejaar die RP inhoud verminder ($P<0.05$) het vanaf 28.2 tot 19.5% vanaf 75 tot 159 dae na plant. Gedurende die 2002 produksiejaar het die ruvesel % van fababone toegeneem vanaf 20.2 tot 22.6%, terwyl gedurende die 2003 produksiejaar het die ruvesel toegeneem vanaf 21.8 tot 26.5%. Die ruvesel % vir heelplant hawer het vir die 2003 produksiejaar toegeneem vanaf 25.6 tot 36.9%. Vir dieselfde tyd, het EE, Ca en P inhoud ook verminder ($P<0.05$), terwyl NBV, RV en SBV inhoud toegeneem ($P<0.05$) het.

Twee melkproduksiestudies is uitgevoer om die effek van fababoonkuilvoer op voerinname, melkopbrengs en melksamestelling van Holsteinkoeie te bepaal. Fababoonkuilvoer (FBKV) is vergelyk met behulp van koeie wat hawerhooi (HH) of hawerkuilvoer (HKV) en in 'n 50:50 kombinasie met FBKV as ruvoere ontvang het. Fababone (*cv*. Ascot) en hawer (*cv*. Sederberg) is gevestig op 'n Glenrosa grond. Heelplant fababone is gesny en ingekuil op 145 dae na plant. Gesnyde materiaal is toegelaat om vir 'n dag te verlep, waarna dit in 'n bogrondse kuilvoersloot ingekuil is met behulp van 'n kommersiële bakteriële entstof.

In die eerste eksperiment is volvoere met FBKV, HH en 'n 50:50 mengsel van FBKV en HH as ruvoer, saam met 'n konsentraat, gevoer aan drie groepe koeie wat bestaan het uit sewe Holsteinkoeie elk. Die eksperiment is uitgevoer volgens 'n ewekansige blokontwerp. Koeie was gemiddeld 112±44 dae in melk en het 24.0±6.2 kg melk/dag geproduseer. Melkproduksie-veranderlikes van koeie wat diëte ontvang het met verskillende ruvoere is met 'n variansie-analise vergelyk. Die DM inname en melkopbrengs van koeie op volvoere bevattende

FBKV, HH of ‘n 50:50 mengsel van FBKV en HH, het nie betekenisvol verskil (P>0.05) nie. Melkopbrengs was 18.9±1.9, 20.6±1.3 en 20.5±1.4 kg/koei/dag, respektiewelik. Met die uitsondering van melkureumstikstof (MUN), het melksamestelling-veranderlikes nie betekenisvol (P>0.10) verskil tussen behandelings nie. Koeie wat HH as ruvoer ontvang het, het ‘n hoër (P=0.06) MUN vlak in die melk gehad. Resultate van hierdie studie dui daarop dat FBKV effektief HH in lakterende melkkoeidiëte kan vervang.

In die tweede eksperiment is volvoere, betsaande uit FBKV, hawerkuilvoer (HKV) of ‘n 50:50 mengsel van FBKV en HKV as ruvoer, saam met ‘n konsentraat aan ses Holsteinkoeie gevoer volgens ‘n dubbel 3 x 3 Latynse Vierkant omskakel proefontwerp. Elke koei het 13 kg DM van FBKV, HKV of ‘n 50:50 mengsel van FBKV en HKV ontvang as ruvoere, saam met drie verskillende konsentrate van 9 kg op ‘n natuurlike vogbasis elk. Koeie was gemiddeld 108±30 dae in melk en het 22.0±2.0 kg melk/dag geproduseer. DM inname, liggaamsmassa, melkopbrengs- en melksamestelling- veranderlikes van koeie op verskillende diëte wat verskillende ruvoere ingesluit het, is statisties vergelyk. Die DM inname en liggaamsmassa van koeie op volvoere bevattende FBKV, HKV of ‘n 50:50 mengsel van FBKV en HKV, het nie betekenisvol (P>0.10) verskil nie. Verandering in liggaamsmassa het betekenisvol (P<0.10) verskil, te wete 4.0±3.2, 8.8±3.2 en -6.0±3.2 kg, respektiewelik. Die melkopbrengs van koeie op volvoere bevattende FBKV, HKV of ‘n 50:50 mengsel van FBKV en HKV as ruvoer, het nie verskil (P>0.10) nie. Melkopbrengs was 22.8±0.4, 21.4±0.4 en 21.9±0.4 kg/koei/dag, respektiewelik. Ten opsigte van die melksamestelling-veranderlikes van die koeie op die onderskeie volvoere, was dit slegs melk RP(%) van koeie wat volvoere met FBKV ontvang het, wat betekenisvol (P<0.05) verskil het van die koeie wat HKV en die 50:50 mengsel van FBKV en HKV as ruvoer ontvang het. Melk RP(%) was 2.82±0.02, 2.93±0.02 en 2.96±0.02%, respektiewelik. Resultate van hierdie studie dui daarop dat FBKV effektief HKV in lakterende melkkoei diëte kan vervang.

Die Suid-Afrikaanse databasis van *in situ* proteïen- en veseldegradeerbaarheidswaardes vir heelplant fababone en hawer is beperk. Die chemiese samestelling van heelplant fababone en hawer verander gedurig soos plante toeneem in ouderdom en groeistadium. Vir optimale stadium van inkuiling en voerformulering sou dit belangrik wees om DM, RP, NBV en SBV degradeerbaarheidswaardes van heelplant fababone en hawer ge-oes op verskillende groeistadiums te hê. Die doel van die studie was om die ruminale degradeerbaarheidswaardes vir heelplant fababone en hawer te bepaal. Effektiewe DM, RP, NBV en SBV degradeerbaarheidswaardes is vir fababone en hawer bepaal vir groeistadiums 117, 131, 145 en 159 dae na plant deur gebruik te maak van die *in situ* nylon sakkie tegniek. Drie nie-lakterende Holsteinkoeie elk toegerus met ‘n rumen- kannula is gebruik om ruminale degradeerbaarheidswaardes te bepaal. Plantmateriaal wat in Dacron sakkies afgeweeg is, is in die rumen geplaas vir 4, 8, 12, 24, 48, 72 en 96 ure. Die degradeerbaarheid van DM, RP, NBV en SBV fraksies van heelplant fababone en hawer vir vier verskillende groeistadiums (117, 131, 145 en 159 dae na plant) het nie betekenisvol (P<0.05) tussen koeie verskil nie. Die degradeerbaarheid van verskillende fraksies van beide ruvoere het verskil (P<0.05) tussen groeistadiums en inkubasie-ure. DM, RP, NBV en SBV verdwyning van heelplant fababone en hawer op 117 en 159 dae na plant het betekenisvol (P<0.05) verskil by 4, 8, 12, 24, 48, 72 en 96 inkubasie-ure. Die DM, RP, NBV en SBV verdwyningswaardes is gepas op ‘n nie-lineêre model $p = a + b(1- e^{-ct})$. Die effektiewe degradeerbaarheid (*P*) kon bereken word met ‘n fraksionele uitvloeitempo van k =

0.05 vanuit die rumen. Vir heelplant fababone het parameter *b* (potensieel degradeerbare fraksie) en parameter c (die tempo waarteen b degradeer word) betekenisvol verskil ($P<0.05$) vir alle groeistadiums (117, 131, 145 en 159 dae na plant) vir degradeerbaarheidswaardes van RP, NBV en SBV. Vir hawer het parameter *b* en parameter *c* nie betekenisvol ($P>0.05$) tussen die vier verskillende groeistadiums (117, 131, 145 and 159 dae na plant) verskil nie.

Die resultate van hierdie studie kan ‘n belangrike bydrae maak tot die Suid-Afrikaanse databasis van fababoon en hawer voedingswaardes, en kan aangewend word in dinamiese voerformulering. Die gebruik van varsgesnyde of ingekuilde heeplant fababone kan in die toekoms ‘n al groter rol speel in melkkoeivoeding in die Winterreënstreek van Suid-Afrika. Soos in die geval met lupiene, maar met ‘n hoër proteïen inhoud, sal produsente hul eie kwaliteit en hoë proteïen ruvoer kan verbou. Die voedingswaarde van fababoonkuilvoer hou groot belofte in as ruvoer vir lakterende melkkoeie.

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Chapter 1

GENERAL INTRODUCTION

The Western Cape, with its Mediterranean climate, has long dry summers and cool wet winters. This means that conserved forages have to be fed during the dry season because of a lack of rainfall for pasture production during the summer months. Mean annual rainfall in the Western Cape varies from 200 to 650 mm (Hardy, 1998). Forages can be conserved either in a dry format as hay or in a wet format as silage. Specifically in the Western Cape, ensiling forage crops result in a higher quality product as haymaking is often problematic because of weather conditions. Ensiling forage crops is a way to better utilize roughage sources in South Africa. Silage is the end product where crops with relative high moisture content (60 – 70%) undergo a fermenting process.

During 1989 there were about 1600 dairy farmers in the Western Cape Province who produced 25% of the milk production of South Africa (Engelbrecht, 1997). Presently the number of dairy farmers has been reduced by probably 50%, the reason for this being the unfavourable economic situation that dairy farmers constantly experience. This situation is even worse for dairy farmers in the Swartland Region of the Western Cape Province (Van der Spuy, 2002), mainly because of a lack of home produced high quality forages. Good quality forages is the basis for an economic dairy farm. It is generally accepted that if a milk producer can produce a roughage source high in energy and protein, the feeding costs of the dairy herd could be reduced significantly.

The availability of high quality forage is one of the major constraints of dairy production in Southern Africa. The lack of a constant supply of quality forage is associated with soil quality and climate (Smith *et al.*, 1993).

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.

Milk production in the Swartland Region of the Western Cape Province is based on zero-grazing systems, using mainly home produced forages, as oat silage, oat hay or wheat straw. Compared to forage crops such as lucerne hay, cultivated grass-clover pastures and maize silage, the feeding value of these cereal forages is low, resulting in higher feeding costs than the aforementioned crops. In the Western Cape Province, crops like lucerne hay and grass-clover pastures can only be produced under irrigation. This occurs mainly in the Southern Cape Region of the Province as that area has a more even rainfall pattern during the year. Lucerne hay has to be transported to the Swartland region mainly from the summer rainfall areas of South Africa. Due to the bulkiness of lucerne hay, the transport cost is high, while the availability and quality are often erratic (Brand *et al*., 1992).

Water for irrigation purposes in pasture production, in the Boland and Swartland Regions of the Western Cape Province, has also become a scarce resource. Irrigation water can be more effectively utilized in the production of vegetables or long-term crops such as fruit.

Regular increases in the price 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 should not affect milk yield negatively. 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).

In Southern Africa, many dairy farmers are changing forage production from hay to silage because of weather and labour factors (Smith *et al*., 1993). According to a survey conducted by Baard (1989), 23.4% of dairy farmers in the Swartland Region of the Western Cape Province use silage as a forage source for dairy cattle. Later, Meeske (2007) observed that about 70% of dairy farmers in the Western Cape use silage as a forage source for dairy cattle during periods of feed shortages.

Conserving forages as silage by these farmers is related to difficult haymaking conditions at the end of winter and the unavailability of storage facilities for hay. Constant forage supply in these areas is met by the utilisation of conserved forages (Smith *et al.,* 1993).

Forages are often grown solely for conservation (Rotz & Muck, 1994). The aim of an effective forage conservation process is to stop the rapid and complete destructive processes which occur after cutting and so as to preserve as much as possible of the yield and feeding value of the original crop (Raymond *et al.,* 1986).

The aim of this study is to determine the feeding value of whole crop faba beans in the feeding regime of lactating dairy cows. This crop is suitable for silage production under dry land conditions in the Swartland region of the Western Cape Province. Whole crop faba beans have a higher protein content than the traditional forage crops such as oats and barley usually conserved as hay or silage. The effects to be tested include the response of faba bean silage on the milk yield and milk composition of Holstein cows in comparison to oat hay or oat silage. The effect on feed costs and profit margins of Holstein cows are also to be determined. The rationale for this study is to determine whether high quality forage (in terms of crude protein and energy content) would improve the milk yield of dairy cows and by reducing their total feed cost thereby increasing profit margins of milk production.

Chapter 2

LITERATURE REVIEW

Introduction

Silage can be used with good results as good quality roughage for dairy cows. The use of silage is not only limited to dairy cattle, but can also be utilized for beef cattle, sheep and horses (Heydenrych *et al*., 1999).

Dairy farmers in South Africa and especially the Western and Southern parts of the Western Cape Province experience problems each year with the production of good quality lucerne hay through the process of natural- or field drying (Du Toit, 2001).

The Swartland Region is one of the major producing areas of small grain cereals such as wheat, oats and triticale in South Africa (Brandt, 1998). The major problem with small grain forages is that they have low levels of crude protein (CP), vitamins and some minerals such as calcium (Ca) (Morrison, 1961), except when used as pasture at a young stage, or harvested early as hay or silage. These low levels of essential feed elements indicate that they cannot be used as the only feed for producing animals therefore needing substantial amounts of supplemental feeds either as protein-rich forages or concentrates to maintain or improve animal performance. The minimum levels at which protein-rich forages or concentrates must be included in diets that include small grain forages without impairing the animal performance remains a problem.

International markets for dairy products are becoming increasingly more available for the South African dairy industry. It has therefore become very important that dairy farmers in the Western Cape must produce milk at international prices. This makes the evaluation of the production potential of whole forage crops that could be produced in the Western Cape extremely important. Using legume forages with much higher crude protein content is an added bonus.

Forage quality

Forage quality can be defined in various ways but is often poorly understood. It represents a simple concept, yet encompasses much complexity. Though important, forage quality often receives far less consideration than it deserves. Forage quality can be defined as the extent to which forage has the potential to produce a desired animal response. The main factors that influence forage quality include the following: palatability, intake, digestibility, nutrient content, anti-quality factors and animal performance (Ball *et al*., 2001).

Adequate animal nutrition is essential for high rates of weight gain, milk production, efficient reproduction, and adequate profits. However, forage quality varies greatly among and within forage crops, and nutritional needs vary among and within animal species and classes. Producing suitable quality forage for a given situation requires knowing the factors that affect forage quality, then exercising management accordingly. Analysing forages for nutrient content can be used to determine whether quality is adequate and to guide proper ration supplementation (Ball *et al*., 2001).

In recent years, advances in plant and animal breeding, and the introduction of new management approaches have made it possible to increase animal performance. However for this to be realised there must be additional focus on forage quality.

Part of this study is to provide information about alternative crops, which can be used to increase animal performance and higher producer profits.

Different crops for the production of silage

Heydenrych *et al*. (1999) reported on the yield (ton DM per hectare) and chemical composition of four different mixtures of cereal crops and five different pure cereal crops during 1998 at the Tygerhoek Research Station near Riviersonderend in the Southern Cape as alternatives for the making of silage under dryland conditions. The crops were planted on a Glenrosa soil. Two months prior to sowing, the soil was fertilized with phosphor, potassium and lime to the recommended levels according to the soil analysis. The experiment was conducted according to a randomized block design with three repetitions. The sizes of the plots were all 1.05 m x 5 m and the seed was drilled into the soil in rows approximately 17.5 cm apart. There were six rows in a plot. No inoculant was used on the legume crops. The grass weeds in the plots were controlled by spraying Gallant S (haloxyfop-R methyl ester). No plant disease control was conducted on any of the forage crops,

The different plots were harvested during the last week of August, approximately at 125 days after planting when it was regarded crops to have achieved maximum dry material (DM) production according to visual observation. The “as is” material yield was recorded by cutting the plant material approximately five centimetre above ground level in four of the six rows by means of pruning shears. The harvested plant material was collected in plastics bags and weighed within an hour after harvesting. In the case of the Japanese radish, plant material above and below the ground was harvested separately and weighed. The dry matter (DM) yield was determined by collecting a wet sample from each plot, weighed and dried in forced air oven at 60ºC. Samples were then milled and analyzed for crude protein (CP), ash, crude fiber (CF), and *in vitro* organic matter digestibility after which the total digestible nutrient (TDN) content was determined. The yield and chemical analysis were not statistically analysed. The yield and chemical analysis of the crops are presented in Table 1.

The “as is” yield of the different crops varied between 12.7 and 35.2 ton/ha of which the canola mixture was the highest (35.2 ton/ha). The “as is” yield of faba beans was 34.0 ton/ha. However, the crops with the highest DM yield per ha were canola combined with faba beans (6.04 ton/ha) and field peas (5.6 ton/ha). The CP content of whole crop faba beans was the highest at 16.5 %.

Table 1. The calculated yield and chemical analysis of whole plant cereals crops grown at the Tygerhoek Research Farm in the Southern Cape region of the Western Cape Province (Heydenrych *et al*., 1999).

Crops	**"As is" Yield (t/ha)**	**DM Yield (t/ha)**	**CP (%)**	**Ash (%)**	**CF (%)**	**TDN (%)**
Faba beans (*cv*. Ascot)	34.0	4.61	16.51	7.91	26.42	62.11
Feed turnip (*cv*. Hobson)	26.5	3.73	12.33	10.18	18.21	73.71
Feed turnip (*cv*. Hobson)	21.5	3.49	14.72	10.21	16.03	74.73
Radish (above ground)	28.4	3.86	12.16	16.46	16.24	67.57
Radish (below ground)	12.7	1.56	10.88	13.02	12.28	70.10
Canola (*cv* Hyola)	24.9	4.64	10.72	7.34	32.54	58.54
Canola + faba beans	35.2	6.04	13.2	7.26	32.32	57.00
Canola + vetch	18.0	3.38	12.34	7.96	33.48	56.89
Canola + field peas	29.3	5.60	12.80	6.55	31.56	59.59
Canola + narbon beans	29.4	1.64	13.08	9.65	30.55	57.21

Yield and chemical analysis were not statistically analysed.
DM = Dry matter
CP = Crude protein
CF = Crude fiber
TDN = Total digestible nutrients

The long-term average annual rainfall for Tygerhoek Research Station is 430 mm / year. During 1998 the annual rainfall was 583 mm. With the exception of the monthly rainfall during May, the rainfall was lower than the long-term rainfall during the growing season.

The Ruêns Region has a 40:60 ratio regarding the summer to winter rainfall ratio, compared to the Swartland and West Coast which has a 20:80 summer to winter rainfall ratio.

The above ground plant material of Japanese radish had the highest percentage ash of 16.4% possibly indicating soil contamination. Mixtures of different crops had the highest percentage fiber mainly attributed to the higher fiber content of canola. This needs to be investigated further by evaluating crops individually. The feed turnips and radish had a very low fiber percentage. This can be attributed to the long growing season of the latter crops as they were still in their vegetative state when being harvested. This is also seen in the higher TDN% for feed turnips and radish.

The growth stage of whole plant forage crops plays an important role in the feeding quality and ensiling process when being harvested for silage production. The CP% at the start of the growing season is much higher than later in the season. Harvesting later has the advantage of a higher DM yield. The conclusion of this experiment recommends that samples be analyzed at different growth stages during the season, and that the trials should be repeated over seasons (Heydenrych *et al*., 1999).

Faulkner (1985) found that undersowing faba beans with barley had little effect on DM concentration. The tall legume overshadowed barley growing among beans, and barley seed set appeared to be poor. Faulkner (1985) concluded that is better to grow faba beans as a pure stand, rather than in a mixture with other cereals, as it does not compete well with other crops in a mixture.

Faulkner (1985) further found that faba bean cultivars yielded relatively well when sown alone and moderately well when undersown, whereas pea cultivars yielded relatively well in combination with barley, if also undersown. The barley growing among peas was pulled down with the lodged pea canopy and almost completely smothered. Oats did not smother to the same extent, as did the barley.

Whole crop faba beans seem to produce an excellent silage crop. Studies have shown growing dairy heifers and beef cattle gaining on faba bean silage at the same rate as animals on grass-legume silage. Dairy cows in early lactation have also performed well on faba bean silage (McVicar *et al*., 2008).

Ingalls *et al.* (1979) reports that faba beans, as an annual crop, planted both as a seed-crop or silage-crop, would be a viable alternative to lucerne in a crop rotation system. Limited information is available regarding the utilization of whole plant faba bean as a feed for ruminants. The yield potentials of faba beans suggest that the whole plant could be an economical feed when used as either silage or as a dehydrated product (cubes or wafers).

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%. Wilting of silage crops is important as a high water content is disadvantageous in forages for ensiling because it increases both the bulk to be transported to the silo or bunker and also the amount of effluent that is produced (Faulkner, 1985; Raymond *et al*., 1986).

The forages are then ensiled and stored in either tower or bunker silos, above ground stacks, bags or wrapped large bales (Rotz & Muck, 1994). Silos must be sealed to prevent air moving in and through the cut forage and causing heating from secondary fermentation. 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 during the ensiling process (Raymond *et al*., 1986). 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).

Raymond *et al.* (1986) notes that it is common temptation for farmers to wait a few days to obtain more bulk, but this will however seriously affect crop quality. Due to the fact that the growth stage of the crop at harvesting will have more influence on the eventual feeding value of the product, than any of the other factors under the farmer's control, accounts for the high priority given to ensiling early.

Similar trials

In a similar trial in Northern Ireland, Faulkner (1985) found that three different faba bean cultivars, i.e. Blaze, Stella Spring and Polar, yielded 9.57, 8.56, and 7.09 ton DM per ha respectively. The CP% for the cultivar Blaze was 15.5 and 16.5%, for the high seed rate and low seed rate respectively.

DM yields over 10 ton per ha have been reported for faba beans in Scotland (Thompson & Taylor, 1982), England (Fascheun & Dennet, 1982) and Holland (Dantuma & Klein Hulze (1979), as cited by Faulkner (1985)).

Faulkner (1985) found that the potential yield of faba beans depends on establishing a sufficient plant density – probably about 50 or more plants per square meter. In 1981 the *cv*. Blaze planted at 34.7 seeds/m² yielded 20% less than when planted at 55.6 seeds/m². The yields of three bean cultivars, sown during 1980 at 240 kg/ha, were inversely related to seed size, and thus directly related to the number of seeds sown. Cultivar Blaze (55.6 seeds/m²) had the highest yield, while *cv*. Stella Spring (45.8 seeds/m²) had an intermediate yield, and *cv*. Polar (33.8 seeds/m²) had the lowest yield.

Mixtures of faba beans and cereal crops did not produce as high yields as stands of pure faba beans. It seems that the introduction of barley or oats into the seed mixture apparently do not compensate for the lower seed rate of the faba beans. These observations reinforce the conclusion that to reap the full benefit of faba beans as forage crop, it is necessary to use a heavy seed rate at sowing.

In the current study, Agenbag (2001) advised that faba beans be sown at the Elsenburg Research Station at a seed rate of 150 kg/ha. Comparatively to other studies, two weeks post-emergence the faba bean plant count was 37.4 and 39.0 plants/m² for the 2002 and 2003 production years respectively.

The stage at which a forage crop is harvested plays a very important role in silage production. That is because the CP% is much higher at the beginning of the growing season than later in the season. Cutting the forage later in the season has the advantage that there is a higher dry matter yield (Engelbrecht, 1997).

Field beans are a high yielding short-term crop that has the potential as a high protein forage crop. Work done in Wales (United Kingdom) by Faulkner (1985) had shown that field beans can produce heavy crops of forage. However, according to Fychan *et al.* (1999) there is limited information available in the literature on the ensiling potential of field beans.

Faba bean, pea and soybean are annual legumes, which are predominantly used for grain production. Their use as a source of forage is currently very limited and in most cases restricted to situations where climatic conditions may have compromised grain production (Sheaffer *et al*., 2001).

Planting other legume crops as faba beans and peas can be ensiled to provide a source of both protein and starch. This will reduce the amount of fermentable carbohydrates required from cereal grains to maximize the supply of readily fermentable carbohydrates, resulting in a possible increase in the microbial protein supply to the small intestine (Dhiman & Satter, 1997). Differences in ruminal nutrient degradabilities have also been reported between legume and grass forages (Holden et al., 1994).

Markets for faba beans and broad beans

World production, export and import data are not compiled for faba beans. Data for dry broadbean, which includes faba beans and Chinese broadbean, is reported by the Food and Agriculture Organization of the United Nations. The Chinese broadbean is consumed mainly as a vegetable. World annual production of dry broadbeans ranged from 4.9 to 5.1 million ton from 2003 - 2006 with China producing almost half of this amount. The major dry broadbean producing countries of the world is (from largest to smallest) China, United Kingdom, Ethiopia, Egypt, France and Australia (McVicar *et al*., 2008).

