

The effect of supplements containing different protein and energy sources and essential oils on the performance of pasture finished heifers

by
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Declaration

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Date: December 2015

Abstract

Title: The effect of supplements containing different protein and energy sources and essential oils on the performance of pasture finished heifers.

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Sixty Bonsmara heifers (328 ± 3.9 kg) on planted pastures were used to evaluate the effect of two energy sources and three growth promoters on body weight gain. Two supplementary feeds with dried apple pulp (A) or maize (M) as main energy source were formulated on an iso-nutrient base. One of three different growth promoters was included in each energy supplement: placebo (no growth promoter, designated as Treatments Ap and Mp), ionofore (monensin, designated as Treatments Am and Mm) and essential oil extract (from oregano, designated as Treatments Ao and Mo). A fixed amount of the supplements was offered to the six treatment groups in a growth/finishing study on cultivated grass-legume pastures.

Animals were stratified according to initial weight in ten blocks and treatments were assigned randomly to animals in each block. The 66 day growth study was conducted during spring (September to November, 2014) in the Western Cape Province of South Africa near Greyton. The cultivated pastures consisted of a perennial grass-legume mixture. A rotation grazing system was applied and animals were moved to new paddocks once a week. Based on falling plate meter readings, the heifers consumed a calculated mean amount of 4.48 ± 0.08 (SEM) kg DM/day over the entire experimental period. A fixed amount of 4 kg ("as is" basis) of the respective supplements were offered daily during the first 42 days, followed by 5 kg/day from 43 days until the end of the study (66 days). Animals were weighed bi-weekly and average daily gain (ADG) was calculated.

The mean ADG of the six treatment groups was 1.44 kg/day. No interactions occurred between the energy sources and growth promoters used in the concentrates and main effects were thus interpreted. The supplements that contained apple pulp as energy source resulted in a higher ($P < 0.02$) ADG (1.54 kg/day) than the maize containing supplements (1.33 kg/day). There were no differences between any of the growth promoters, with the placebo resulting in similar growth rates than monensin and oregano oil extract. Mean ADG values (kg/day) of the different growth promoter treatments were 1.44 (placebo), 1.49 (monensin) and 1.38 (oregano). All the heifers were slaughtered at the end of the trial. Carcass weight and dressing percentage did not differ between energy sources or growth promoters. The mean dressing percentage was 52.5%.

The mean income over feeding cost for the 66 day period of the three maize energy source treatments was R254.20/heifer, while that of the apple pulp treatments was R524.75/heifer. According to this study, concentrate supplements containing apple pulp as main energy source were economically more desirable than those containing maize as primary energy source.

Uittreksel

Titel:	Die invloed van suplemente wat verskillende proteïen- en energiebronne, asook essensiële olies bevat, op die prestasie van vleisbeesverse wat op aangeplante weidings afgerond word.
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Sestig Bonsmaraverse (328 ± 3.9 kg) op aangeplante weiding is gebruik om die invloed van twee energiebronne en drie groeibevorderaars op massatoename te ondersoek. Twee suplemente met gedroogde appelpulp (A) of mielies (M) as hoofenergiebron is op 'n isonutriëntbasis geformuleer. Een van drie groeibevorderaars is in elk van die energiesupplemente ingesluit: placebo (geen groeibevorderaar, aangedui as Behandlings Ap en Mp), 'n ionofoor (monensin, aangedui as Behandlings Am en Mm) en 'n essensiële olie-ekstrak (van oreganum, aangedui as Behandlings Ao en Mo). 'n Vasgestelde hoeveelheid van die suplemente is aan elk van die ses groepe in 'n groei/afroondingsproef op aangeplante weidings aangebied.

Diere is volgens aanvangsmassa in tien bloke gestratifiseer en behandelings is ewekansig aan diere in elke blok toegeken. Die 66-dae groeistudie is gedurende die lente (September tot November) in die Wes-Kaapprovinsie van Suid-Afrika naby Greyton uitgevoer. Die weidings het uit 'n meerjarige gras-klawermengsel bestaan. 'n Rotasiebeweidingsstelsel is gevolg en diere is weekliks na nuwe kampies verskuif. Volgens die lesings van 'n valplaatmeter het die verse 'n gemiddelde weidingsinname van 4.48 ± 0.08 (SEM) kg DM/dag getoon. 'n Vasgestelde hoeveelheid van 4 kg (lugdroë basis) van die onderskeie suplemente is daagliks gedurende die eerste 42 dae van die proef aangebied, gevolg deur 5 kg/dag vanaf 43 dae tot aan die einde van die proef (66 dae). Diere is tweeweekliks geweeg en die gemiddelde daaglikse toename is (GDT) bereken.

Die gemiddelde GDT van die ses behandelingsgroepe was 1.44 kg/dag. Geen interaksies tussen die energiebronne en groeibevorderaars is waargeneem nie en hoofeffekte is gevolglik geïnterpreteer. Die suplemente wat appelpulp as energiebron bevat het, het tot 'n hoër ($P < 0.02$) GDT (1.54 kg/day) gelei as die mieliebevattende suplemente (1.33 kg/dag). Daar was geen verskille tussen enige van die groeibevorderaars nie met die placebo wat soortgelyke resultate as monensin en oreganum olie-ekstrak gelewer het. Gemiddelde GDT waardes (kg/dag) van die onderskeie groeibevorderaars was 1.44 (placebo), 1.49 (monensin) en 1.38 (oreganum). Al die verse is teen die einde van die proef geslag. Karkasmassa en uitslagpersentasie het nie tussen energiebronne of groeibevorderaars verskil nie. Die gemiddelde uitslagpersentasie was 52.5%.

Die gemiddelde wins bo voerkoste van die drie energiebronsuplemente was R254.20/vers, terwyl dié van appelpulpbehandelings R524.75/vers was. Volgens hierdie studie was die suplemente wat appelpulp as hoofenergiebron bevat het, meer winsgewend as dié wat mielies as hoofenergiebron bevat het.

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List of abbreviations

ADF	Acid detergent fibre
ADG	Average daily gain
Am	Apple monensin
Ao	Apple oregano
Ap	Apple placebo
ATP	Adenosine triphosphate
BW	Body weight
cm	Centimetre
CNCPS	Cornell net carbohydrate and protein system
cm	Centimetre
CP	Crude protein
°C	Degree Celsius
DF	Degrees of freedom
DM	Dry matter
DMI	Dry matter intake
EE	Ether extract
eNDF	Effective neutral detergent fibre
EO	Essential oils
FAO	Food and agriculture organisation
FPM	Falling plate meter
FCR	Feed conversion ratio
g	Gram
GH	Growth hormone
h	Hour
Ha	Hectare
iBW	Initial body weight
IVOMD	In vitro organic matter digestion
Kg	Kilogram
kPa	Kilopascal
L	Litre
La	Lactic acid
LAB	Lactic acid bacteria
LS	Least square
LW	Live weight
MCP	Microbial crude protein
ME	Metabolizable energy
MP	Metabolizable protein

MS	Mean Square
N	Nitrogen
NDF	Neutral detergent fibre
NE	Net energy
NE _g	Net energy for gain
m	Meter
ME _m	Net energy for maintenance
mm	Millimetre
mM	Millimolar
Mm	Maize monensin
Mo	Maize oregano
Mp	Maize placebo
NFC	Non-neutral detergent fibre polysaccharides
NH ₃ -N	Ammonia nitrogen
NPN	Non protein nitrogen
NRC	National research counsel
NSC	Non-structural carbohydrates
OM	Organic matter
peNDF	Physically effective neutral detergent fibre
%	Percentage
R	South African Rand
RDP	Rumen degradable protein
RFC	Readily fermentable carbohydrate
RPM	Rising plate meter
RTA	Relative Trade Advantage
RUP	Rumen undegradable protein
SC	Structural carbohydrate
SD	Standard deviation
SEM	Standard error of the mean
SOC	Soil organic carbon
SOM	Soil organic matter
SS	Sum of squares
TDN	Total digestible nutrients
TMR	Total mixed ration
VFA	Volatile fatty acids

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

Livestock is the largest agricultural sector in South Africa with a population of 13.8 million cattle (Department of Agriculture, Forestry and Fisheries, 2013). South Africa produces 85% of its meat requirements with 15% imported from Botswana, Namibia, Australia, New Zealand and the EU (SAI, 2015). Cattle and calves slaughtered in South Africa contributed 10.3% (R18 171 million) of the total gross value of agriculture production during 2012 (SAYB 1013/14). With 844 000 ton of beef produced annually, it is one of South Africa's main agricultural sectors.

Beef is mostly bred in extensive farming systems in the more rural parts of South Africa such as the Eastern Cape, KwaZulu-Natal, Free State, Limpopo and Northern Cape Province (SAI, 2015). Typically, weaners or long weaners are sold from these extensive systems into feedlots. The feedlot industry delivers approximately 75% of all beef in South Africa (SAFA 2015). This beef is mainly produced by mega feedlots because they are able to survive narrow margins through minimizing their overhead costs per unit produced. There is usually a correlation between the weaner calf price and the slaughter price of 'A' class meat, therefore it is very important to minimize the feeding cost and maximize the feed conversion ratio (FCR) in order to produce meat cheaper than competitors so as to maximise profits. The main challenge of the agriculture sector is to feed the expected global population of 9 billion in 2050 (AAF, 2015). The Food and Agriculture Organization projects that meat consumption will rise with nearly 73% by 2050 (FAOSTAT, 2015).

Carbohydrates in ruminant feeds can be divided into the following two major fractions: i.) structural carbohydrates (mainly neutral detergent fibre, or NDF, and acid detergent fibre, or ADF) and ii.) non-structural carbohydrates, or NSC. The NSC fraction is sometimes also referred to as non-fibre carbohydrates, or NFC, although it contains soluble fibre. Generally, NSC includes sugars, starch, organic acids, pectin, fructans, galactans and β -glucans (generally considered as the energy containing feeds). Decreasing either the forage or energy costs *ceretus paribu* would decrease the total feeding cost. Maize is the energy source that is used most commonly in South African beef finishing systems. The most expensive part of any total mixed ration (TMR) or concentrate is the energy fraction. Therefore, maize, hominy chop and maize silage are the main cost determinants in South African cattle finishing rations. The maize industry in South Africa (and world-wide) is under tremendous pressure. According to Ray *et al.*, (2013) maize production world-wide has to double by 2050 in order to supply the growing population's demand. The expected global growth rate to meet this challenge is 2.4% while the current rate is 1.6% per year (Ray *et al.*, 2013). The increase is not just as a primer food and energy source but also because of developing countries consuming more meat. Finweek, (2015) calculated that the calories lost by feeding cereals to livestock instead of using them for human food could feed an extra 3.5 billion people.

Because maize is an expensive energy source, alternatives are often considered to replace maize in feedlot diets. Apple pulp may present an alternative, although the seasonality could limit continuous availability. South Africa is one of the most competitive apple exporters in the world (BFAP, 2014), however, not all apples meet the stringent quality criteria set by the importing countries, resulting in a large volume of apples that are also being processed particularly into apple juice. The resulting apple pulp may be available in a wet form or it could be dried which makes transport and storage easier. This non-starch energy source was thus investigated in the current study as an alternative to maize.

Another way of decreasing costs would be to finish cattle on planted and irrigated pastures (Allen, 2000). Very little pasture finishing research has been done with beef cattle in South Africa: mainly because South Africa is a water scarce country. However, there are regions in some of the provinces such as the Eastern Cape, Free State and KwaZulu-Natal, where water is available for irrigation. Pasture is the cheapest source of cattle nutrition because of the minimal labour cost required and there is very little loss and wastage compared to labour-intensive feed producing systems (Clark *et al.*, 1998; Stocdale, 2000; Barco *et al.*, 2003). Pasture is mainly responsible for the roughage content of a diet. The nutrition value of pasture is determined by the pasture type, the climate and also the soil characteristics. It was therefore important to do a soil analyses in the trial plots in order to determine deficiencies which could have affected pasture quality.

Energy and protein are the first limiting factors for increasing growth in beef cattle (Poppi & McLennan, 1995). A concentrate supplementation (energy and protein) is frequently necessary to obtain maximum growth rates in rapid growing cattle. Maximum growth cannot be achieved by pasture alone, not even by established high quality pasture. A concentrate supplement is characterised as having a high concentration of readily fermentable carbohydrates. This is usually achieved by including high levels of maize (Bargo *et al.*, 2003). Maize and other concentrate feed ingredients, such as canola oilcake and soybean oilcakes, together may contribute 60 to 80% of a typical finishing total mixed ration (TMR). At prices of R2050 for maize (Farmer's weekly, March 2015) and R4800 for soya (Farmer's weekly, May 2015), concentrate feeds are expensive. A study by Lingnau (2011) indicated the possibility to replace a high starch concentrate supplement which is highly digestible with a low starch and high fibre concentrate supplement, which is less digestible, without negatively impacting milk production or rumen health.

The inclusion of hormonal and infeed growth promoters in meat production is a controversial subject. Export of meat to many parts of the world has strict regulations regarding growth promoters. Monensin is one of the well-known ionophores, also classified as a polyether antibiotic, but it results in significant consumer resistance (Calsamiglia *et al.*, 2007). An essential oil (EO) obtained from oregano (OO) is a so-called "natural" product that might act as a growth promoter in ruminants (Busquet *et al.*, 2005b). Oregano might be a possible substitute to the "antibiotic" growth promoter monensin. Very little research has been done on artificial and natural growth promoters used in pasture-fed beef animals.

The emphasis of this study was to evaluate and determine whether maize could be substituted with apple pulp when supplied in concentrates as a supplementary feed to beef heifers grazing on pasture. The two different energy sources were further investigated in combination, or without, monensin and OO. A growth study was

therefore performed on irrigated pastures to determine the effect of treatments on daily gains, dressing percentage and the cost of finishing heifers on cultivated pastures.

This study lays the foundation for further research using non-starch energy sources with high quality roughage to improve growth rate and enhance cheaper meat production systems. Further studies can also be conducted with different levels of oregano to discover if it can act as an alternative growth promoter to monensin.

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CHAPTER 2

LITERATURE REVIEW

2.1 Soil characteristics of the Southern Cape

The soil fertility status of an area has a strong influence on the pasture quality and yield produced. In general, the fertility status of soils found in the southern Cape region of South Africa meets the nutritive requirements for cultivated pasture crops. The soil of the southern Cape region is historically derived from Table Mountain Sandstone which has a low fertility and high free acid concentration (Swanepoel *et al.*, 2014a). However, production in this region has been improved by installing irrigation systems and applying fertilization (Swanepoel *et al.*, 2015). The dominant soils of the experimental region comprise sandy loams or well-sorted sands: they form part of the duplex or podzol soil groups (Soil Classification Working Group, 1991).

Soil fertility of podzolic soils managed with no-tillage pasture mixtures in the southern Cape region is threatened by loading of the soil with Zn and P, which originated from excessive fertilization to obtain higher pasture yields as well as from animal feed rations eventually excreted on pastures. According to Swanepoel *et al.*, (2015) the mean soil pH in the region is within the critical range for cultivated pastures. Limitations are based on the ratio between exchangeable Ca and Mg. The exchangeable Ca and Mg ratio is balanced using lime recommendations according to the Eksteen method (Swanepoel *et al.*, 2014b). In some parts of the region there are also high levels of K, extractable S and micronutrients Cu and Mn are low but, usually adequate for kikuyu based pastures. Concentrates of Zn are variable but rather high, while B concentrations are low, but still adequate for grass-pasture systems. Soil in these areas is considered rich in soil organic matter (SOM: 5.00%) and soil organic carbon (SOC: 4.06%) making it convenient for cultivation of irrigated pastures (Swanepoel *et al.*, 2014b).

2.2 Southern Cape grass legume pastures

2.2.1 Production potential

Plant photosynthesis rates are dependent on leaf size, temperature and the availability of raw materials; Carbon dioxide, light and water (Parsons & Chapman, 2000; Fulkerson & Donaghy, 2001). During winter months, low temperature and low light intensities both result in a lower growth rate and lower production potential of pasture (Weihsing, 1963). As example the maximum growth rate ryegrass achieves during colder months (April to August) is 15 kg/ha DM per day, which is less than half of that achieved during spring months. From September to October ryegrass pasture can reach growth rates up to 60-70 kg/ha DM per day (Dickenson *et al.* 2004). Seasonal differences therefore definitely need to be taken into consideration when investigating finishing of beef cattle on pasture.

2.2.2 Pasture management

Assessing the leaf re-growth stage reflects the stage of pasture recovery from the previous grazing session as well as the nutritive value of the pasture (Fulkerson & Donaghy, 2000). According to Reefs & Fulkerson (1996) the optimum time to graze pasture is when the plant is in its three leaf stage of growth (**Figure 2.1**). Grazing at late pasture maturity levels will cause a decrease in potential yield (kg/day DM). This happens because of the decrease in photosynthetic capacity due to the shadowing effect of the increased leaf mass (Tainton, 2000). Grazing too early will result in high moisture levels which can cause the 'filling effect' where the dry matter intake (DMI) of ruminants cannot be satisfied due to limited space in the rumen. Early grazing can sometimes be observed in cattle's slushy faeces, especially when they only have access to pasture. According to Parsons & Penning (1988) regrowth of at least 14 days but less than 28 days will be effective in achieving not only close to the maximum growth rate of highly digestible material, but also sustain a dense tiller leafy sward that is able to regrow rapidly after severe grazing.

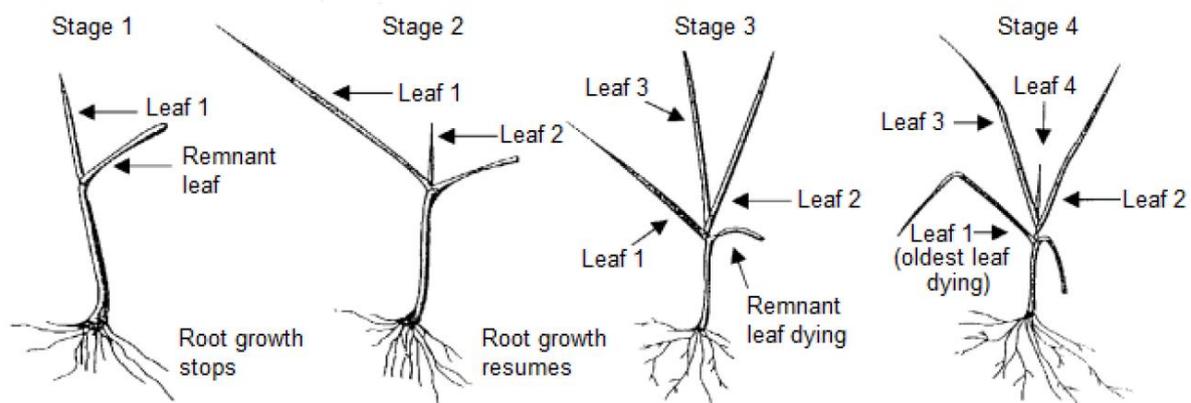


Figure 2.1. The regrowth pattern of ryegrass tillers after grazing (Donaghy, 1999)

Continuous early grazing will lead to overgrazing which will have a negative influence on pasture re-growth due to a reduction in root number and branching (Schuster, 1964). The amount of reduction is directly related to the severity and frequency of grazing (Graber, 1931). Stockdale (2000) reported that the correct pasture allocation is of immense importance as under-utilization of pastures will affect pasture quality and over-utilization impedes pasture regrowth.

For pasture to resume optimal growth after grazing, it should be grazed without removing the meristematic tissue at the apex (De V. Booysen, 1966). A large number of active apices will ensure more rapid re-growth. Grazing pasture to a height of 4-6 cm will ensure that sufficient meristematic tissue remains and will therefore ensure optimal re-growth and quality of pasture (Stockdale, 2000; Irvine *et al.*, 2010). In the Western Cape of South Africa grass legume pastures can be grazed every 21 to 28 days during spring time (Botha, 2009).

Rapid growth occurs during this season because of moderate temperatures, satisfactory amounts of rain, and enough solar radiation.

2.2.3 Botanical composition and morphology of grasses

When different species of grasses and legumes are established it is important to do a botanical composition analysis in order to determine not only the chemical composition but also the optimal grazing strategy for the pasture. Most scientific researchers use the following standard principles to assess botanical composition; cut, separate, dry and weigh pasture samples that has been collected over a representative area of the pasture. The different fractions are then calculated on a DM base. Many researchers agree that the most accurate measurement of botanical composition is provided through the use of the above method (Holeckeczek *et al.*, 1982).

2.2.4 Chemical composition of pasture

The chemical composition of pastures is not only influenced by season of growth and regrowth period (Wilman *et al.*, 1976; Demarquilly & Andrieu, 1988), but also by time of day (Holt & Hilst, 1969). There is also a chemical difference at the different heights of a pasture sward. For example, more structural parts, stems and dead tissue appear at the bottom of the pasture sward while the leaves are more dominant on the upper part of the sward (Wilkinson *et al.*, 1970). There is little chemical differences between the stems and leaves of immature pasture, while the stems of mature pasture show higher concentrations of structural fibre compared to leaves. Leaves are generally richer in crude protein and more digestible (Wilman *et al.*, 1976; Buxton & Redfearn, 1997). The neutral detergent fibre (NDF) fraction of pasture will therefore increase as the pasture matures (Shaver *et al.*, 1988). The chemical composition of the same pastures can therefore vary substantially during different seasons, physiological stage and also the height of harvesting. The soil and the species that the pasture comprises of also play a major role in the chemical composition thereof.

2.2.5 Reason for choosing grass legume mixtures

A perennial grass legume pasture mixture often used in the southern Cape region consists of the following species: ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*), white clover (*Trifolium repens*) and red clover (*Trifolium pratense*) (Swanepoel *et al.*, 2014a). According to De Bruyn (2015, J. De Bruyn, Pannar salesmen, 2 Cooper street, Swellendam, Western Cape, South Africa) this mixture contains both diploid and tetraploid species, each of which requires more or less water and sunlight for reproduction. Clovers are nutritionally superior to grasses in protein and mineral content, their nutritive value also decreases less with age (McDonald, 2002). The inclusion of legume species red and white clover is mainly because of their nutritional value as they are high in protein and the cost saving on nitrogen fertilizer (Botha *et al.*, 2008). Red clover is included because it is more dominant than white clover during the summer time (Botha, 2009). Legumes have a faster digestion rate than grasses as they have almost half as much fibre as grasses (Buxton & Redfearn, 1997), but grasses have a better total digestibility because they have a longer retention time in the rumen (Ishler & Varga, 2001). More grasses are produced due to the longer retention time of

grasses in the digestive tract of ruminants which also leads to quicker gut fill than legumes. Therefore, higher intake of legumes (up to 20% DM of the same metabolisable energy content) is possible (Ishler & Varga, 2001).

The portions in which the different grass species occur usually vary according to the region's climate, grazing management and specific soil type. According to De Bruyn (2015, J. De Bruyn, Pannar salesmen, 2 Cooper street, Swellendam, Western Cape, South Africa) legume inclusion usually stays consistent at 6 kg/ha. Tall fescue and cocksfoot are perennial grass species that comfortably outlive ryegrass. Although, compared to ryegrass tall fescue and cocksfoot deliver greater DM yields during colder climates, ryegrass produce higher yields of DM forage during warmer seasons and offers early grazing possibilities. The above diverse species offer a reasonable yield and quality balance during changing seasons therefore farmers in the southern Cape region mostly use this grass-legume pasture mixture. Unfortunately, a typical grass-legume mixed pasture also has a lower than required ME content for optimal production in growing cattle. Supplementary feeding will therefore be necessary in order to reach the optimal animal output (Bargo *et al.*, 2003).

2.2.6 Measuring pasture intake

In order to determine pasture intake, pasture yield before and after grazing have to be determined (Earle & McGowan, 1979; Gabriels & Berg, 1993; Sanderson *et al.*, 2001). There are many methods available to determine pasture intake; internal and external markers, digestibility studies and faeces collection. Unfortunately these methods do not provide an estimation of pasture yield before grazing and all of them are time-consuming and expensive in practise (Steyn, 2012).

Methods of pasture yield estimation before grazing include; visual assessment, sample cutting and the use of capacitance meters. Unfortunately all of these methods also have disadvantages: sample cutting is time-consuming and continuous recalculation of reference quadrants is required, capacitance meters have to be calibrated daily, which is time-consuming and inconsistent (Fletcher & Robinson, 1956; McGowan, 1979; Gabriels & Berg, 1993), and visual assessment can be used for quicker estimation over large areas but is ineffective for determining post-grazing pasture yield (Haydock & Shaw, 1975; Stockdale, 1984). More than one experienced observer is also required to ensure accurate visual estimations (Earle & McGowan, 1979).

Alternatively, pasture disk meters are another method available for the estimation of pasture biomass. In principle, a plate is positioned on the pasture canopy to enable a height measurement. The height measurement is a function of canopy resistance or the ability of the pasture to repel compression when a force is placed on it (Harmony *et al.*, 1997). This means that the height measurement does not only give an indication of available pasture, but also pasture height in relation to density which are both factors affecting the pasture quality. Therefore it can be said that the plate meter also gives an indication of pasture quality (Fulkerson & Slack, 1993; Delagarde *et al.*, 2000).

In 1976 a researcher at Hannah Research Institute in Scotland designed the pasture plate meter method (Castel, 1976). Since then the pasture plate meter has been developed into many different models, but the same basic principle still applies; using height to predict pasture yield. One of the most commonly used methods is the falling plate meter (FPM) but this method has some disadvantages. The FPM is based on

dropping the plate from a certain height above the pasture canopy, the pasture height is then measured on a pole inserted through the centre of a plate (Douglas & Crawford, 1994). The disadvantages include: firstly, the distance travelled by the plate of the FPM is not always consistent, although the plate is always dropped from the same height the height of the pasture differs. Secondly, the FPM plate does not always have the same weight therefore the velocity differs, complicating comparison between different FPM readings (Harmony *et al.*, 1997). Although falling plate meters are made from various materials and are put together in different designs, Bransby & Tainton (1977) concluded that estimation accuracy was not significantly affected by the material and weight of the FPM plate, as long as calibration was done separately for each specific FPM plate weight and design.

A FPM has to be calibrated for specific circumstances to determine accurate pasture yield. According to Sanderson *et al.* (2001) the main reason for inaccurate yield prediction is the linear regression formulas developed to convert plate meter readings to pasture yield. In order to minimize the standard error the correct calibration according to season, pasture composition and area has to be implemented. Many researchers have found that separate regressions for pre- and post-grazing have yielded higher accuracies (Stockdale, 1984; Sanderson *et al.*, 2001; Steyn, 2012).

In conclusion, using pasture disk meters is the easiest and least time-consuming method to predict pasture yield. It is also as accurate as any of the other methods discussed above (Sanderson *et al.*, 2001).

2.3 Nutrient requirements of beef cattle

2.3.1 The rumen environment

The stomach of a ruminant is divided into four compartments. As calves begin to eat solid foods the rumen and reticulum start to develop until they reach 85% of the stomach capacity (McDonald, 2002). The rumen therefore plays an essential role in supplying the body with energy and nutrients. Saliva dilutes the feed during consumption and again during rumination, a cow will typically produce 150 L of saliva per day (McDonald, 2002). The rumen has a lower and higher liquid phase with an average of 850-930 g water per kg of solids. The rumen is continually mixing its content (through rhythmic wall contraction) breaking food down, partly by physical and partly by chemical processes. The anaerobic conditions and temperature (38-42 °C) in the rumen supply a favourable environment for rumen microbes to play their symbiotic role in the rumen (McDonald, 2002). There are two metabolic systems in the rumen that need nutrients; the rumen tissue, and the rumen micro-organisms (Chalupa *et al.*, 1996). The rumen micro-organisms consume the cellulose energy components which cannot be broken down to glucose by rumen enzymes (Varga & Kolver, 1997). In exchange, the microbes supply the fermented end products of fibre digestion (acetate, propionate, butyrate and amino acids) (Russell & Wilson, 1996).

The rumen micro-organisms consist of bacteria, protozoa and fungi. According to Russell & Hespell (1981) many interrelationships appear among these ruminal micro-organisms. Over 200 bacteria species have been identified in the rumen content, containing about 10^9 - 10^{10} bacteria per ml. Over 100 species of protozoa have also been identified in the rumen but are present in much smaller numbers (10^6 per ml) than bacteria

(McDonald, 2002). The protozoa total mass is, however, equal to bacteria because of their size differences. The exact role of the fungi is not yet fully characterized. Fungi are strictly anaerobic and they can penetrate cell walls by attaching to food particles with their rhizoids. Fungi cannot utilize all carbohydrates, but are capable of utilising most polysaccharides and many sugars (McDonald, 2002).

Many nutritionists conclude that it is impossible to understand or express the complex rumen ecosystem in quantitative terms (Russell *et al.*, 1992). Optimistic ruminant nutritionists have however attempted to model some aspects with models such as the Cornell Net Carbohydrate and Protein System (CNCPS) (Fox *et al.*, 2004). According to the CNCPS, the luminal microbial ecosystem is divided into structural carbohydrate (SC) fermenters and non-structural carbohydrate (NSC) fermenters. The SC fermenters use only ammonia as N source, ferment only cell wall carbohydrates and do not ferment amino acids or peptides. While the NSC bacteria use either ammonia or peptides and amino acids as N source, ferment starch, sugars, pectin, etc., and can produce ammonia. The bacteria yields are therefore influenced by the diets of the ruminants, for example the total number of bacteria decreases when forage NDF is less than 20% (Russell *et al.*, 1992). The population ratios of individual bacteria species also change according to available nutrients, for example the presence of proteins or peptides increase the NSC bacteria by as much as 18.7% (Russell *et al.*, 1992).

The composition of rumen micro-organisms is very important because 20% of the nutrients absorbed are synthesized microbial nutrients. Bacterial dry matter contains approximately 100g N/kg, 80% of this is in an amino acid form while 20% is in the nucleic acid N form (McDonald, 2002).

2.3.2 Energy requirement

The most commonly used energy measurement for ruminants is metabolizable energy (ME). Metabolizable energy is defined as total energy minus faecal energy, urinary energy and gaseous energy losses and is an estimate of the available energy to the animal (NRC, 2000). Immature beef cattle usually use more than 40% of their ME for maintenance, even when at their maximum energy intake. According to the definition of ME, it can only appear as heat production or retained energy (NRC, 2000). The net energy (NE) concept is predominantly based on this relationship mentioned above. Advantages of the NE system are that the different physiological requirements of the ruminants can be estimated separately. The requirements can be determined independent from the diet; for example, net energy for maintenance NE_m , net energy for growth NE_g , etc. Ruminant scientists such as Garrett (1980) have developed relationships for converting ME values to NE_m and NE_g values. The understanding of maintenance requirements is very important in successful management of beef cattle, whether for maximal production or survival in poor nutritive environments. Maintenance energy vary with breed, age, sex, temperature, season, physiological state, body weight and previous nutrition, therefore it also determines the dry matter intake of the animals (NRC 2000).

2.3.2.1 Factors affecting dry matter intake

The dry matter intake (DMI) has the most profound effect on animal growth (Jolly & Wallace, 2006). A relationship between DMI and dietary energy concentration has been established by researchers (NRC, 2000). It was found that consumption of less digestible, low energy diets is usually restricted by physical factors such

as ruminal fill and digesta passage rate due to the high fibre content in for example pastures and roughages. On the other hand the DMI of high digestible energy diets such as concentrated supplements are controlled by the animal's energy demands (NRC, 2000). When the terminology 'high digestible energy diets' is used, it refers to non-neutral detergent fibre polysaccharides (NFC) such as starch, sugar, pectin, organic acids, β -glucans, galactans and fructans, which are practically fully (90 to 100%) fermented (Van Soest *et al.*, 1991). Some of these NFC's will be discussed in 2.4.2 (Starch vs non-Starch supplementation). Factors regulating ruminant DMI are not completely understood, yet intake prediction models are empirically formed by nature. However, all of the following factors have an influence on cattle feed intake:

a) Physiological factors

Body composition is one of the main DMI determinants with body fat percentage being one of the more important components. It seems that adipose tissue has some kind of feedback role in controlling intake: the maintenance energy is 20% less in a very thin animal compared to very fleshy animals with the net energy for maintenance (NE_m) increasing 5% per body condition score (NRC, 2000). Therefore thin animals will have compensatory growth and fat deposition when placed on high energy diets. The compensatory growth and fat deposition will mainly be due to the decreased maintenance requirement and increased energy intake (Abdalla *et al.*, 1988; Byers *et al.*, 1989). Sex also has an influence, but differences rather appear to be due to the level of maturity, therefore feed intake is rather predicted using the parameter of frame equivalent weight (Fox *et al.*, 1988). Age also plays a role in DMI with younger animals consuming less feed per unit body weight (BW) than older ones. The physiological state of the animal can also cause feed intake increases with lactating animals consuming more than non-lactating animals with equal BW's.

b) Environmental factors

Temperature plays a major role in DMI. Many studies have shown that feed intake increases when temperature drops below the animal's thermo neutral zone and decrease above it (Kennedy *et al.*, 1986; Minton, 1987; Young *et al.*, 1989). Conditions such as wind, rain, mud, etc., also have an influence on ruminant energy use which influences DMI. Day length and seasonal change also have an influence. It is, however, difficult to evaluate the separate effects of temperature, day length, seasonal change and other environmental factors when animal variation and management differences can all contribute to performance differences (Hicks *et al.*, 1990).

c) Dietary factors

The quality and quantity of available pasture have a huge influence on pasture intake. Pasture with a higher DM content is less bulky and therefore rumen fill is not reached as readily as pastures with low DM contents (Kokkonen *et al.*, 2000). According to Botha *et al.* (2008) a NDF content of 50% and lower will have a positive effect on DMI and digestibility. In order for cattle to meet their requirements without too much energy expenditure, they have to harvest pasture efficiently. Energy expenditure by grazing cattle is determined by the following three factors; bite size (DM harvested with each bite), bite rate (bites per minute) and grazing time. Irrigated pastures usually supply maximum bite size, high bite rates and therefore grazing time is less than the average of 8 hours. The relatively short (12-15 cm) and dense sward of pasture helps to decrease grazing

time and energy expenditure (McDonald, 2002). Rayburn (1986) found that pasture intake was maximized when pasture availability was approximately 2250 kg/ha DM.

Foods with high digestibility promote higher intakes as the faster rate of digestion causes the digestive tract to empty more frequently and the next meal can then be started (McDonald, 2002). The fibre content also plays an important role in DMI because the amount of rumination (will be discussed in 2.3.6) are determined by the fibre content of the feed.

Different feed additives such as monensin can also have a reducing effect on dietary intake (Will be discussed in 2.4.3) (Fox *et al.*, 1988). Provision of nitrogen (e.g. urea) will also have an increased effect on DMI when a low protein, high fibre pasture is grazed (Galyean & Goetsch, 1993). Other dietary factors such as grinding or fermenting; for example in silage the DM content or undesirable fermentation can increase or decrease DMI (Milson, 2012). Summarised, the DMI is affected by digestibility, rumen outflow rate, fibre content, palatability and DM content of the feed (Manso *et al.*, 1998; McDonald, 2002).

2.3.2.2 Prediction of dry matter intake

According to the NRC (2000), initial animal weight, with adjustments to the intercept for certain frame sizes, sex and age, have shown to be responsible for 59.78% of the variation in DMI.

A heifer weighing 320 kg at one year of age will typically consume:

$$\text{DMI} = 3.212 + 0.01937 \times \text{Initial body weight (iBW)}$$

$$\text{Thus, DMI} = 3.212 + (0.01937 \times 320) = 9.41 \text{ kg DM per day}$$

It is important to keep in mind that these calculations only provide a guideline and not an absolute prediction because of all the factors mentioned above in 2.3.2.1 (Factors affecting dry matter intake).

2.3.3 Energy metabolism

The major part of carbohydrates are fermented in the rumen to pyruvate and converted to acetic, propionic and butyric acids. These volatile fatty acids (VFA's) are the prime energy source for ruminants and have different metabolism pathways (Russell *et al.*, 1992; McDonald, 2002). Butyric acid passes the rumen wall over the portal blood system as (D-) β -hydroxybutyric acid (BHBA) and is then transported to the liver. Acetic acid is also transferred over the rumen wall and together with BHBA it can be transported to various organs and tissues via the systemic blood from the liver (McDonald, 2002). Acetate and butyrate are efficiently used to fatten animals, but cannot make a contribution to glucose supply, while propionate can be used for gluconeogenesis in the liver where it then joins the liver glucose pool (Russell *et al.*, 1992).

Ruminant researchers suggest that meals can be terminated by signals via the vagus nerves from the liver to the brain. They suggest that these signals are affected by hepatic oxidation of fuels and generation of Adenosine triphosphate (ATP). Propionate is the primary satiety signal of the metabolized fuels in the liver due to its increased flux during meals. Propionate is utilized for glucose production or oxidized in the liver to

stimulate oxidation of acetyl CoA (Allen *et al.*, 2009). By oxidising, rather than exporting, the pool of acetyl-CoA increases ATP production and causes satiety despite glucose synthesis by propionate. Propionate inhibits β -oxidation during meals; the hypophagic effect of fatty acid oxidation in the liver is not necessarily from promoting satiety but rather from delaying hunger (Allen *et al.*, 2009). It can therefore be said that propionate decreases DMI according to the Hepatic oxidation theory.

2.3.3.1 Acidosis risk

An acidosis risk occurs in the rumen when energy dense rations with large amounts of rapidly fermentable starch and sugars are fed (Beauchemin & Penner, 2009). The rumen contains a group of Lactic acid bacteria (LAB) that produce lactic acid (La) and a group of lactic acid utilizers that ferment La to volatile fatty acids (VFA's) (Dunlop & Hammond, 1965; Owens *et al.*, 1998; Mills *et al.*, 2014). A drop in ruminal pH encourages the growth of LAB and inhibits the lactic acid utilizers, causing a spiral effect in reducing the rumen pH from an optimal value of 6.5 to below 5.5 and, in extreme cases to 2.5 – 3.0 (McDonald, 2002; Nagaraja & Titgemeyer, 2007). The occurrence of this imbalanced homeostatic condition is known as lactic acidosis. In this state, cellulose fermenting organisms do not attach to the fibre particles and if the time period of this lower pH is extended, the microbes would die and will wash out, and therefore cellulose degradation will be depressed (Hoover, 1986). Acute acidosis is caused by improper adaption to highly fermentable concentrates (Nagaraja & Titgemeyer, 2007), while subclinical acidosis is caused by an accumulation of VFA's (Beauchemin & Penner, 2009). The first and most observable sign of subclinical acidosis is reduced feed intake and it is therefore difficult to diagnose from other diseases. Possible indications of subclinical acidosis include the following: diarrhoea, panting, lethargy, excessive salivation, kicking at the belly and general signs of discomfort and stress. In order to prevent acidosis, either La utilizers have to be increased or La producers have to be decreased. For example a La utilizer such as *Megasphaera eldsenii* can be fed to beef cattle, reducing the La concentration and increasing the rumen pH. The supply of enough roughage or the inclusion of sodium bicarbonate can also prevent acidosis (Krause & Oetzel, 2006). Ruminant health, with regard to digesta flow, ruminal movements and pH can be achieved with as little as 10-15% forage included in the diet (Russell & Wilson, 1996).

2.3.4 Protein requirement

Protein requirements will vary according to the ruminant's different physiological stages. These requirements have to be met in order to ensure optimum growth and development, especially in young growing animals. Protein can be divided into three fractions; non protein nitrogen (NPN) e.g. urea, true protein or rumen degradable protein (RDP) e.g. oil seed cakes and rumen undegradable protein (RUP) e.g. fishmeal. Protein is usually expressed in terms of crude protein (CP). However, metabolizable protein (MP) is a better rationale for expressing protein requirement as it is the measurement of the true protein absorbed by the intestine which is supplied by microbial protein and RUP. CP is also based on an invalid assumption that all feedstuffs are degraded equally in the rumen and that CP are converted to MP with equal efficiencies in all diets (NRC, 2000).