Faba beans are sold into the human consumption and animal feed markets. Human consumption markets exist largely in the Mediterranean and Middle East regions or Mediterranean ethnic markets of North America. These markets traditionally demand large-sized seeds with a size up to 650 g/1000 seeds. The animal feed markets use faba bean as a source of protein and energy. The crude protein content of faba beans is 24 to 30%. Feeding studies have shown that faba beans can be a good poultry feed, if supplemental methionine is added. It can replace soybean meal in rations for pigs weighing 36.3 kg (80 lb.) and more, as well as for calves, lactating dairy cows, beef cattle and sheep. Faba bean varieties used for animal feed usually have a smaller seed size to reduce the cost of seeding. Recent varietal developments for feed use include low-tannin cultivars with reduced anti-nutritional factors such as trypsin inhibitors. Varietal development for feed in Saskatchewan (Canada) is focussed on producing varieties with seed size of 250-300 g/1000 seeds for use in either grain or silage form (McVicar *et al*., 2008).

Morphology of the faba bean plant

According to Wikipedia (2008) faba beans are classified as follows:

Domain: Eukaryota
Kingdom: Plantae
Subkingdom: Embryophyta
Division: Magnoliophyta (flowering plants)
Class: Magnoliopsida
Order: Fabales
Family: Fabaceae (legumes)
Subfamily: Papilionoideae (Robertson, 2004).

Genus: *Vicia*
Species: *faba* Eudicotyledons;

Faba beans looks like a smaller version of the garden broad bean. Plants grow upright, ranging from 1 to 1.5 meters tall. It is an annual legume with one or more strong, hollow erect stems. Faba beans have a strong taproot, compound leaves and large, white flowers with dark purple markings. A flower cluster may produce one to four pods. The pods are large (18 to 20 cm long and 1 to 2 cm wide) and green, turning dark at maturity – from brown to black. Three to four oblong to oval shaped seeds are contained within each pod.

Flowering occurs from 45 to 60 days after planting and faba beans reach maturity after 83 to 114 days.

Faba beans should not be grown on the same field more than once every three to five years, and should not follow oilseeds or other legume crops in the rotation because of the danger of a rapid increase in soil-borne diseases. Faba beans are able to withstand heavy frost, which may occur in late May or June in Canada (Saskatchewan Interactive Agriculture, 2002).

The plant flowers profusely but only a small proportion of the flowers produce pods. The faba bean plant is very cold hardy, but cannot take excessive heat during flowering. As faba bean plants mature, the lower leaves turn dark after which they drop off while pods turn black and dry progressively up the stem. Faba bean seeds tend to shatter if left standing until maturity (Oplinger *et al*., 1999).

Faba beans are well adapted to the more moist agricultural areas and do best under relatively cool growing conditions. Hot, dry spells will result in wilting of the plants and may reduce seed set. Faba bean should be grown with caution in dark soils and on droughty, light-textured soils unless irrigation is available, as faba bean responds very well to irrigation (McVicar *et al*., 2008).

Historical perspective of *Vicia faba*

Vicia faba seeds, also known as broad beans, faba beans, horse beans or tic beans, and very young pods are also eaten as a vegetable (Robertson, 2004). Many authors in the literature refer to *Vicia faba* beans as field beans (Bond, 1976; d'Hangest d'Yvoy, 1990; Griffiths & Jones, 1977; Faulkner, 1985).

In Europe faba beans is grown primarily as a livestock feed. Britain, where both winter and spring types are grown, is the largest producer of faba beans in Europe. Commercial production of faba beans in Western Canada first occurred in 1972 and since then the area under production has fluctuated (McVicar *et al*., 2008).

The seeds of faba beans have a high protein content of about 20 – 25 %. Broad beans was probably domesticated in the eastern Mediterranean region in the late Neolithic (about 6800 – 4500 BC) but precise evidence is lacking and in addition no information is available on the wild plant species from which it was derived. All the species of *Vicia* that have been discovered and that are in the same group as *Vicia faba* (section *Faba* of the genus *Vicia*), have diploid chromosome number (2n) of 14 whereas *Vicia faba* has 12 chromosomes. For this reason it cannot be crossed with known wild species. This means that either the wild species has not yet been discovered or that it has gone extinct (Robertson, 2004).

Remains of broad bean seeds dating back to 6800 – 6500 BC have been found in an archeological excavation near Nazareth in Northern Israel but these seeds are small and could have been from wild plants. No other Neolithic village excavations (i.e. farming villages in the near East dating back further than 4500 BC) have revealed any further remains. Numerous remains of *Vicia faba* suddenly start appearing in archeological excavations in the Mediterranean basin and Central Europe dating to the 3rd millennium BC (Robertson, 2004).

McVicar *et al*. (2008) reports that the oldest seeds of *Vicia faba* were found in Jericho and dates as far back as 6250 BC. The crop is now commonly grown in the Mediterranean region as food for human consumption.

Present day varieties of broad beans can be divided into four main groups (Phillips & Rix, 1993), namely:

(i) Broad beans (*V. faba* var. *faba* or *major*) are eaten as a vegetable for human consumption. It is also known as Windsor Beans, with short pods that have up to four large seeds per pod.
(ii) Horse beans (*V. faba* var. *equina*) are grown for animal feed.
(iii) Tic beans or pigeon beans (*V. faba* var. *minor*) with long pods (up to 8 seeds per pod); and
(iv) *V. faba* var. *paucijuga* is similar to the tic bean and grown in Central Asia. Unlike other varieties, it is mainly self-pollinating.

Broad beans are the principle protein source for poor people in some Asian and Mediterranean countries such as Egypt. The protein content of bean seeds is high, amounting to about 20 – 25 percent (Robertson, 2004).

Production and whole bean *Vicia faba* bean seed

The broad bean plant has the advantage of being frost tolerant so that in Europe it is possible to successfully sow seed in autumn yielding plants that are harvested in early summer (Robertson, 2004).

Locally as early as 1990, d'Hangest d'Yvoy (1990) suggested that faba beans could be a high potential crop for livestock production, specifically dairy cows, in the Western Cape. Faba beans have proven to be extremely adaptable and can be cultivated successfully in most of the high rainfall cropping areas of the Winter Rainfall Region. In Australia where faba beans have been used for a number of years as a rotation crop with wheat, it is regarded as an important alternative to lupins. Apart from having the same beneficial effect on the soil, the faba bean has several additional advantages in that it appears to be more resistant to root diseases, compared to lupins. The crop also has a high seed yield and produces palatable protein-rich forage which may be either grazed or conserved as silage (d'Hangest d'Yvoy, 1990).

Since faba beans is a leguminous plant, the advantage of applying less nitrogen fertilizer can only be attained if the soil pH is 5.5 (KCl) or above. Trials conducted at the Langgewens Research Farm near Malmesbury in the Swartland Region, and Tygerhoek Research Farm near Riviersonderend in the Rûens area of the Western Cape Province showed that faba beans do well on a soil with pH of 5.5. Faba beans prefer a neutral to slightly acidic soil. Faba beans do best on well-drained silt loam soil. Lime should be applied if pH levels are below 5.5. Faba beans also produce a higher seed yield than lupines (Agenbag, 1997).

This annual legume grows best under cool, moist conditions. Hot, dry weather is injurious to the crop, so early planting is important. Medium textured soils are ideally suited for faba bean production, since the crop requires a good moisture supply for optimum yields. Faba beans do not tolerate standing water (Oplinger *et al*., 1999).

Faba beans are slow to emerge, approximately 20 plus days and seeds must preferable be in constant contact with moisture until seedlings are well established. The time from seeding till harvest ranges from 80 to 120 days. For best results a fine seedbed should be prepared, to insure good soil contact. Since faba beans are slow emergers, time spent in preparing a fine seedbed will help reduce germination problems with faba bean and with early weed control. Faba bean plants are capable of fixating atmospheric nitrogen, which results in increased residual soil nitrogen for use by subsequent crops. Faba beans should be grown once every four years in the same field to avoid a build-up of soil-borne diseases. Their susceptibility to diseases, which are common in rapeseed and in sunflower, limits their place in a crop rotation with other speciality crops (Oplinger *et al*., 1999).

Drought conditions may extend carryover of residual herbicides by an additional season for each drought year experienced (McVicar *et al*., 2008).

Newton & Hill (1983) also reports that faba beans have to be rotated with grains or other crops to reduce damage from soil-borne diseases. Crop residues of lettuce, carrots, cabbage, parsnips, and cucurbits may harbour white mould sclerotia.

A number of anti-nutritive factors such as tannins, a trypsin inhibitor and hemaglutinins are present in the seeds of certain faba bean varieties. Although these anti-nutritive factors are important in the nutrition of monogastric animals, they are with the exception of tannins seemingly unimportant in ruminant nutrition (Newton & Hill, 1983).

According to Griffiths & Jones (1977) tannins are known to occur in the skins or testae of faba beans. They appear to exert a negative effect on the *in vitro* digestibility of the bean itself by either binding soluble protein in the fermentation media thus creating a nitrogen deficiency, or by direct inhibition of certain cell wall digesting enzymes. Bond (1976) observed that white flowered faba bean cultivars had higher *in vitro* digestibilities than cultivars with coloured flowers and related this to the absence of tannins in the testae of white flowered faba beans. However, he conceded that some factor other than tannins might be involved. This was later confirmed in a series of experiments by Buckley *et al.* (1983) who found that both tannin and a high degree of lignification in the cell walls of the testae of cultivars with coloured flowers had a negative effect on the *in vitro* digestibility of the whole bean plants.

Inoculation of faba beans

Faba beans are a legume crop and are able to provide a significant level of nitrogen from the soil air using a symbiotic relationship with *Rhizobium* bacteria. Faba beans are the most efficient nitrogen fixer of pulse crops grown in Western Canada. For nitrogen fixation to occur, the seed or soil must be inoculated with the appropriate strain of *Rhizobium* bacteria (McVicar *et al*., 2008).

The *Rhizobium* bacteria enter the root hairs and induce nodule formation. The plant provides energy for the bacteria living inside the nodules and, in return, the bacteria convert atmospheric nitrogen into plant-useable forms. Maximum benefit is derived if the supply of available soil nitrogen is low and the soil moisture and temperature levels are adequate for normal seedling development from the time of seeding until seedlings are well established (McVicar *et al*., 2008).

High available soil nitrogen levels (amounts over 55 kg nitrogen/ha) delay the onset of nodulation and inhibit nitrogen fixation since the faba bean plant will preferentially use the soil nitrogen rather than fix nitrogen. *Rhizobium* bacteria can live in the soil for a number of years; however, the most efficient nitrogen-fixing bacteria may not be among those that survive (McVicar *et al*., 2008).

Faba bean silage

Increasing interest in the use of faba bean silage in the Winter Rainfall Region, culminated in a pilot laboratory trial at Elsenburg Research Station in which the nutritional value of faba bean silage was evaluated. Plant material was treated with either dried molasses, or a propionic acid base acidifier or a bacterial inoculant at ensiling (d'Hangest d'Yvoy, 1990). The results from this study are presented in Table 2. The chemical composition of faba bean silage was compared to that of lupin silage obtained from the literature.

The high CP values obtained for faba bean silage in this study are in close agreement with the results reported by McKnight & MacLeod (1977) and Thorlacius & Beacom (1981), i.e. 20.1 and 19.8% (on a DM basis) respectively. Mean pH and ADF values are also similar to those described by the latter authors. In both papers swathing began when the lower bean pods have started turning black while the ensiled material was described as being dark brown in colour and having a tobacco-like smell.

Most seeds also easily detach from the hilum at this discolouration stage. At this stage the moisture content of the beans ranges from 35 to 45%. Swathing at this moisture range provides the highest bulk density and 1000-

kernel weight. The high moisture content requires a fairly long drying period in the swath, so it is advisable to lay a fairly light swath (Oplinger et al., 1999).

Table 2. The nutrient composition of faba bean silage (*Vicia faba cv.* Fiord) treated with different products in comparison to white lupin silage (values on a DM-basis) (d'Hangest d'Yvoy, 1990).

Nutrient content	Faba bean silage treatments			White lupin silage*
	Dried molasses	**Organic acid**	**Bacterial inoculant**	
pH	4.5	3.9	4.0	-
Crude protein (%)	17.2	19.5	18.8	15.4
IVOMD (%)	68.5	68.2	70.0	74.9
Crude fiber (%)	23.2	25.4	24.6	29.7
Neutral detergent fiber (%)	33.8	36.6	36.8	42.9
Acid detergent fiber (%)	30.6	31.9	33.0	29.8
Ash (%)	11.9	8.6	8.1	4.7

IVOMD – *in vitro* organic material digestibility

*: Literature values by comparison

In a feeding trial described by McKnight & MacLeod (1977), lactating Holstein cows were fed either faba bean (FB) silage or grass-legume (GL) silage. Although the intakes of the fresh silage were comparable, intakes of FB dry matter and total DM intakes (FB silage + grain concentrate) were significantly higher ($P<0.05$). Furthermore, while daily milk yields were similar for all treatments, cows fed FB silage had significantly higher ($P<0.05$) milk fat levels than cows consuming GL silage.

Level of grain concentrate fed can often have a significant effect on the consumption of roughage. Ingalls *et al.* (1979) found that cows receiving a medium level of supplementary grain consumed more FB silage dry matter than those on a high grain level. Wilting of the plant material from 33 to 37% DM prior to ensiling appeared to have no significant affect on total DM intake and on milk production. Level of milk production was also not affected when the amount of supplementary grain fed was reduced from 56 to 43% of total DM intake with wilted FB silage. Energy requirements were partly compensated for by an increase in the intake of the wilted silage.

Evaluating on-farm silage

A recent study (Shields, 2003) of silage making practices in Australia showed that only 31% of farmers who make silage on farm had it analyzed. In an era in which dairy farmers are relying on silage more than ever before, and with the high degree of variability in silage quality, it is surprising that a large number of farmers do not value the nutrient composition and feeding value of ensiled crops used for animal production.

This is particularly important because nutritionists need this information to design a feed programme or to balance diets. Using the "best guess", or sight or smell, to estimate the silage quality is risky and could be costly if inaccurate. For a small cost, it is easy to have a sample tested and get some useful data on the nutritional specification and preservation quality of the silage. The information is useful in a number of ways. First, it tells the silage maker how successful the silage-making process has been. The ME (Metabolisable Energy) content is the most important figure and usually the most limiting in silages. Information such as digestibility, NDF and ADF provide information as to whether the crop was cut too early or too late. High NDF and ADF figures are indicative of crops that have matured. The pH value gives a clue as to how acidic the crop has become and a low figure of 4 - 4.3 is highly desirable and achievable in all but the legume silages (Shields, 2003).

Having a quality standard for on-farm roughages is useful as a guideline to optimal ruminant nutrition. The quality standards proposed by the Hay Marketing Task Force of the American Forage and Grassland Council which are based on Relative Feed Value's (RFV's), for legumes and grasses are presented in Table 3 (Linn & Martin, 1989).

Table 3. Forage quality standards for legumes, grasses and legume-grass mixtures (Linn & Martin, 1989).

Quality standard[a]	**RFV[b]**	**ADF[c]**	**NDF[c]**	**DDM[d]**	**DMI[e] % of BW**
		% of DM			
Prime	>151	<31	<40	>65	>3.0
1	151-125	31-35	40-46	62-65	3.0-2.6
2	124-103	36-40	47-53	58-61	2.5-2.3
3	102-87	41-42	54-60	56-57	2.2-2.0
4	86-75	43-45	61-65	53-55	1.9-1.8
5	<75	>45	>65	<53	<1.8

[a] Standard assigned by Hay Market Task Force of the American Forage and Grassland Council.

[b] Relative Feed Value (RFV) calculated from (DDM X DMI) / 1.29.

Reference RFV of 100 = 41% ADF and 53% NDF.

[c] ADF = Acid Detergent Fiber, and NDF = Neutral Detergent Fiber.

[d] Dry matter digestibility (DDM, %) = 88.9 - (.779 X ADF%)

[e] Dry Matter Intake (DMI, % of body weight) = 120 / forage NDF (% of DM).

The aim of this study was to harvest faba beans and oats over a two year period on a weekly interval from 75 to 166 days after planting. The weekly fresh forage production (ton/ha) of field planted faba bean and oats were determined. Weekly samples were analyzed for dry matter (DM), crude protein (CP), ash, crude fiber (CF), nitrogen free extract (NFE), fat (EE), calcium (Ca) and phosphorus (P) neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents.

A further two experiments were conducted to determine the effect of faba bean silage (FBS) in comparison to oat hay (OH) and to oat silage (OS) on the feed intake and milk yield and milk production parameters of Holstein cows.

The ruminal degradation of DM, CP, NDF and ADF of whole crop faba beans and oats, harvested at different stages of maturity (117, 131, 145 and 159 days after planting), by using the *in situ* Dacron bag technique was determined. The data will expand the existing South African database on ruminal degradation of DM, CP, NDF and ADF degradation.

Chapter 3

THE EFFECT OF GROWTH STAGE ON DRY MATTER PRODUCTION AND CHEMICAL COMPOSITION OF WHOLE PLANT FABA BEANS AND OATS

Introduction

Good quality forages are the basis of an economic milk production system. Milk production in the Swartland Region of the Western Cape Province is based on zero-grazing systems using mainly oat silage, oat hay or wheat straw as forages. The feeding value of these forages is low, compared to lucerne hay, cultivated grass-clover pastures and maize silage, resulting in high feeding costs. In the Western Cape Province lucerne hay and grass-clover pastures are mainly produced under irrigation. Often lucerne hay is transported to the Swartland region from other regions in South Africa. Due to the bulkiness of forages, transport costs are high, with a variable availability and quality. Limited water is available for irrigating purposes and is used mostly for vegetables, vines or fruit production.

Feed cost can be reduced by providing higher quality forages as silage that fit in as rotation crops in the wheat producing areas of the Swartland. One of these crops is faba beans (*Vicia faba*). In this study the dry matter (DM) production and chemical composition of whole crop faba beans and whole crop oats were determined as fresh material.

Materials and Methods

Faba beans and oats production

The study was conducted at the Elsenburg Research Station (altitude 177 m, longitude 18° 50’ and latitude 33° 51’) in the Western Cape Province of South Africa. Elsenburg is situated 12 km north-west of Stellenbosch and approximately 50km east of Cape Town. Elsenburg is in the winter rainfall region of South Africa which makes it possible to grow small grain forages and legume crops.

Faba beans (*cv*. Ascot) and oats (*cv*. Sederberg) were drill planted separately in the soil on two Northwest facing fields. The soil in the two fields was mostly a Glenrosa type varying in clay content of 20 %.

Faba bean production

Faba beans (*cv*. Ascot) were planted at a seeding rate of 150 kg/ha. Seeds were treated with a lupine inoculant (*Rhizobium lupini*). The soil pH was 5.5, as recommended being the minimum pH for leguminous plants. Soil testing was done four months prior to planting for specific recommendations for nutrients. Calcitic lime was broadcasted on the field the previous year during November to ensure that chemical neutralization of the soil acidity had occurred.

Prior to sowing, the soil was fertilized with phosphor, potassium and lime to the recommended levels according to the soil analysis (Agenbag, 2001). Soil phosphorus was 40 p.p.m. (citric acid method). At planting Superphosphate (8.3 % P) was applied at 150 kg per ha. The potassium content of the soil was 115 p.p.m. which was well above the minimum requirement of 80 p.p.m.

In this study planting of both the faba beans and oats commenced on 17 May during the 2002 production year, and 16 May during the 2003 production year.

LAN-fertilizer (28% N) was applied at a rate of approximately 15 kg nitrogen per hectare on the day previous to sowing. The reason for applying nitrogen to a legume crop is that the *Rhizobium* bacteria inoculated on the seeds only commence binding atmospheric nitrogen from eight to ten weeks after planting (Agenbag, 2001).

Five kg Zinc per ha was given as a soil application. 150 g Sodium molibdate / ha was also dissolved in the tank with the zinc oxide. This application was given concurrently when the herbicide was applied. Sodium molibdate was provided to enhance *Rhizobium* activity.

The soil was lightly cultivated during April to stimulate weed germination. Roundup (Glyphosate 360 g/l) was applied at two liter / ha with a wetting agent one week prior to sowing to give a good control of Knotweed (*Polygonum aviculare*). One week later a deep primary tine cultivation was given.

On the same day, prior to sowing, Simazine (500 g/l) was applied as a pre-emergence herbicide at two liter / ha (Triazine resistant cultivars only) and was sprayed on the loose ground to control broadleaf weeds. Inoculated faba bean seed was planted by means of a drill at a rate of 150 kg / ha at a maximum planting depth of 50 mm.

Two weeks post-emergence the faba bean plant count was 37.4 and 39.0 plants / m² for the 2002 and 2003 production years respectively. According to (McVicar *et al*., 2008) the optimum faba bean plant population in dryland production should be 44 plants / m².

Faba bean production guidelines

Faba beans should be planted at a seeding rate of 150 kg/ha. Seeds must be treated with a bean inoculant (*Rhizobium phaseoli*) to enable optimum use of atmospheric nitrogen (Strijdom & Wasserman, 1980). As for most leguminous plants, the minimum soil pH should be 5.5, as being the minimum pH where Rhizobium activity can still effectively take place (Agenbag, 1997). Soil testing must be done three to four months prior to planting for specific recommendations for nutrients. If lime needs to be broadcasted, enough time of at least two months can be provided, to ensure that chemical neutralization of the soil acidity has occurred.

Prior to sowing, the soil needs to be fertilized with phosphor, potassium and lime to the recommended levels according to the soil analysis (Agenbag, 2001). Soil phosphorus needs to be at least 45 p.p.m. (citric acid method). If phosphorus levels are lower, Superphosphate (8.3 % P) can be applied at 150 kg per ha. This will also provide adequate amounts of sulphur to the S-requirements of faba beans. The potassium content of the soil should also be a minimum of 80 p.p.m. (Agenbag, 2001).

It is generally recommended that for the Swartland and West Coast, legume crops such as faba beans be planted early in the growing season. It is advisable that faba beans should be planted during the last week of April, if the soil type and climatic conditions allow this (Agenbag, 2001). This however can only be done after at least 20 mm of rain had fallen.

LAN-fertilizer (28% N) should be applied at a rate of approximately 15 kg nitrogen per hectare. The reason for applying nitrogen to a legume crop is that the *Rhizobium* bacteria inoculated on the seeds only commence binding atmospheric nitrogen from eight to ten weeks after planting (Agenbag, 2001).

The zinc requirements of faba beans are much higher than any other crop. Five kg Zinc per ha should be given as a soil application prior to sowing. Alternatively Zinc can also be given as a leaf spray at 1.5 kg Zinc oxide / ha at 40 to 45 days after germination. 150 g Sodium molibdate / ha can also be dissolved in the tank with the zinc oxide. This application can be given concurrently when the herbicide is to be applied. The sodium molibdate will enhance *Rhizobium* activity (Agenbag, 2001).

It is generally recommended that if early rain falls during April, the soil be lightly cultivated to stimulate weed germination. Roundup (Glyphosate 360 g/l) applied at two liter / ha with a wetting agent one week prior to sowing will give good control of Knotweed (*Polygonum aviculare*) where this weed is a problem.

One week later a deep primary tine cultivation can be done to extensively loosen the soil.

For broadleaf weed control, Simazine (500 g/l) can be applied at two liter / ha (Triazine resistant cultivars only) as a pre-emergence herbicide and can be sprayed on the loose ground.

Inoculated faba bean can then be planted by means of a drill at a rate of 150 kg / ha at a maximum planting depth of 50 mm.

If full control of broadleaf weeds is not obtained at sowing, a follow-up Basagran (Bendioxide 480 g/l) application can be applied at two liter / ha. Legume crops do not grow well in competition with weeds and especially not any grass weeds. Be sure that the camp is free from any weeds by planting legumes in a crop rotational system (Agenbag, 2001).

Faba bean is very well adapted to production under irrigation. Agronomy of irrigated faba bean is similar to dry land production. Yields can be much higher than dry land production; however, special attention must be paid to prevent losses due to diseases, such as botrytis and ascochyta (McVicar *et al*., 2008).

Oats production

Residual material in the field to be planted with oats (*cv*. Sederberg) was burnt during February 2002. This was done to rid the field of herbicide resistant ryegrass seed (*Lolium* species), which has become prevalent at Elsenburg Research Station (Van Tonder, 2001).