In order to obtain optimal growth, rumen micro-organisms need sufficient ammonia, peptides and amino acids, and therefore their diet has to contain sufficient degradable protein. Degradable protein helps micro-organisms

to digest nutrients and increases the microbial nitrogen (Khandaker *et al.*, 2012). Diets that are too high in protein would result in energy wastage through the production of too much ammonia from excess protein. Microbial crude protein (MCP) supplies at least 50% of all the metabolizable protein (MP) required by beef cattle, depending on the diet RUP. Rumen undegradable protein is approximately 80% digestible, therefore ($MP_{\text{feed}} = RUP_{\text{intake}} \times 0.8$).

Non protein nitrogen (NPN), such as urea, can be converted to amino acids and true protein by the rumen micro-organisms. Urea increases the digestibility of cellulose and crude fibre and also the flow through rate in the rumen. Urea is also used in high grain diets as a source of readily available N because of the rapid rumen degradation of starch (NRC, 1984). Optimum use of rumen degraded protein and NPN occurs when both protein and carbohydrate degradation happens simultaneously. Unfortunately this does not always happen as protein degradation of forages is rapid while NDF (energy component of forages) degradation is much slower. The exact opposite happens in grain diets where rapid starch and slow protein degradation occur. The ruminant tries to compensate through nitrogen recycling, but cannot always do it efficiently therefore additional NPN enhances high grain diets. However, NPN has a less significant effect in low protein high forage diets (Clanton, 1978). The reduced gain when using urea and not a natural protein might be because of insufficient RUP and not the faster rate of rumen ammonia release (NRC, 2000). When energy intake exceeds maintenance requirements, the protein synthesis becomes the first limiting factor thereby causing fat deposition of excess energy (NRC, 2000). Sufficient protein is therefore necessary to ensure proper growth before excessive fat deposition.

The contribution of microbial crude protein to MP depends on the MCP yield. Synthesis of MCP is therefore very important in order to meet the protein requirements. According to Burroughs *et al.* (1974), MCP synthesis is 13.05% of total digestible nutrients (TDN) on average ($MCP_{\text{feed}} = 0.13 \times \text{TDN} \times \text{eNDF}$). Although this value is a good generalization, it does not fit either high or low feed digestibility scenarios. High digestible feeds (grain based) cause lower rumen pH values and slower bacterial turnover, resulting in low efficiency in converting fermented protein and energy to MCP. Low quality forage diets have lower MCP synthesis as more digestible energy is used for microbial maintenance and cell lysis due to slow passage rates (Russell & Wallace, 1988). Microbial crude protein is assumed to be 80% true protein and 80% of this true protein is digestible, therefore $MP_{\text{bact}} = MCP \times 0.64$ and $MP_{\text{tot}} = MP_{\text{bact}} + MP_{\text{feed}}$. According to Susmel *et al.* (1994) the estimated protein maintenance requirement for cattle is 3.8g MP/kg $BW^{0.75}$ when the above assumptions are applied (NRC, 2000). A validation for finishing beef cattle was reported by Wilkerson *et al.* (1993) where cattle received diets from 90% low quality roughage to 90% concentrate, with ADG that varied from 0 to 1.5 kg. The validation data set resulted in a required MP maintenance of 3.8 x $BW^{0.75}$ g/day. It is very difficult to validate data where energy intake increases with protein supplementation as it is then unknown if the growth results are due to an increase in MP or NE_g . Validation with finishing diets containing high grains are also very difficult; for example maize has a CP content of 8-10%, but approximately 60% of the protein escape during ruminal digestion (NRC, 2000).

2.3.5 Protein metabolism

Post-rationally proteins are digested to monomers or polymers of amino acids and small peptides. These amino acids and peptides are absorbed into the portal blood system by the intestinal villi and are transported to the liver to join the amino acid pool. From there they are used for protein synthesis *in situ* or they may go into the systemic blood. Catabolism of tissue also produces amino acids in the systemic blood which are then provided as raw materials for protein synthesis and other biologically important (nitrogen containing) activities. Excess amino acids are transported to the liver and broken down to ammonia and keto acids. This ammonia is then mainly transformed to urea (at an ATP cost) and excreted in the urine or recycled in the saliva (McDonald, 2002). The rate of protein degradation varies, for example proteins found in forages and soybeans are very soluble and rapidly degraded while distillers by-products, fish meal and brewers grain is insoluble (Russell *et al.*, 1992). However heat treatment can decrease the rate of protein degradation through the denaturation of proteins in the feeding sources.

2.3.5.1 Nitrogen balance

An optimum nitrogen balance has to be achieved in all ruminants to maintain growth, pregnancy and lactation. The nitrogen balance requires a wide range of adaptive responses to supply different physiological processes with the necessary nitrogenous metabolites. The gastrointestinal tract and liver play key roles in the supply of these specific nitrogenous nutrients to the peripheral tissues. An interface between the intake and the requirements of the ruminant are formed by the gastrointestinal tissue. The flux of nitrogenous nutrients obtained from the gut lumen into the blood stream is directly influenced by the gastrointestinal tissue. The liver forms the central metabolic junction for productive functions such as muscle deposition, etc. (Abdoun *et al.*, 2006). Ammonia is generated as a result of hydrolysis of urea from the blood and as a result of saliva and microbial degradation of protein, peptides, amino acids and nucleic acids.

Soluble nitrogenous compounds of either concentrate or forage-based diets and, particularly silage based feeds, are rapidly degraded in the rumen and results in peak ammonia concentrations of 18-20 mM from base levels of 2 - 4 mM. These levels can be decreased by including acid formaldehyde to reduce N solubility before ensilage (Thompson *et al.*, 1981) or by providing readily fermentable carbohydrates such as maize to supply energy for the rumen micro-flora in order to capture N (Rooke *et al.*, 1987). It is important that fluctuations of ammonia be minimized between the optimal values of 3.5 mM (Satter & Slyter, 1974) and 6 mM (Kang-Meznarich & Broderick, 1980) in order to optimize microbial protein production from N and minimize loss of rumen ammonia across the gut wall. Fifty percent of all dietary N entering the rumen would have already passed through the rumen; recycling through the rumen ammonia nitrogen (NH₃-N) pool (Abdoun *et al.*, 2006).

2.3.6 Fibre requirement

All ruminant feeds require a fibre fraction. Fibre is a non-starch polysaccharide that cannot be digested by monogastric enzymes, but only by the rumen micro-organisms (Buxton & Redfearn, 1997). The structural fibre fraction can be nutritionally defined as the slow digestible fraction of the feed and also includes most of the indigestible matter. The fibre fraction plays an important role to ensure a healthy rumen environment (Mertens,

1997). The structural fibre content also determines the time spent on rumination; in grazing cattle rumination time is about equal to the time spent grazing, around eight hours per day (McDonald, 2002).

Fibre can be chemically divided into neutral detergent (NDF) and acid detergent fibre (ADF); both of which are inversely related to energy density (Kawas *et al.*, 1991). Neutral detergent fibre consists of cellulose, lignin and hemicellulose and form part of the slowly digestible fraction, while ADF represents the indigestible fraction consisting of lignin and cellulose (Smith, 2008). Neutral detergent fibre measurements are generally used to describe and formulate feeds because it includes all the insoluble fibre. However, NDF is still a chemical component and does not say much about the fibre effectiveness to stimulate rumination. The particle size of fibre has a significant effect on the chewing activity and rumen health as it determines the physical effectiveness of the NDF (peNDF; Mertens, 1997).

When cattle graze, the pasture would increase the peNDF intake and would also increase the time spent ruminating because of the roughness and particle size. More rumination results in more saliva secretion reaching the rumen fluid and therefore more phosphate and bicarbonate are available to buffer the rumen pH (Mertens, 1997). Acidosis can be prevented through the supply of sufficient roughage and also the inclusion of sodium bicarbonate (Krause & Oetzel, 2006).

2.3.7 Mineral requirements

Cattle require both macro and micro minerals. Macro minerals required include calcium, phosphorus, potassium, magnesium, sodium, chlorine and sulphur. Required micro minerals that play a role in maintaining equilibrium in the body include cobalt, copper, chromium, iodine, iron, molybdenum, manganese, selenium, nickel and zinc, while the following minerals do not have evidence to have practical importance in beef cattle; arsenic, boron, lead, vanadium and silicon (NRC, 2000). It is however, important not to oversupply minerals, as possible environmental problems might occur from the excess minerals that are excreted by the cattle. Toxicity in beef cattle can also occur through excess or unwanted elements. The most abundant mineral in the body is Ca, with an approximate 98% structural function. Phosphorous works together with calcium in bone formation with 80% of phosphorus being found in bones and teeth, the ratio between these two have been overemphasized in the past and does not play a big role (Alfaro *et al.*, 1988). Phosphorous also plays a major role in the metabolism within the cell (e.g. a core function in ATP synthesis) as well as various other functions such as reproduction. Phosphorus is generally the first limiting mineral in South African pastures and the supplementation thereof results in improved cow fertility and higher weaning weights of calves (Dunn & Moss, 1992).

2.3.8 Growth and development rate of beef cattle

All farm animals have a sigmoidal growth curve post-natal. According to their growth patterns there are three phases. During the first phase animals have a slow growth rate, after which they enter a faster growth rate until puberty. After puberty growth rate declines again and reaches a plateau at maturity (Lawrie & Ledward, 2006). Younger animals in the second phase of growing will have the best feed conversion ratio (Figure 2.2). From economical perspective it is therefore very important to supply cattle with concentrated diets from the

right time up until just before their body growth rate decreases too much and fat composition increases too rapidly. Towards the end of the third phase, protein accretion decreases while fat deposition increases up to approximately 36% of carcass weight (Owens *et al.*, 1995). The high requirement needed for fat deposition will make it economically unviable to keep on feeding during the third phase of growth, especially with South Africa's beef classification system which penalises excess fat deposition.

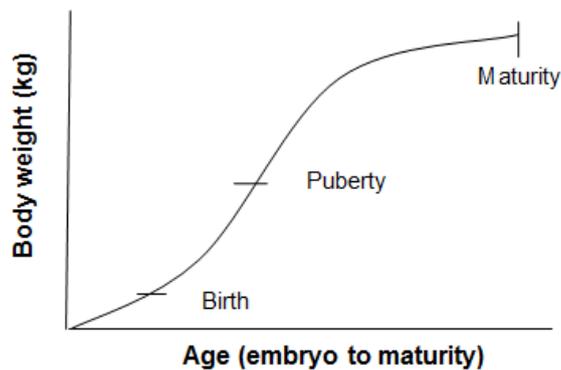


Figure 2.2. Sigmoidal growth curve of beef cattle from birth to maturity

The most important hormone determining growth is growth hormone (GH). It is secreted from the hypothalamus and its influence is of major importance in young animals. When animals become more mature, the GH concentrations decrease and the secondary sexual hormones start to play a more prominent role in body growth (Batt, 1980). The inflection point in Figure 2.2 indicates that the growth rate is starting to decrease; it also indicates the age of puberty (on the x-axis). Beef heifers are expected to reach puberty at ~60% of mature weight (Stewart *et al.*, 1980). The inflection point can therefore be used to determine the maturity differences between breeds and genders. The diets of heifers also has an influence on the age of puberty for example, crossbred Angus-Hereford heifers reached puberty at 433, 411 and 388 days, while being fed to gain 0.27, 0.45 and 0.68 kg/day, respectively (Short & Bellows, 1971). This also supports Stewart's statement of puberty being reached at a 60% of mature weight, although numerous data indicates that a threshold value of both age and weight has to be reached in order to initiate puberty.

The different tissues in cattle also have different growth coefficients; bone 0.82, muscle 1.05 and fat tissue 1.08 (Berg & Butterfield, 1976) although, it should be remembered that the growth coefficients are relative to a specific time of maturity. In an animal that is post puberty, this implies that while the body weight increases the bone % decreases, muscle % slowly increases and the fat % increases the most in relation to total weight gain. The fat tissue is therefore the last tissue to mature and bone the earliest. There are also different fat deposit areas which have different maturity levels. Arranging them from earliest to latest matured they will be anabolised as follows: kidney and channel fat first then subcutaneous fat, intermuscular fat, and lastly intramuscular fat. The fat depositing is however highly integrated with fat being deposited simultaneously in different depots. As inter-and-intramuscular fat is deposited at the last anabolic phase, they will also be catabolised first when starvation, sickness or any stress appears (Swatland, 1984).

The South African feedlot industry prefers to feed medium maturing breeds, as they can be fed to a heavier carcass before an excess of fat is deposited. The feedlots also prefer bull or steer calves above heifers because of their later maturity rate. Abattoirs, however, prefer heifers as they have heavier back quarters compared to steers and bulls due to the secondary sexual hormone effects. They will therefore have a larger proportion of high quality expensive meat (Bures & Barton, 2012). In feedlots, late maturing cattle are favoured especially when low feeding cost and high beef prices occur. South African cattle normally get slaughtered at a stage when the percentage of intermuscular fat is still much lower than the subcutaneous fat. On average only a small percentage of intramuscular fat (1%) is found in beef slaughtered in South Africa, compared to 3-7 % intramuscular fat in the USA; the latter tend to slaughter their feedlot animals at an older age than South Africa. The USA has a grading system with two different descriptions namely: 'Quality grade' and 'yield grade'. The yield grade can be compared to South Africa's classification system while the quality grade has a direct relation with the percentage intramuscular fat, also called marbling fat (Tatum & Collins, 1997).

2.3.9 Bonsmara cattle in general

Bonsmara cattle are a cross breed that was developed and is well established in South Africa. Professor Jan Bonsma developed the breed from crossing the Afrikaner 5/8 (*sanga*-type), Hereford 3/16 and Shorthorn 3/16 (both *taurine*-type) in 1964 (Mostert & Exley, 2000). Since then the breed has grown tremendously, being the leading commercial farmed breed in South Africa (Maiwashe *et al.*, 2002). The Bonsmara is well adapted to the extensive regions of South Africa. It has a high natural resistance against many diseases with the indigenous Afrikaner accounting for the largest portion of the breed composition. With its smooth coat it is not easily susceptible to tick borne diseases. Bonsmara cattle are classified as a medium maturing breed (Maiwashe *et al.*, 2002). Depending on their DMI and nutrition composition, Bonsmara heifers can be slaughtered at about 400 kg according to South African consumer demands.

2.4 Supplementation

2.4.1 Beef cattle supplementation on pastures

The ultimate purpose of supplementation on pasture is to overcome the relative low total DMI and energy intake of cattle subjected to pasture only diets (Stockdale, 2000). Supplementing concentrates increases the total dietary energy. When concentrates are supplemented on pastures, rumen N deficiency is less of a problem while rumen pH and buffering becomes more important. The concentrate is usually provided in restricted quantities as it acts as a substitute to the pasture which is the cheaper feeding source (Bargo *et al.*, 2003).

Energy supplementation for grazing ruminants is usually performed to either stretch inadequate pasture supply or increase livestock performance. When concentrates are fed to improve livestock growth performance, the quality of forage, type of concentrate and the amount of concentrate fed are the main determinants of growth rate. Lower quality pasture results in more rumination and the effect of energy supplements on rumen pH will be reduced by rumen buffering. Therefore greater amounts of readily fermentable carbohydrates (RFC) (e.g. maize supplementation) can be fed without a dramatic drop in the rumen pH. High quality pasture with low

fibre values is mainly used for intensive cattle finishing systems because smaller amounts of concentrates are required to increase energy density. If excess RFC is fed, an excess of volatile fatty acids (VFA) will be produced decreasing the rumen pH due to a lack in buffering capacity (Ranathunga *et al.*, 2010). High quality pasture is ruminated less and fermented more rapidly therefore, less saliva will be secreted resulting in a lower rumen pH. A decrease in fibre digestion and/or washout of cellulolytic bacteria might also occur (Ranathunga *et al.*, 2010). The particle length of grazed pastures has an optimal length when compared to the forage fraction in TMR; the length of the particles also plays an important role in the buffering of the rumen as discussed in 2.3.6 (Fibre requirement).

2.4.2 Starch vs non-Starch supplementation

2.4.2.1 Classification of carbohydrates

Carbohydrates consist of sugars and non-sugars. Sugars can be divided into monosaccharides with subgroups: trioses ($C_3H_6O_3$), tetroses ($C_4H_{14}O_7$), pentoses ($C_5H_{10}O_5$), hexoses ($C_6H_{12}O_6$), heptoses ($C_7H_{14}O_7$) and oligosaccharides (disaccharides, trisaccharides and tetrasaccharides). In general the term “sugar” refers to carbohydrates that contain less than ten monosaccharide residues, while oligosaccharides include all sugars other than monosaccharides (McDonald, 2002).

Both polysaccharides and complex carbohydrates are classified as ‘non-sugars’ (Figure 2.3). Polysaccharides, also called glycans, are polymers of monosaccharide units and complex carbohydrates are divided into glycolipids and glycoproteins. Polysaccharides are polymers of monosaccharides and can be divided into homoglycans, containing only a single type of monosaccharide unit, and heteroglycans, which contain mixtures of monosaccharides and derived products after hydrolysis. Starch, dextrans, glycogen, cellulose and callose form part of the glycan group homoglycans (McDonald, 2002).

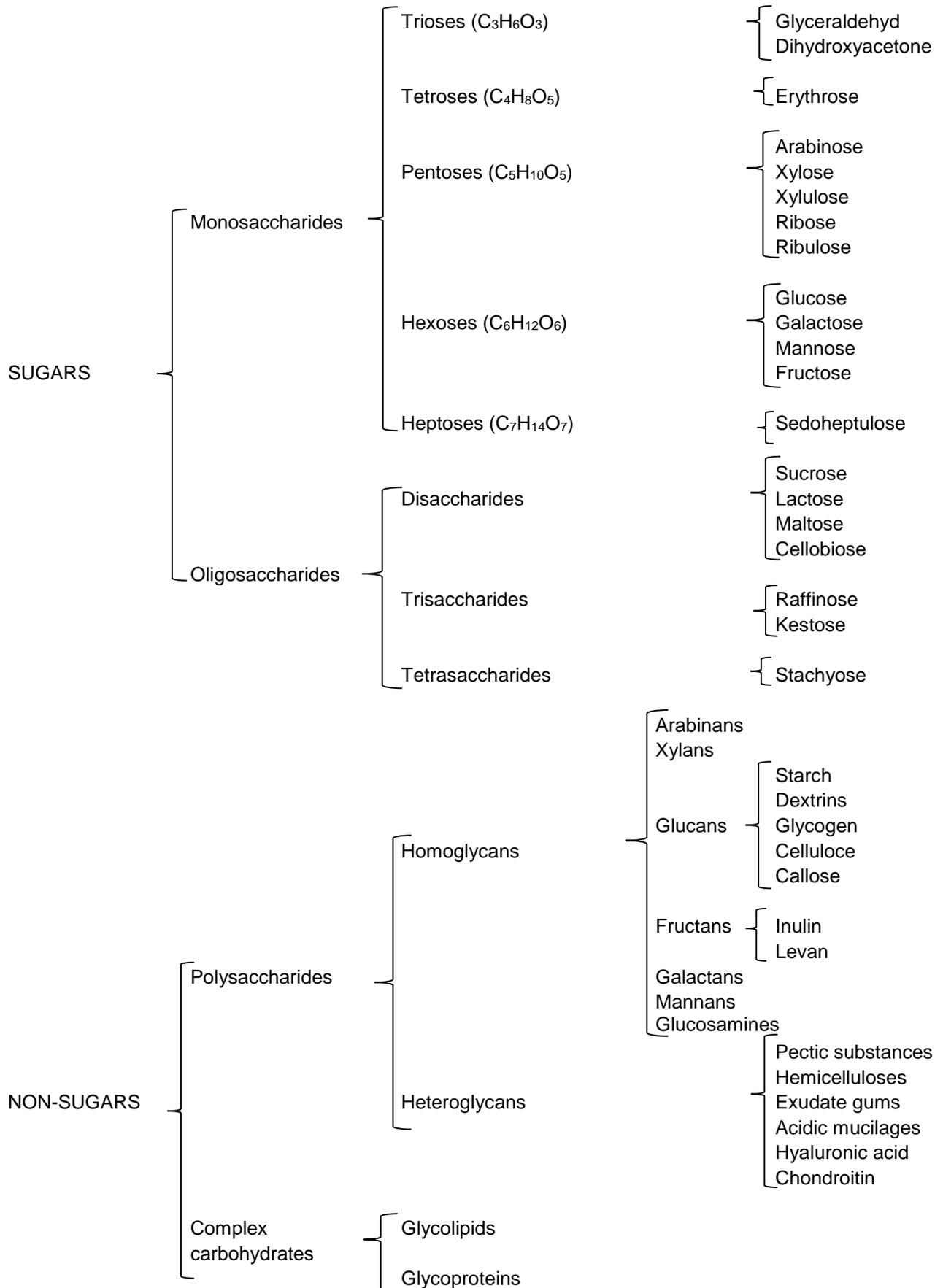


Figure 2.3. Classification of carbohydrates (McDonald, 2002)

2.4.2.2 Digestion of carbohydrates

Ruminant diets mainly consist of celluloses, hemicelluloses, starch and carbohydrates. All carbohydrates except for lignin are attacked by rumen microbes. Carbohydrates are first broken down to simple sugars in the rumen. This is done by the extracellular microbial enzymes that give ruminants the ability to break down for example cellulose to cellobios with β -1,4-glucosidases, which can then be converted to glucose (McDonald, 2002). Starch is also first transformed to maltose and isomaltose by amylases and then to glucoses or glucose-1-phosphate by maltase, 1,6-glucosidases or maltose phosphorylases. Micro-organisms immediately consume and metabolize any simple sugars coming from the first stage carbohydrate digestion therefore, they are rarely detected in the rumen liquor (McDonald, 2002). The fermentation rate and digestibility of starch can be very variable with influences such as feed treatment (for example grinding rolling and pelleting), storage method (for example silage vs dried shell maize) and the type of serial grain used (barley vs maize) (Orskov, 1976).