Soil preparation started during the first week of April. This consisted of loosening the topsoil with a light tine implement. This was done to stimulate weed germination in a way to control weeds as the field was sprayed one week prior to sowing using a commercial herbicide, i.e. Sting (Glyphosate 180 g/l) at two liter / ha.

Also the day prior to sowing, the soil was again cultivated with a light tine implement. At the same time fertiliser was applied at 30 kg of nitrogen in the form of Limestone Ammonium Nitrate (LAN). Oats was then drill planted at 80 kg. The soil pH was 5.0.

Thirty-five days after planting a follow-up application of 30 kg / ha nitrogen fertiliser was given. This was followed by another fertiliser application of 40 kg / ha of nitrogen at 65 days after planting.

Harvesting of faba bean and oats and preparation of samples

From 75 to 166 days after planting, whole faba bean and oat plants were cut at weekly intervals at a height of *ca.* 10cm above the ground on five randomly selected areas each. Faba bean samples were cut with a pruning-shears, while oat samples were collected by means of using a sheep-shears. In order to harvest material, a wooden square (measuring $0.25m^2$), with inside width of 0.5 x 0.5 m, was placed at random in the field and material was cut at that position.

Fresh material harvested from the plots were weighed and then oven-dried individually for three days at 55°C. The individual samples were weighed again and the sample DM content was then determined. The DM forage production per hectare was then calculated. The study was conducted over a two-year period.

During the 2003 production year, the third sample collected (day 89), could not be analyzed in a laboratory. The faba bean plants took longer to dry completely due to their thick stems, rain and dew during the night. It was decided to increase the drying temperature to 60°C.

Plant material was milled using a Scientec RSA hammer mill with a 2mm screen, because the samples were also used for the digestibility trials. Composite samples were analyzed for dry matter (DM), crude protein (CP), ash, crude fiber (CF), nitrogen free extract (NFE), fat (EE), calcium (Ca) and phosphorus (P) contents were determined according to standard laboratory techniques (AOAC, 1990) and acid detergent fiber (ADF) and neutral detergent fiber (NDF) according to Van Soest *et al.* (1991). The NFE and TDN were calculated using the formula and method of Van Es & Van der Meer (1980). The following equation was used to calculate the total digestible nutrient (TDN) content of samples i.e. TDN(%) = (0.8 x CP%) + (0.4 x CF%) + (0.9 x NFE%) + (0.9 x EE% x 2.25). The nitrogen free extract (NFE) content of the samples was calculated by the following equation, i.e. NFE(%) = 100% - (Moisture % + CP% + CF% + EE% + TA%).

After the crop was harvested for silage production, the camp was grazed intensively with sheep after which a broad-spectrum herbicide was applied to minimize the build-up of a weed seed bank.

Results and Discussions

Dry Matter production and rainfall

The calculated forage production (ton/ha) of field planted faba bean and oats at Elsenburg for two seasons is presented for illustrative purposes in Table 1. For both the 2002 and 2003 production year, faba bean and oats were planted on different fields. There was no statistical block design. Faba bean and oat samples were cut on five randomly selected areas each as discussed under “Material and methods” section.

As expected in both production years, the fresh and DM production of whole crop faba beans and oats increased with advancing growth stage. During 2002 the weekly growth rate for faba beans was 0.575 ton DM/ha/week (R^2=0.95) and 0.515 ton DM/ha/week (R^2=0.86) for oats. For the 2002 production year, fresh yield production of both faba beans and oats reached a peak at 131 days after planting, i.e. 44.7±6.9 and 28.4±7.1 ton/ha respectively. For the 2002 production year peak DM yield of faba beans was, however, reached at 159 days after planting, i.e. 9.4±1.3 tons DM/ha, and at 152 days after planting for oats at 8.8±0.7 tons DM/ha.

Table 1. The forage production (±SD ton DM/ha) of field planted faba bean and oats at Elsenburg Research Station for two seasons.

Days after planting	Production year 2002				2003			
	Faba beans		Oats		Faba beans		Oats	
	DM (%)	Yield[1] (t DM/ha)	DM (%)	Yield[1] (t DM/ha)	DM (%)	Yield[1] (t DM/ha)	DM (%)	Yield[1] (t DM/ha)
75	9.7	1.7±0.3	-	-	10.0	1.1±0.3	18.7	2.3±0.2
82	11.2	2.6±0.8	16.3	2.5±0.7	10.4	1.2±0.2	19.6	2.6±0.9
89	8.9	2.2±0.8	15.4	2.2±0.5	21.8	2.8±1.3	28.8	4.0±0.1
96	11.1	3.6±0.9	14.7	4.1±0.5	9.7	1.5±0.2	17.3	2.6±0.3
103	10.1	3.4±0.7	15.1	3.9±0.9	12.3	1.6±0.5	18.7	3.8±0.4
110	12.3	5.0±0.3	18.3	4.8±0.4	13.1	2.3±0.3	21.2	3.5±0.8
117	13.5	4.5±1.3	19.2	4.3±0.9	11.7	2.5±0.3	17.0	4.2±0.5
124	13.6	6.0±1.1	20.4	4.4±0.8	13.7	2.8±0.6	24.9	4.9±0.5
131	15.2	6.8±1.2	22.6	6.4±1.6	13.8	2.7±0.1	25.8	5.2±0.3
138	18.9	6.8±2.1	28.2	7.6±1.6	15.8	4.7±0.6	30.4	5.6±1.2
145	20.6	6.1±1.2	32.6	5.2±0.8	16.9	6.1±1.3	32.4	8.5±1.2
152	27.3	7.8±3.1	34.1	8.8±0.7	20.1	4.9±0.1	35.6	6.2±0.1
159	35.9	9.4±1.3	31.8	7.2±2.1	30.4	7.1±0.2	45.0	5.6±0.9
166	68.5	9.0±1.6	45.5	8.6±2.0	-	-	-	-

[1]: Calculated Dry Matter (DM) Production

For the 2003 production year peak DM yield of faba beans was also reached at 159 days after planting, i.e. 7.1±0.2 tons DM/ha, and at 145 days after planting for oats at 8.5±1.2 tons DM/ha.

For the 2003 production year, fresh yield production of both faba beans and oats reached a peak at 145 days after planting, i.e. 36.1±3.1 and 26.1±2.9 ton/ha respectively. This lower fresh yield production was due to the lower rainfall during the 2003 production year.

The DM forage production of field planted faba bean and oats for the 2002 and 2003 production years is presented in Figure 1 and Figure 2 respectively.

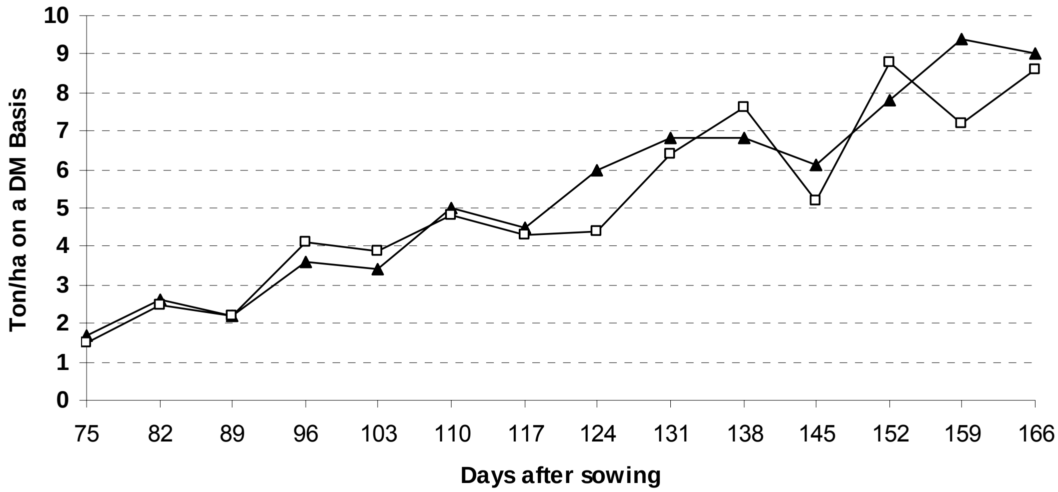

Figure 1. The DM forage production of field planted faba beans (▲) and oats (□) for the 2002 production year.

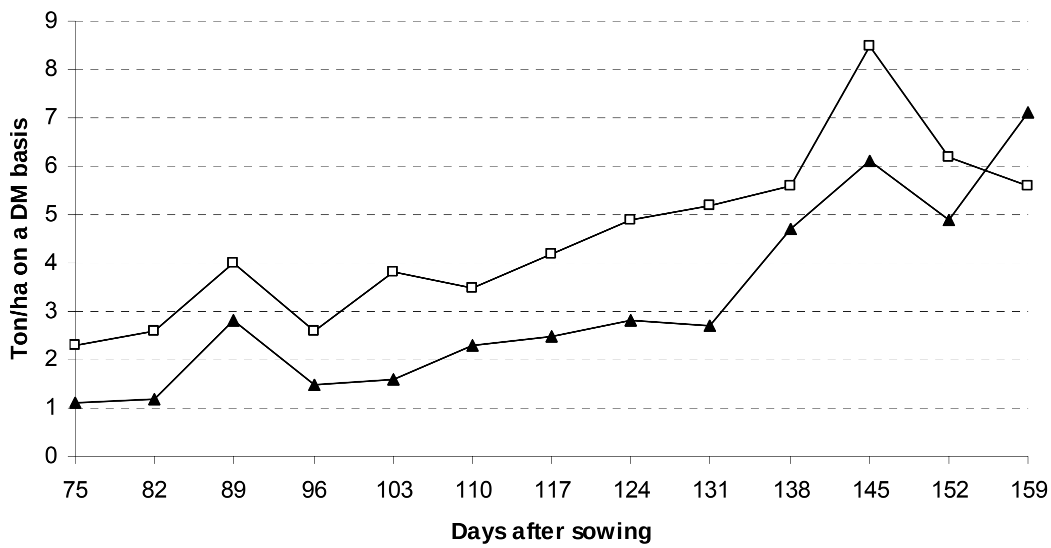

Figure 2. The DM forage production of field planted faba beans (▲) and oats (□) for the 2003 production year.

During April to July of the 2003 production year the rainfall was less than the long-term average rainfall for this area (Agromet, 2003).

Another factor that could have resulted in a lower production of faba beans was the seasonal drought in the Swartland and Boland Region of the Western Cape Province. Large colonies of Egyptian geese (n > 250) were observed feeding daily on the newly emerged faba beans. Although these fields were on the perimeter of the farm, no culling or shooting of the wild geese was allowed.

Due to this lower rainfall during the 2003 production year, the weekly crop growth was less than during 2002. The weekly growth for faba beans was 0.440 ton/ha/week (R^2=0.79) and 0.380 ton/ha/week (R^2=0.73) for oats. The DM production was more than a ton less per week for both crops than during the 2002 production year.

Table 2. The monthly rainfall (mm) for the 2002 and 2003 production years, as well as the long-term average (LTA) rainfall at the Elsenburg weather station (Agromet, 2008).

Month	2002	2003	LTA
January	105.0	12.4	17.7
February	18.0	10.0	8.8
March	18.8	83.2	26.3
April	63.6	42.8	47.2
May	109.6	49.8	92.2
June	92.8	30.4	82.1
July	141.8	59.2	114.6
August	110.2	187.6	112.3
September	53.2	100.0	59
October	46.4	41.8	41.5
November	27.4	5.2	29.7
December	39.4	43.2	17.7

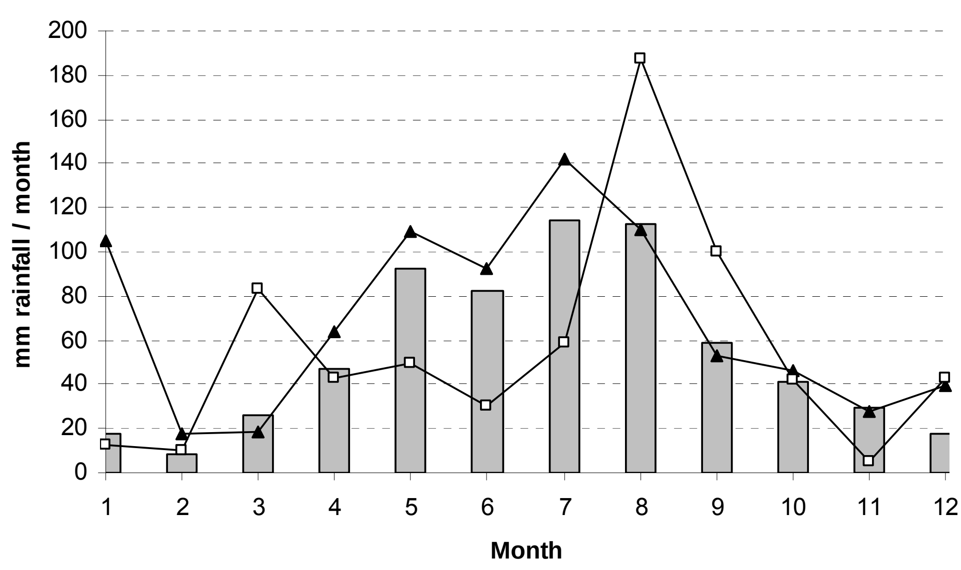

Figure 3. The rainfall (mm/month) for the 2002 (▲) and 2003 (□) production years, measured against the long-term average rainfall (gray columns) at the Elsenburg weather station (Agromet, 2008).

The average rainfall is 649mm per annum with the highest precipitation occurring between May and August. The rainfall during these winter months ranges between 92.2 to 112.3mm per month, whereas during the summer months it ranges between 17.7 mm (December) and 8.8 mm (February) per month (Agromet, 2008).

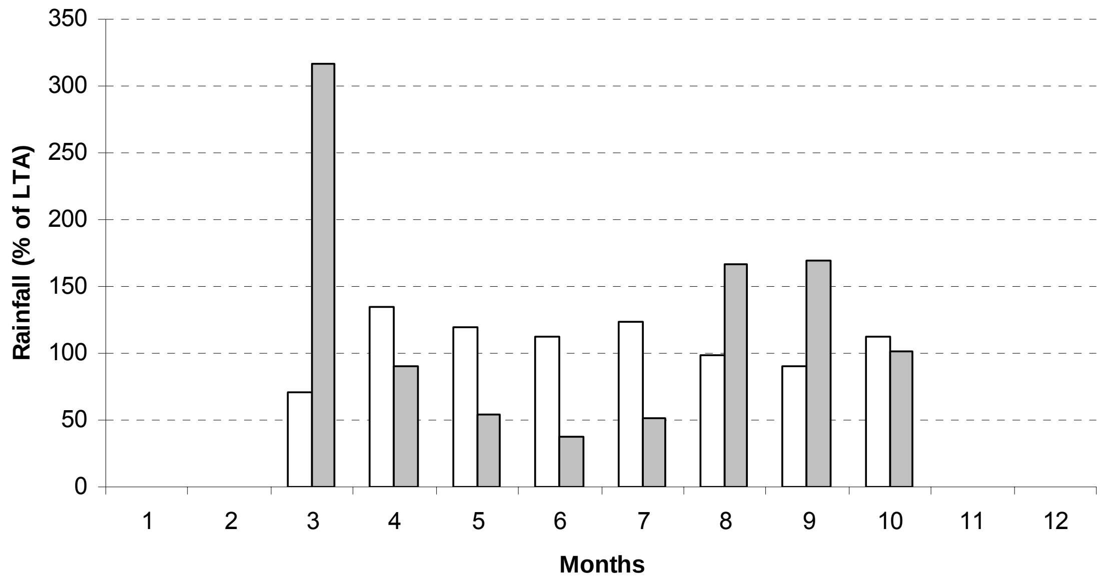

Figure 4. The monthly rainfall as a percentage of the long-term average (LTA) at Elsenburg during the 2002 (white columns) and 2003 (gray columns) production years.

During the 2002 production year, oats was cut and ensiled for silage from 135 to 145 days, while faba beans were cut from 145 days after planting. The bottom leaves of the faba beans started to disappear fast after 138 days after planting.

During the 2003 production year, oats was cut and harvested for silage from 152 to 162 days, while faba beans were cut from 159 days after planting. In both production years the starting date of ensiling the crops were more than two weeks later than the optimum stage for harvesting, mainly because of logistical problems. For both years the oats had surpassed its optimum ton/ha DM at the time of cutting and ensiling.

In a study done in Wales (United Kingdom) Fychan *et al.* (1999), found that the yield of faba beans at different growth stages at 10 weeks (70 days), 12 weeks (84 days) and 14 weeks (98 days) to be 3.698, 5.167 and 7.760 ton DM/ha respectively. The faba beans were drilled into the soil on 29 April 1998 at a seed rate of 280 kg/ha.

The higher yield may have been to their higher rainfall during the growing season, as well as the higher seeding rate.

In the Winter Rainfall Region of South Africa it is also the practice to plant during the last week of April at a seeding rate of 140 kg/ha (Agenbag, 2001). It is however not always possible to plant that early in the winter rainfall region of South Africa as many years the first winter rain only precipitates during the last week of May. It is only after these first winter rains that it is possible to mechanically cultivate the soils in this area.

Chemical Composition

The samples cut on the five randomly selected areas of both the whole crop faba beans and whole crop oats, for both the 2002 and 2003 production years, were pooled for chemical analysis.

The change in chemical composition of faba bean plants in the weekly growth stages from 75 to 166 days after sowing for the 2002 production year is presented in Table 3.

In Table 4 and 5 the change in chemical composition of whole crop faba beans and oats plants in weekly growth stages from 75 to 159 days after sowing for the 2003 production year is presented.

Table 3. The change in chemical composition of faba bean plants in different growth stages on a 100% DM basis for the 2002 production year.

Days after planting	CP (%)	TDN (%)	EE (%)	NFE (%)	CF (%)	NDF (%)	ADF (%)	Ca (%)	P (%)	Ash (%)
75	23.5	68.8	2.8	40.2	20.2	28.9	26.9	0.85	0.53	12.3
82	25.3	67.0	2.0	38.1	21.2	30.6	27.9	0.93	0.63	12.6
89	23.6	68.8	3.0	38.3	23.3	30.0	29.2	0.96	0.43	10.7
96	20.5	68.6	2.5	41.0	25.7	35.4	32.7	0.83	0.40	9.4
103	20.8	69.2	3.1	40.3	25.1	33.0	32.7	0.83	0.37	9.8
110	17.6	71.2	2.6	46.5	25.1	34.3	30.3	0.74	0.34	7.5
117	17.5	71.7	2.5	47.5	24.9	34.3	30.7	0.90	0.35	7.0
124	18.8	68.0	2.0	41.4	29.3	37.4	32.0	0.88	0.38	7.8
131	18.9	69.1	2.1	42.9	28.0	36.7	34.0	0.84	0.42	7.5
138	14.2	69.7	1.8	47.4	30.3	36.4	33.2	0.71	0.36	5.8
145	14.8	73.1	1.9	53.0	24.4	34.4	29.1	0.69	0.37	5.5
152	14.5	70.9	1.2	50.2	27.6	37.4	31.1	0.64	0.38	5.7
159	15.4	69.8	1.3	48.1	29.2	39.4	33.5	0.63	0.46	5.6
166	18.4	73.3	1.3	52.2	22.6	36.1	27.3	0.57	0.43	5.1

Samples pooled for chemical analysis.

Table 4. The change in chemical composition of faba bean plants in different growth stages on a 100% DM basis for the 2003 production year.

Days after planting	CP (%)	TDN (%)	EE (%)	NFE (%)	CF (%)	NDF (%)	ADF (%)	Ca (%)	P (%)	Ash (%)
75	28.2	62.6	2.1	30.0	21.8	30.3	30.1	0.44	1.18	16.5
82	26.9	65.5	2.6	33.3	21.8	29.7	27.6	0.46	1.25	14.2
89	*									
96	26.1	64.2	2.9	30.5	25.0	36.0	31.0	0.49	0.97	14.3
103	26.4	64.9	2.2	32.9	24.5	31.1	30.8	0.50	0.90	13.0
110	22.9	68.2	2.3	38.8	25.6	33.7	30.6	0.48	1.04	9.5
117	24.9	64.3	1.8	31.8	30.1	35.2	34.0	0.47	1.14	10.5
124	24.2	68.9	2.2	40.0	22.9	29.9	28.1	0.58	1.49	9.9
131	23.7	68.7	2.3	39.6	23.8	31.7	29.7	0.45	1.07	9.8
138	20.8	71.7	1.9	47.0	22.1	32.4	26.9	0.32	0.89	7.4
145	21.7	69.7	1.5	42.8	27.0	37.7	29.7	0.32	0.93	6.5
152	20.5	69.1	1.3	43.5	27.2	37.0	29.7	0.54	0.97	6.8
159	19.5	70.9	1.0	47.5	26.5	38.6	29.8	0.35	0.70	5.1

*: Sample contaminated.

Table 5. The change in chemical composition of oats plants in different growth stages on a 100% Dry Matter Basis for the 2003 production year.

Days after planting	CP (%)	TDN (%)	EE (%)	NFE (%)	CF (%)	NDF (%)	ADF (%)	Ca (%)	P (%)	Ash (%)
75	18.6	70.0	3.2	42.6	25.6	46.4	26.7	0.39	0.36	9.1
82	15.6	69.5	2.6	45.2	27.8	51.1	30.2	0.40	0.40	8.1
89	12.5	68.2	2.3	45.8	30.9	59.1	33.4	0.33	0.33	7.8
96	12.0	69.5	2.4	48.7	28.4	54.6	32.7	0.30	0.30	7.9
103	14.6	64.5	1.7	38.0	37.8	62.5	35.1	0.34	0.34	7.3
110	10.3	68.2	1.6	48.3	33.3	61.9	37.7	0.26	0.26	6.0
117	9.1	67.4	1.5	48.0	34.5	63.7	39.3	0.29	0.29	6.3
124	9.3	65.8	1.4	44.7	38.4	68.9	41.7	0.25	0.25	5.8
131	8.6	67.0	1.5	47.1	37.1	71.5	41.6	0.25	0.17	5.4
138	8.6	69.9	2.7	48.1	36.2	66.7	40.0	0.25	0.18	4.2
145	8.9	71.6	3.0	50.4	32.8	64.8	-	0.30	0.16	4.7
152	8.2	69.9	2.5	49.2	35.1	73.3	39.8	0.23	0.18	4.6
159	7.4	67.5	2.3	46.9	36.9	67.2	43.3	0.33	0.16	6.1

The CP (%) for both the faba bean and oats showed a distinctive downward trend with increase in age of plant maturity. The CP content of whole crop faba beans decreased ($P<0.05$) from 25.3 to 18.4 % (on DM basis) from 82 to 166 days after planting for the 2002 production year. This high CP percentage of 18.4 % is due to the sample containing mature faba bean seeds. The CP content of whole crop faba beans for the 2003 production year also decreased ($P<0.05$) from 28.2 to 19.5 % from 75 to 159 days after planting.

The crude protein production of field planted faba bean and oats for the 2002 and 2003 production years is presented in Figure 5.

Similarly during the 2003 production year the CP content of whole crop oats also decreased ($P<0.05$) from 18.6 to 7.4 % from 75 to 159 days after planting.

The CP percentage of the faba beans in the 2003 production year decreased at -0.68 percentage points per week ($R^2=0.90$), while during the 2002 production year the CP % decreased at -0.88 percentage points per week ($R^2=0.85$). This can be attributed to the slower growth due to the lower rainfall experienced during the 2003 growing season.

The CP% of the oats in the 2003 production year decreased at a rate of -0.78 percentage points per week ($R^2=0.80$).

Table 6 presents the CP and TDN yield (ton/ha) of whole plant faba beans and oats in different growth stages on a 100% DM basis for the 2003 production year.

The CP yield (ton/ha) of whole crop faba beans in the 2003 production year increased (0.10 percentage points per week; $R^2=0.84$) more per week than whole crop oats for the different growth stages (0.01 percentage points per week; $R^2=0.13$) from 75 to 159 days after planting. Over the same period the TDN yield (ton/ha) of whole crop faba beans increased at a rate of 0.36 percentage points per week ($R^2=0.85$), while whole crop oats increased at a rate of 0.27 percentage points per week ($R^2=0.70$).

Heydenrych *et al*. (1999) also found that the growth stage of maturity at harvesting plays an important role in ensiling a crop for silage. The CP% at the start of the growing season is much higher than later in the season. Harvesting later has the advantage of a higher DM yield.