Pyruvate is the key intermediate between the pathways shown in

Figure 2.4. Propionate production is achieved reached through several pathways; When cattle diets mainly consist of roughage, the pathway through succinate is mainly employed while the lactate and acrylate pathways dominates when concentrate diets are consumed. When less matured forages are consumed lower proportions of acetate and higher portions of propionate are produced. When total mixed rations (TMR) are consumed propionate may exceed acetate proportions (McDonald, 2002).

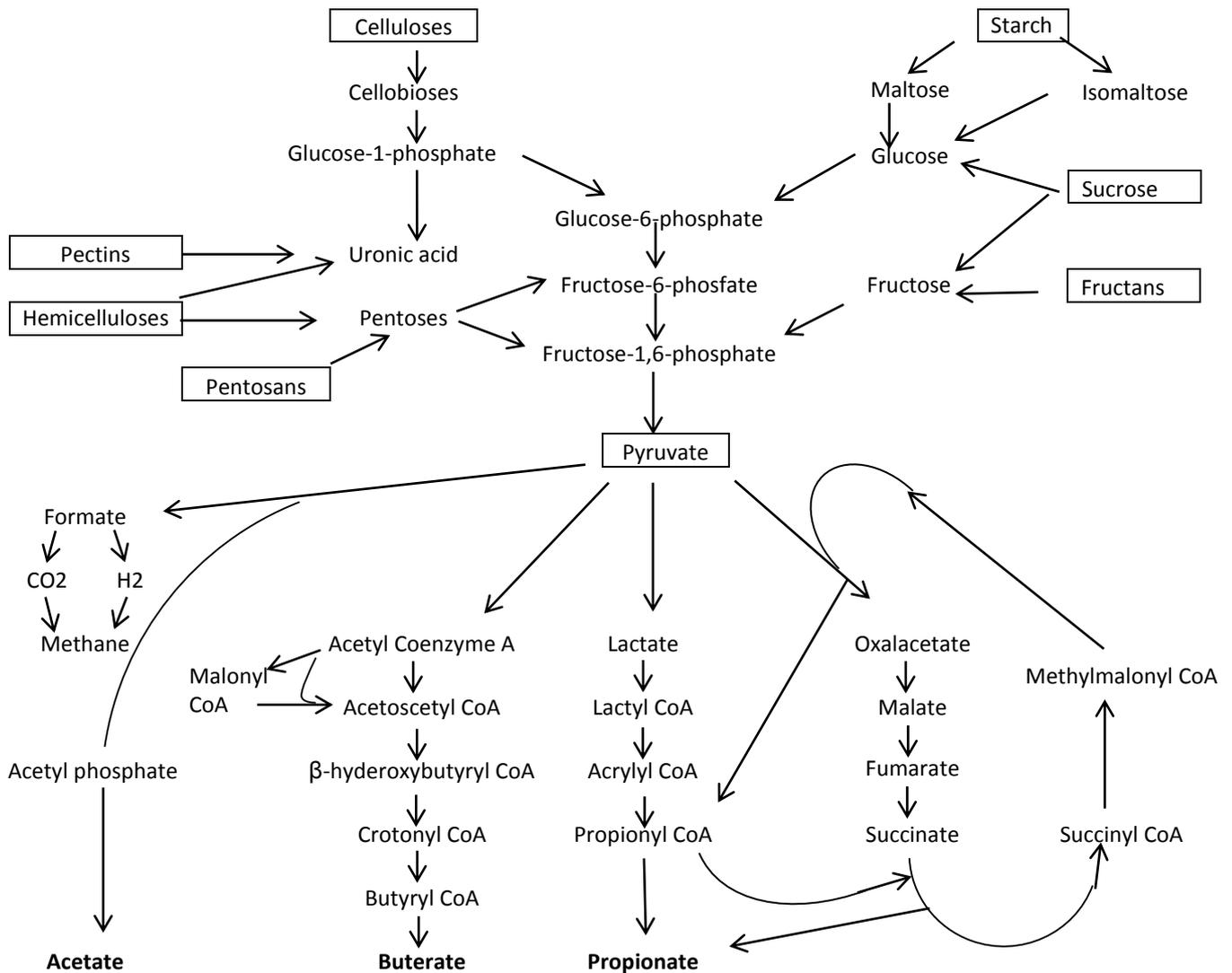


Figure 2.4. Fermentation of carbohydrates to pyruvate and pyruvate to volatile fatty acids in the rumen

One of the by-products of carbohydrate fermentation is gas excretion. Immediately after a meal cattle excrete gasses (up to 30 L/h) that mainly contain carbon dioxide (40%) and methane (30 - 40%). Ruminants can lose up to 7% of their consumed energy as methane (McDonald, 2002). From a greenhouse gas point of view it is said that livestock production contributes up to 18% of the global greenhouse gas emissions (Finweek, 2015).

The consumption of the three most common Non-neutral detergent fibre polysaccharides (NFC) is discussed below:

a) Starch

Starch is mostly found in grain cereals with a large variation in starch digestion between different grains. For example starch in maize is only fermented 40%. This is much less than barley, wheat or oats fermentation (90%) (Orskov, 1986). Orskov (1986) noted that ruminants cannot utilize the VFA production of starch at 90% fermentation. It is very important to process grains because the grains cannot be digested by the micro-organisms if the pericarp is still present (Huntington, 1997). The micro-organisms will only penetrate the whole

grain after a few days if it was not cracked during chewing or rumination. If maize is not processed, up to 30% of the grain will be found in the faeces (Orskov, 1986). As processing (for example grinding) increases the digestibility it is important to remember that the increase in fermentation rate might lead to metabolic disorders. Starch digestion depends on the starch source, amount of feed consumed, dietary composition, processing and adaption of rumen microbes (Huntington, 1997).

b) Pectin

Pectin is found in legumes, grass forages (low levels), beet citrus apple and other pulp. The fermentation rate of pectin does not vary as much as starch and sugar because it is not affected by the carbohydrate quality and origin source of sugar (Van Soest *et al.*, 1991). Pectin has a very high fermentation rate and intestinal bacteria can degrade 99% of pectin administered abomasally (Grassley & Armentano, 2005). Because of the galacturonic acid structure, pectin does not yield lactic acid, it also does not affect cellulose digestion. Therefore pectin is able to provide a stable buffered rumen environment, notwithstanding the high fermentation rate (Van Soest *et al.*, 1991). The micro-organisms that digest pectin are particularly sensitive to pH fluctuations, even more than starch and sugar microbes (Strobel & Russell, 1986). A study by Sparkes *et al.* (2010) showed that the inclusion of pelleted citrus pulp increased DM digestibility linearly, whereas forage DM and total NDF was unaffected. A faster passage rate could be the explanation for this. Grassley & Armentano (2005) noted that pectin decreases urinary nitrogen and increases faecal nitrogen, which indicates that pectin increases energy supply for microbial growth.

c) Sugars

Sugars are degraded promptly by rumen microbes, resulting in an increased passage rate. Sugars, such as found in molasses, can be included in diets to increase the utilization of non-protein nitrogen (NPN/Urea) or rapid soluble proteins (Hoover *et al.*, 2006). Bacteria present in the large intestine utilise the rapidly available energy which may increase the rumen degradable protein requirement to digest fibre (Grassley & Armentano, 2007). Many studies have shown that sugars decrease the rumen pH, but the mean is usually above the cellulolytic threshold, with pH dropping below 6 only for short time periods (Migwi *et al.*, 2011). Despite this pH drop below 6, the DM and organic matter digestibility still increased. When the time period spend below a pH of 6 is not significant, no negative effects would be observed in terms of the cellulose activity of the rumen microbes. Migwi *et al.* (2011) also found that sucrose results in a decreased digestibility, not because of a drop in pH but because of the easily fermentable carbohydrates present. Hoover *et al.* (2006) stated that sucrose is less digestible than starch, therefore fewer carbohydrates will be available when starch is supplemented with sucrose.

2.4.3 Monensin as feed additive

Monensin is a carboxylic polyether ionophore that is produced by a natural strain of *Streptomyces cinnamonensis*. Monensin is a product that is approved for inclusion in cattle feeds when used at levels between 50 and 360 mg per day in the USA. Most of the monensin research has been done under feedlot conditions. Goodrich *et al.* (1984) found that diets containing monensin resulted in 1.6% faster growth rates and 6.4 %

less feed consumed than the control in a feedlot study with 16 000 cattle. However monensin is also approved for increasing the rate of gain in pasture cattle at a daily feeding level of 200 mg (NRC, 1984).

2.4.3.1 Mode of action

Ionophores are potent antibiotics against gram-positive bacteria. Ionophores work through a mechanism that channels ions through cell membranes which have a particular effect on microbial cells (Bergen & Bates, 1984). Energy and protein utilization in the rumen can be more efficient when the microbial population is manipulated. Monensin is the antibiotic ionophore (active compound) in Rumensin; it has the ability to improve energy utilization in the rumen and feed intake (Van Nevel and Demeyer, 1988). Monensin influences the production of volatile fatty acids (VFA) in the rumen by increasing the propionic proportion whilst reducing butyrate and acetate levels (NRC, 2000). Monensin also prevents and controls coccidiosis in the intestinal environment by killing it at three different stages in its life cycle (Elanco, 2015).

In vivo experiments with monensin showed propionate increases of 49% and 76%, respectively, for high roughage and high concentrate diets when compared to standard concentrates (Van Maanen *et al.*, 1978). Fermentation studies by Horn *et al.* (1981) showed that ruminal fluid pH increased and VFA concentrations at 4 and 24 h post feeding decreased in steers receiving monensin (200 mg/day). They also found that the propionate ratio of the steers was decreased by 40%. Metabolisable energy (ME) values of feeds should increase with consumption of ionophores because more efficient capturing of feed energy in ruminal fermentation is obtained and less methane is produced.

Monensin increased the efficiency of energy used for maintenance by 5.7% in a comparative slaughter trial (Byers, 1980). According to the NRC (2000), ionophores increase the efficiency of NE_m by approximately 12%. Monensin reduces fasting heat production and NE_m values to a greater extent than it decreases dietary NE_g . Several studies with both high and low concentrate diets found increases in feed efficiency and BW gain, while dry matter intake decreased (Goodrich *et al.*, 1984; Raun, 1990). Fox *et al.* (1988) stated that feed intake will decrease with 10 and 6% respectively when monensin is applied at 33 and 22 mg/kg feed. Monensin also has a reduced effect on lactic acid production (Goodrich *et al.*, 1984). According to Dinius *et al.* (1976) and Van Nevel & Demeyer (1977), ionophores decrease ammonia production *in vivo* and *in vitro* but both teams of authors mentioned that it had little effect on proteolysis.

Hobson & Stewart (1997) reported that monensin has not only been proven to be effective in improving the efficiency of energy utilization but also that of protein utilization. According to Poos *et al.* (1979), this might happen because monensin slows protein degradation and inhibits bacterial protein syntheses. Goodrich *et al.* (1984) also noted that monensin has a protein sparing effect. Retention of the following minerals has been increased in monensin fed concentrates: phosphorus, zinc, magnesium, selenium and nitrogen while inconsistent effects on sodium, potassium and calcium were recorded (Spears, 1990).

In conclusion, it can be said that protein, energy and mineral feed values (specifications) may be influenced by monensin in cattle (NRC, 1984).

2.4.4 Essential oils as feed additives

Public concern regarding antibiotic use in livestock production has increased tremendously during the past few years. Possible contribution of resistant strains of bacteria and also their transmission from livestock to humans are issues commonly mentioned in health research. Numerous studies on essential oils (EO) to investigate the possibility of modifying the rumen microbial population have commenced after the EU announced the banning of antibiotics as feed additives (Calsamiglia *et al.*, 2007). After the banning, numerous studies tried to manipulate the rumen microbial population in order to be more efficient, searching for results that could be comparable with ionophores. A positive outcome of these studies was an increase in propionate and a decrease in acetate, ammonia and methane production in the rumen, without reducing the total volatile fatty acid (VFA) production (Calsamiglia *et al.*, 2007).

Plant extracts contain secondary metabolites such as saponins, tannins and EO (Wallace, 2004). These secondary metabolites have antimicrobial activities that make them potential alternatives to manipulate microbial activity and therefore improve nutrient utilization in the rumen (Wang *et al.*, 1996; Hristov *et al.*, 1999). Essential oils with their antimicrobial activities are currently considered safe for human and animal consumption and are categorized as GRAS (Generally Recognized as Safe; FDA, 2004) in the USA (Calsamiglia *et al.*, 2007). According to Benchaar *et al.* (2008) EO appears promising as a feed additive in ruminant nutrition for the improvement of feed efficiency and the control and spread of pathogens in livestock. Essential oils have a wide variety of effects on a ruminant's health. However, the most important aspects of these compounds are their antiseptic and antimicrobial properties (Burt, 2004).

Ruminant nutritionists were initially interested in EO mainly for its role in reducing the palatability of some plant species (Oh *et al.*, 1967). Later studies by Nagy & Tengerdy (1968) investigated the effect of EO on rumen microbial fermentation and discovered that the EO extract used inhibited activity of ruminal bacteria *in vitro*. Since then large numbers of *in vitro* studies have been done to examine the effect of EO and their active compounds on rumen microbial fermentation. These *in vitro* batch culture studies provided evidence that EO's and their components have the potential to improve feed efficiency and nutrient utilization by improving N and/or energy utilization in ruminants (Benchaar *et al.*, 2008). However, most of the studies have only been done *in vitro* and still need to be confirmed by *in vivo* studies. Hristov *et al.* (2012) stated that differences between *in vitro* systems and the living rumen do sometimes exist. It is argued that it might be due to the rumen's much greater adaption and recovery potential against intensive inhibitors such as carvacrol and also the rumen's buffering potential against environmental stressors.

Although only a limited number of EO's and EO components have been evaluated to date there is an indication of possible effective growth promoting activities in ruminants. According to Van de Braak & Leijten (1994) there are more than 3000 EO's available for experimentation which makes them difficult to evaluate. Large inter and intra species variations in experimental animals also complicate the evaluation of essential oils. Large variation in application rates and also the compilation of the feeds used makes it challenging to compare results from different studies (Calsamiglia *et al.*, 2007).

2.4.4.1 Extraction of essential oils

Steamed distillation or solvent extraction is used to extract essential oils obtained from the volatile fraction of edible, medicinal and herbal plants (Simon *et al.*, 1990; Greathead, 2003). Extraction is possible due to the volatility of the aromatic compounds in plants. The EO's can be extracted from nearly any part of a plant including the root, bark, stem, flower, leaves and seeds. The composition of the EO can, however, differ among the different parts of the plant (Dorman & Deans, 2000). Essential oils are a blend of the secondary metabolites in plants. They can be classified into two chemical groups synthesized through separate pathways, namely terpenoids, the more diversified and numerous group which is derived from an isoprenoid structure (C₅H₈) and phenylpropanoids, which are derived from a three carbon bound to an aromatic ring of 6 carbons (Calsamiglia *et al.*, 2007). Both terpenoid and phenylpropanoids developed their action against bacteria by interacting with the cell membranes (Griffin *et al.*, 1999; Dorman & Deans, 2001).

Leakages of ions across the cell membranes appear because of these interactions which cause ionic gradient distractions (Griffin *et al.*, 1999). As a result of this action, EO's are effective against gram positive bacteria where the cell membrane directly interacts with hydrophobic compounds of EO (Calsamiglia *et al.*, 2007). However, in contrast with monensin and other ionophores, the small molecular weight of most EO's allows them to cross the external hydrophilic cell wall of gram-negative bacteria (Griffin *et al.*, 1999; Dorman & Deans, 2000). This property of being active against a broad range of gram-positive and negative bacteria (Helander *et al.*, 1998; Elgayyar *et al.*, 2001) makes the selectivity of these compounds against specific populations more difficult in the modulation of rumen microbial fermentation (Calsamiglia *et al.*, 2007).

Oregano is an EO product that mainly consists of the monoterpenoids, carvacrol and thymol. Carvacrol and thymol have phenolic structures (Figure 2.5). Due to their hydroxyl group in their phenolic structure they are more effective than antimicrobials with non-phenolic secondary plant metabolites (Helander *et al.*, 1998; Ultee *et al.*, 2002). Most of the current research is focused on improving the ruminal N and energy utilization with EO combinations such as carvacrol and thymol (Calsamiglia *et al.*, 2007).

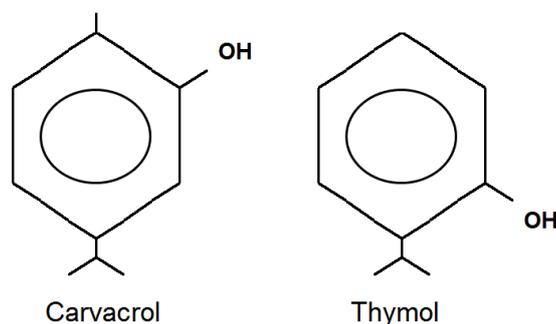


Figure 2.5. Monoterpenoids of the essential oil oregano; carvacrol and thymol

2.4.4.2 Selection and combination of essential oils

Appropriate EO's have to be selected carefully as EOs may act at different levels of protein and energy metabolic pathways (Calsamiglia *et al.*, 2007). Nutritionists and rumen microbiologists believe that the right

combination of EO's may provide a useful tool to manipulate the microbial fermentation in the rumen as the chemical composition of EO do have an influence on the activity of ruminal micro-organisms (Benchaar *et al.*, 2008). Oregano oil is one of the most popular EO's because it contains a combination of carvacrol and thymol. A specific oregano product, Dosto 500, has been developed which can be safely used in the following animals: pigs, poultry, ruminants, calves, lambs, foals, goat kids and rabbits. One of Dosto's main characteristics is that it said to be appetite stimulating (Dostofarm, 2015).

2.4.4.3 The influence of carvacrol and thymol on rumen fermentation

Thymol and carvacrol have very small molecular weights which allow them to gain access through the pores of external walls into the cell membranes of bacteria. Therefore thymol and carvacrol have a strong and wide spectrum activity against gram negative and positive bacteria. This wide spectrum of activity can explain why such a narrow margin between optimal and toxic doses appear and why study results are not always as desired. Castillejos *et al.* (2006) suggested that the antibacterial activity of EO may be too non-specific and strong to manipulate the fermentation of a complex microbial environment such as the rumen.

2.4.4.4 Previous results of EO's

An *in vitro* study by Busquet *et al.* (2005a) found that carvacrol (2.2 mg/L) increased ammonia-N and decreased peptide concentrations two hours after feeding which indicates that it either stimulated peptide lyses or inhibited proteolysis. When doses were increased (300 mg/L), the pH and butyrate proportion increased while acetate and propionate proportions decreased; however the total volatile fatty acids (VFA) concentration also decreased. Results indicating that thymol inhibits deamination were reported by others (Borchers, 1965; Broderick & Balthrop, 1979). More recently, Evans & Martin (2000) observed that thymol affected energy metabolism of some rumen bacteria (*Streptococcus bovis* and *Selenomonas ruminantium*) grown in pure culture. It also reduced lactic acid and methane concentrations when applied at low doses. Unfortunately, it also inhibited total microbial metabolism by reducing the total VFA produced and overall nutrient digestion. Moderate doses did, however, result in an increase in the acetate:propionate ratio. Castillejos *et al.* (2006) reported that thymol had no effects on rumen microbial fermentation at low doses (50 mg/L) while higher doses (500 mg/L) decreased the ammonia-N concentration and total VFA, whilst also increasing the acetate propionate ratio.

Applying EO as feed additive is unfortunately not as straightforward as Brochers (1965) suggested. Several *in vivo* studies suggested that the effect of thymol is dependent on the diet and the rumen pH (Cardozo *et al.*, 2005; Castillejos *et al.* 2006). Castillejos *et al.* (2006) found that thymol increased the acetate to propionate ratio at a high pH of 6.4 with a 60, 40% lucerne hay -concentrate diet. On the other hand, Cardozo *et al.* (2005) reported a reduction in the acetate to propionate ratio when thymol was nurtured in rumen fluid with a low pH (5.5) from cattle fed a 10, 90% straw:concentrate (corn, barley and soybean meal based) diet. The optimum inclusion level of EO and their components is still unknown due to their complexity and variability in composition which leads to differing results (Benchaar *et al.*, 2008).

In conclusion it can be seen that these different results complicates quantifying the specific effect of EO and their active components, the inclusion levels thereof and the specific formulated feed it is included in. However, some EO's do modify rumen fermentation by influencing VFA production and/or protein metabolism at doses between 50-500mg/L (Calsamiglia *et al.*, 2007). According to the fermentation profile, inhibition of methanogenesis and deamination appears to be the main mechanism, but these effects might be due to diet and pH differences. This, however, does not exclude the possibility of potential synergies that might occur, based on the mechanisms of action of different active components on nutrient degradation and fermentation in the rumen (Calsamiglia *et al.*, 2007).

It is necessary to set an exact definition of the activities that have to be modified. A combination of EO's or their active compounds have to be selected accordingly in order to make a possible nutrient utilization efficiency improvement in the rumen. It is therefore important that more *in vivo* studies have to be conducted to determine the effect of different EO's on ruminant performance.

2.4.5 South African beef classification system

2.4.5.1 Carcass classification

Carcass classification in South Africa is according to age, fatness, conformation, damage and sex. Fat classification is based on the visual appraisal of subcutaneous fat (classes 0 to 6) cover and depth where: Class 0 indicates no fat, 1: very lean, 2: lean, 3: medium, 4: fat, 5: slightly over fat and 6 indicates excessively over fat (

Figure 2.6) (SAMIC, 2015). The age classification is divided into four classes (A, AB, B & C) according to the permanent teeth development with A: before the first permanent tooth appears (15-18 months depending on the maturity type of the animal), AB: before second set of teeth/ first intermediates appear (24 months), B: before more than six permanent teeth appear and C when animals have more than six permanent teeth.

Age	Class
0 Teeth	A
1-2 Teeth	AB
3-6 Teeth	B
More than 6 Teeth	C
Fatness	Class
No fat	0
Very lean	1
Lean	2
Medium	3
Fat	4
Slightly over fat	5
Excessively over fat	6

Conformation	Class
Very flat	1
Flat	2
Medium	3
Round	4
Very round	5
Damage	Class
Slight	1
Moderate	2
Severe	3

Sex: The carcass of a bull or ox showing signs of late castration of the AB, B or C age classes are identified.

Figure 2.6. Classification characteristics of beef according to SAMIC

The South African fat classification does not always give a good indication of total carcass fat because only the subcutaneous fat is used as parameter. Early matured animals such as Aberdeen Angus will have a thick layer of subcutaneous fat while a late mature breed will have less subcutaneous fat when slaughtered at the same age or body weight.

Different prices are usually obtained for the different age and fatness categories. With A-class beef being more expensive than AB, B and C-class beef. The optimum fatness class in South Africa is either class 2 or 3. Classes 0 and 1 have too little fat while classes 4 to 6 have too much, according to consumers. The conformation of the cattle is also classed into 5 categories with 1 being very flat and 5 being very fleshy, however, the conformation does not have an influence on the price per kilogram beef. Damaged parts on the carcass are removed during health inspections with the producer losing these trimmings as weight. The last category of classification is the sex of the animal; only the carcasses that show properties of either late or no castration get marked as an intact male (bull) and the producer is penalised.

Some of the South African abattoirs do allow that 2% of the slaughtered animals may be classified either lower than class 2 or higher than class 3 fat without being penalised on the price paid (Beefmaster, Kimberly 8301, 2 Carlstein Street, 053 841 0145). It is also important to note that there is a difference between hot and cold carcass weights. The abattoirs pay per kg cold weight which is between 2-3% less than the hot weight (McKiernan *et al.*, 2007).

2.4.5.2 Factors influencing the dressing percentage of cattle

Steers and bulls have higher dressing percentages than heifers because of their more muscular conformation and lower intestinal fat depot weight. Dressing percentages of finished heifers are usually slightly above 50% while dressing percentage of finished steers and bulls (A-class) can reach percentages above 55% (McKiernan *et al.*, 2007). The first major determinant of dressing percentage is the time of feeding before weighing and slaughtering (gut fill during these weightings). Other factors that affect dressing percentage include age, weight

(maturity level), body condition score (fat), muscularity (conformation), bruising, pregnancy status and also inclusion of feed additives such as Zilmax (that change the ratio of muscle to fat in the carcass).

It can be clearly seen that breed will play a role in dressing percentage as it plays a role in maturity level at a certain age and also in the conformation of the cattle. The distance travelled to the abattoir can also be responsible for a 2% live weight loss (McKiernan *et al.*, 2007). Conformation within a breed may be responsible for a 1-1.5% increase in dressing percentage per unit increase in conformation score. Fatter cattle also have a higher dressing percentage than lean ones. Zilmax is a beta-adrenergic agonist that inhibits fat production and enhances muscle growth (Thompson *et al.*, 2010), therefore the inclusion thereof will also increase the dressing percentage.

The total fat percentage of beef consumed in South Africa is about 13% (this includes the subcutaneous fat on the specific cut evaluated), whereas American beef contains fat percentages from 30% up to 35% for the same cuts (SAFA 2014). Marbling in US beef could reach up to 10% while SA grain fed beef contains just over 1% (SAFA 2014). These higher levels in the USA beef cuts is attributed to this industry slaughtering heavier and older carcasses compared to SA.

2.5 Conclusion

Beef production in South Africa can follow various methods and systems in delivering the final beef product on the consumer's plate. With the increasing global human population, food security will always be challenging to the food producers. Especially as pertaining to protein and beef production, as it competes with other human feed sources such as maize. In order to supply this growing demand producers have to use all available recourses at the least costs and produce a maximum output.

Viable agricultural land and water availability for agricultural use are some of the first production limitations. Therefore, it is important to have knowledge of the characteristics of specific soil types and also their mineral contents, in order to produce a maximum output for example maximum forage DM, without using excessive fertilizer or water. As water is also a scarce resource for agricultural production in South Africa, it cannot be wasted on low quality soil types that cannot produce efficiently.

Maize is one of the world's main food resources, hence the maize industry is under tremendous pressure to meet the demands, this while most of the high quality agricultural land is already being cultivated with maize or other food sources. Alternatives to maize in the ruminant feed industry would relieve the pressure on projected maize demands. With expansion in the food processing industry, available products in different areas, such as apple pulp in the Western Cape of South Africa, have to be considered as alternative energy source. Other ways of relieving the pressure on the maize industry would be to optimize the use of less marginal land for forage production, as ruminants are able to utilize plant fibre as source of energy.

The correct combinations of different forages cultivated in a specific soil type with a satisfying chemical composition would contribute tremendously to produce high yields of forage DM throughout the year, which would increase the efficiency of beef production. In order to finish cattle efficiently on pasture, optimum

managements systems have to be applied to secure a consistent fodder flow and ensure optimal pasture regrowth. It is important that all the requirements of the cattle have to be met in order to maximize beef production. It is therefore of equal importance to know what the exact requirements of the cattle are at different maturity stages.

Concentrate supplements containing different ingredients (depending on availability) have to be investigated for each specific area in order to establish an optimal beef output at the lowest cost. Within these different concentrate supplements, different growth promoters can be included and the beef output can then be evaluated as it might differ between different beef producing systems.

The consumption of both the energy ingredients and growth promoters included in the concentrate has an influence on the carcass composition of finished animals. Some growth promoters are also classified as 'antibiotics' which results in consumer resistance. From a production perspective it is important to always satisfy the consumers as they are responsible for the survival of the producer. It is therefore important to produce a carcass that satisfies the consumer regarding carcass size, fat percentage and method of beef production system - something the consumers are becoming more and more aware of when purchasing beef.

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CHAPTER 3

GENERAL MATERIALS AND METHODS

3.1 General information

The study was carried out at The Oak Estate near Greyton in the Western Cape of South Africa. The location of the Estate is at 19° 40' 50.67" E and 34° 6' 3.256" S with an altitude of 187 meter above sea level. The area has a temperate climate with long term minimum temperatures of 9 °C to 15 °C and maximum temperatures of 23 °C to 30 °C (Greyton weather, 2013). The experimental area received 125 mm rainfall and an additional 39 mm of irrigation was provided to the pasture during the study period. The rainfall was measured by three different rain meters located in different spots (**Error! Reference source not found.**).

The growth study started on 5 September 2014 and ended on 14 November 2014. By the time that the growth study started, the heifers had already adapted to the pastures. Therefore, an adaptation period of only four days was required for the heifers to get used to the electrical fencing. Collection of the first data was done on 9 September 2014. The weight gain collection period was 66 days, from 9 Sep'14 until 14 Nov'14, three days prior to the harvest date.

Ethical clearance was obtained through the Research Ethics Committee: Animal Care and Use (REC: ACU) and a protocol number, SU-ACUD15-00075 was received.

3.2 Animals, experimental design and treatments

Sixty Bonsmara heifers (12 months of age) were selected from more than hundred heifers that have been on the experimental farm for more than three months. The heifers were stratified according to initial body weight from heavy to light and each consecutive ten heifers were considered as a block. A heifer from each block was then randomly assigned to one of the six treatments (a seventh treatment where animals received a general farm mixed concentrate formed part of the grazing system but these animals were not part of the trial). The mean initial body weight of the heifers was 328 ± 3.9 kg (SEM).

All the animals were kept on pasture for the duration of the study. The six treatment groups were arranged according to a 2 x 3 factorial design with two energy sources (maize and apple pulp) and three growth promoting supplements (containing either monensin, oregano essential oil or a placebo). For practical reasons, each of the six concentrate supplements were bagged in different colour bags and the treatment- animals were tagged with similar colour coded ear tags: Apple placebo = white, Apple monensin = green, Apple oregano = red, Maize placebo = blue, Maize monensin = purple, Maize oregano = Orange.

During the first 42 days of the growth study, all heifers received an average of 4 kg ("as is" basis) of the concentrate supplement per day. Each treatment group was fed once a day at 8:30 am and each group received a 40 kg bag of the supplement, offered in two big round feeding troughs, approximately 100 cm in diameter (Figure 3.1). From day 43 until the last day of the study (day 66), each heifer received 5 kg on average

of the supplement per day (“as is” basis). Fresh drinking water was available *ad libitum* to all groups for the duration of the trial (Figure 3.1). The water troughs were cleaned weekly before the animals were moved to new camps.



Figure 3.1. Water troughs and feeding trays used during the study period.

The different concentrates were stored on wooden pallets in a storage facility with cement floors that protected it from rain and excessive sunlight. All the concentrates were stored at the same facility to prevent any unknown external effects.



Figure 3.2. Storage of the treatment concentrates. Colour codes matched those of animal ear tags.

The heifers were weighed every second week on a ‘Scales incorporated’ cattle beam scale (accurate to 1 kg). The heifers were always weighed during morning hours after supplement feeding.



Figure 3.3. Cattle pen and crush where the cattle were vaccinated and weighed during the study period.

The total pasture area was divided into five camps. Each camp was then sub-divided into seven paddocks with the aid of electrical wires. A rotation grazing system was implemented and all the treatment groups consisting of ten animals each were moved to a new camp on a weekly basis. The treatments were also rotated within the paddocks to ensure that no treatment group would graze the same paddock twice during the study period. The groups were always moved separately to their new paddocks just after they had finished their concentrate supplement, approximately 2 hours after feeding. Just before the animals were moved to their new paddocks, markers (made from specific treatment feeding bags) were taken to each paddock to ensure that the treatment was allocated to the correct paddock (Figure 3.4). The water troughs and the feeding troughs were then moved to the new paddocks just after all the treatment groups had been moved.



Figure 3.4. Feeding bag markers of different treatments indicating to which paddock the treatment groups had to be moved.

After completion of the 66 day growth study, the experimental animals were slaughtered at the Roelcor abattoir (Malmesbury) where their carcass weights were taken and dressing percentage calculated. All the heifers were

slaughtered except for two. The reason for this is that a few months before the study, it is presumed that a bull had broken into the camp of heifers and mated with them. It was only observed that the two heifers were pregnant during the last month of the study and both calved during the last two weeks of the study. These heifers still formed part of the pasture study as they were grazing and consuming supplements but they were not slaughtered at the end of the trial and their data was not used in the analysis, they were instead treated as missing values.

3.2.1 Vaccination and treatment of experimental animals

The following vaccinations were applied to the experimental animals one month prior to the trial (± 300 kg):

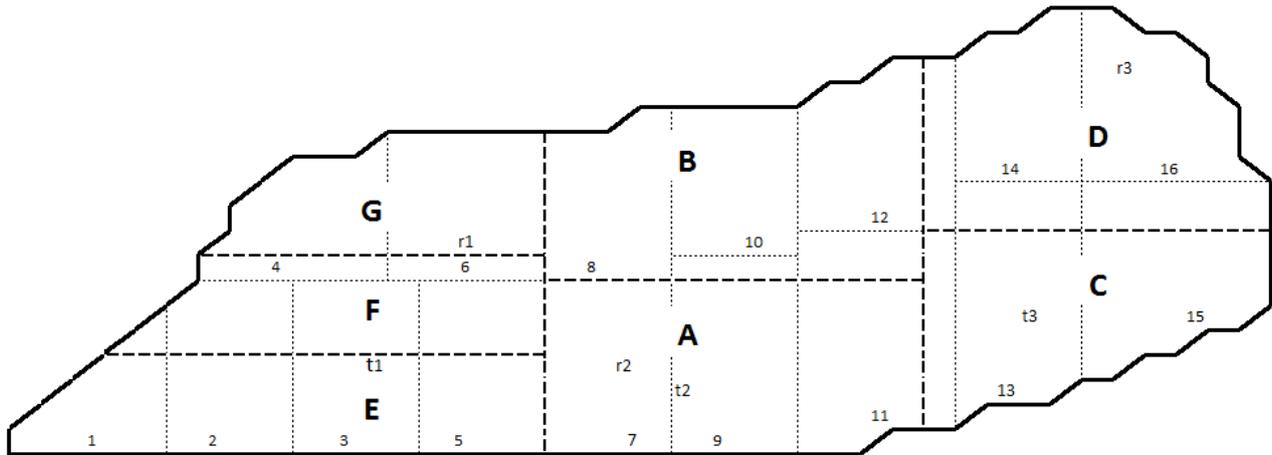
- 1ml Bovitect iii (Intervet, Isando, Gauteng, South Africa) for Mannheimia (pasteurella) haemolytica IRB (Infectious bovine rhinotracheitis) and DBV (bovine virus diarrhoea).
- 2ml Covexin (Cooper Veterinary Products, Isando, Gauteng, South Africa) for active immunisation against *Clostridium perfringens* type A, B, C and D.
- 2ml Bothutrax (Intervet, Isando, Gauteng, South Africa) for active immunisation against botulism and anthrax, 5ml Forray (Scering-plough, Isando, Gauteng, South Africa) for the killing and prevention of Red water (Babesiosis) and tick-borne Gall sickness (Anaplasmosis).
- 6ml Solution 3.5 LA (Intervet, Isando, Gauteng, South Africa) remedy for killing of internal and external parasites, 1ml Lumpyvax (Intervet, Isando, Gauteng, South Africa) for prophylactic immunisation of cattle against Lumpy Skin Disease.
- 35ml Amipor (Virbac RSA (Pty) Ltd, Private Bag X115, Halfway House 1685, South Africa) for controlling external parasites; various species of ticks, flies and lice.
- The experimental animals also received Amipor once during the experimental period (21 Oct '14).

3.3 Pasture

3.3.1 Soil and fertilization

During the study period, 11.1 ha of pasture were contained. To determine the variation in soil type pasture, the total pasture area was divided into seven random blocks (not to be confused with the camps that were discussed earlier). Representative soil samples were taken from the top 10 cm soil layer as recommended by Elsenburg (Institute for Plant Sciences, Department Agriculture, Western Cape, South

Africa). At least 20 subsamples were taken at random in each of the blocks A to G (



). The samples were sent to the Western Cape Department of Agriculture in Stellenbosch for analyses.

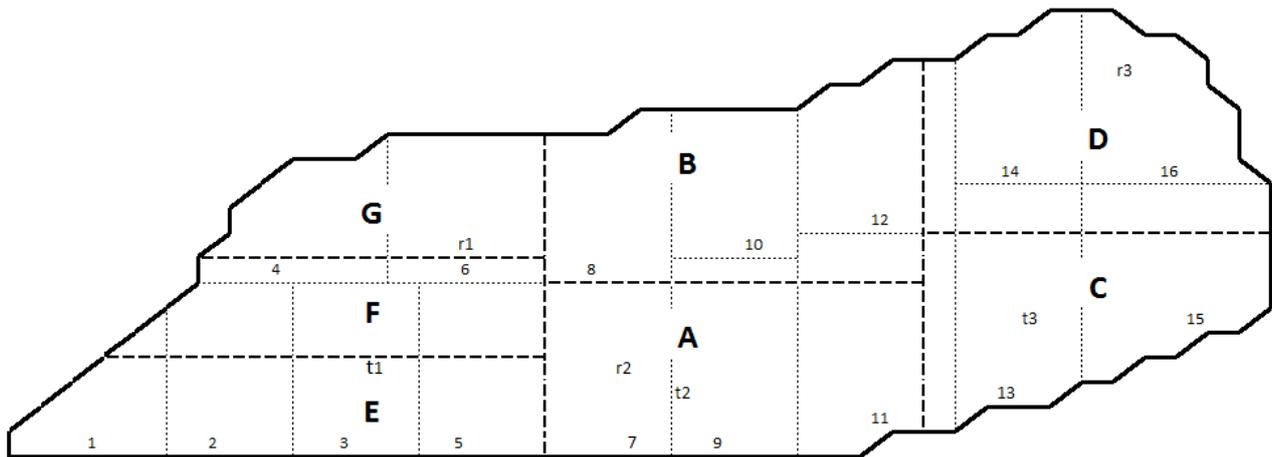
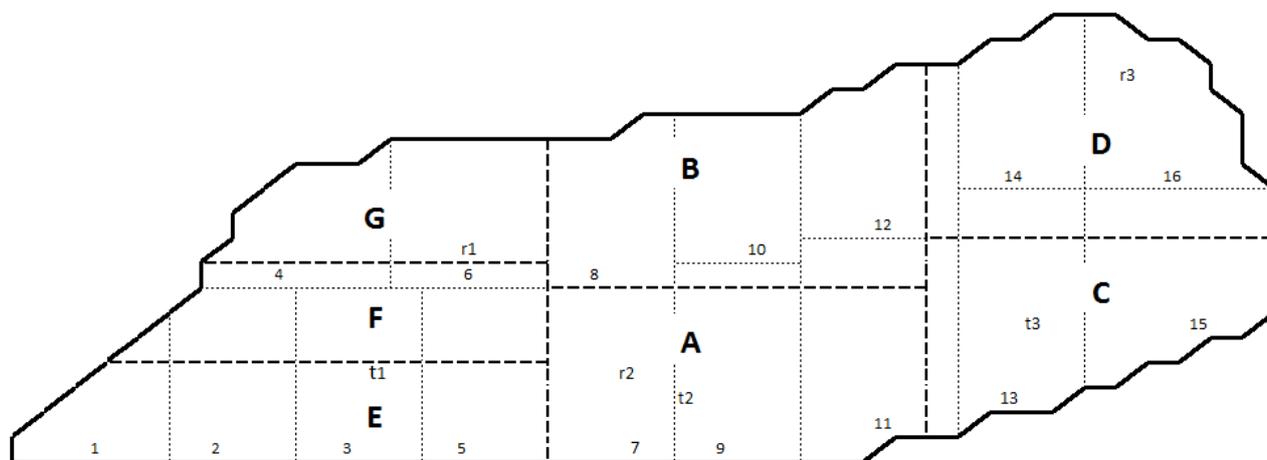


Figure 3.5. Experimental area divided into seven different blocks for soil samples. The small blocks 1-16 show the different irrigation areas. Markers r1 - r3 indicate the areas where rain meters were installed and t1 - t3 represent the areas where tensiometers were installed.