Newton & Hill (1983) found a wide variation in the CP and energy content of the faba bean seed depending on the bean variety and time of harvesting during the growing season.

Table 6. The CP and TDN yield (ton/ha) of whole plant faba beans and oats in different growth stages on a 100% DM basis for the 2003 production year.

Days after planting	Faba beans		Oats	
	CP (ton/ha)	TDN (ton/ha)	CP (ton/ha)	TDN (ton/ha)
75	0.31	0.69	0.43	1.61
82	0.32	0.79	0.41	1.81
89	*	*	0.50	2.73
96	0.39	0.96	0.31	1.81
103	0.42	1.04	0.55	2.45
110	0.53	1.57	0.36	2.39
117	0.62	1.61	0.38	2.83
124	0.68	1.93	0.46	3.22
131	0.64	1.85	0.45	3.48
138	0.98	3.37	0.48	3.91
145	1.32	4.25	0.76	6.09
152	1.00	3.39	0.51	4.33
159	1.38	5.03	0.41	3.78

*: Sample contaminated.

Toynbee-Clarke (1973) found a CP average of 17.1% for faba beans forage cut on six dates from 29 June to 31 August, but those cut on 21 July had less CP (14.9%) than those cut earlier or later. Tisserand & Roux (1976) (as cited by Faulkner, 1985) observed decreases in CP concentrations in faba beans from about 19.0% at the start of flowering to 12.7% during seed ripening, but in the following season it dropped to a minimum of 16.1% in late flowering and then increased slightly.

In Scotland, Potts (1982) reported a CP content of 18.5% in peas and 10.7% in oats. He further states that CP concentrations are similar in pea and bean forages and that, although they may vary with environment or cutting time, they are consistently much higher in these legumes than in oat forage.

As expected the CF % in faba beans planted during 2002 increased from 20.2 to 22.6 %, while during the 2003 production year CF % increased from 21.8 to 26.5 %. The CF % for faba beans for the 2003 production year increased at a rate of 0.31 percentage points per week (R^2=0.24).

The CF % for oats during the 2003 production year increased from 25.6 to 36.9 %. The CF % for oats increased at a rate of 0.76 percentage points per week (R^2=0.51).

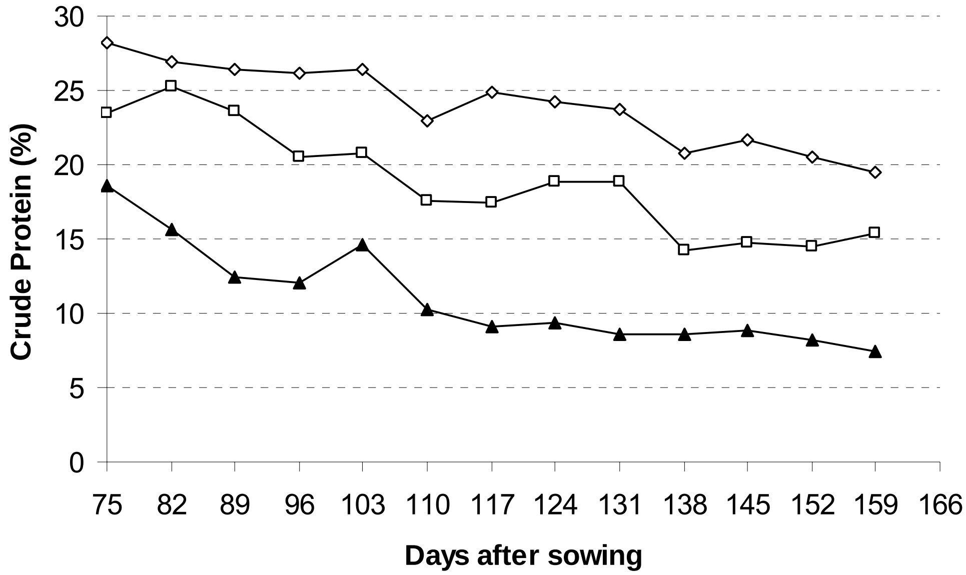

Figure 5. The crude protein percentage of field planted faba beans (□: 2002; ◊: 2003) and oats (▲: 2003) for the 2002 and 2003 production years.

During the same time the EE, Ca and P contents also decreased ($P<0.05$), while the NDF, CF and ADF contents increased ($P<0.05$). This is mainly due to plants maturing with advancing growth stages.

The chemical composition (on DM basis) of the faba bean ensiled during 2002, concerning CP, CF, EE, NFE, NDF, ADF, calculated TDN, Ca and P levels was 14.0, 44.4, 5.8, 28.0, 56.7, 51.2, 64.5, 0.89 and 0.23% respectively.

The lower CP obtained from the faba bean camp during the 2002 production year, compared to the 2003 production year, was due to poor growth performance of faba beans planted to a camp with lower soil pH in large areas. This camp had been treated with calcitic lime two years prior to planting the faba beans. The soil analysis of the previous year showed that the pH was close the optimum of 5.5, and was sufficient to produce quality faba beans.

Fraser *et al*. (2001) compared the ensiling potential of faba bean and field pea. The authors found that at a given harvest date (e.g. 12 wks after seeding), both silages had a similar CP content (20.2 % on DM basis), while the pea silage had a lower ADF and NDF (36.4 and 41.7 vs. 40.1 and 44.6% on DM basis) than faba bean silage. Results from this trial also showed that total tract DM digestibility of pea silage was higher than that of faba bean silage, while NDF digestibility was similar for both species.

The TDN % of the faba beans for both production years showed an increase with increasing plant maturity. The TDN % of the faba beans increased at 0.29 percentage points per week (R^2=0.43) and 0.65 percentage points per week (R^2=0.75) for the 2002 and 2003 production years respectively. On the other hand, the TDN % of oats showed no difference over the same time period (R^2=0.002) with an increase in plant maturity.

The percentage NDF and ADF of field planted faba beans for the 2003 production year is presented in Figure 6.

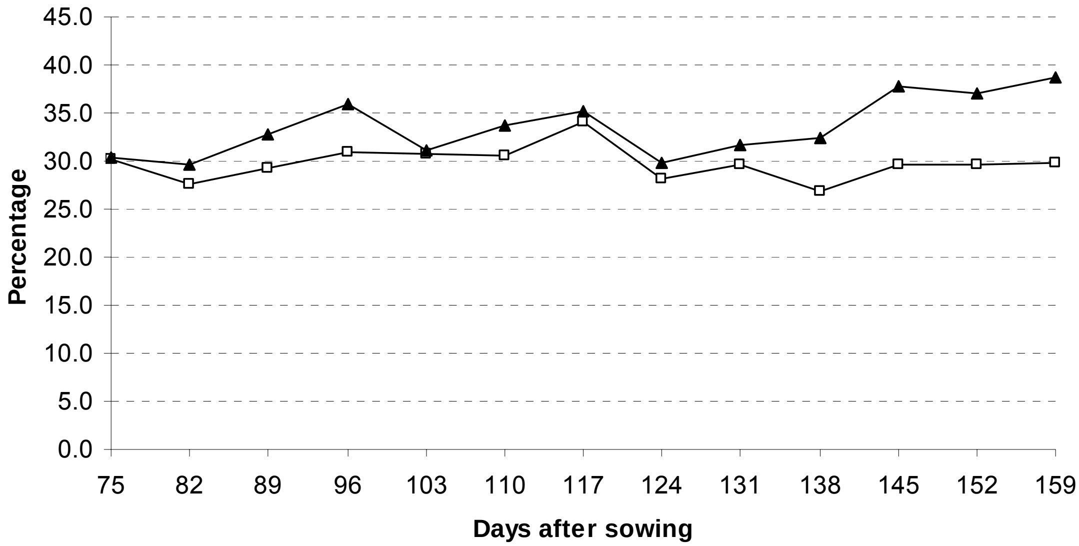

Figure 6. The percentage NDF (▲) and ADF (□) of field planted faba beans for the 2003 production year.

For the 2003 production year, the NDF % of the field planted faba beans showed an increase with increase in age of plant maturity, while the ADF % did not change with increase in age of plant maturity. The NDF % increased at 0.51 percentage points per week (R^2=0.41)..

Mustafa & Seguin (2003) reported that data on protein fractions of legume silages is limited. Mustafa & Seguin (2003) reported on the chemical composition of whole crop faba beans in Eastern Canada on the day before ensiling. They found the CP, NDF and ADF to be 20.0%, 45.7% and 30.5% (DM basis) respectively. Forty-five days after ensiling, the chemical composition in terms of CP, NDF and ADF changed to 22.2%, 42.8% and 31.3% (DM basis) respectively.

The percentage NDF and ADF of field planted oats for the 2003 production year is presented in Figure 7.

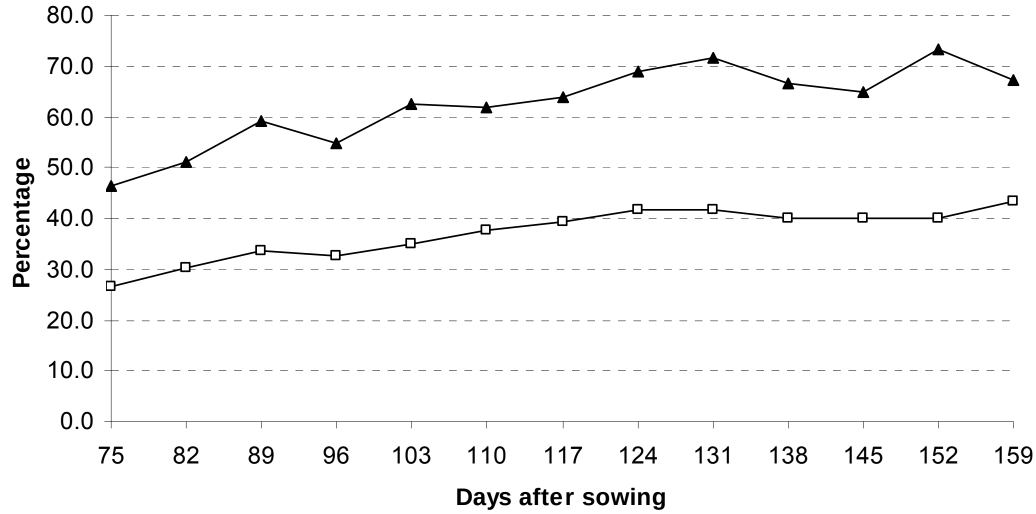

Figure 7. The percentage and NDF (▲) and ADF (□) of field planted oats for the 2003 production year.

For the 2003 production year, both the NDF % and ADF % of the field planted oats showed an increase with increase in age of plant maturity. The NDF % increased at 1.76 percentage points per week (R^2=0.75), while the ADF % increased at 1.17 percentage points per week (R^2=0.82).

Differences in NDF and ADF can be attributed to differences in stage of maturity and differences in fiber characteristics.

Minimum acid detergent fiber (ADF) levels required in the feed DM are 19-21%. Neutral detergent fiber (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).

The nutritional value of 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), as cited by Bangani (2002)). At the milk stage, CP averages 12%, NDF 48%, ADF 35% and *in vitro* digestibility averages 62%.

For lactating cows, the recommended minimum concentration of NDF is 25 percent of the diet DM with 19 percent of forage origin. When the amount of fiber from forage is reduced to 15 percent, the amount of NDF in the diet should be at least 33 percent DM (Kononoff, 2005).

In this study, the data reported for the 2003 production year for both faba bean and oats are in general good agreement with reported values.

Conclusions

The fresh and DM production of whole crop faba beans and oats increased with advancing growth stage and age of plant maturity. Depending on the rainfall during the growing season, the fresh material production of both faba beans and oats reached a peak between 131 to 159 days after planting. DM production reached a peak at 166 days after planting. The CP % of faba beans decreased with advancing growth stage.

For faba beans, the NDF % showed an increase with increase in age of plant maturity, while the ADF % remained close on constant though decreased very slightly with increase in age of plant maturity. For oats both the NDF and ADF percentages increased with increasing plant maturity.

The results from this study indicate that both whole crop faba beans and oats could be ensiled from 131 to 166 days after planting. Although the DM yield would be higher at 166 days after planting, the nutrient quality in terms of chemical composition of the field crops would be higher from 131 to 152 days after planting.

Given proper growing, harvesting and ensiling practices, whole plant faba beans may be a satisfactory alternative to traditionally grown forage crops like oats and barley for the Swartland region of the Western Cape Province. However, in limited experience to date, there have not been consistently high DM yields of faba bean silage.

It is thus important to consider whether the improvement in the quality of faba beans and oats harvested at an earlier stage will bring about an improvement in cow production versus a lower DM yield in terms of a crop cut at an earlier stage. Results from this study can make a valuable contribution towards the South African databases on faba bean and oats nutrient values and can be used in dynamic feed formulation models.

Chapter 4

THE EFFECT OF FABA BEAN SILAGE COMPARED TO OAT HAY, AND OAT SILAGE ON FEED INTAKE, MILK YIELD AND MILK COMPOSITION PARAMETERS

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 most dairy enterprises (Gordijn & Whitehead, 1995). Reducing feed cost of milk production is always the aim of a dairy farmer as it results in higher net returns; however, a reduction in feed cost should not compromise the milk yield of cows. 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 Swartland region of the Western Cape Province, home produced forages are mainly small grain cereal crops such as oats, barley and wheat.

Organisations such as the Protein Research Trust in South Africa advise farmers to include legume crops in a rotational system with small grain cereal crops. This is done to increase the amount of home grown feeds containing high levels of crude protein, i.e. lupines, faba beans, field peas etc. By using a rotational crop system, cereal crops have a much lower risk regarding plant diseases, as well as cutting down on nitrogen fertiliser in the year following the legume crop (Agenbag, 2001).

In this study two experiments were conducted to determine the effect of faba bean silage (FBS) in comparison to oat hay (OH) and to oat silage (OS) on the feed intake and milk yield and milk production parameters of Holstein cows.

In the first experiment that was conducted, the effect of FBS compared to OH, and a 50:50 mixture of FBS and OH, was determined on the feed intake, milk yield and milk production parameters of Holstein cows.

In the second experiment that was conducted, the effect of FBS compared to OS, and a 50:50 mixture of FBS and OS, was determined on the feed intake, milk yield and milk production parameters of Holstein cows.

Experiment 1:

Materials and methods

The study was conducted at the Elsenburg Research Station (altitude 177m, longitude 18°50' and latitude 33°51') near Stellenbosch. Elsenburg is situated approximately 50 km east of Cape Town in the winter rainfall region of South Africa.

Twenty-one multiparous lactating Holstein cows, on average 8 weeks post-calving, from the Elsenburg herd were used in the experiment. Cows were divided into three groups of seven cows each. The experiment was conducted according to a randomized block design.

Thirteen kg DM of either FBS, OH or a 50:50 mixture of FBS and OH as forages were fed, together with three different concentrates of nine kg "as is" each, to three groups consisting of seven lactating Holstein cows. Cows were on average 112±44 days post calving producing 24.0±6.2 kg milk/day and were on average in lactation number 2.5±1.7.

The experimental period consisted of a three-week adaptation period and an eight-week experimental period. Groups consisted of seven cows each. They were fed in bulk to determine dry matter (DM) intakes. Samples of FBS and OH were collected once a week.

The CP content of the concentrate fed to the cows was based on a total diet CP content of 15% (Table 1). Concentrates fed to cows receiving FBS, 50:50 mixture of FBS and OH, and OH as forage had CP levels of 17.0%, 22.5% and 28.0% respectively. The CP of the FBS and OH was based on laboratory values. The laboratory CP of the FBS was found to be lower than that of the green material harvested at weekly intervals during the growing season (see Chapter 3). The reason for this is due to the poor growth performance of faba beans planted to a camp with lower soil pH in large areas.

FBS and OH were mixed by hand. Concentrates were fed together with the forages and placed on top of the forage.

Table 1. The estimated feed intake (kg/day) and crude protein content (%) of feeds used in the experiment (values on a dry matter (DM) basis).

Parameters	Roughage	Concentrate	Total CP (%)
FBS	14	17	15.2
MIX	10	22.5	15.1
OH	6	28	15.0
Feed Intake (kg/day)	13 kg	9 kg	22 kg

CP = Crude protein
FBS = Faba bean silage
MIX = 50:50 mixture of faba bean silage and oat hay
OH = Oat hay

Six silage samples were taken from the faba bean silage over the trial period for testing of pH. The faba bean silage pH was on average 4.11, which is within the 3.8 to 4.2 ranges suggested by Rotz & Muck (1994), indicating well-preserved silage. Silage had been preserved with the use of a water-soluble bacterial inoculant (Sil-All 4x4 W.S, Alltech, Stellenbosch) at a rate of 250g per 25 ton ensiled crop. Three sachets (250 g each) were dissolved in 50 liters of water and applied during chopping of the crop.

All diets formulated for the experiment contained at least 50% forage and had a 15% CP content (Table 1). This composition agrees with the guidelines by Dugmore (1995) that 35-40% of the dairy cow's diet must be forage and that protein should make up 14 to 19% of the total feed (Grant, 1990).

The ingredient composition of the concentrates, as well as the chemical composition of the feeds used in this study is presented in Table 2.

Table 2. The feed ingredients and the chemical composition (on a DM basis) of the concentrates fed with the forages.

Parameters	FBS	MIX	OH
Ingredients:			
Wheat	400	400	400
Wheat bran	120	67.5	15
Cottonseed oilcake meal	150	235	320
Maize	295	225	155
Salt	5	5	5
Urea	5	10	15
Fishmeal	10	43	76
Feed lime	15	14.5	14
Total:	1000	1000	1000
Chemical composition:			
Crude protein (%)	17.0	22.5	28.0
Total Digestible Nutrients (%)	76.0	76.0	76.0
Calcium	0.64	0.64	0.65
Phosphorus	0.47	0.51	0.54
Crude fiber (%)	4.6	4.72	4.85

FBS = Faba bean silage; MIX = 50:50 mixture of faba bean silage and oat hay; OH = Oat hay

Diets contained FBS, OH and a 50:50 combination of FBS and OH as forages. Concentrate mixtures were formulated for each forage type using a least cost linear programme. The chemical composition of feedstuffs was based on values obtained from Van der Merwe (1983).

The 21 Holstein cows were divided into three groups of seven cows each. During the experimental period, a weighed amount (sufficient for *ad lib* feeding) of fresh forage (i.e., either FBS, OH, or a 50:50 mixture of FBS and OH) was given daily to each group of cows after every milking. The forages were provided in feed troughs at the stalls during the time when cows were being milked in the milking parlour. Diets were fed at 07h00 and 16h00. Refusals from the previous feeding were collected and weighed before fresh feed was provided.

Dry matter intake of cows was determined twice a week, by taking samples from both refusals and fresh feed. Samples were weighed and dried separately for 72 hours in a forced-air draught oven at a temperature of 60ºC. The percentage DM was calculated as kilogram feed after drying in relation to kilogram feed before drying. The dry matter intake was expressed as the difference between the amount of DM fed and DM refused.

Dry matter intake of the FBS, 50:50 mixture and OH was on average 9.3±1.9, 11.1±1.3 and 11.0±0.8 kg/cow/day. Dry matter intake of the concentrates corresponding to the FBS, 50:50 mixture and OH was on average 7.70±0.05, 7.72±0.05 and 7.71±0.06 kg/cow/day.

During the day, from 10:30 to 14:00, cows were put in a soil based open camp to socialize, for heat detection purposes and to reduce the time spent on concrete. There was no edible material in the open camp. Drinking water was provided *ad libitum* in a drinking trough within the camp.

Fresh drinking water was available *ad libitum* inside each grouped stall. The stalls were cleaned every day and fresh straw put down on the floor to ensure a soft sleeping area

Cows were machine-milked twice a day at 05h00 and 15h00 in a milking parlour approximately 100m from the housing barn. Standard operating procedures were followed. Cows were brought into the parlour, the udders washed down with running water after which the teats and most of the udder dried with a separate paper towel for each cow. Cows were tested for mastitis by stripping a small amount of milk into a mastitis cup. If no mastitis clots were observed on the lid of the mastitis cup, the milk clusters were attached to the teats. The clusters were removed after the milk flow had stopped. Stripping was allowed for a period not longer than 30 seconds after the milk flow had stopped.

The milk yield of each cow was recorded at each milking session. During the trial period, milk samples were collected on Monday afternoon, Tuesday morning and afternoon, Wednesday morning and afternoon and on Thursday morning of each week from each cow at the milking and then combined. Intervals between milking were 14 hours from the afternoon till morning milking, and 10 hours from the morning to the afternoon milking. Two ml milk was collected for every two hours between milking, thus collecting 28 ml from the morning milking and 20 ml from the evening milking. Milk samples were analysed for milk urea nitrogen (MUN), fat, protein and lactose contents using a Milko-Scan Infrared Analyser.

A 1000 kg capacity BERKEL electronic scale was used to weigh the cows. They were weighed after the afternoon milking at the beginning and end of each experimental period.

During the 3-week trial period, cows were group fed. The daily dry matter intake (DMI) of each group of seven cows were determined three times a week, i.e. Monday afternoon through to Tuesday afternoon, Wednesday afternoon through to Thursday afternoon and Friday afternoon through to Saturday afternoon. An amount of forage expected to ensure an *ad libitum* intake was weighed daily before being provided to each cow. Half of the daily allotment was provided after the evening milking and the other half of the daily feed was provided after the following morning's milking. The residues of the total daily allotment given were collected during the afternoon's milking session when the cows were being milked. The total amount of residue was weighed after which a sample of approximately one kg was collected. This sample was put into a drying pan, weighed and then put in a draught oven at 70^{o}C to be dried for 48 hours. After 48 hours the dried sample was weighed again and the DM content of the residue determined. A sample of the experimental diet was collected on the first day of feeding of the weighed amount of feed and then dried in a draught oven at 70^{o}C. From this the DM content of the feed was determined. The daily feed intake of cows over a 24-hour period could then be determined on a DM basis.

Samples of the FBS and OH 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). FBS was evaluated weekly for pH and DM content.

The chemical composition (on DM basis) of the faba bean ensiled, concerning CP, CF, EE, NFE, NDF, ADF, calculated TDN, Ca and P levels was 14.0, 44.4, 5.8, 28.0, 56.7, 51.2, 64.5, 0.89 and 0.23% respectively.

The chemical composition (on DM basis) of the oat hay, concerning CP, CF, EE, NFE, NDF, ADF, calculated TDN, Ca and P levels was 6.0, 34.3, 1.2, 41.7, 65.7, 45.6, 60.3, 0.18 and 0.16% respectively.

Statistical procedures and analysis

Production and feed intake data were analysed according to a multi-factor analysis of variance using the Statgraphics programme (1991). Differences among treatments were declared at $P<0.10$.

Results and Discussion

The effect of feeding different forages in total mixed rations on the milk yield, milk composition, feed intake and live weight parameters of Holstein cows is presented in Table 3.

Table 3. The mean (±SE) production parameters of Holstein cows receiving three total mixed rations containing either faba bean silage (FBS), oat hay (OH) and a 50:50 mixture of faba bean silage and oat hay (MIX) as forages.

Production Parameters	Treatments			SEM	P
	FBS	MIX	OH		
Milk (kg/day)	18.9 ± 1.9	20.5 ± 1.4	20.6 ± 1.3	0.9	0.68
Fat (%)	3.99 ± 0.19	3.69 ± 0.10	3.59 ± 0.17	0.09	0.22
Fat (kg/day)	0.722 ± 0.057	0.734 ± 0.045	0.721 ± 0.041	0.028	0.98
Protein (%)	3.07 ± 0.09	3.14 ± 0.10	3.22 ± 0.09	0.05	0.54
Protein (kg/day)	0.560 ± 0.041	0.621 ± 0.028	0.645 ± 0.023	0.018	0.17
Lactose (%)	4.75 ± 0.05	4.76 ± 0.07	4.71 ± 0.10	0.04	0.91
MUN (mg/dl)	14.0 ± 0.6 [a]	14.9 ± 0.5 [a]	16.2 ± 0.6 [b]	0.3	0.06
Live weight at start	523 ± 28	549 ± 20	537 ± 32	16	0.80
LW difference (start minus end weight)	19.0 ± 12.0	11.6 ± 16.4	28.6 ± 3.7	6.9	0.61

MUN = milk urea nitrogen
SE: Standard error
SEM: Standard error of the mean
P: Significance level
[ab:] Means within rows with different superscripts differed significantly (P<0.10).