Dr. Pieter Swanepoel of the Department of Agronomy at Stellenbosch University compiled a report in which he stated that there were no agronomical important differences between the blocks in terms of soil nutrient contents (Table 3.1). According to him the soils were well balanced for pasture purposes, but certain minerals were deficient. The pH was satisfactory, the resistance was lower than the critical value for pasture crops, the Ca:Mg ratio was sufficient, and the potassium concentrations were sufficient, except for Block B where a single application 50 kg K (Potassium) was recommended. The phosphate levels were low and a once off 20-30 kg/ha P (Phosphorus) application was suggested across all the blocks. Because of low sulphur levels, the phosphate addition was recommended to be in the form of either a single superphosphate application or, alternatively, the nitrogen application to be in the form of ammonium sulphate (Swanepoel *et al.*, 2014b). Boron and manganese levels were also low in all blocks, therefore a supplementary micro mineral application (Solubor) and manganese sulphate, manganese chloride or manganese oxide was recommended.

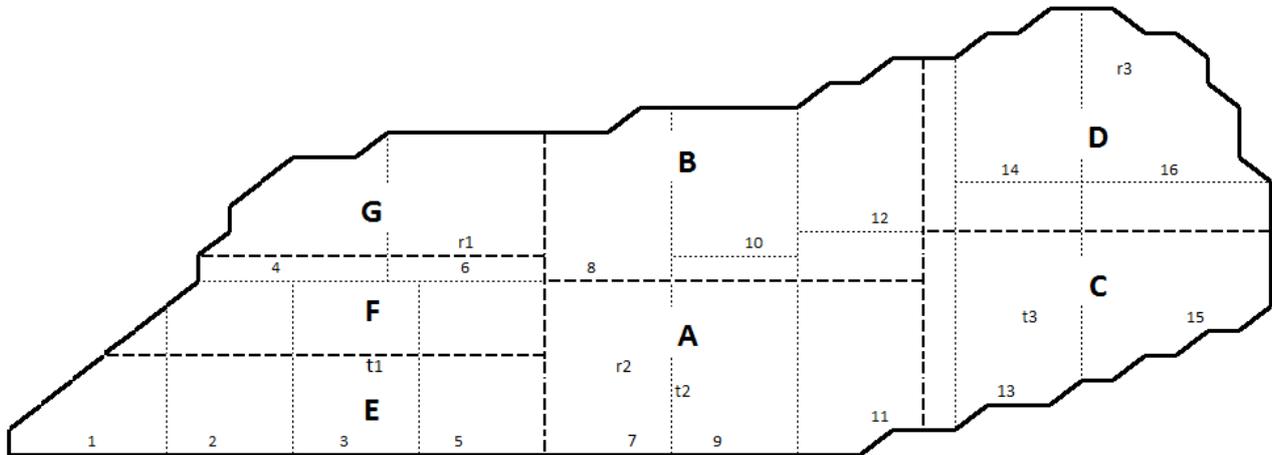
The pasture was fertilized with 90 kg/ha of AmniPlus (40% N, 6% S) after grazing during October. During March, 160 kg/ha of Nitrophoska (45% N, 15% P) was applied and during July 130 kg/ha of Curaa45 (Nitrogen with Potassium).

Table 3.1. Results of the seven top soil (10cm) samples taken in the different blocks of the experimental area as shown in

Elements tested for	Different soil sample blocks							Measure
	Block A	Block B	Block C	Block D	Block E	Block F	Block G	
pH(KCl)	5.7	5.4	5.8	5.9	5.8	5.9	5.8	-
Resistance	1010	1840	1250	1310	470	560	760	Ohms
Texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	-
Calcium	3.58	2.19	4.01	3.74	4.33	4.12	3.67	cmol(+)/kg
Magnesium	1.16	0.76	1.21	1.25	1.23	1.12	0.95	cmol(+)/kg
Potassium	98	59	74	97	97	150	114	mg/kg
Sodium	50	27	64	36	83	53	30	mg/kg
P (citric acid)	52	45	47	53	37	47	45	mg/kg
Total cations	5.22	3.76	5.7	5.4	6.18	5.86	5.05	cmol(+)/kg
copper	1.62	0.87	1.89	1.91	1.64	1.67	1.26	mg/kg
Zinc	2.13	1.27	1.43	2.24	1.69	1.8	1.64	mg/kg
Manganese	12.74	7.01	11.08	13.08	14	16.38	12.91	mg/kg
Boron	0.25	0.13	0.24	0.2	0.26	0.24	0.2	mg/kg
Carbon	1.43	0.82	1.22	1.05	1.18	1.08	0.96	%
Sulphur	4.8	3.7	4.7	3.5	8	5.2	7.2	mg/kg

3.3.2 Irrigation management

To ensure that the pastures were irrigated according to requirements, manual tensiometers were used. Tensiometers were installed at three evenly spread places on the pasture (



). Irrigation was initiated at a tensiometer reading of -25 kPa and ended at a reading of -10 kPa (Botha, 2002). However, heavy and continuous rains and very hot and dry conditions caused exceptions to these rules. Tensiometer readings were taken at least every second day. The irrigation system was divided into sixteen blocks (**Error! Reference source not found.**). It took a while to irrigate all the blocks sufficiently because of the free flow pressure system. Insufficient pressure allowed only two blocks to be irrigated simultaneously. When required each of the sixteen blocks received one hour of irrigation per day (5 mm/h), and it took 8 hours to irrigate the total experimental area.



Figure 3.6. Installation of a tensiometer.

3.3.3 Perennial grass-legume mixed pastures

The pasture utilized during the study consisted of a perennial mixture of ryegrass (*L. Perenne*), cocksfoot (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*), white clover (*Trifolium repens*) and red clover (*T. pratense*), as assessed by Swanepoel *et al.* (2014). This mixture contained both diploid and tetraploid species. According to De Bruyn (2015, J. De Bruyn, Pannar salesmen, 2 Cooper street, Swellendam, Western Cape, South Africa) each of these species requires a different amount of water and sunlight for reproduction which give it a reasonable balance during different seasons. The grass legume mixture was planted in September 2013.

According to De Bruyn (2015, J. De Bruyn, Pannar salesmen) this pasture mixture is not a fixed mixture, but rather depends on the climate of the specific region, the soil and also the grazing management. The portions

in which the different species in the mixture occur vary, but the white and red clover usually remains relatively consistent at 3 kg/ha each. Tall fescue and cocksfoot are perennial grass species that comfortably outlives ryegrass. Although, compared to ryegrass, tall fescue and cocksfoot delivers higher yields during cold climates, ryegrass produces more rapidly during warmer seasons and ensures early grazing possibilities. Ryegrass supports pasture yields during the summer, yielding up to 70 kg/ha DM while yields during winter drop to 30 kg/ha DM (Fulkerson & Donaghy, 2001). Compared to white clover, red clover is more dominant during summer. The inclusion of the legume species red and white clover in the mixture is mainly because of the nutritional value and the cost saving on nitrogen fertilizer (Botha, 2009). Another reason why perennial grass-legume mixtures are preferred above annual mixes is because of their much lower establishment cost per annum. The pastures were planted using a minimum-till seed drill.

Also according to De Bruyn (2015, J. De Bruyn, Pannar salesman), it is crucial not to overstock perennial pastures during the first grazing season, especially during summer. He suggested that although the mixture is classified as perennial, the pasture can be complemented by establishing ryegrass annually in-between.

3.3.4 Botanical composition

A fractioning of the pastures was done once during the experimental period. It was not necessary to do more than one fractioning as the experimental period did not stretch over different seasons. The method used to determine the botanical composition was very similar to the study done by Quigley *et al.* (1992). Three representative samples were randomly taken in each of the five camps (Figure 3.7). Samples were cut using the same round metal ring as discussed in 2.2.6 (Measuring pasture intake) to sample a specific area at a height of 3 cm. The fifteen samples were then visually classed and divided into three different groups namely; grass (ryegrass, tall fescue, and cocksfoot), legumes (white and red clover) and other species. Each group was then weighed and dried with the same method discussed in 3.3.6 (Pasture measurement) to calculate the different fractions the pasture comprised of.

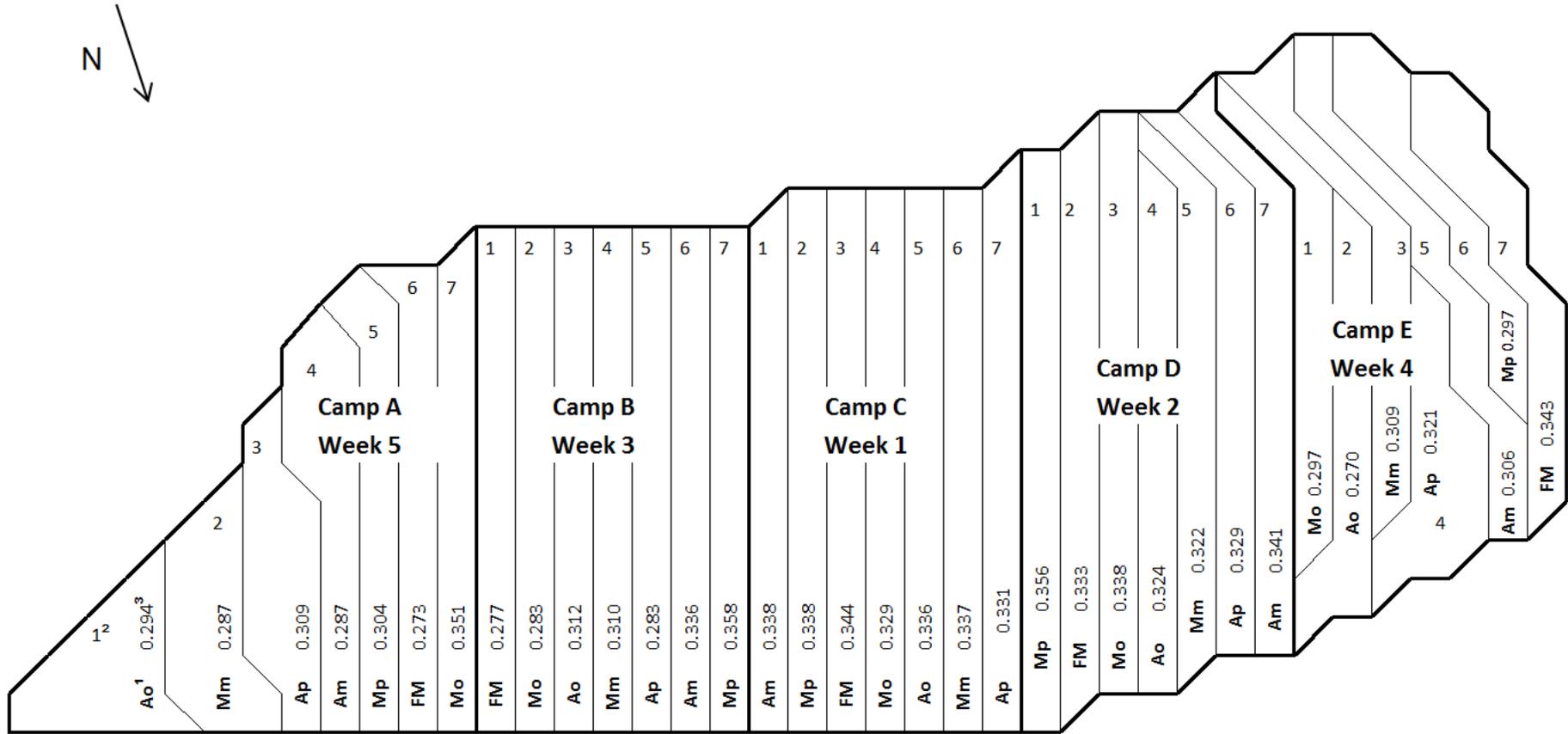
3.3.5 Grazing system and camp design

A rotational grazing system was applied during the growth study. This implies that pastures were grazed at high stocking rates for short periods. The heifers harvested most of the available pasture to approximately 5-6 cm stubble height, and the pastures were then rested for longer periods of recovery (McDonald, 2002). Dr Botha (2014, Dr P. Botha, Specialist scientist, 083 641 1395) assisted with the basic lay-out of the camps to ensure sufficient pasture recovery periods and reasonable stocking rates.

A permanent irrigated pasture (11.1 ha) was divided into five Camps (A-E) and each camp was divided into seven paddocks using electrically charged poly wire. These poly wires were attached to irrigation poles that were 15 m from each other. The layout of the camps and paddocks were done to ensure that all the paddocks in a camp were similar (**Figure 3.7**). While all the treatment groups (heifers) were grazing in one camp, the following camp's fences were prepared. Each camp's paddocks were divided in fairly equal surface areas, with those in Camp A = 0.30 ± 0.025 ha, Camp B = 0.31 ± 0.030 ha, Camp C = 0.34 ± 0.005 ha, Camp D = 0.33 ± 0.012) and Camp E = 0.31 ± 0.023 ha with the aid of a Garmin Origen 550 GPS.

Camp C was grazed during the first week of the experimental period (Figure 3.7). The different treatments (Ap, Am, Ao, FM, Mp, Mm and Mo), were kept in paddocks one to seven. From the second week onwards, Camp D, Camp B, Camp E and Camp A were grazed accordingly. While grazing in Camp D, heifers in treatment Am moved to paddock seven and all other treatments shifted one paddock to the left (minus one paddock) to ensure that no treatment would graze twice in the same paddock during the experimental period.

This rotation system assured a growth period of 24 to 28 days before the next grazing. Unfortunately, the pastures in each block were not 24-28 days of age during the first rotation cycle. Up until 28 days prior to the study sheep grazed all the camps to a 3 cm height. This implied that pasture in Camp C (week 1) was 28 days of age, but each camp grazed thereafter was one week older until one grazing cycle was completed. During the experimental period each camp was grazed either two or three times.



¹Treatments: Ap = Apple placebo; Am = Apple monensin Ao = Apple oregano; FM = Farm mixture; Mp = Maize placebo; Mm = Maize monensin; Mo = Maize oregano

²Paddock number

³Camp size (ha)

Figure 3.7. Camp design and size of the experimental areas, showing the rotation system of the different treatment groups for the first five weeks.

3.3.6 Pasture measurement

In order to determine the pasture yield, the pasture height was measured using the falling plate meter (FPM) method as described in 2.2.6 (Measuring pasture intake). The FPM has to be calibrated for the specific pasture type before and after grazing, in order to make yield estimates more accurately (Stockdale, 1984).

Thirty six pasture samples were taken throughout the study period to calibrate the FPM for the specific pasture. Twenty measurements between 5 and 25 cm were used to calculate the “before grazing” regression and sixteen measurements between 3 and 11 cm were used to calculate the “after grazing” regression. After measuring the height of a specific pasture canopy, a metal ring with the same known area (0.166 m²) as the FPM was used to obtain a circle and all the forage inside the circle was cut to a height of 3 cm (Figure 3.8). The samples were then placed into a bag and weighed accurately to the nearest 1 g (Electronic Compact Scale, CTS-5). A moisture analyser (Radwag moisture balance, Max 50/NH) was used to dry two small representative samples to calculate the DM content of the pasture samples.



Figure 3.8. The falling plate meter (FPM), metal ring and scissors used to measure and cut the pasture samples in order to calibrate the FPM.



Figure 3.9. Electronic Compact Scale CTS-5 used to weigh pasture samples, and a Radwag moisture balance, Max 50/NH used to calculate the DM content of the pasture in order to calibrate the falling plate meter (FPM)

The pasture weight (DM) was then correlated with the FPM reading to develop a linear equation $Y = (a \times H) + b$ between FPM reading and pasture yield kg/ha DM (Earle & McGowan, 1979). Where 'Y' = DM yield (kg/ha), 'a' = gradient, 'H' = recorded height of FPM, and 'b' = intercept value. The two linear regression equations were then used to estimate the yield as well as the DMI of the cattle in each treatment.

In each camp, 140 FPM readings were taken every week (70 readings before and 70 readings after grazing). Ten readings were taken in a zig-zag pattern approximately 20 m from each other in every paddock. Eleven camps were grazed during the study period resulting in a total of 1540 FPM readings during the study period. All FPM readings were taken during the morning hours, from 6 am to 11 am.

The main aim of the pasture management was to make sure that all the treatments had sufficient material for *ad libitum* grass intake during the study period. According to Reeves & Fulkerson (1996) plate meters are inaccurate in predicting DMI. The FPM was mainly used as a management tool, to assure equal quantity and quality of pasture to all treatments and to monitor post-grazing heights, thereby determining the time intervals of moving to another camp.

As mentioned in 3.3.5 (Grazing system and camp design), a rotation grazing system was used for the study. This was mainly done to supply continuous high quality pasture through the allowance of adequate regrowth periods. The rotation intervals were determined by both FPM and visual assessment (human observation). The heifers were rotated at an average pasture height of 5.7 ± 0.7 cm, according to the FPM which falls within the widely accepted post grazing range of 5 to 6 cm (Irvine *et al.*, 2010).

3.4 Supplementation

3.4.1 Feed formulation and level of supplementation

The two main concentrate supplements were formulated on an iso-nutrient base with the aid of the AMTS.Cattle v 2.1.31 software (10.77 ME, 11.88 CP, 0.8 Ca, and 0.54 P (**Table 3.4**). Afgri Feeds (Klapmuts,

Western Cape, South Africa) formulated, mixed and bagged all the different treatment concentrates in 40 kg bags. Four tons of each of the six concentrates were produced and supplied in a ground form. One of the two main concentrates primarily contained maize (50%) and the other one primarily dried apple pulp (50%). The nutrient values of apple pulp differ quite a lot when compared to maize (Table 3.2)

Table 3.2. Nutrient values of dried apple pulp and maize

Parameters ¹ (g/kg DM, or as stated)	Dried apple pulp ²	Maize ³
CP	63.7	94
ME (MJ/kg)	11.61	13.5
NDF	424.0	131
OM	973.9	985
EE	55.0	42
Ca	1.25	0.5
P	1.50	2.5

¹ CP - Crude Protein; ME - Metabolizable Energy; NDF - Neutral Detergent Fibre; OM - Organic Matter; EE - Ether Extract; Ca - Calcium; P - Phosphorous.

²Values according to the analyses of the pulp used during the study.

³Values according to NRC 2001

Maize has a higher crude protein and metabolizable energy content than dried apple pulp (Table 3.2). In order to give the starch and non-starch concentrates iso-nutrient values, the non-starch (apple pulp) concentrates had to contain more canola oilcake (204.3 g/kg vs. 50 g/kg in starch concentrate) which consists of higher CP (38 %) and high energy. Megalac (rumen-protected fat) was also included in the non-starch concentrate to increase the energy content of the concentrate. The starch (maize) concentrates, on the other hand, had to be 'diluted' with wheat bran (192.8 g/kg vs. 15 g/kg in non-starch concentrate) in order to reach iso-nutrient values (Table 3.3).

As mentioned in 3.2 (Animals, experimental design and treatments), all treatments received a fixed amount of concentrate supplement. Initially each animal received, 4 kg of concentrate ("as is" basis) daily (day 1 to 42). From day 43, the amount was increased to 5 kg/day until the end of the feeding period on day 66. The concentrate supplements were formulated as seen in Table 3.3.