Of the milk composition parameters, only the MUN from cows fed OH was significantly (P=0.06) higher than the MUN of the milk of cows receiving FBS, i.e. 16.2±0.6 vs. 14.0±0.6 mg/dl. This could probably be related to the high CP content of the concentrate fed to the cows in this group. The concentrate fed with the OH was higher in urea, cottonseed oilcake meal and fishmeal as source for protein. Other production parameters did not differ (P>0.10) between treatments.

Milk urea nitrogen (MUN) is the fraction of milk protein that is derived from blood urea nitrogen (BUN). MUN normally represents about 0.19 percentage point of the total 3.2 percent total protein in Holstein milk (Hutjens, 2008). Although the MUN content of the milk of cows receiving the diet containing OH was higher than the MUN content of other diets, a MUN value of 16.2±0.6 mg/dl was in range as generally accepted for dairy cows. The MUN values for FBS and the MIX were 14.0 ± 0.6 and 14.9 ± 0.5 respectively. According to Hutjens (2008) MUN values of dairy cows normally range from 8 to 14 mg/dl.

When cows consume feed containing protein, part of the protein is degraded to ammonia by rumen microbes (rumen degradable protein or RDP). When the rumen bacteria are not able to capture the ammonia converting it over to microbial protein, the excess ammonia is absorbed across the rumen wall. Because ammonia can shift blood pH, the liver converts ammonia to MUN to be excreted or recycled. Because milk is synthesized from blood and if MUN blood values are elevated, MUN values in milk can be higher. If MUN values are too high, the herd is possibly wasting feed protein. If MUN values are too low, the rumen bacteria yield will be reduced, limiting milk production and milk protein yield (Hutjens, 2008). When the weekly farm baseline MUN changes by more than three MUN points up or down, changes can be traced back in the herd feeding and handling (Hutjens, 2008).

Conclusions

In the present study, with the exception of the MUN content of milk, no significant differences were observed of the cows on different forages for milk yield or other milk production parameters. Cows fed FBS and OH produced similar amounts of milk while the protein and total solids contents were the same. Whole crop FBS and OH were equally well consumed and utilized by the dairy cows. The CP content of FBS is more than double that of OH. This resulted in a major cost saving in the concentrate fed with FBS. The feeding value of FBS in a total mixed diet for lactating dairy cows as suggested by results from this trial indicates that milk producers can reduce their total feed cost and increase profit margins of milk production, if compared to that of good quality OH.

Experiment 2:

Materials and methods

The study was conducted at the Elsenburg Research Station (altitude 177m, longitude 18°50' and latitude 33°51') near Stellenbosch. Elsenburg is situated approximately 50 km east of Cape Town in the winter rainfall region of South Africa.

Six multiparous lactating Holstein cows, 8 weeks post-calving, from the Elsenburg herd were used in the experiment in a double 3 x 3 Latin Square cross-over experimental design. The three treatments were mixed rations containing either faba bean silage (FBS), oat silage (OS) or a 50:50 mixture of FBS and OS as forages (MIX), fed together with a concentrate.

Thirteen kg DM of either FBS, OS or a 50:50 mixture of FBS and OS as forages were fed, together with three different concentrates of nine kg "as is" each, to each cow. Cows were on average 108±30 days post calving producing 22.0±2.0 kg milk/day.

In this experiment, cows received a specific diet for an initial 14-day adaptation period followed by a 21-day trial period during which specific parameters were recorded. The parameters were milk, butterfat and lactose yields and butterfat, protein and lactose %, milk urea nitrogen (MUN), somatic cell count (SCC), dry matter intake (DMI) of forages, DMI of concentrates, total DMI, starting bodyweight (BW), end BW and difference in BW (start – end BW).

Table 4 represents the sequential order in which each treatment and period was allocated to each cow.

Table 4. The sequential order in which each treatment and period was allocated to each cow.

Cow number	Period	Treatment
1	1	1
1	2	2
1	3	3
2	1	3
2	2	1
2	3	2
3	1	2
3	2	3
3	3	1
4	1	3
4	2	2
4	3	1
5	1	2
5	2	1
5	3	3
6	1	1
6	2	2
6	3	3

Treatments:
1 = Faba bean silage (FBS)
2 = 50:50 mixture of faba bean silage and oat silage (MIX)
3 = Oat silage (OS)

The diets were fed twice a day in sufficient amounts to ensure an *ad libitum* feed intake. FBS and OS were mixed by hand. Concentrates were fed together with the forages and placed on top of the forage.

During the trial cows were kept in a closed barn in separate stalls with free access to drinking water and feed. The stalls were cleaned every day and fresh straw put down on the floor to ensure a soft and clean sleeping area. After each milking, diets were fed at 07h00 and 16h00. Every day, between 10h30 and 13h30, cows were let out in a soil based open camp for heat detection purposes, for cows to socialize and to reduce the time they spent on concrete. The camp was clear of any edible material. Drinking water was provided *ad libitum* in a drinking trough within the camp.

Cows were milked twice a day at 05h00 and 15h00 in a milking parlour approximately 100m from the housing barn. Standard operating procedures were followed. Cows were brought into the parlour, the udders washed down with running water after which the teats and most of the udder dried with a paper towel. Each cow was tested for mastitis by squirting a small amount of milk into a mastitis cup. If no mastitis clots were observed on the lid of the mastitis cup, the milk clusters was attached to the teats. The clusters were removed after the milk flow had stopped. Stripping was allowed for a period not longer than 30 seconds after the milk flow had stopped.

The milk yield of each cow was recorded at each milking session. During the trial period, milk samples were collected on Monday afternoon, Tuesday morning and afternoon, Wednesday morning and afternoon and on Thursday morning of each week from each cow at the milking and then combined. Intervals between milking were 14 hours from the afternoon till morning milking, and 10 hours from the morning to the afternoon milking. Two ml milk was collected for every two hours between milking, thus collecting 28 ml from the morning milking and 20 ml from the evening milking. These milk samples were combined and analyzed by LactoLab (Pty) at the Irene Research Station for butterfat, protein, lactose content as well as milk urea nitrogen (MUN).

A 1000 kg capacity BERKEL electronic scale was used to weigh the cows. They were weighed after the afternoon milking at the beginning and end of each experimental period.

During the three-week trial period, the daily dry matter intake (DMI) of each individual cow was determined three times a week, i.e. Monday afternoon through to Tuesday afternoon, Wednesday afternoon through to Thursday afternoon and Friday afternoon through to Saturday afternoon. An amount expected to ensure an *ad libitum* intake was weighed daily before being provided to each cow. Half of the daily allotment was provided after the evening milking and the other half of the daily feed was provided after the following morning's milking. The residues of the total allotment given were collected during the afternoon's milking session when the cows were being milked. The total amount of residue was weighed after which a sample of approximately one kg was collected. This sample was put into a drying pan, weighed and then put in a draught oven at 70^{o}C to be dried overnight. The following morning the dried sample was weighed again and the DM content of the residue determined. A sample of the experimental diet was collected on the first day of feeding of the weighed amount of feed and then dried in a draught oven at 70^{o}C. From this the DM content of the feed was determined. The daily feed intake of cows over a 24-hour period could then be determined on a DM basis. To ensure an *ad libitum* feed intake, the daily TMR amount was adjusted after each DM intake calculation.

Table 5. The estimated feed intake (kg/day) and crude protein content (%) of feeds used in the experiment (values on dry matter (DM) basis).

Parameters	Roughage	Concentrate	Total CP (%)
FBS	15.8	18	16.7
MIX	11.7	24	16.8
OS	7.6	30	16.8
Feed Intake (kg/day)	13 kg	9 kg	22 kg

CP = Crude protein
FBS = Faba bean silage
MIX = 50:50 mixture of faba bean silage and oat silage
OS = Oat silage

The CP content of the concentrate fed to the cows was based on a total diet CP content of 16.75%. The CP of the FBS and OS was based on laboratory values.

Fourteen silage samples were taken from both the oats and faba bean silage over the trial period for the testing of pH. The silage pH of the oats and faba bean was on average 4.46±0.25 and 4.90±0.17 respectively. The DM content of the faba bean silage and oat silage was on average 35% and 37% DM.

The silage pH was above the 3.8 to 4.2 ranges suggested by Rotz & Muck (1994), indicating that the silages were well-preserved. Unfortunately the silage was not chemically analysed for OM, Lactic acid, VFA and NH3-N as % of TN.

All diets formulated for the experiment contained at least 50% forage and had a 16.75% CP contents (Table 5). 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).

The feed ingredients and their chemical composition, of the concentrates fed with the forages, which are used in this current study, are presented in Table 6.

Diets contained combinations of FBS, OS and a 50:50 mixture of FBS and OS as forages. A concentrate mixture was formulated using a least cost linear programme using feed analysis data, for the concentrate ingredients only, based on values obtained from Van der Merwe (1983).

The CP of the faba bean silage used was on average 15.8%. Values for faba bean silage from the literature are generally higher. The CP of FBS used in two Canadian studies reported by McKnight & MacLeod (1977) and Thorlacius & Beacom (1981) was 20.1 and 19.8% respectively. Mean pH and ADF values are also similar to those described by the latter authors. In both papers whole plant faba beans were harvested when the lower bean pods had started to turn black while the ensiled material was described as being dark brown in colour and having a tobacco-like smell. In a laboratory trial done at Elsenburg Research Station, d'Hangest d'Yvoy (1990) found that the CP content of faba bean silage ensiled with dried molasses, a propionic acid base acidifier or a bacterial inoculant, was 17.2, 19.5 and 18.8% respectively.

Table 6. The feed ingredients and the chemical composition (on a DM basis) of the concentrates fed with the forages.

Parameters	**FBS**	**50:50 FBS:OS**	**OS**
Ingredients:			
Wheat	300	250	200
Wheat bran	100	100	100
Cottonseed oilcake meal	168	209	250
Maize	348	257	166
Sunflower oilcake meal	50	148	246
Salt	10	10	10
Urea	4	9	14
Feed lime	20	17	14
Total:	1000	1000	1000
Chemical composition:			
Crude protein (%)	18.0	24.0	30.0
Total Digestible Nutrients (%)	75.0	74.6	74.1
Calcium (%)	0.84	0.76	0.68
Phosphorus (%)	0.48	0.54	0.61
Crude fiber (%)	< 5.0	< 5.0	< 5.0

FBS = Faba bean silage
MIX = 50:50 mixture of faba bean silage and oat silage
OS = Oat silage

Statistical procedures and analysis

A double 3x3 Latin square cross-over design experiment was performed with 6 Holstein cows. The three treatments were mixed rations containing either faba bean silage (FBS), oat silage (OS) or a 50:50 mixture of FBS and OS as forages (MIX). The six cows represent the rows of the squares and the three columns present the successive periods of application with a "rest period" between. The treatments were arranged such that every treatment being preceded twice by each of the other treatments, therefore two Latin squares needed. Designs with this property have been called balanced with respect to residual effects and make it easier to calculate (Cochran & Cox, 1957).

The data was subjected to appropriate analyses of variance using the method of Cochran and Cox (Cochran, 1957). Shapiro-Wilk's test was performed to test for non-normality (Shapiro & Wilk, 1965). The analysis of variance is represented in Tables 7 and 8, and the means adjusted for carry over effects. Student's t-Least Significant Differences (LSD) were calculated at a 5% Significance level to compare treatment means. The SAS ver. 9.1 statistical software was used (SAS, 1999).

Results and Discussion

The chemical composition (on DM basis) of the faba bean and oats ensiled, concerning CP, CF, EE, NFE, NDF, ADF, calculated TDN, Ca and P levels is presented in Table 7 .

The effect of the different treatments of Holstein cows receiving three total mixed rations containing either FBS, OS or a 50:50 mixture of FBS and OS as forages, in total mixed rations for dairy cows on different milk production parameters is presented in Table 8.

Table 7. The chemical composition (on DM basis) of the ensiled faba bean and oats.

Chemical composition	Faba bean silage	Oat silage
Crude protein (%)	15.8	7.6
Crude fiber (%)	44.4	38.4
Ether extract (%)	5.8	3.4
Nitrogen free extract (%)	27.9	43.0
Total Digestible Nutrients (%)*	64.5	66.9
Acid detergent fiber (%)	51.1	43.9
Neutral detergent fiber (%)	56.7	69.3
Phosphorus (%)	0.89	0.23
Calcium (%)	0.23	0.22

*: Calculated

Table 8. The mean (±SE) milk production parameters of Holstein cows receiving three total mixed rations containing either faba bean silage (FBS), oat silage (OS) or a 50:50 mixture of faba bean silage and oat silage (MIX) as forages.

Production Parameters	Treatments				
	FBS	MIX	OS	SEM	P
Milk yield (kg/day)	22.8 ± 0.4	21.4 ± 0.4	21.9 ± 0.4	0.1	0.22
Fat (%)	3.40 ± 0.06	3.40 ± 0.06	3.57 ± 0.06	0.01	0.21
Fat (kg/day)	0.78 ± 0.02	0.73 ± 0.02	0.77 ± 0.02	0.004	0.32
Protein (%)	2.82 ± 0.02 [a]	2.93 ± 0.02 [b]	2.96 ± 0.02 [b]	0.004	0.01
Protein (kg/day)	0.65 ± 0.01	0.63 ± 0.01	0.64 ± 0.01	0.002	0.30
Lactose (%)	4.62 ± 0.04	4.63 ± 0.04	4.63 ± 0.04	0.009	0.97
Lactose (kg/day)	1.06 ± 0.02	0.99 ± 0.02	1.00 ± 0.02	0.005	0.18
MUN (mg/dl)	23.10 ± 0.58	22.60 ± 0.58	22.83 ± 0.58	0.135	0.86
SCC (x 1000)	402 ± 81	254 ± 81	386 ± 81	19	0.49

MUN = milk urea nitrogen
SCC = Somatic cell count
SE: Standard error
SEM: Standard error of the mean
P: Significance level
[ab:] Values within rows with different superscripts differed significantly (P<0.05).

The milk production parameters between treatments for FBS, OS and the 50:50 mixture of FBS and OS (MIX), for kg milk/day, milk fat (%), milk fat (kg/day), milk protein (kg/day), lactose, MUN and SST did not differ significantly ($P>0.05$). Type of silage had no effect on total milk yield.

Although the milk protein percentage differed significantly ($P<0.05$) between treatments of FBS and the MIX, as well with the OS, the protein percentage difference was biologically small, i.e. 5%. Furthermore statistical differences could be attributed to a lower variation in milk protein percentage for individual cows within each treatment, and because of a higher content of cottonseed oilcake meal and sunflower oilcake meal in the concentrates fed with the OS and the MIX as forages.

The effect of the different treatments of Holstein cows receiving three total mixed rations containing either FBS, OS or a 50:50 mixture of FBS and OS as forages, in total mixed rations for dairy cows on dry matter intake (DMI) and live weight (LW) parameters is presented in Table 9.

Table 9. Different mean (±SE) production parameters of Holstein cows receiving three total mixed rations containing either faba bean silage (FBS), oat silage (OS) or a 50:50 mixture of faba bean silage and oat silage (MIX) as forages.

Production Parameters	Treatments				
	FBS	MIX	OS	SEM	P
DMI (concentrate)	7.75 ± 0.02	7.72 ± 0.02	7.69 ± 0.02	0.005	0.29
DMI (silage)	8.42 ± 0.41	7.82 ± 0.41	8.08 ± 0.41	0.096	0.66
DMI (total)	16.17 ± 0.43	15.54 ± 0.43	15.73 ± 0.43	0.100	0.65
LW at start (kg)	542.3 ± 6.0	542.9 ± 6.0	552.3 ± 6.0	1.4	0.52
LW at end (kg)	546.3 ± 3.8	551.7 ± 3.8	546.3 ± 3.8	0.9	0.60
LW difference (kg)	4.0 ± 3.2 [b]	8.8 ± 3.2 [a]	-6.0 ± 3.2 [b]	0.7	0.08

DMI = Dry matter intake
LW = Live weight
SE: Standard error
SEM: Standard error of the mean
P: Significance level
[ab]: Values within rows with different superscripts differed significantly ($P<0.10$).

The production parameters between treatments for FBS, OS and the 50:50 mixture of FBS and OS, for DMI (concentrate), DMI (silage), DMI (total), LW (at start) and LW (at end) did not differ significantly ($P>0.05$).

The live weight difference of cows between the start and end of the trial, differed significantly at $P=0.08$ between the 50:50 FBS-OS Mix and OS treatments. Cows receiving the OS lost weight during the trial while the cows on the other treatments showed an increase in body weight.

Ingalls *et al.* (1979) compared feed intake and performance of dairy cows fed whole plant faba bean silage containing two levels of DM (direct cut at 33% and wilted at 37% DM) and two levels of grain supplements (high grain, HG and medium grain, MG). Cows receiving the medium level of grain feeding and wilted faba bean silage consumed significantly (P>0.05) more silage DM than those fed the higher grain level and either of the other silages. This might be expected with the medium level of grain feeding compared to high grain diets since supplementation with cereal diets can cause substantial reductions in rate of cellulose digestion and therefore decrease voluntary intake of roughage (Ørskov & Fraser, 1975). Wilting the whole plant faba bean material from 33 to 37% had no significant effect on total DM intake and milk production of the lactating Holstein cows at the level of grain feeding used.

Average daily milk production, milk composition and yield of milk fat and protein were similar for the four treatments. The level of milk production was not affected when the amount of grain was reduced from 56 to 43% of the total DM intake with the wilted FB silage. However, the energy requirements were partly met by the increased consumption of wilted silage DM that resulted in similar energy intake for all the treatments (Ingalls *et al.*, 1979).

In a similar study conducted in Canada, McKnight & MacLeod (1977) found that cows consuming whole plant faba bean silage and grass-legume silage (GL) as the sole forage, had a higher faba bean silage DM and total DM intake than GL silage (P< 0.05). During the 30-day feeding periods, cows increased body weight more on FBS than GL silage (10.4 vs. 3.4 kg). Apparent digestibilities of faba bean silage ration DM, CP and gross energy were higher than those of GL silage diet although not significantly (P>0.05).

Cows fed FBS produced as much milk of similar protein and total solids contents as when GL silage was fed. Milk from cows fed FBS was higher in fat (P< 0.10) than that from GL silage-fed cows, although intake of fiber as a percent of diets was higher for the grass silage diet than for the FBS diet (20.6 vs. 18.7%; McKnight & MacLeod, 1977).

Conclusions

In the present study, with the exception of the protein percentage of milk, no significant differences (P>0.10) were observed in other milk yield parameters. Cows fed faba bean silage produced as much milk of similar total solids contents as when oat silage was fed.

The cows receiving the OS had a slightly significant (P<0.10) lower body weight than that cows receiving the 50:50 FBS-OS Mix. The DMI of the faba bean and oat silage, concentrate and mix was not significantly (P>0.10) affected.

The CP content of FBS is more than double that of OS. Due to the exceptional high nutritional value of faba bean silage, it has the advantage of reducing the total feed costs in milk production compared to oat hay and oat silage, resulting in a higher margin above feed cost.

Given proper growing, harvesting and ensiling practices, whole plant faba beans may be a satisfactory alternative to other protein- and energy-rich forages.

Chapter 5

THE EFFECT OF GROWTH STAGE ON THE *IN SACCO* DEGRADABILITY OF DRY MATTER AND DIFFERENT FRACTIONS OF WHOLE PLANT FABA BEANS AND OATS

Introduction

As forages grow the physical and chemical composition of the plant constantly change. The stage at which crops are harvested for hay or silage has a great effect on the feeding value of the final product. As plants mature, their fiber content increases resulting in a lower digestibility and a reduction in the crude protein (CP) content (West, 1998).

Studies showed that differences in the ensiling characteristics of legumes greatly influence their ruminal nutrient degradability. Information on the fermentation quality and nutrient availability of whole crop faba bean silage remains limited (Mustafa *et al*., 2000).

After cutting a forage crop, plant proteases generate a rapid and extensive proteolysis, which can be restricted by decreasing the moisture content or by lowering the pH of the crop. In silage, not only the attainment of a low final pH but also the rate of pH decline is considered to be important factors in limiting proteolysis (McDonald *et al*., 1991).

While direct acidification of herbage at ensiling lowers the pH rapidly, inoculating of silage with lactic acid-producing bacteria accelerates the drop in pH when compared to no additives by compensating for the low levels of acid-producing bacteria and by introducing a homofermentative flora that can rapidly begin producing lactic acid (Lindgren *et al*., 1988).

In situ as well as *in vivo* and a variety of *in vitro* methods exist to characterize the extent of proteolysis undergone by forage during conservation. The *in situ* method is the most widely used and after being reviewed on several occasions was adopted by the National Research Council (NRC, 2001). The method has the advantage of exposing feedstuffs to digestive conditions similar to *in vivo* conditions.

The increase in fiber content in plants is because of an increase in the acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents. This usually results in a decreased feed intake while the degree of lignification that increases with maturity of the crop, decreases the digestibility of the plant material (Van Soest, 1982, as cited by West, 1998).

Linn & Martin (1989) found that for each percentage point increase in the lignin content of lucerne, the digestible dry matter (DDM) decreases by three to four percentage points. When the quality of the forage decreases in terms of energy value due to an increase in maturity, the cost of the ration is also increased. This is because the lower energy content of mature forages must be substituted with high-energy feeds such as grain.

Fiber is a measure of the plant's cell walls, which are the structural building blocks of the plant, lending it support. Some of the characteristics of fiber are that it limits digestion, requires repeated chewing to reduce particle size and is bulky, which means it occupies a lot of space in the rumen. Fiber contains the less rapidly degraded components of feed, such as cellulose and hemicellulose. The indigestible chemical, lignin, is also contained in the fiber fraction. Fiber is important in the diet of dairy cattle because of the important role it plays in rumination. Adequate levels of fiber will prevent acidosis and low milk fat (Grant, 1991).

Different methods can be employed to determine the fiber content of forages. A detergent fiber analysis system can be used to separate forages into different parts. The two different parts are: cell contents or neutral detergent solubles, which include sugar, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible compounds found in the fiber fraction (Linn & Martin, 1989).

The fiber fraction of forages can be divided into neutral detergent fiber (NDF) and acid detergent fiber (ADF). The NDF fraction consists of the cell wall fraction and includes cellulose, hemicellulose, lignin, and heat damaged protein. These chemical components are associated with the bulkiness of a feed and are closely related to feed intake and rumen fill in cows. ADF contains cellulose, lignin and heat-damaged protein. This fraction can be related to indigestibility of feeds and it is also used in calculating energy values. The lignin component found in cell walls can be measured by acid detergent lignin (ADL) (Linn & Martin, 1989).

The different fiber fractions with their chemical components and digestibilities are presented in Table 1.

According to West (1998) forage quality is a complex interrelationship of many factors that affect among other things, intake potential, nutrient content, digestion and gut fill. He found that there is a negative correlation between DM digestibility, dry matter intake (DMI) and digestible DMI with ADF and NDF. This means that these variables will decline when the ADF and NDF content of a forage increases.

Acid detergent fiber (ADF) content of 300 g kg^{-1} is desirable to prevent diarrhea, but levels higher than this can reduce feed conversion (Juskiw *et al*., 2000).

Table 1. Different fiber fractions in forages with their chemical components and digestibilities (Linn & Martin, 1989).

Fraction	Components	Digestibility (%)
Cell walls (NDF)	Hemicellulose Cellulose Lignin Heat damaged protein Keratin	20-80 50-90 0-20 Variable Variable
ADF	Cellulose Lignin Heat damaged protein	50-90% 0-20% Variable
ADL	Lignin	0-20%
Cell solubles (100-NDF%)	Starches	95-100%

NDF = Neutral Detergent Fiber
ADF = Acid detergent Fiber
ADL = Acid Detergent Lignin

The correlation that exists between cattle response and fiber concentration is shown in Table 2.

Table 2. Correlation between fiber concentration and cattle response (West, 1998).

Item	ADF(%)	NDF(%)
DM digestibility	-0.39	-0.32
DM intake	-0.52	-0.41
Digestible DM intake	-0.55	-0.43
NDF intake	0.30	0.50

ADF = Acid detergent Fiber
NDF = Neutral Detergent Fiber
DM = Dry Matter

Determining NDF has a shortcoming in the sense that it only measures the chemical characteristics of fiber. It does not measure the physical properties, such as particle size, that affect the effectiveness of fiber in meeting the cow's minimum requirements (Mertens, 1997, as cited by Cruywagen, 1999). Mertens (1997) proposed two additional definitions that could be used in the formulation of diets. He proposed the use of effective NDF (eNDF) and physically effective NDF (peNDF). The eNDF is related to the ability of the feed to maintain milk fat production. Physically effective NDF is related to the physical properties of the fiber and its ability to stimulate chewing activity as well as the establishment of the biphasic stratification of ruminal contents. The biphasic stratification of the ruminal contents is the floating mat of large particles on a pool of liquid and small particles (Mertens, 1997, as cited by Cruywagen, 1999).

Diets containing large quantities of forages can have an effect on feed DMI, because of the amount of fiber present, the digestibility of the fiber, and the passage rate of undigested residues from the digestive tract. There are differences in the digestibility and rate of digestion for different forage species. However intake is considered more important than digestibility for influencing digestible DMI from forages. When both grasses and legumes were considered, relative contributions to intake of digestible DM were 70% for DMI and 30% for digestibility (Crampton *et al*., 1960, as cited by West, 1998).

Mertens (1992) as cited by West (1998) suggests that the maximum NDF intake that will not reduce milk yield below the cow's potential is 1.2% of body weight (BW). However, the potential for distension of the rumen may allow for greater content of bulky feeds.

The objective of this study was to determine the extent of the ruminal degradation of DM, CP, NDF and ADF of whole crop faba beans and oats, harvested at different stages of maturity, by using the *in situ* Dacron bag technique. Different stages of plant maturity were at 117, 131, 145 and 159 days after planting. The data would also expand the existing South African database on ruminal degradation of DM, CP, NDF and ADF degradation.

Materials and Methods

Faba bean and oats production

The study was conducted at the Elsenburg Research Station (altitude 177 m, longitude 18° 50' and latitude 33° 51') near Stellenbosch. Elsenburg is situated approximately 50 km east of Cape Town in the winter rainfall region of South Africa.

Faba beans (*cv*. Ascot) and oats (*cv*. Sederberg) were drill planted separately on two Northwest facing fields. The soil in the two fields was mostly a Glenrosa varying in clay content of 20 %.

The study consisted of a DM, CP, NDF and ADF degradability study of four different growth stages of faba beans and oats. The four growth stages are 117, 131, 145 and 159 days after planting.

Harvesting of faba beans and oats and preparation of samples

The Boland Region at Elsenburg experienced a seasonal drought during the year of sampling, resulting in plants maturing and being harvested earlier.

From 75 to 159 days after planting, whole faba bean and oat plants were cut at weekly intervals at a height of *ca.* 10cm above the ground on five randomly selected areas. Pruning shears were used to cut faba bean samples, while oat samples were collected by means of using sheep-shears. A wooden square (measuring

$0.25m^2$), with inside width of 0.5 x 0.5 m, was placed on a random basis in the field and material was cut at that position.

The fresh material harvested from the plots were weighed and then oven-dried individually for three days at 55°C. The individual samples were weighed again and the sample DM content was then determined. The fresh and DM forage production per hectare was then calculated. The oven-dried samples were then pooled for use in the *in sacco* trial.

To prepare the samples for use in the digestibility trial, the plant material was milled using a Scientec RSA hammer mill with a 2mm screen. The CP, crude fiber (CF), NDF, ADF, nitrogen free extract (NFE), fat (EE), calcium (Ca) and phosphorus (P) contents of all samples were determined according to standard laboratory techniques (See Chapter 3 for full chemical analysis).

***In situ* trial**

Three non-lactating Holstein cows were used in the trial. All the cows were fitted with 100 mm Bar Diamond rumen cannulae (Bar Diamond, Inc., P.O. Box 60, Parma, Idaho, 83660-006, U.S.A.). Cows were kept in a closed barn in separate stalls with free access to drinking water. Cows each received 20 kg per cow per day of a TMR prior to a three-week adaptation period to a 16 kg silage diet, consisting of 8 kg faba bean silage and 8 kg oat silage. The cows were slowly adapted to the 50:50 faba bean silage and oat silage diet. The cows were fed more silage from the Monday in a step-down adaptation diet (16:4, 14:6, 12:8, 10:10, 8:12, 0:16) through to the Saturday, hence the cows only receiving 16 kg silage, consisting of 8 kg faba bean silage and 8 kg oat silage. The three cows received this 16 kg silage for a further adaptation period of two weeks. The silage was given in equal proportions during the early morning and late afternoon.

The CP content of the faba bean silage and oat silage was on average 15.8 and 7.6% (on a DM basis), respectively.

Dacron bags (53 µm pore size, Bar Diamond, Inc., P.O. Box 60, Parma, Idaho, 83660-006, U.S.A.) were dried in an oven at 100°C and then put in a desiccator to cool down after which they were weighed while still oven-dry. Approximately 5 g (on a air dry basis) of test feed material was weighed into the tared bags, providing a minimum sample to surface ratio of *ca.* 14 mg/cm² to comply with standard procedures (Vanzant *et al*., 1998). Dacron bags were closed with cable ties and weighed again together with the contents and cable tie.

The nylon bags were then put in sequence (according to the time of incubation in the rumen, i.e. bags to be incubated for 96 hours were put in at the toe part) into a pair of Cameo Winter Opaque pantyhose, which was previously cut into two whole leg sections. The different sections of the leg, containing the nylon bags, were partitioned with a cable tie.

To ensure that the bags were completely submerged in the ruminal contents during the digestibility trial, two large tapered steel ball bearings (16 mm in diameter, length 24 mm, 42 g each) was inserted into the bottom toe part of each leg. The upper side of the pantyhose section was tied by means of a cable tie to the wire catcher, which was attached to the rumen cannula. The deeply submersed bags could move freely within the ruminal contents.

Incubation times longer than 48 hours would not leave enough residues for all the chemical analysis and therefore duplicate bags were prepared for the 72 and 96-hour incubation times. Bags with the substrates were incubated in the rumen for 4, 8, 12, 24, 48, 72 and 96 hours (NRC, 2001). Nine nylon bags, corresponding to the 7 different incubation times, were put in a whole leg section of the Cameo Winter Opaque pantyhose, making one string of bags. Four different strings of bags, containing the four different growth stages of whole plant faba beans or whole plant oats (in total 28 bags/cow) were placed simultaneously via the cannula into the rumen of each of the three cows. One empty blank bag used as the Bag Correction Factor (BCF) was also placed with the four different strings of bags at the 48-hour incubation time, within each cow.

All bags that were to be incubated were inserted in the rumen at 08h00 on the Monday morning at the beginning of the week. Bags were removed at 12h00, 16h00, and at 20h00, and then at 08h00 every morning, until the Friday morning of the week. The appropriate time intervals were to allow for the relevant incubation times.

During the first week bags containing the samples of the four different growth stages of whole crop faba beans were placed into the rumen of the cows, while during the second week, the process was repeated with the same Holstein cows, using the bags containing the samples of the four different growth stages of whole crop oats.

After the bags had been removed from the rumen, they were plunged into a bucket of ice water for 5 to 10 minutes to arrest microbial activity. They were then gently rinsed by hand under running cold tap water. Bags were gently squeezed to get rid of excess moisture and then frozen in a deep freezer (-15 ºC) until retrieval, when all samples of the week had been collected. The following week the bags were thawed out for two hours and then washed without detergent in cold water in a twin-tub washing machine for a total of fifteen minutes using the gentle cycle (Erasmus & Prinsloo, 1988). The bags were washed with fresh tap water for five minutes and then drained. This was repeated twice more until clean water was obtained. The bags containing feed samples, which were not submitted to ruminal incubation (0 hours), were washed like the other bags to determine the readily soluble fraction. Bags were dried in a forced-air oven at 55°C for 48 hours. At the end of the drying period, bags were allowed to cool in a desiccator and weighed individually to calculate the residual DM. The cable ties were not removed before the bags were weighed. The content was pooled by incubation time and cow. The forage residues were then emptied from the bags for chemical analyses of CP, NDF and ADF.

Chemical analyses and degradability calculations

Samples of the initial feeds and residues from the bags were analyzed for CP according to the methods of the AOAC (1990) and ADF and NDF content was analyzed with an ANKOM^{200} fiber analyzer (ANKOM Technology corporation, 140 Turk Hill Park Fairport, NY 14450). The contents of duplicate bags (72 and 96h) were composited before analysis.

The mass of the dried blank bag after incubation divided by mass of dried blank bag before incubation was used as Bag Correction Factor (BCF). Dried cable tie mass was subtracted from DM to determine dried mass plus bag (DM + B). The dried empty bags mass x BCF = Calculated Bag Mass (CBM)

Residues were assayed for DM, CP, NDF and ADF. Percentages of disappearance of DM, CP, NDF and ADF were calculated from the residue remaining in the bags after incubation in the rumen using the following equation:

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

Statistical procedures and analyses

Successive trials were performed with two whole crop roughages, i.e. faba beans and oats. For each roughage, a split-plot experimental design replicated in the rumens of three cows as block effects was used. The main plots consisted of four strings of Dacron bags with the experimental roughage that was put into artificial-fiber bags (Cameo Winter Opaque's). Each of the individual strings contained roughage harvested at one of the four stages (117, 131, 145 and 159 days from planting). This was repeated for whole crop oats. Material was incubated in each cow's rumen, and the sub-plots consisted of the bags within each string, removed at each of the eight incubation times (0, 4, 8, 12, 24, 48, 72 and 96 hours).

Variables measured were DM percentage (DM %), CP percentage (CP %), NDF percentage (NDF %) and ADF percentage (ADF %).

The data were subjected to a standard Split-Plot Analysis of variance (Snedecor & Cochran, 1980). Standardized residuals were calculated and used to test for deviations from normality using Shapiro-Wilk's test (Shapiro & Wilk, 1965). Outliers were identified and removed before final analysis was performed. The analysis of variance is represented in table 3 and 4, and the means adjusted for carry-over effects. Student's t-Least Significant Differences (LSD) were calculated at a 5% significance level to compare treatment means for significant effects. The SAS ver. 9.1 statistical software was used (SAS, 1999).

In the second part of the statistical procedures and analyses, the DM, CP, NDF and ADF disappearance values were fitted to the following non-linear model as suggested by Ørskov & McDonald (1979):

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

where p = the proportion degraded at time t,
a, b, and c = non-linear parameters estimated by an iterative least square procedure,
and t = time of rumen incubation (h).

Parameter a = the intercept representing the readily soluble fraction (% of total).
Parameter b = the insoluble but potentially degradable fraction (% of total).
Parameter c = the degradation rate of the b fraction (% h^{-1}).
and $a + b$ represent the maximum extent of degradation or the asymptote of the equation.

The non-linear parameters a, b and c were estimated from the fitted equation $p = a + b\,(1- e^{-ct})$ (Ørskov & McDonald, 1979) with fitted initial constants a = 15, b = 60 and c = 0.05 by the NLIN iterative least-square procedure of SAS v9.1 statistical software (SAS, 1999) and best-fit values were chosen using the sum of squares after convergence. An analysis of variance was performed on the data. Significance was declared at $P \leq 0.05$ unless otherwise indicated.

By introducing the fractional ruminal outflow rate, k, the effective degradabilities (ED) or (P) could be calculated from the following equation (Ørskov & McDonald, 1979):

$$\mathrm{P} = a + \frac{bc}{c + k}$$

A fractional outflow rate of k = 0.05 was used as suggested by Erasmus *et al*. (1990).

Results and Discussion

In sacco DM, CP, NDF and ADF degradability of whole crop faba beans and oats

The results of the statistical analyses concerning the DM, CP, NDF and ADF fractions of whole crop faba beans and oats as affected by growth stages and incubation time in the rumen of cows are shown in Table 3 and Table 4.

Table 3. The analysis of variance of the effect of growth stage on the *in sacco* degradability of DM, CP, NDF and ADF fractions of four different growth stages (117, 131, 145 and 159 days from planting) of whole plant faba beans.

		%DM		%CP		%NDF		%ADF	
Source	df	MS	P	MS	P	MS	P	MS	P
Cows	2	49.1	0.48	29.6	0.11	30.8	0.71	17.9	0.75
Growth stage	3	347.1	**0.03**	85.1	**0.01**	534.7	**0.03**	1920.0	**<0.01**
Error (a)	6	59.1		8.9		83.5		58.4	
Hours	7	3588.5	**<0.01**	1799.4	**<0.01**	6425.9	**<0.01**	6614.8	**<0.01**
Growth stage x hours	21	18.1	**0.01**	18.6	**<0.01**	40.2	**<0.01**	83.0	**<0.01**
Error (b)	55	8.5		5.5		8.2		9.4	
Corrected Total	95								
Shapiro-Wilk (Pr < W)			0.711		0.076		0.081		0.774

MS = Means Square
DM = Dry matter
CP= Crude protein
NDF = Neutral detergent fiber
ADF = Acid detergent fiber
Differences are significant at P < 0.05

The degradability of DM, CP, NDF and ADF fractions of whole plant faba beans in four different growth stages (117, 131, 145 and 159 days from planting) did not differ (P<0.05) among cows.

Table 4. The analysis of variance of the effect of growth stage on the *in sacco* degradability of DM, CP, NDF and ADF fractions of four different growth stages (117, 131, 145 and 159 days from planting) of whole plant oats.

		%DM		%CP		%NDF		%ADF	
Source	df	MS	P	MS	P	MS	P	MS	P
Cows	2	17.0	0.52	5.0	0.75	2.5	0.93	4.8	0.82
Growth stage	3	753.2	**<0.01**	844.1	**<0.01**	828.5	**<0.01**	737.8	**<0.01**
Error (a)	6	23.0		16.7		33.4		23.7	
Hours	7	2259.6	**<0.01**	1227.8	**<0.01**	4191.1	**<0.01**	3581.7	**<0.01**
Growth stage x hours	21	47.3	**<0.01**	14.8	**<0.01**	121.1	**<0.01**	97.2	**<0.01**
Error (b)	56	5.0		4.5		9.2		8.6	
Corrected Total	95								
Shapiro-Wilk (Pr < W)			0.407		0.601		0.505		0.262

MS = Means Square
DM = Dry matter
CP= Crude protein
NDF = Neutral detergent fiber
ADF = Acid detergent fiber
Differences are significant at P ≤ 0.01

The degradability of DM, CP, NDF and ADF fractions of whole plant oats in four different growth stages (117, 131, 145 and 159 days from planting) did not differ (P<0.05) among cows.

The degradability of different fractions for both roughages were affected (P<0.05) by growth stage and incubation hours.

The average ruminal disappearance of DM, CP, NDF and ADF for whole crop faba beans at different incubation periods for four different growth stages at 117, 131, 145 and 159 days after planting are presented in Figures 1 to 4.

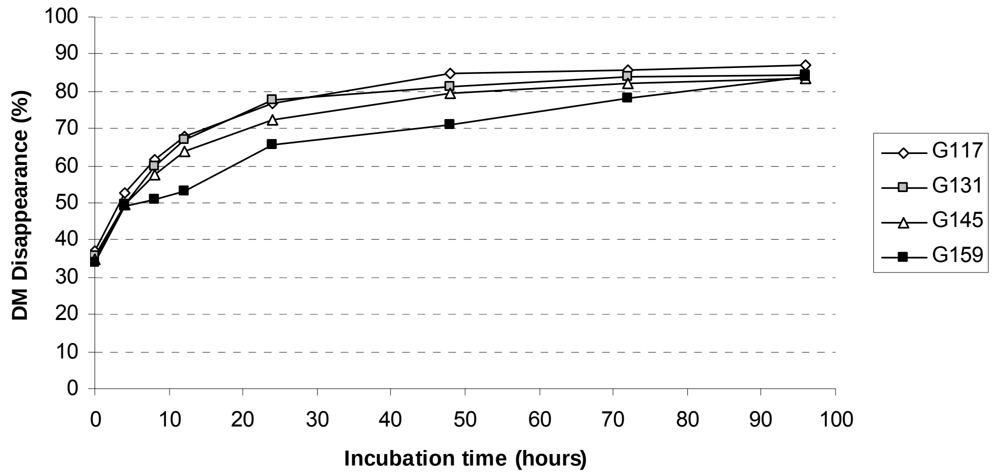

Figure 1. Average ruminal DM disappearance of whole crop faba beans as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The DM disappearance of whole crop faba beans at 117 and 159 days after planting differed ($P<0.05$) at 8, 12, 24, 48 and 72 hours of incubation time in the rumen (LSD=4.8). Similarly, the DM disappearance of whole crop faba beans at 117 and 145 days after planting also differed ($P<0.05$) at 48 hours of incubation time. This indicates that DM degradability was reduced with advancing growth stage.

For faba beans the asymptote for DM disappearance was obtained at 48 hours for growth stages 117, 131 and 145 days after planting. The same end result for DM disappearance for growth stage 159 days is only reached at 96 hours.

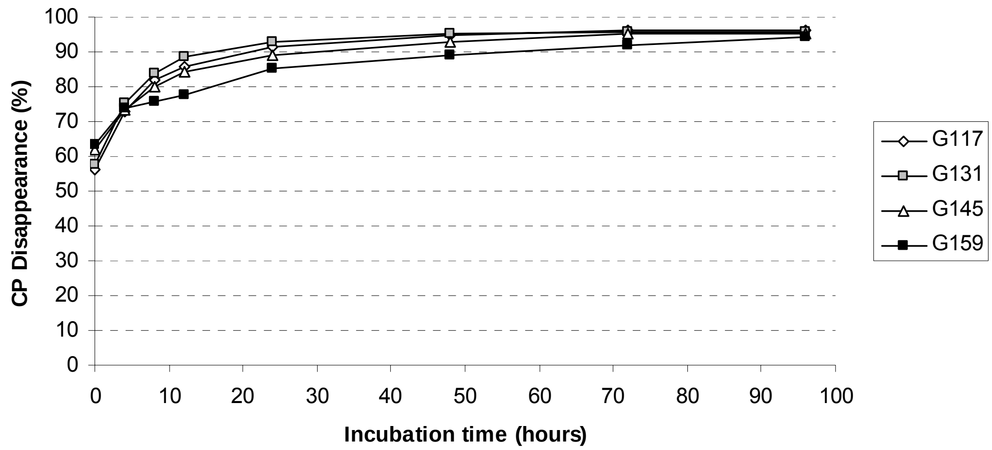

Figure 2. Average ruminal CP disappearance of whole crop faba beans as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The CP disappearance of whole crop faba beans at 117 and 159 days after planting differed ($P<0.05$) at 8, 12, 24, 48 and 72 hours of incubation time in the rumen (LSD=3.8). This indicates that CP degradability was reduced with advancing growth stage. Similarly, the CP disappearance of whole crop faba beans at 117 and 145 days after planting also differed ($P<0.05$) at 0 hours of incubation time.

For whole crop faba beans the asymptote for CP disappearance was obtained at 48 hours for growth stages 117 and 131 days after planting. The same end result for DM disappearance for growth stage 145 and 159 days, after a further slight upward trend, is only reached at 96 hours.

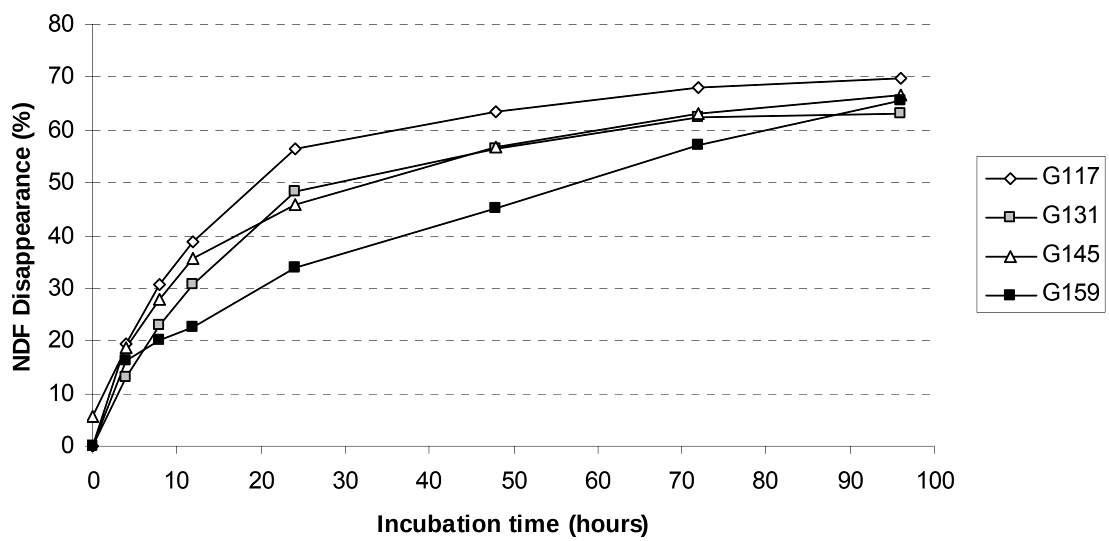

Figure 3. Average ruminal NDF disappearance of whole crop faba beans as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The NDF disappearance of whole crop faba beans at 117 and 131 days after planting differed (P<0.05) at 4, 8, 12, 24, 48, 72 and 96 hours of incubation time in the rumen (LSD=4.7). Similarly, the NDF disappearance of whole crop faba beans at 117 and 145 days after planting also differed (P<0.05) at 0, 4, 8, 12, 24, 48 and 72 hours of incubation time. The NDF disappearance of whole crop faba beans at 117 and 159 days after planting also differed (P<0.05) at 8, 12, 24, 48 and 72 hours of incubation time.

For whole crop faba beans, at growth stages 117, 145 and 159 days after planting, the asymptote for NDF disappearance was not reached even at 96 hours of incubation. NDF disappearance for growth stage 131 reached asymptote at 48 hours of incubation in the rumen. This may be due to more mature plants being included in the sample when the wooden square was placed at random in the field and material was cut at that position.

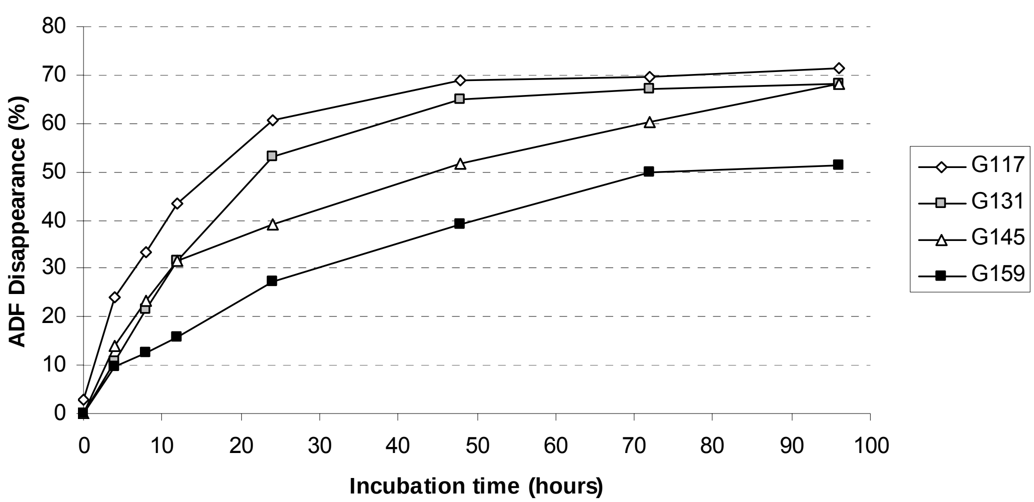

Figure 4. Average ruminal ADF disappearance of whole crop faba beans as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The ADF disappearance of whole crop faba beans at 117 and 131 days after planting differed (P<0.05) at 4, 8, 12 and 24 hours of incubation time in the rumen (LSD=5.0). Similarly, the ADF disappearance of whole crop faba beans at 117 and 145 days after planting also differed (P<0.05) at 4, 8, 12, 24, 48 and 72 hours of incubation time. The ADF disappearance of whole crop faba beans at 117 and 159 days after planting also differed (P<0.05) at 4, 8, 12, 24, 48, 72 and 96 hours of incubation time.

For faba beans, at growth stages 117, 131 and 159 days after planting, the asymptote for ADF disappearance was reached at 48 hours of incubation. ADF disappearance for growth stage 145 did not reach asymptote at 96 hours of incubation in the rumen, although reached the same disappearance percentage of ±70%.

The degradability of different fractions for both roughages were affected ($P<0.05$) by growth stage and incubation hours.