Table 3.3. Ingredients (g/kg) of two concentrates (starch vs non-starch energy source) used as supplemental concentrates to the heifers during the growth study (formulated with AMTS.Cattle v.2.1.31)

Ingredient	Treatment concentrate (g/kg)	
	Starch	Non starch
Yellow maize std	500	0
Apple pulp	0	500
Soya oilcake 46	50	25
Canola oilcake (CP 38%)	50	204.3
Chop std. 8.9	124.6	153
Wheat bran	192.8	15
Megalac	0	21.4
Molasses 3.5	40	40
Limestone	16.8	10.5
Mono-Calcium Phosphate	4.7	10.5
Salt	20.8	20
Premix ¹	3	3

¹The premix was provided by FeedPharm (Strand, Western Cape Province) and the composition is shown in Table 3.6.

Table 3.4. Calculated nutrient values of the two concentrates (starch vs non-starch energy source) as formulated with AMTS.Cattle As Fed basis

Nutrient values ¹ (g/kg, or as stated)	Treatment concentrate	
	Starch	Non starch
ME (MJ/kg)	10.77	10.77
CP	118.8	118.8
Fat	37.0	58.9
Starch	409.2	79.6
Ca	8.0	8.0
P	5.4	5.4
Ca:P ratio	1.48	1.48

¹ME - metabolizable Energy; CP - crude protein; Ca - calcium; P – phosphorous; Ca:P – ratio between calcium and phosphorous

The two main treatments were iso-nutrient (Table 3.4). The only difference was the energy sources used; with the maize containing treatment described as the 'starch' concentrate having 40.92% starch while the non-starch (apple pulp) concentrate only had 7.96% starch. Except for the starch differences, a definite difference in palatability was observed during the trial. The apple pulp containing concentrates appeared to have been more palatable than the maize containing concentrates. The heifers receiving apple pulp containing concentrates finished their feed in about 45 minutes while those consuming the maize containing treatments took up to eight hours. Ranking the concentrates from most palatable to least palatable according to time it

took to finish their concentrate supplements would be as follows: Apple oregano (Ao), Apple placebo (Ap), Apple monensin (Am), Maize oregano (Mo), Maize placebo (Mp), Maize monensin (Mm).

The contribution of energy in the starch containing concentrate mainly came from yellow maize while the energy in the non-starch containing concentrate mainly came from apple pulp (Table 3.5). Differences between growth performances of the different treatments would therefore be mainly as a result of the different energy sources used in the two diets.

Table 3.5. Contribution of the different raw materials to the total metabolizable energy (ME) of the two different concentrates (AMTS.Cattle)

Contribution of raw materials towards metabolizable energy	Treatment concentrate (%)	
	Starch	Non starch
Yellow maize std	56.53	0
Apple pulp	0	50.09
Soya oilcake 46	16.48	20.28
Canola oilcake (CP 38%)	13.66	16.79
Maize chop	5.42	5.89
Wheat bran	4.96	2.95
Megalec	0	2.71
Molasse 3.5	2.95	1.28

3.4.2 Premix formulation

The inclusion levels of the ionophore (monensin) and the essential oil extract (oregano) were calculated and included in the concentrate supplements to ensure the following intake levels per heifer when fed at 4 kg/day; monensin at 60 mg/kg = 240 mg/day and oregano included at 135 mg/kg = 540 mg/day. These amounts fell well within the boundaries of the amounts reported in the literature. The placebo premix contained the same minerals as the monensin and oregano premixes, but without a growth promoter. The premixes were produced by FeedPharm (5 Crompton Street, Strand, Western Cape, 7140). Premixes were formulated to have an inclusion level of 3 kg per ton of concentrate.

Table 3.6. Composition of the three different premixes used in each of the concentrates supplemented to the different treatments

Ingredient Information			Premix Information			
Products	Source	Activity/Unit	Unit	Placebo Per unit	Monensin Per unit	Oregano Per unit
Vitamins						
Vitamins A	Retinol	1000000 iu	iu	7 000 000	7 000 000	7 000 000
Vitamins D3	Cholecalciferol	500000 iu	iu	1 000 000	1 000 000	1 000 000
Vitamins E	Tochopherol	500 iu	iu	5 000	5 000	5 000
Vitamins B1	Thiamine Mono	98%	g	3	3	3
Iodine	Calcium Iodate	10%	g	1	1	1
Cobalt	Sulphate	21%	g	1	1	1
Selenium	Sodium Selenite	10%	g	0.1	0.1	0.1
Micro						
Monensin	Romensin 200	20%	g	0	60	0
Oregano	Dosto 500	10%	g	0	0	135
Minerals						
Maganese	Sulphate	31%	g	40	40	40
Zinc	Sulph	35%	g	60	60	60
Copper	Sulphate penta	25%	g	15	15	15
Ferrous	Sulphate	32%	g	60	60	60
Magnesium	Oxide	50%	g	150	150	150
Sulphur		100%	g	500	500	500
Unit size per ton			kg	3	3	3

3.5 Data collection

3.5.1 Concentrate and pasture sampling and analyses

Grab samples of the six different feeds were taken at three evenly spread times during the study period, two dried apple pulp samples were also taken before the feeds were mixed. Each of these samples was thoroughly mixed and a representative samples were then taken. Samples were ground through a SCW Hammer mill (serial number 372), using a 1.5 mm sieve where after they were stored in airtight plastic containers which were clearly marked for further analysis.

Throughout the study period, eleven representative samples of the allocated pastures were taken at a stubble height of 3 cm the day before grazing. One pooled sample was taken per camp on the day before the heifers were moved to the relevant camps. Each of the eleven samples was placed in a clearly marked plastic bag and stored at 4 °C until it was dried. The samples were dried at 60 °C for 48 hours after which they were ground through a hammer mill, using a 1.5 mm sieve. Samples were stored in clearly marked, airtight plastic containers for further analysis. The data of the samples were pooled into three different timeslots: 10 Sep to 1 Oct, 2 Oct to 27 Oct and 28 Oct to 10 Nov.

The following chemical analyses were performed on both the pasture and the concentrate samples (all analyses were done in duplicate): dry matter (DM; oven drying at 100 °C for twenty four hours; method 934.01;

AOAC, 2002); crude protein (CP; using the Leco N analyser, model FP 528, N6.25, method 990.03; AOAC, 2002); ash (method 942.05; AOAC, 2002), ether extract (EE; AOAC, 2002; method 920.39). The desiccator cool down method of weighing for samples and crucibles was used in the above analyses.

Concentrates and pasture samples were analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF) and *in vitro* organic matter digestion (IVOMD) using the hot weighing technique, which is not necessarily more accurate but is less time consuming. Both the neutral detergent fibre (NDF) and acid detergent fibre (ADF) were calculated according to methods used by Van Soest *et al.*, (1991) IVOMD according to McDonald (2002) and starch according to AOAC (2002; method 996.11). The metabolizable energy (ME) was calculated using the following calculations: $ME = 0.014 \times DIGY + 0.025 \times Oil$ (McDonald, 2002). The mineral analyses were done by the analytical laboratory at Elsenburg (Institute for Plant Sciences, Department Agriculture, Western Cape, South Africa).

3.5.2 Growth rate of heifers

As mentioned in 3.2 (Animals, experimental design and treatments) the heifers were weighed every fortnight. They were weighed individually on a cattle beam scale (Scales incorporated, accurate to 1 kg). All weights were recorded during the morning hours just after they had finished their supplements.

3.5.3 Dressing percentages

The dressing percentages of the heifers were calculated according to their last experimental body weight and the warm carcass weight provided by Roelcor abattoir (Roelcor abattoir Malmesbury, Western Cape, South Africa). The carcass classification was also provided as it determines the price per kg discussed in 2.4.5.1 (Carcass classification).

3.6 Statistical analysis

Data of the experimental heifers were subjected to a two way factorial design. Some of the advantages of a two way factorial design are that the same data could be obtained with fewer animals being used in a specific experimental design. Heifers were blocked according to initial body weight and animals within each block were randomly assigned to the six treatments. Production efficiency data were subjected to a factorial ANOVA (Statistica; Data analysis software system, Statsoft Inc. 2011, version 10.0). The null hypothesis was stated as: $H_0: \mu_1 = \mu_2 = \mu_3 = \mu \dots$ and was rejected where $P < 0.05$. Least Square Mean tests were analysed to see if any significant differences occurred. Shapiro Wilk tests were used to test for normality.

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CHAPTER 4

THE EFFECT OF SUPPLEMENTS CONTAINING DIFFERENT PROTEIN AND ENERGY SOURCES AND ESSENTIAL OILS ON THE PERFORMANCE OF PASTURE FINISHED HEIFERS

4.1 Abstract

Sixty Bonsmara heifers (328.0 ± 3.9 kg), 12 months of age, were used in a study where heifers were finished on planted pastures with different concentrate supplements. Animals were stratified according to initial body weight before being randomly allocated to one of six treatments in a factorial arrangement. Treatment supplements were either starch based (M; maize as primary energy source) or non-starch based (A; dried apple pulp as primary energy source). Each of the two energy supplement treatments was further divided to contain either monensin (m) or an oregano oil extract (o) as potential growth promoters, or a placebo (p). Treatments were thus designated as Mm, Mo, Mp, Am, Ao and Ap. Pasture and water were supplied *ad libitum* during the 66 day study period. Calculations according to the falling plate meter (FPM) showed that the heifers consumed an average of 4.5 ± 0.08 kg DM pasture per day throughout the study. A fixed amount of the concentrate supplement ("as is" basis) of 4 kg/day was fed per heifer from Day 1 to Day 42. From Day 43 to Day 66, supplements were offered at 5 kg/day. No interactions between "energy source" and "growth promoter" were observed and main effects could therefore be interpreted. The supplements containing apple pulp as primary energy source resulted in a significantly higher ADG (1.54 kg/day) than the maize containing supplements (ADG = 1.33 kg/day). There were no differences between any of the growth promoters compared to the placebo treatments. All the heifers were slaughtered and dressing percentages were calculated. No interactions or differences were found among treatments regarding dressing percentage. The results, under the conditions of this growth study, suggested that supplements with apple pulp as primary energy source yielded better weight gains than maize containing supplements, whereas the respective growth promoters had no effect on weight gain.

Key words: pasture, apple pulp, maize, oregano, monensin, growth study, beef heifers

4.2 Introduction

Ruminants have the special ability to digest fibre due to the microbial population in the rumen- (Buxton & Redfearn, 1997). The ever-growing demand for meat with an expected world population of 9 billion in 2050 places tremendous pressure on the maize and beef production sectors. All resources have to be used optimally in order to reach these ever-growing demands. Therefore, by-products of the food processing sector have to be considered for ruminant use. Antibiotic growth promoters, such as monensin, results in significant consumer resistance, therefore alternative 'natural' growth promoters, such as essential oils have to be investigated, of which oregano is an example.

A growth study was performed with Bonsmara heifers on irrigated grass-legume pastures. The utilization of pastures is a cheaper way of finishing cattle compared to a feedlot system (Allen, 2000), as minimal labour cost is required to supply the roughage (Bargo *et al.*, 2003). The study was conducted during spring (growth season) near Greyton in the Western Cape Province of South Africa. Analyses of soil samples showed that the soil was sufficient in terms of organic properties and only required mineral fertilization to support abundant pasture growth (Swanepoel *et al.*, 2014a).

Grass-legume pastures, at the correct maturity (21-28 days) and climate conditions (Botha, 2009) provide high concentrations of rumen degradable nitrogen and highly digestible fibre to cattle (Botha *et al.*, 2008). Most of the protein in the pasture is rapidly degraded in the rumen. Urinary nitrogen excretion would therefore increase if adequate amounts of rapidly fermentable carbohydrates are not included in the diet. The inclusion of rapidly fermented carbohydrates (maize or apple pulp) should improve nitrogen utilization by reducing ruminal nitrogen excretion and ruminal ammonia nitrogen (NH₃-N; Rooke *et al.*, 1987). According to Poppi & McLennan (1995) energy and protein are the first limiting factors for increasing the growth of beef cattle. Sufficient energy and protein are therefore important in finishing diets. Apple pulp has lower energy and crude protein values than maize; however, as the experimental concentrate supplements in the current study were formulated to have iso-nutrient values, the apple pulp required higher inclusion levels of ingredients such as canola- and soybean oil cake which is high in both energy and protein.

Monensin is a well-known ionophore, also classified as a polyether antibiotic. Natural organic products, such as oregano oil extracts that contain essential oils (EO) may act as a growth promoter (Busquet *et al.*, 2005b). Such a product could substitute “antibiotic” growth promoters. Very little research has been done on growth promoters used in pasture-fed beef systems.

The emphasis of this study was to evaluate and discover if maize could be substituted with apple pulp when supplied in concentrate supplements fed to beef heifers grazing on pasture. Another aim was to see if the growth promoter (monensin) could be substituted with a natural product (oregano oil). The ADG differences were used to evaluate treatments. After the growth study had been concluded, the heifers were slaughtered to detect if any treatment differences occurred in terms of carcass yield and dressing percentage.

4.3 Materials and methods

A perineal grass-legume pasture mix was planted in 2013 at The Oaks Estate near Greyton in the Western Cape of South Africa. The pasture consisted of the following species: ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*), white clover (*Trifolium repens*) and red clover (*T. pratense*). Botanical composition was done once during the study period to quantify grass, legumes and other species. A commercial fertilizer program was applied according to the requirements of the pasture and shortages in the soil. The study was performed during the growth season (September to November, 2014) and at the end of the winter rainfall season. The pasture was irrigated according to the measurements of three installed tensiometers. Irrigation was initiated at a tensiometer reading of -25 kPa and ended at a reading of -10 kPa (Botha, 2002). A rotational grazing system with 5 different camps was applied on the 11.1 ha of experimental pasture. Each camp was divided into different paddocks with electrical wires to separate the

different treatments. The heifers harvested most of the available pasture to approximately 5-6 cm stubble height and were then moved to the next camp on a weekly basis and returned to the specific camp within 28 days. Falling plate meters (FPM) were used to manage the rotation system and estimate the pasture yield.

Sixty Bonsmara heifers (12 months of age) were stratified according to initial weight from heavy to light and each consecutive ten animals were considered as a block. Treatments were then randomly assigned to each block. The heifers were used in a 66-day growth study with a 2 x 3 factorial design. All concentrate supplements were formulated to have iso-nutrient values (**Error! Reference source not found.**). With two energy sources (maize and apple pulp) and three growth promoting supplements (containing either monensin, oregano essential oil or a placebo). The six treatments were as follow: Apple placebo (Ap), Apple monensin (Am), Apple oregano (Ao), Maize placebo (Mp), Maize monensin (Mm), Maize oregano (Mo). The heifers were all vaccinated and drenched for external and internal parasites a month prior to the study. Ethical clearance was obtained through the Research Ethics Committee: Animal Care and Use (SU-ACUD15-00075).

During the first 42 days of the growth study, all heifers received an average of 4 kg ("as is basis") of the concentrate supplement per day. From day 43 until the last day of the study (day 66), each heifer received 5 kg per day ("as is basis"). All treatments were fed once a day at 8:30 am. Fresh drinking water was available *ad libitum* to all groups for the duration of the trail. The heifers were taken to a cattle pen to be weighed fortnightly in order to determine their average daily gain (ADG). The heifers were always weighed during morning hours just after they had finished their concentrate supplement. After the growth study was concluded the heifers were slaughtered, and dressing percentages were calculated from the last weighing.

4.4 Sample collection and analyses

Grab samples of the six different concentrates were taken at three evenly spread times during the study period. Each of the six samples was thoroughly mixed. A representative sample was then taken and ground through a SCW Hammer mill (Ser No 372) using a 1.5 mm sieve. Samples were stored in airtight plastic containers, which were clearly marked for further analysis. Throughout the study period eleven representative pasture samples were taken at a stubble height of 3 cm the day before grazing. One pooled sample was taken weekly for eleven weeks. Each of these collected samples was placed in a clearly marked plastic bag and stored at 4 °C until it was dried. The samples were dried at 60 °C for 48 hours and then ground and treated the same as the feed samples. The results of the pasture samples were pooled into three different timeslots: 10 Sep to 1 Oct, 2 Oct to 27 Oct and 28 Oct to 10 Nov.

The following chemical analyses were performed on both the pasture and the concentrate samples: (all analyses were done in duplicate) dry matter (DM) (oven drying at 100°C for twenty four hours; method 934.01; AOAC, 2002); crude protein (CP) (using the Leco N analyser, model FP 528, N6.25, method 990.03; AOAC, 2002); ash (method 942.05; AOAC, 2002), ether extract (EE) (AOAC, 2002; method 920.39). The desiccator cool down method of weighing for samples and crucibles was used to perform the above analyses. Concentrates and pasture samples were analysed for neutral detergent fibre (NDF), acid detergent fibre (ADF) and in vitro organic matter digestion (IVOMD) using the hot weighing technique, which is not necessarily more accurate but is less time consuming. Both the neutral detergent fibre (NDF) and acid detergent fibre (ADF)

were calculated according to Van Soest et al. (1991), IVOMD according to McDonald (2002) and starch according to (AOAC, 2002; method 996.11).

4.5 Pasture composition and quality

When determining pasture quality it is important to investigate the different species the pasture comprises of. A fractioning was done once during the study period to identify and quantify the different species in the pasture, which also helped to explain some of the results obtained. The results of the pasture fractioning were as follows: grass 84.0% (ryegrass, cocksfoot, tall fescue), legumes 14.4% (red clover and white clover), and other 1.6%. The method used to calculate the different fractions was described in 3.3.4 (Botanical composition). According to Van Heerden (1986), pasture with a high grass component has a higher grazing capacity than pure clover pastures or pasture with a high clover component.

The data of the eleven weeks (11 samples) were pooled into three different timeslots: Initial period (10 Sep - 1 Oct), Middle period (2 Oct - 27 Oct) and End period (28 Oct - 10 Nov). Pasture quality did not change much during the experimental period (Table 4.1). The chemical analyses were done as discussed in the previous chapter, 3.5.1 (Concentrate and pasture sampling and analyses).

Table 4.1. Chemical composition (mean \pm SEM) of the grass-legume pasture (n = 11) grazed during the study period which was pooled into three different time periods

Chemical composition ¹ (g/kg DM, or as stated)	Pasture		
	Initial Period	Middle Period	End period
DM	174.8 \pm 6.20	183.2 \pm 7.41	162.3 \pm 8.61
OM	896.3 \pm 5.49	904.4 \pm 1.53	906.3 \pm 3.15
EE	24.9 \pm 0.99	25.1 \pm 1.16	25.9 \pm 0.61
CP	185.6 \pm 6.97	182.1 \pm 10.53	188.0 \pm 10.33
NDF	519.8 \pm 10.80	499.0 \pm 25.20	552.0 \pm 7.40
ADF	280.0 \pm 9.62	289.0 \pm 13.14	274.6 \pm 7.12
IVOMD	628.72 \pm 2.21	600.97 \pm 2.74	632.12 \pm 0.91
ME (MJ/kg)	9.42 \pm 0.33	9.04 \pm 0.35	9.50 \pm 0.13
Ca	4.6 \pm 0.34	5.4 \pm 0.78	4.0 \pm 0.04
P	3.6 \pm 0.05	3.6 \pm 0.27	3.3 \pm 0.21
Na	42.5 \pm 6.70	25.5 \pm 0.65	33.9 \pm 3.91
Mg	2.6 \pm 0.09	2.6 \pm 0.09	2.6 \pm 0.06
Ca:P	1.28	1.5	1.21

¹ DM - dry matter; OM - organic matter; EE – ether extract; CP – crude protein; NDF - neutral detergent fibre; ADF – acid detergent fibre; IVOMD – in vitro organic matter digestion; ME - metabolisable energy (calculated: ME = 0.014 x DIGY + 0.025 x Oil); Ca - calcium; P - phosphorous; Na – potassium; Mg – magnesium Ca:P – ratio between calcium and phosphorous;

It is difficult to find chemical composition analyses of similar pasture species in the literature, as they are not often used in these specific combinations. As ryegrass was used as base grass species, the evaluation

parameters were compared to ryegrass pastures. Accordingly, the pasture quality was very similar to data obtained by Van der Colf (2011) and Steyn *et al.* (2014). The data obtained were used to detect if any differences had occurred between the different camps and also to see if the progression of season had an influence on the chemical composition of the pasture.