The average ruminal disappearance of DM, CP, NDF and ADF of whole plant oats at different incubation periods for four different growth stages at 117, 131, 145 and 159 days after planting are presented in Figures 5 to 8.

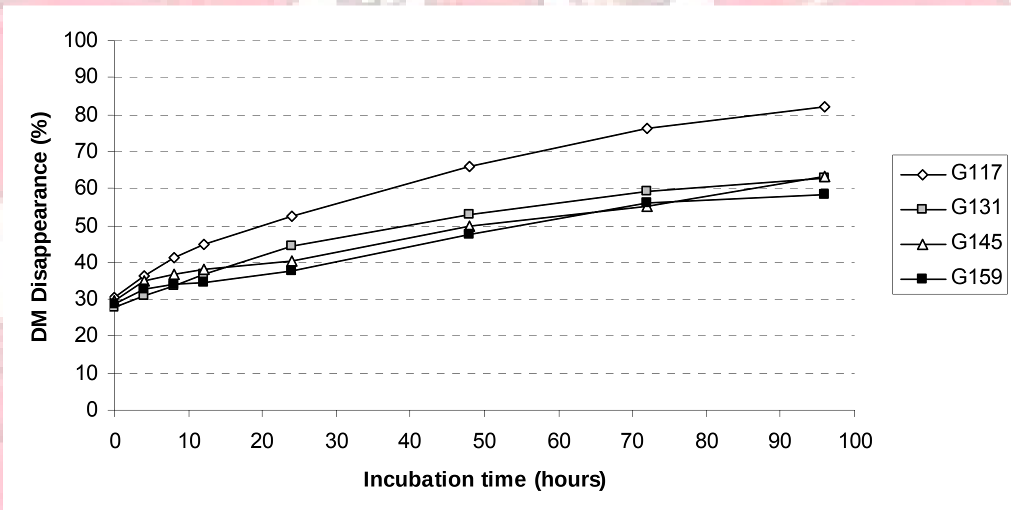

Figure 5. Average ruminal DM disappearance of whole crop oats as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The DM disappearance of whole crop oats at 117 and 131 days after planting differed ($P<0.05$) at 4, 8, 12, 24, 48, 72 and 96 hours of incubation time in the rumen (LSD=3.7). Similarly, the DM disappearance of whole crop oats at 117 and 145 days after planting also differed ($P<0.05$) at 8, 12, 24, 48, 72 and 96 hours of incubation time. The DM disappearance of whole crop oats at 117 and 159 days after planting also differed ($P<0.05$) at 8, 12, 24, 48, 72 and 96 hours of incubation time. This indicates that DM degradability was reduced with advancing growth stage.

For oats, at growth stages 117, 131, 145 and 159 days after planting, the asymptote for DM disappearance was not reached even at 96 hours of incubation in the rumen. This may be due to the fact that the year was drier during the growing season, and that oats matured at an earlier stage than faba beans.

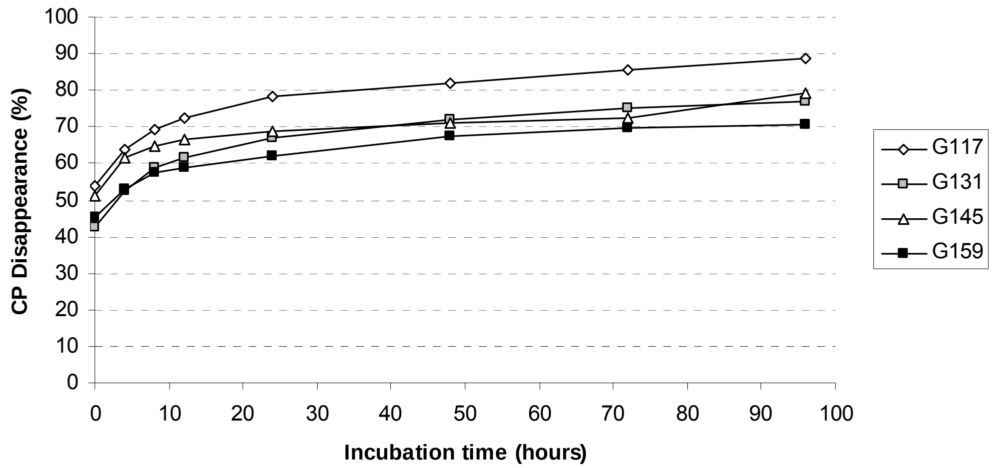

Figure 6. Average ruminal CP disappearance of whole crop oats as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The CP disappearance of whole crop oats at 117 and 131 days after planting differed ($P<0.05$) at 0, 4, 8, 12, 24, 48, 72 and 96 hours of incubation time in the rumen (LSD=3.5). Similarly, the CP disappearance of whole crop oats at 117 and 145 days after planting also differed ($P<0.05$) at 8, 12, 24, 48, 72 and 96 hours of incubation time. The CP disappearance of whole crop oats at 117 and 159 days after planting also differed ($P<0.05$) at 0, 4, 8, 12, 24, 48, 72 and 96 hours of incubation time.

For whole crop oats the asymptote for CP disappearance was obtained at 96 hours for growth stages 117, 131, 145 and 159 days after planting, though there is only a slight increase in CP disappearance after 48 hours of incubation in the rumen.

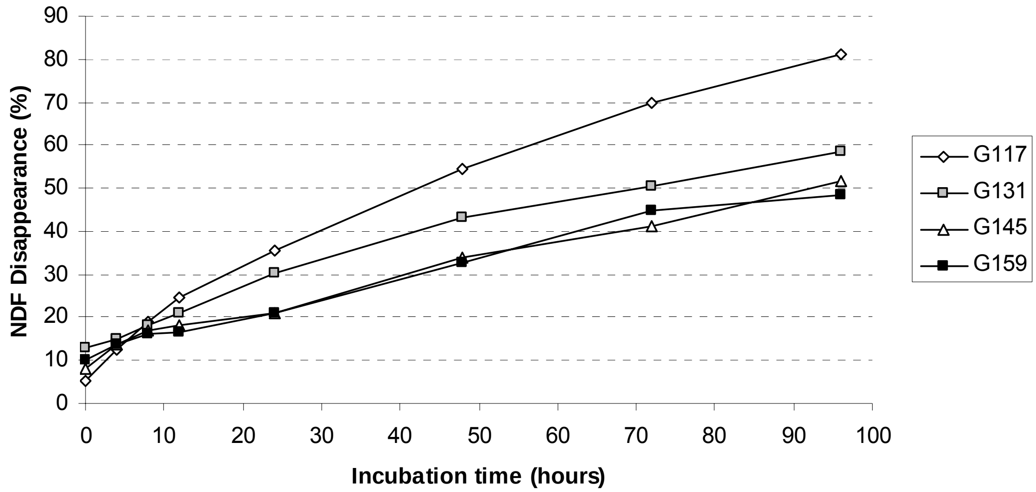

Figure 7. Average ruminal NDF disappearance of whole crop oats as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The NDF disappearance of whole crop oats at 117 and 131 days after planting differed (P<0.05) at 24, 48, 72 and 96 hours of incubation time in the rumen (LSD=5.0). Similarly, the NDF disappearance of whole crop oats at 117 and 145 days after planting also differed (P<0.05) at 12, 24, 48, 72 and 96 hours of incubation time. The NDF disappearance of whole crop oats at 117 and 159 days after planting also differed (P<0.05) at 12, 24, 48, 72 and 96 hours of incubation time.

For whole crop oats, at growth stages 117, 131, 145 and 159 days after planting, the asymptote for NDF disappearance was not reached even at 96 hours of incubation. This is because, for fiber 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 & Kolver, 1997). This therefore prolongs the lag phase and results in a longer period required for fiber digestion.

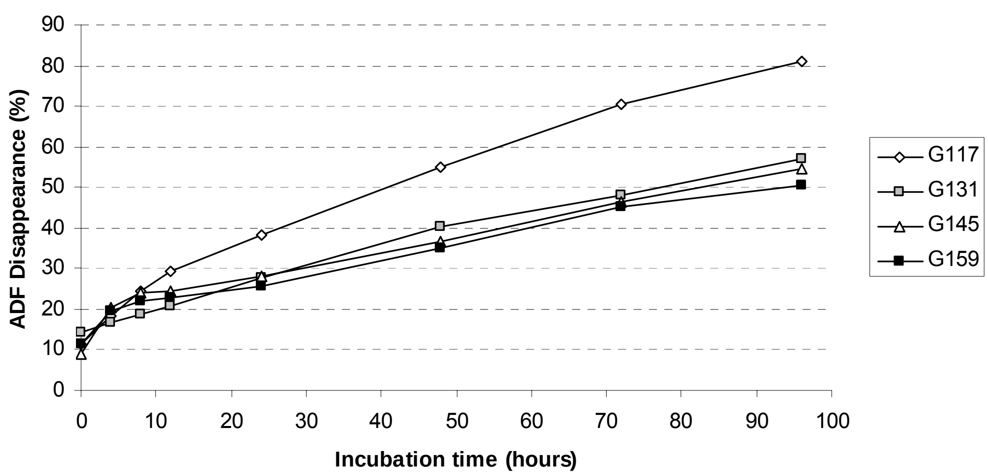

Figure 8. Average ruminal ADF disappearance of whole crop oats as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

The ADF disappearance of whole crop oats at 117 and 131 days after planting differed (P<0.05) at 8, 12, 24, 48, 72 and 96 hours of incubation time in the rumen (LSD=4.8). Similarly, the ADF disappearance of whole crop oats at 117 and 145 days after planting also differed (P<0.05) at 24, 48, 72 and 96 hours of incubation time. The ADF disappearance of whole crop oats at 117 and 159 days after planting also differed (P<0.05) at 12, 24, 48, 72 and 96 hours of incubation time.

For both the whole crop faba beans and oats the asymptote for NDF and ADF disappearance was not obtained even at 96 hours. This is because, for fiber 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 & Kolver, 1997). This therefore prolongs the lag phase and results in a longer period required for fiber digestion.

Differences in fiber composition between whole crop faba beans and oats can be attributed to differences in stage of maturity and to differences in fiber characteristics between grasses and legumes (Mustafa *et al*., 2000).

Estimation of the values of parameters *a*, *b* and *c*

The non-linear parameters a, b and c were estimated from the fitted equation $p = a + b\,(1 - e^{-ct})$ (Ørskov & McDonald, 1979) with fitted initial constants a = 15, b = 60 and c = 0.05 by the NLIN iterative least-square procedure of SAS v9.1 statistical software (SAS, 1999) and best-fit values were chosen using the sum of squares after convergence.

The a-value represents the readily soluble fraction of the feed and should be similar to the value (t_0) obtained from bags that were washed but not incubated in the rumen. The *a*- value is a function of the feed not influenced by other factors. The *b*- and *c*-values are derived functions of feed and microbial interactions.

The effect of growth stage on the estimated non-linear parameters a, b and c for ruminal DM-, CP-, NDF- and ADF-disappearance of whole plant faba beans and oats harvested at four different growth stages (117, 131, 145 and 159 days from planting) of maturity is presented in Table 5 and Table 6 respectively.

Table 5. The effect of growth stage (117, 131, 145 and 159 days after planting) on the estimated non-linear parameters a, b and c for DM-, CP-, NDF- and ADF-disappearance (%) of whole crop faba beans from the rumen.

	Growth stage (days)				
Component	**117**	**131**	**145**	**159**	**P**
Dry matter					

a	37.79±0.79	35.78±1.29	35.98±0.47	37.26±2.21	0.27
b	49.27±0.60	47.64±0.97	45.87±0.62	44.59±5.65	0.29
c	0.09±0.04	0.09±0.01	0.08±0.02	0.04±0.02	0.21
Crude protein					
a	57.28±1.88 ^{b}	57.97±0.45 ^{b}	62.64±0.73 ^{a}	64.75±3.52 ^{a}	0.01
b	38.21±2.69 ^{a}	37.16±0.49 ^{ab}	31.70±0.75 ^{bc}	28.63±5.37 ^{c}	0.01
c	0.12±0.04	0.15±0.02	0.09±0.01	0.07±0.05	0.11
NDF					
a	1.03±2.31 ^{b}	-0.09±1.36 ^{b}	7.24±1.97 ^{a}	5.92±0.79 ^{a}	0.01
b	67.25±2.58 ^{a}	62.99±2.15 ^{b}	57.42±3.16 ^{b}	64.17±4.07 ^{a}	0.03
c	0.07±0.01 ^{a}	0.06±0.01 ^{ab}	0.05±0.01 ^{b}	0.02±0.00 ^{c}	<0.01
ADF					
a	3.64±1.38 ^{a}	-2.18±0.75 ^{b}	3.34±2.96 ^{a}	1.78±2.82 ^{ab}	0.04
b	67.05±1.73 ^{ab}	71.75±3.71 ^{a}	61.86±6.17 ^{bc}	54.92±7.15 ^{c}	0.02
c	0.08±0.01 ^{a}	0.06±0.01 ^{b}	0.04±0.01 ^{bc}	0.03±0.00 ^{c}	<0.01

a = soluble fraction
b = potentially degradable fraction
c = rate of degradation
CP= Crude protein
NDF = Neutral detergent fiber
ADF = Acid detergent fiber
P: Significance level
$^{ab:}$ Means with the same letter are not significantly different within rows.

Parameter *a* (the readily soluble fraction), parameter *b* (potentially degradable fraction) and parameter *c* (the rate at which *b* is degraded) of the DM ruminal disappearance of whole plant faba beans did not differ between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity (P>0.05).

The *a* and *b* values for CP ruminal disappearance in faba beans differed significantly (P=0.01) between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity, while the *c* value did not differ (P>0.05).

The soluble DM fraction (*a*-values, Table 5) did not increase with advancing maturity of the whole crop faba beans, while the soluble protein fraction increased (P=0.01).

The *a*, *b*, and *c* values for both NDF and ADF in whole crop faba beans differed significantly (P<0.05) between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity.

The data in Table 5 indicate that for whole crop faba beans, parameter *a* (the readily soluble fraction) and parameter *b* (potentially degradable fraction) all differed significantly (P<0.05) between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity for CP, NDF and ADF.

The rate of NDF and ADF degradation (*c*) of whole crop faba beans decreased with advancing growth stages (117, 131, 145 and 159 days from planting) of plant maturity (P<0.01).

The potentially degradable fraction *b* of DM for whole crop faba beans with advancing growth stages (117, 131, 145 and 159 days from planting) of plant maturity did not decrease significantly (P>0.05), while the potentially degradable fraction *b* of CP, NDF and ADF decrease significantly (P<0.05).

The rate of DM and CP degradation *c* of whole crop faba beans tended to decrease with advancing growth stages (117, 131, 145 and 159 days from planting) of plant maturity, but did not decrease significantly (P>0.05).

Table 6. The effect of growth stage (117, 131, 145 and 159 days after planting) on the estimated non-linear parameters a, b and c for DM-, CP-, NDF- and ADF-disappearance (%) of whole crop oats from the rumen.

Component	Growth stage (days)				P
	117	131	145	159	
Dry matter					
a	32.01±1.02[a]	27.65±1.18 [b]	32.53±1.58 [a]	29.07±0.88 [b]	0.01
b	63.43±6.63	54.75±29.00	61.78±11.69	42.13±18.88	0.67
c	0.02±0.00	0.02±0.01	0.01±0.00	0.02±0.01	0.44
Crude protein					
a	55.31±0.99[a]	43.70±2.27 [b]	53.54±1.55 [a]	46.80±3.85 [b]	<0.01
b	30.62±3.51[a]	31.24±4.07 [a]	20.79±1.65 [b]	22.96±5.06 [b]	0.02
c	0.07±0.01	0.07±0.02	0.09±0.04	0.06±0.01	0.71

Table 6 (continue). The effect of growth stage (117, 131, 145 and 159 days after planting) on the estimated non-linear parameters a, b and c for DM-, CP-, NDF- and ADF-disappearance (%) of whole crop oats from the rumen.

NDF					
a	7.99±1.40	11.20±2.25	11.08±1.27	10.23±1.51	0.32
b	91.28±6.05	64.28±11.29	80.79±1.57	57.48±27.39	0.25
c	0.02±0.00	0.02±0.01	0.01±0.00	0.01±0.01	0.34
ADF					
a	13.83±2.42	13.26±1.29	15.08±1.99	13.93±2.20	0.78
b	85.34±7.34	76.68±30.27	67.91±33.09	47.64±25.03	0.60
c	0.02±0.00	0.01±0.01	0.01±0.01	0.02±0.01	0.64

a = soluble fraction
b = potentially degradable fraction
c = rate of degradation
NDF = Neutral detergent fiber
ADF = Acid detergent fiber
P: Significance level
ab: Means with the same letter are not significantly different within rows.

For the DM ruminal disappearance of whole plant oats, parameter *a* (the readily soluble fraction) differed significantly (P<0.01), while parameter *b* (potentially degradable fraction) and parameter *c* (the rate at which *b* is degraded) did not differ between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity (P>0.05).

As with the whole crop faba beans, the *a* and *b* values for CP in whole crop oats differed significantly (P<0.01 and P=0.02 respectively) between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity, while the *c* value did not differ (P>0.05).

The data in Table 6 indicates that for whole crop oats, parameter *a* (the readily soluble fraction), parameter *b* (potentially degradable fraction) and parameter *c* (the rate at which *b* is degraded) did not differ significantly (P>0.05) between the four different growth stages (117, 131, 145 and 159 days from planting) of plant maturity for NDF and ADF.

The soluble fraction *a,* for both NDF and ADF, of whole crop faba beans was much lower than that of whole crop oats (P<0.05). Similarly the potentially degradable fraction *b* for both NDF and ADF of whole crop faba beans was much lower than that of whole crop oats. From 75 to 159 days after planting the crude fiber (CF) of whole crop faba beans increased from 21.8 to 26.5 %, while the CF for whole crop oats increased from 25.6 to 36.9 (data from Chapter 2). This data confirms that whole crop oats is much more fibrous than whole plant faba beans.

When compared with silages, hay had a lower content of soluble DM or fraction *a* in agreement with other studies (Martineau *et al*., 2006). Soluble DM includes, among others, soluble CP, water-soluble carbohydrates, and small particles lost from the bag during rumen incubation, stomacher pummeling and washing. Even though the extent of small particle losses was not estimated, washing losses of NDF were greater in silages than hay (+ 33g.kg^{-1} NDF) suggesting increased small particle loss in silages than in hay given that NDF is not soluble in water per se (Van Soest *et al*., 1991).

Calculating effective degradability (ED) or (*P*)

By introducing the fractional ruminal outflow rate, *k*, the effective degradabilities (ED) or (*P*) could be calculated from the following equation (Ørskov & McDonald, 1979):

$$\mathrm{P} = a + \frac{bc}{c + k}$$

A fractional outflow rate of *k* = 0.05 was used as suggested by Erasmus *et al*. (1990).

The effective degradability percentage (*P*) of DM, CP, NDF and ADF for four different growth stages (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) of whole crop faba beans and oats at fractional outflow rate of 0.05/h from the rumen are presented in Table 7.

The highest effective DM degradability was found for whole crop faba beans cut at 117 days after planting (67.4%) and degradability decreased as the whole crop faba beans matured in growth stage to 159 days after planting (57.5%).

The mean effective DM degradability of whole crop faba beans for three different growth stages, i.e. 117, 131 and 145 days after planting, differed significantly (P<0.05) from whole crop faba beans cut at 159 days after planting. Similarly the mean effective CP degradability of whole crop faba beans for three different growth stages, i.e. cut at 117, 131 and 145 days after planting, differed significantly (P<0.05) from whole crop faba beans cut at 159 days after planting.

There was a decrease in CP degradability as whole crop faba beans matured. Whole crop faba beans cut at 117 days after planting had a protein degradability of 84.1% and decreased to 79.9% at 159 days after planting. The decrease in protein degradability is associated with maturing of the faba bean plants.

For growth stages 117, 131, 145 and 159 days after planting, the effective CP degradability of whole plant faba beans was higher than that of whole plant oats at a fractional outflow rate of 0.05/h. This can be attributed to both the higher soluble fraction of faba beans compared to oats.

Table 7. The mean (±SE) effective degradability percentage (*P*) of DM, CP, NDF and ADF for four different growth stages (117, 131, 145 and 159 days after planting) of whole crop faba beans and oats at fractional outflow rate of 0.05/h from the rumen from Holstein cows.

Component	Outflow rate / hr	Growth stage G117	G131	G145	G159	SEM	P
Faba beans							
DM	0.05/h	67.44±3.41 [a]	66.04±1.13 [a]	63.69±1.53 [ab]	57.50±1.85 [b]	2.162	0.048
CP	0.05/h	84.07±1.59 [a]	85.73±0.56 [a]	83.32±0.18 [ab]	79.87±1.47 [b]	1.122	0.03
NDF	0.05/h	40.45±2.49 [a]	33.46±1.95 [b]	36.16±2.14 [ab]	26.57±1.28 [c]	2.015	<0.01
ADF	0.05/h	44.39±1.79 [a]	35.40±1.53 [b]	31.30±2.53 [b]	20.51±1.54 [c]	1.894	<0.01
Oats							
DM	0.05/h	47.91±0.95 [a]	39.70±1.55 [b]	39.71±1.40 [b]	37.83±0.26 [b]	1.411	<0.01
CP	0.05/h	72.76±0.30 [a]	61.91±1.42 [c]	66.16±0.08 [b]	59.24±1.32 [c]	0.979	<0.01
NDF	0.05/h	30.82±0.75 [a]	26.08±0.93 [b]	20.51±1.41 [c]	21.09±0.30 [c]	0.935	<0.01
ADF	0.05/h	34.30±0.24 [a]	25.59±1.06 [b]	25.69±0.98 [b]	25.29±1.06 [b]	1.018	<0.01

DM = Dry matter
CP= Crude protein
NDF = Neutral detergent fiber
ADF = Acid detergent fiber
SE: Standard error
SEM: Standard error of the mean
P: Significance level
[ab:] Means with the same letter are not significantly different within rows.

The mean effective NDF degradability of whole crop faba beans cut at growth stages 117, 131 and 159 days after planting differed significantly (P<0.01) between one another. Similarly the mean effective ADF degradability of whole crop faba beans cut at growth stages 117, 131 and 159 days after planting differed significantly (P<0.01) between these three growth stages.

Whole crop faba beans cut at 117 days after planting had the highest NDF and ADF degradability (40.5% and 44.4% respectively). The lowest effective NDF and ADF degradability was obtained for whole crop faba beans at 159 days after planting (26.6% and 20.5% respectively). It has been stated by Smith *et al*. (1972) that many of the maturity stage effects on forage digestibility are associated with the increase in forage NDF content and an increase in the lignification of the NDF. It would therefore not be improbable to believe that total nutrient utilisation would be negatively affected by a decrease in rumen NDF digestibility. These results suggest that whole crop faba beans harvested at an earlier growth stage would be of better quality in terms of effective DM, CP and NDF degradability and that the degradabilities tend to decrease as the plants mature.

The highest effective DM degradability was found for whole crop oats cut at 117 days after planting (47.9%) and degradability decreased as the oats matured in growth stage to 159 days after planting (37.8%).

The mean effective DM degradability of whole crop oats for growing stage 117 days after planting differed significantly (P<0.01) from the three growth stages of whole crop oats cut at 131, 145 and 159 days after planting.

The mean effective CP degradability of whole crop oats for growing stage 117 days after planting differed significantly (P<0.01) from the three growth stages of whole crop oats cut at 131, 145 and 159 days after planting.

There was a decrease in CP degradability as whole crop oats matured. Whole crop oats cut at 117 days after planting had a protein degradability of 72.8% and decreased to 59.2% at 159 days after planting. The decrease in protein degradability is associated with maturing of oats plants.

Whole crop oats cut at 117 days after planting had the highest NDF and ADF degradability (30.8% and 34.3% respectively). The lowest effective NDF and ADF degradability was obtained for oats at 159 days after planting (21.1% and 25.3% respectively).

The mean effective NDF degradability of whole crop oats for different growth stages, i.e. 117, 131 and 145 days after planting, differed significantly (P<0.01) between growth stages.

The mean effective ADF degradability of whole crop oats cut at 117 days after planting differed significantly (P<0.01) from the three growth stages of whole crop oats cut at 131, 145 and 159 days after planting.

Mustafa & Seguin (2003) found that the effective degradability of DM, CP and NDF of whole crop faba beans silage to be 66.2%, 79.4% and 34.2% respectively. Factors influencing the level of different protein fractions in silages include DM content at ensiling, drying conditions and packing density (Janicki & Stallings, 1987). The effective DM degradability of whole plant faba beans in this study was 66.0% at 131 days after planting, while the effective CP degradability of whole plant faba beans was 79.9% at 159 days after planting. Effective NDF degradability of whole plant faba beans was 33.5% at 131 days after planting.

Empirical fit to incubation data

The equation $p = a + b\ (1- e^{-ct})$ provides an empirical fit to the incubation data (Ørskov & McDonald, 1979). By using the first derivatives *a*, *b* and *c*, obtained by the iterative least square procedure (SAS, 1999) and calculating them in the equation to the different incubation times (0, 4, 8, 12, 24, 48, 72 and 96 hours), different graphs could be generated for DM, CP, NDF and ADF disappearance for both whole plant faba beans and oats.

Table 8 presents the mean measured and fitted crude protein disappearance percentage for four different growth stages (117, 131, 145 and 159 days after planting) of whole crop faba beans.

The data in Table 8 is included for example purposes. Table 8 shows that, compared to the original measurements, there is good agreement between the mean measured CP disappearance percentage and the estimated or fitted CP disappearance percentage from the equation [$p = a + b\ (1 - e^{-ct})$].

Table 8. Mean measured and fitted crude protein disappearance percentage for four different growth stages (117, 131, 145 and 159 days after planting) of whole crop faba beans.

Incubation time (h)	Mean measured CP disappearance (%) Growth stage				Fitted CP disappearance (%)* Growth stage			
	117	131	145	159	117	131	145	159
0	56.4	57.7	62.0	63.4	57.3	58.0	62.6	64.8
4	72.9	75.1	73.2	73.9	72.1	74.6	72.6	71.9
8	82.0	84.0	79.9	75.9	81.1	83.8	79.4	77.3
12	85.8	88.6	84.5	77.5	86.7	88.9	84.1	81.4
24	91.3	92.6	89.0	85.3	93.5	94.1	91.0	88.3
48	94.7	95.0	92.9	89.0	95.4	95.1	94.0	92.5
72	96.0	95.7	95.2	92.1	95.5	95.1	94.3	93.2
96	96.2	95.8	95.5	94.3	95.5	95.1	94.3	93.4

*: Values calculated from the fitted equation $p = a + b\ (1 - e^{-ct})$ to the different incubation times (fitted constants: a = 57.3; b = 38.2; c = 0.122).

The ruminal degradability of DM, CP, NDF and ADF for whole crop faba beans calculated by the model $p = a + b$ $(1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours) in the rumen of Holstein cows are presented in Figures 9 to 12.

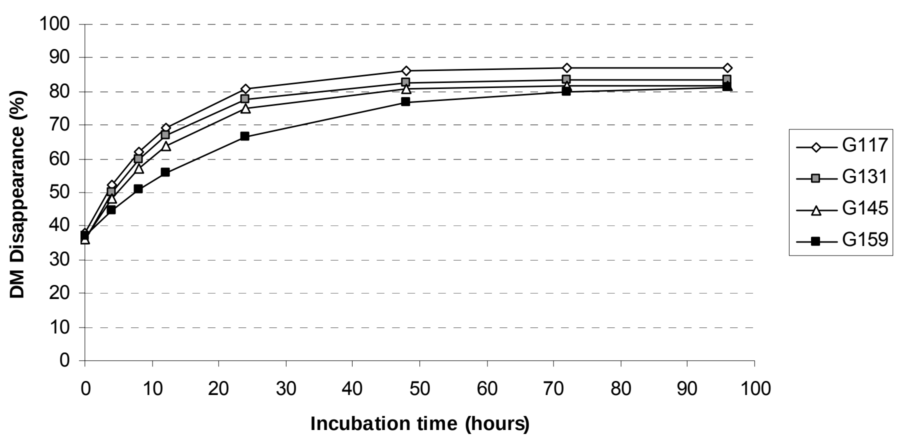

Figure 9. The calculated ruminal degradability of dry matter (DM) for whole crop faba beans, represented by the model $p = a + b\ (1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

For faba beans the asymptote for DM disappearance was reached at 72 hours for all growth stages at 117, 131, 145 and 159 days after planting.

Effective DM degradabilities for whole crop faba beans calculated at an outflow rate of 0.05 for the different growth stages at 117, 131, 145 and 159 days after planting were at 66.9, 66.1, 64.0 and 58.4 percent respectively. It was expected that DM degradabilities of whole crop faba beans decrease with advancing growth stage and increasing fiber as plants mature.

Cherney and Marten (1982) found that stage of maturity at harvest has a major effect on biomass yield and quality of cereals.

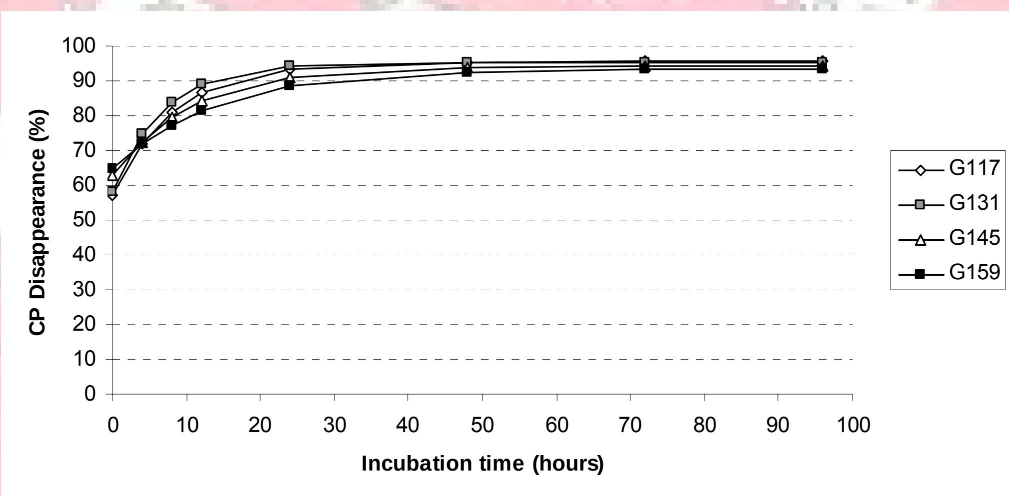

Figure 10. The calculated ruminal degradability of crude protein (CP) for whole crop faba beans, represented by the model $p = a + b\ (1- e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

Hoffman *et al*. (1993) found that legumes have higher ruminal DM degradability than grasses. The higher ruminal DM degradability is likely due to their higher *in situ* soluble DM fraction.

For faba beans the asymptote for CP disappearance was nearly obtained at 24 hours, and reached at 48 hours for all growth stages at 117, 131, 145 and 159 days after planting.

This indicates that all CP has been dissolved from the faba bean plants within a 24-hour period. Effective CP degradabilities for whole crop faba beans calculated at an outflow rate of 0.05 for the different growth stages at 117, 131, 145 and 159 days after planting were at 84.4, 85.8, 83.4 and 81.7 percent respectively.

Factors influencing the level of different protein fractions in silages include DM content at ensiling, drying conditions and packing density (Janicki & Stallings, 1987).

High soluble and low intermediately and slowly degradable protein levels suggest that protein of pea silage, alfalfa silage and barley silage will be extensively degraded in the rumen (Mustafa *et al*., 2000).

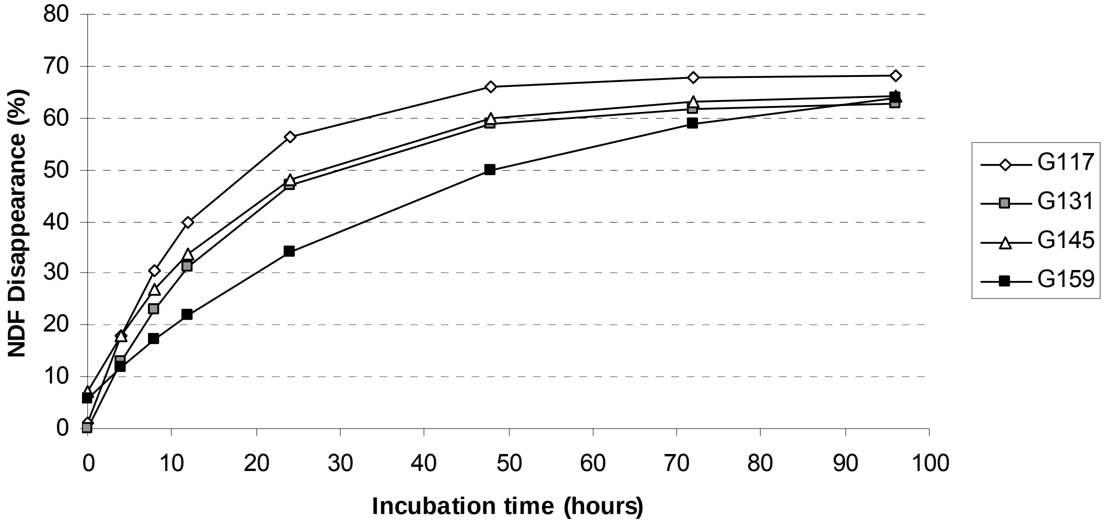

Figure 11. The calculated ruminal degradability of Neutral Detergent Fiber (NDF) for whole crop faba beans, represented by the model $p = a + b\ (1- e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

For whole crop faba beans the asymptote for NDF disappearance was nearly reached at 96 hours for all growth stages at 117, 131, and 145.

Effective NDF degradabilities for whole plant faba beans calculated at an outflow rate of 0.05 for the different growth stages at 117, 131, 145 and 159 days after planting were at 40.6, 33.5, 36.5 and 26.8 percent respectively.

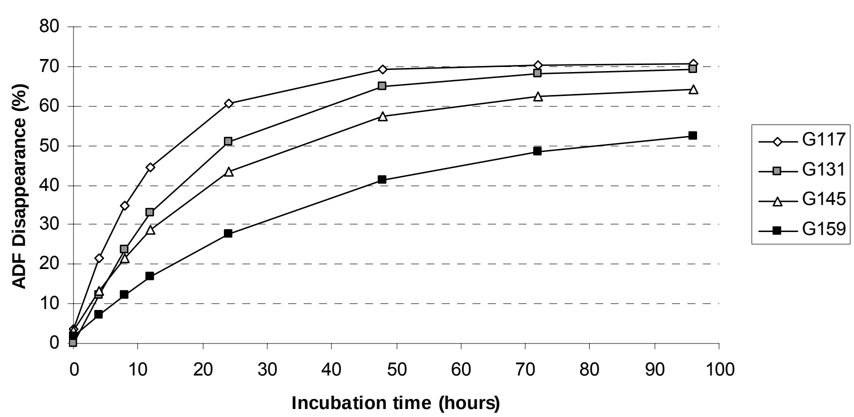

Figure 12. The calculated ruminal degradability of Acid Detergent Fiber (ADF) for whole crop faba beans, represented by the model $p = a + b\,(1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

For whole crop faba beans the asymptote for ADF disappearance was reached at 48 hours for growth stage 117.

Effective ADF degradabilities for whole plant faba beans calculated at an outflow rate of 0.05 for the different growth stages at 117, 131, 145 and 159 days after planting were at 44.6, 35.8, 32.1 and 20.8 percent respectively.

The ruminal degradability of DM, CP, NDF and ADF for whole crop oats calculated by the model $p = a + b\,(1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours in the rumen) of Holstein cows are presented in Figures 13 to 16.

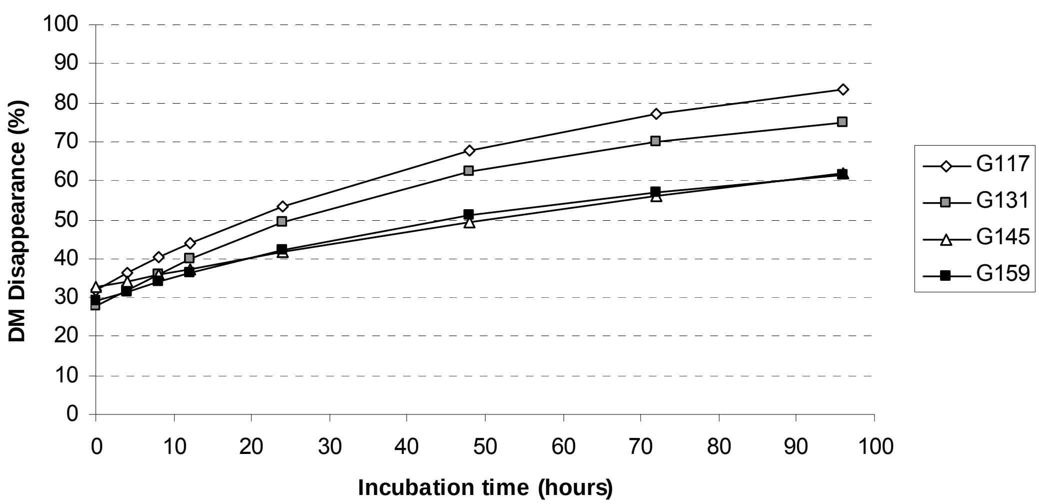

Figure 13. The calculated ruminal degradability of dry matter (DM) for whole crop oats, represented by the model $p = a + b\,(1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

For whole crop oats the asymptote for DM disappearance was not reached at 96 hours for all growth stages 117, 131, 145 and 159 days after planting, while whole crop faba beans reached the asymptote at 48 hours (except growth stage 159 days after planting which reached asymptote at 72 hours) at between 80 and 90 %.

Effective DM degradabilities calculated at an outflow rate of 0.05 (Erasmus *et al*., 1990) for the different growth stages of whole crop oats at 117, 131, 145 and 159 days after planting were at 48.2, 43.7, 39.8 and 38.9 percent respectively. It was expected that DM degradabilities of whole oats decrease with advancing growth stage and increasing fiber as plants mature.

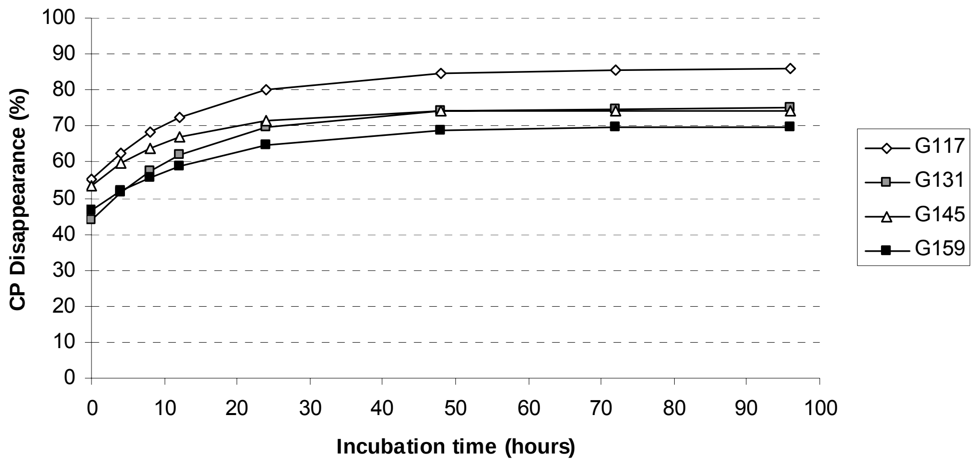

Figure 14. The calculated ruminal degradability of crude protein (CP) for whole crop oats, represented by the model $p = a + b\ (1- e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

For whole crop oats the asymptote for CP disappearance was obtained at 48 hours for all growth stages at 117, 131, 145 and 159 days after planting, while whole crop faba beans nearly reached the asymptote at 24 hours for all growth stages, being all above 90 %.

This indicates that all CP has been dissolved from the oat plants within a 48-hour period. Effective CP degradabilities calculated at an outflow rate of 0.05 (Erasmus *et al.*, 1990) for the different growth stages of whole crop oats at 117, 131, 145 and 159 days after planting were at 73.0, 62.2, 66.7 and 59.5 percent respectively.

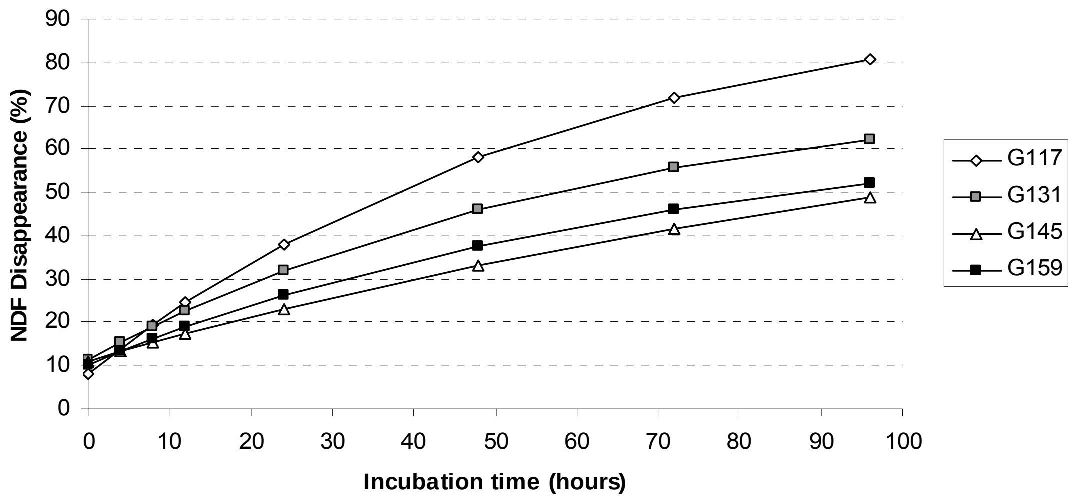

Figure 15. The calculated ruminal degradability of Neutral Detergent Fiber (NDF) for whole crop oats, represented by the model $p = a + b\ (1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

For whole crop oats the asymptote for NDF disappearance was not reached at 96 hours for all growth stages 117, 131, 145 and 159 days after planting.

Effective NDF degradabilities calculated at an outflow rate of 0.05 (Erasmus *et al*., 1990) for the four different growth stages of whole crop oats at 117, 131, 145 and 159 days after planting were at 30.8, 27.0, 20.5 and 22.4 percent respectively.

Juskiw *et al.* (2000) found three cultivars of whole crop mature oats in seven mixtures to have NDF values range between 64.2 and 52.8 ± 4.3%. Similarly ADF values ranged between 37.2 and 30.4 ± 3.6%.

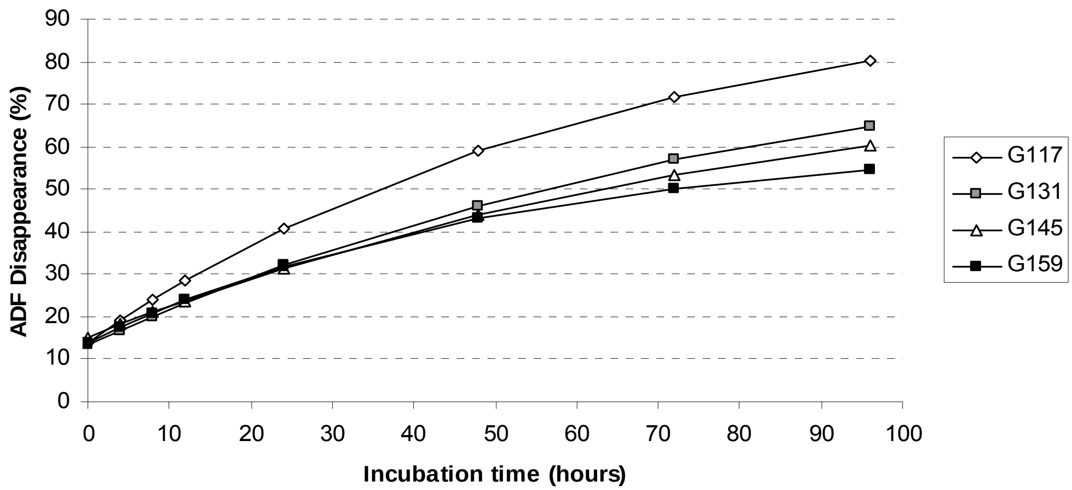

Figure 16. The calculated ruminal degradability of Acid Detergent Fiber (ADF) for whole crop oats, represented by the model $p = a + b\ (1 - e^{-ct})$ as affected by growth stage (G117, G131, G145 and G159 = 117, 131, 145 and 159 days after planting) and incubation time (0, 4, 8, 12, 24, 48, 72 and 96 hours).

Effective ADF degradabilities calculated at an outflow rate of 0.05 (Erasmus *et al*., 1990) for the different growth stages at 117, 131, 145 and 159 days after planting were at 34.3, 27.8, 27.8 and 27.4 percent respectively

For whole crop oats the asymptote for ADF disappearance was not obtained even at 96 hours. This is because, for fiber 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 & Kolver, 1997). This therefore prolongs the lag phase and results in a longer period required for fiber digestion.

Conclusion

The chemical quality of faba beans and oats decreased as plants matured during the different growth stages from 117 to 159 days after planting. The decrease in quality of the maturing plants was confirmed by results from the *in situ* rumen digestibility trial. It was found that the effective DM, CP, NDF and ADF degradability values of faba beans and oats decreased as plants matured. A reduction in rumen degradability associated with the maturing of whole plant faba beans and oats could have a negative effect on the production of dairy cows as it would cause a reduction in the microbial CP production because of a reduction in the fermenting ability of the forage.

The results from this study also indicate that it would be advisable to harvest faba beans and oats at an earlier stage in terms of DM, CP, NDF and ADF degradability values. Although the faba beans and oats harvested at 131 and 145 days after planting is of better quality, the DM yield would be less than it would be if the faba beans and oats were harvested at a more mature stage such as 159 days after planting. It is thus important to consider whether the improvement in the quality of the plants harvested at an earlier stage will bring about an improvement in cow production that can offset the loss in DM yield when material is cut at an earlier stage. Results from this study can make a valuable contribution towards South African databases on faba beans and oats nutrient degradability values and can be used in dynamic feed formulation models.

Chapter 6

GENERAL CONCLUSIONS

Increasing the use of annual legumes like faba beans into crop rotations, either as sole crops or as intercrops with cereals, may be a viable alternative to continual cereal cropping because annual legumes contribute nitrogen through biological nitrogen fixation, reduce weed competition, reduce disease carry-over and increase the input to root mass in the soil.

In an era in which dairy farmers are relying on silage more than ever before, and with the high degree of variability in silage quality, it is of the utmost importance that farmers analyze their silage to obtain the nutrient specification of each ensiled crop.

ME (Metabolisable Energy), and CP in the event of legume silages, is the most important figure and usually the most limiting in silages. Information such as digestibility, NDF and ADF provide valuable information as to whether the crop was cut too early or too late.

The use of faba beans as a forage crop is not a common practice in South Africa, and it is with this study that we wish to enhance the use of faba beans as a viable alternative legume forage crop not only as a rotational crop in a wheat production system. Results from this study could make a valuable contribution towards the South African databases on faba bean and oats nutrient values and can be used in dynamic feed formulation models.

It was found that the effective DM, CP, NDF and ADF degradability values of faba beans and oats decreased as plants matured. A reduction in rumen degradability is associated with the maturing of whole plant faba beans and oats. The results from this study also indicate that it would be advisable to harvest faba beans and oats at an earlier stage in terms of DM, CP, NDF and ADF degradability values. Although the faba beans and oats harvested at 131 and 145 days after planting is of higher quality, the DM yield would be lower in comparison to a later harvest date. It is thus important to consider whether the improvement in the quality of the plants harvested at an earlier stage will bring about an improvement in cow production that can offset the loss in DM yield when material is cut at an earlier stage.

Faba beans cut as fresh crop or silage may in the foreseeable future play an increasingly larger role in the feeding of dairy cattle in the Winter Rainfall Region of South Africa. The nutritive properties of faba bean silage holds great promise as a forage in lactating dairy cows. As in the case of lupin silage, though with much higher protein content, farmers will be able to produce their own high quality and high protein roughage. Farmers will be able to cut transport costs, by not importing bulky lucerne from other parts of the country. By cutting transport costs on roughages, milk production costs will lessen, making dairy farming much more viable in the Western Cape. This highlights the importance of faba bean roughage as an alternative to other good quality roughages.

The exceptionally high nutritional value of faba bean silage will hopefully encourage farmers to turn more to this form of roughage.

Chapter 7

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