The pasture quality could nearly be described as high; however, the NDF values of the “End period” were not between the “high quality” ranges (400 – 527 g/kg) suggested by Muller *et al.* (1998). These results were most probably because of the change in season with warmer conditions and less rain resulting in higher structural components. However, on average the NDF values were within the range of high quality pastures. All the CP values were in the range of 156 to 298 g/kg for ryegrass as specified by Van Vuuren *et al.* (1991). The NDF content of the pasture in the current study was higher than the optimal range of 400 to 500 g/kg suggested by Clark *et al.* (1998) and Bargo *et al.* (2003).

Reasons why clear trends could not be picked up in the chemical composition of the grass-clover pastures could be due to the following reasons: firstly, samples were all collected during the same season. Secondly, it might be that the irrigation system maintained nutrient composition throughout the changing seasons (Stockdale, 1999). Although the irrigation management was done according to tensiometers mentioned in 3.3.3 (Perennial grass-legume mixed pastures), the extreme temperatures and heavy rainfall experienced during some weeks in the study period could have affected the pasture composition in those particular weeks. Thirdly, it might be difficult to identify any trends because of the different species of grass and legumes the pasture comprised of. Variation between grab samples could exist and have an influence on the chemical composition, especially the contribution of clover in a grab sample which has a higher CP value than the grass species (Botha *et al.*, 2008).

4.6 Pasture yield

As mentioned in 3.3.6 (Pasture measurement), the falling plate meter (FPM) had to be calibrated with both before-grazed and after-grazed pasture. The calculated linear equation for the before and after grazing calibration generated the following equations $Y = 156.42 \times H + 769.72$ and $Y = 294.39 \times H + 588.07$ as seen in Figure 4.1 and Figure 4.2, respectively, where ‘Y’ = available pasture kg/ha DM and ‘H’ = FPM reading. It is important to remember that the regressions were formed by samples that were cut 3 cm from the top soil. Figure 4.1 and Figure 4.2 were results obtained from the thirty six calibration samples collected during the study period.

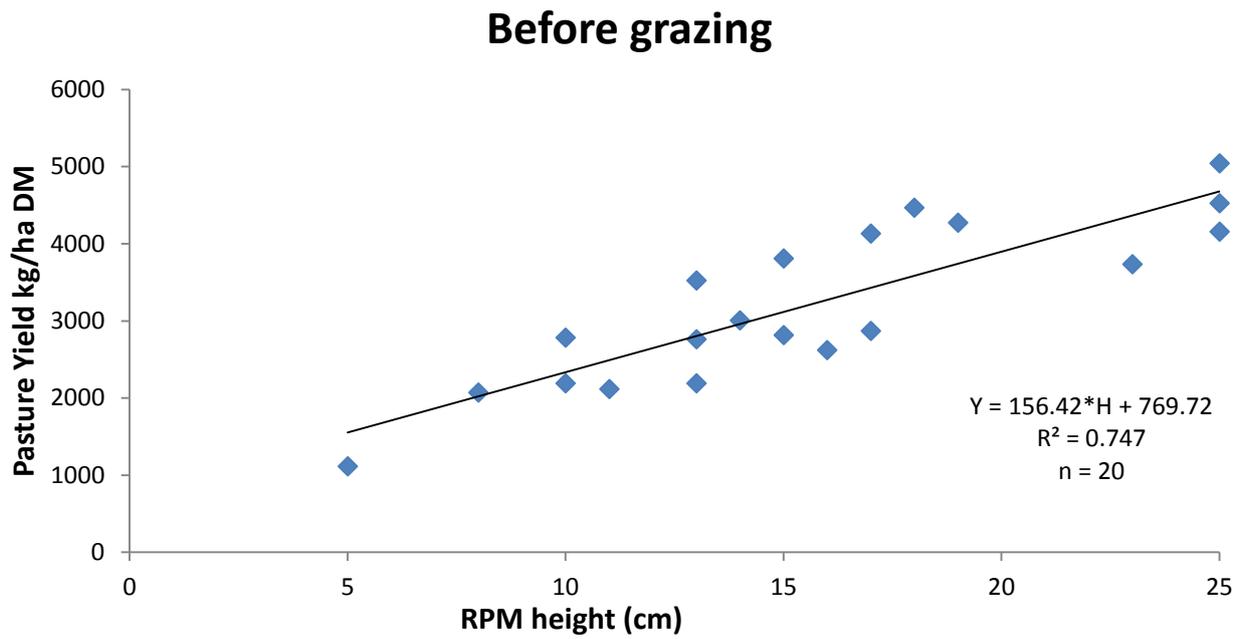


Figure 4.1. Regression used for the determination of pasture yield (kg DM/ha) before the grazing period commenced.

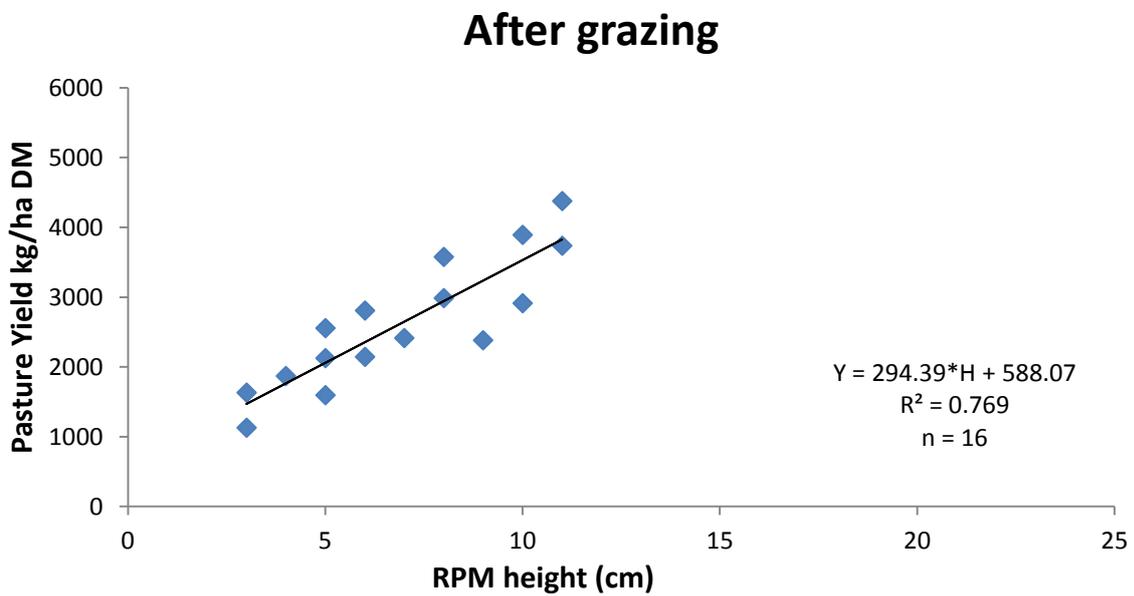


Figure 4.2. Regression used for the determination of pasture yield (kg DM/ha) after grazing, as determined with the falling plate meter (FPM).

4.7 Pasture intake

The regressions obtained were used to predict the pre- and post-grazing pasture yields to estimate dry matter intake (DMI), as presented in Table 4.2.

Table 4.2. Mean (\pm SEM) values of the pre-and post-grazing falling plate meter (FPM) readings ($n = 1470$), pasture yield and estimated dry matter intake (DMI) of pastures used in the current study.

Parameter	Pasture Values
Pre-grazing	
FPM reading (cm)	15.0 \pm 0.21
Pasture yield (kg/ha DM)	3109 \pm 23
Post-grazing	
FPM reading (cm)	5.7 \pm 0.07
Pasture yield (kg/ha DM)	2262 \pm 32
Pasture removed per grazing (kg/ha DM)	847 \pm 16
DMI per animal (kg DM/day)	4.5 \pm 0.08

The mean DMI per treatment was also calculated to determine possible treatment effects. It should be kept in mind that calculated values are estimates of pasture intake per paddock and not per individual animal, therefore it was not possible to determine individual feed efficiency ratios of animals. The results obtained suggested that there were no major differences among treatments regarding pasture intake.

Table 4.3. Mean (\pm SEM) daily dry matter intake (DMI) of each treatment during the eleven weeks of the study period.

Treatment ¹	DMI of heifers (kg/day)
Ap	4.5 \pm 0.90
Am	4.2 \pm 0.95
Ao	4.7 \pm 0.70
Mp	4.2 \pm 0.73
Mm	4.7 \pm 0.82
Mo	4.6 \pm 0.77

¹Ap = Apple placebo; Am = Apple monensin; Ao = Apple oregano; Mp = Maize placebo; Mm = Maize monensin; Mo = Maize oregano

4.8 Chemical composition of the starch and non-starch concentrates

The chemical composition of the two concentrates as formulated with AMTS.Cattle was presented earlier (Table 3.3). The actual composition was based on samples collected throughout the experimental period and analysed according to methods described in 3.5.1 (Concentrate and pasture sampling and analyses). Results are presented in Table 4.4.

Table 4.4. Mean (\pm SEM) of the nutrient composition of the starch and non-starch concentrate supplements. Three samples of each concentrate were collected during the experimental period.

Chemical composition ¹ (g/kg DM, or as stated)	Concentrate	
	Apple-pulp/Non-starch	Maize/Starch
DM	893.0 \pm 0.36	903.8 \pm 2.05
OM	907.2 \pm 2.62	929.1 \pm 1.59
EE	55.5 \pm 0.99	36.7 \pm 0.59
CP	139.1 \pm 3.32	123.5 \pm 0.89
NDF	293.4 \pm 2.27	169.7 \pm 2.53
ADF	231.1 \pm 3.92	80.3 \pm 1.82
Starch	123.6 \pm 3.22	312.6 \pm 11.02
IVOMD	773.3 \pm 4.92	868.8 \pm 6.44
ME (MJ/kg)	12.21 \pm 0.09	13.08 \pm 0.09
Ca	16.1 \pm 0.61	11.6 \pm 1.65
P	7.4 \pm 0.14	5.8 \pm 0.08
Na	8.6 \pm 0.04	7.9 \pm 0.08
Mg	2.8 \pm 0.06	2.5 \pm 0.05
Ca:P	2.18	2

¹ DM - dry matter; OM - organic matter; EE - ether extract; CP - crude protein; NDF - neutral detergent fibre; ADF - acid detergent fibre; IVOMD - in vitro organic matter digestion; ME - metabolisable energy (calculated: ME = 0.014 x DIGY + 0.025 x Oil); Ca - calcium; P - phosphorous; Na - potassium; Mg - magnesium Ca:P - ratio between calcium and phosphorous.

There were no major differences between supplements regarding chemical composition (Table 4.4). The analysed values for both supplements were higher than the formulated values (10.77 MJ/kg) according to AMTS.Cattle (Table 3.4). The crude protein levels of the analysed concentrates were also slightly higher than the AMTS.Cattle values of 118.8 g/kg. Differences in starch content were smaller as analysed (Table 4.4) compared to the formulated values (Table 3.4). When looking at the minerals there were also differences between the AMTS.Cattle values and the analysed values.

4.9 Results and discussion of growth study

Data were subjected to a completely randomised two way factorial ANOVA to detect if any interaction occurred. The statistical analysis program Statistica (Data analysis software system, Statsoft Inc. 2011, version 10.0) was used to analyse all data. The null hypothesis was always stated as: $H_0: \mu_1 = \mu_2 = \mu_3 = \mu_a$ and rejected when $P < 0.05$. ANOVA's was used to compare the treatment Least Square Means at a 5% significant level. Shapiro Wilk tests were used to test for normality and Levene's test were used to test for homoscedasticity. All the data were normally distributed and homoscedastic. Two of the heifers (treatment Mm and Mp) were treated as missing values as they calved during the last 2 weeks of the study period and were therefore not slaughtered. Both of them did however partake in all the other aspects of the study to ensure that all treatments were equally treated.

4.9.1 Interactions

A complete ANOVA were calculated to detect if any interactions of the ADG during the 66 day growth study between combined treatments 'Energy' and 'Growth promoter' occurred. The null hypothesis stated that there would be no interactions. According to the *P*-value (0.396) there was no statistical evidence that the null hypothesis could be rejected. Therefore further analyses could be done to detect if any differences between the main effects occurred.

4.9.2 Main effects: energy source and growth promoter

The ADG of main effect factor A; starch vs non-starch containing concentrates (maize vs apple pulp) was subjected to a least square (LS) means test to detect if any treatment differences occurred. The null hypothesis stated that there were no differences between main treatments ($H_0: \alpha_1 = \alpha_2 = \alpha... = 0$). The *P*-value (0.0196) provided sufficient evidence to reject the null hypothesis. The ADG of the maize treatments were 1.33 ± 0.063 kg/day during the study period while the ADG of the apple pulp treatments were 1.54 ± 0.060 kg/day (Figure 4.3). Therefore, it was concluded that the apple pulp-treatments resulted in significantly higher ADG results than the maize treatments.

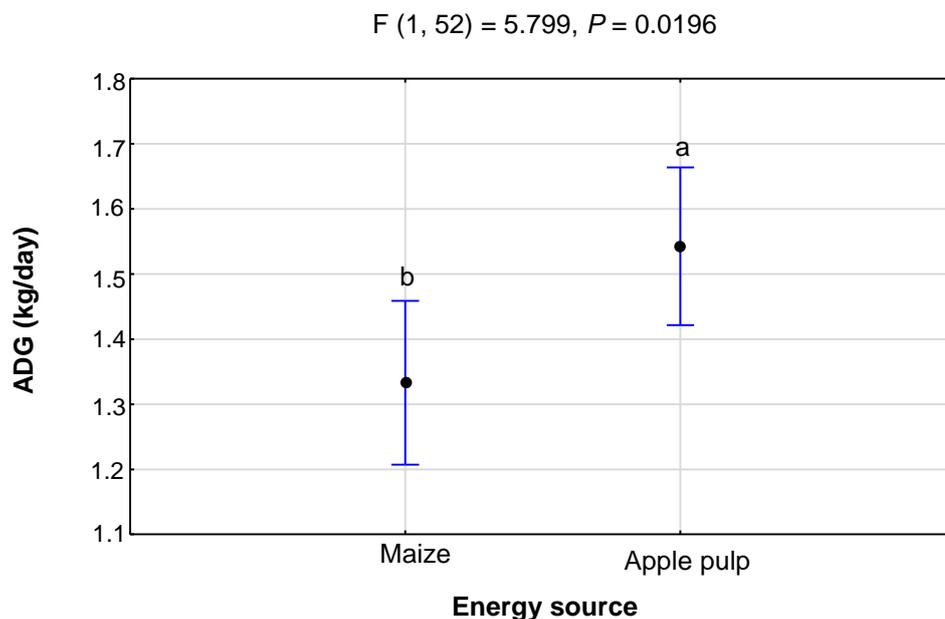


Figure 4.3. Least Square Means test for average daily gain (ADG) of heifers subjected to factor A (different energy sources): maize containing concentrate and apple pulp containing concentrate with 95% confidence intervals.

The effect of factor B; growth promoters (placebo, monensin and oregano) were then subjected to LS mean test. The null hypotheses stated that no differences would appear ($H_0: \beta_1 = \beta_2 = \beta... = 0$). The *P*-value (0.573) confirmed that the null hypotheses cannot be rejected therefore no evidence of differences between the

placebo, monensin and oregano growth promoters could be announced. The ADG of the different growth promoters were as follows: placebo = 1.44 ± 0.076 kg/day; monensin = 1.49 ± 0.076 kg/day and oregano = 1.38 ± 0.074 kg/day (Figure 4.4).

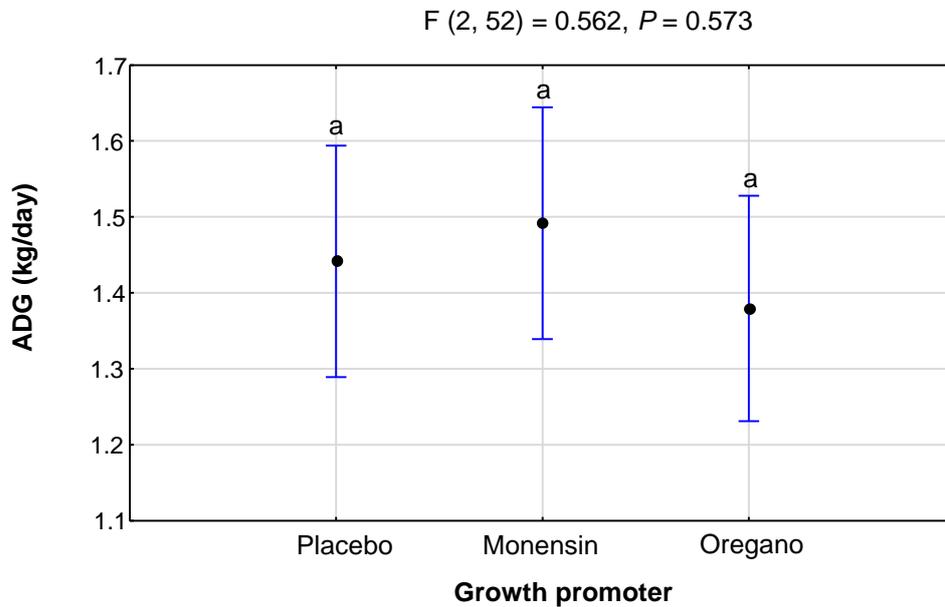
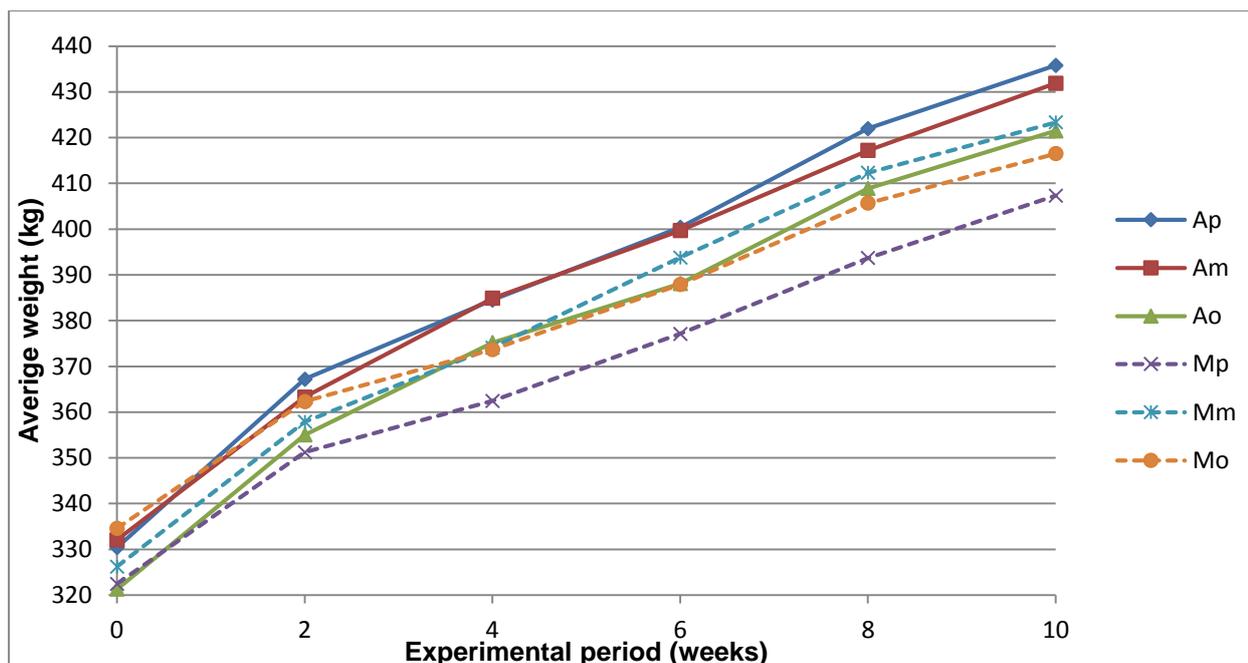


Figure 4.4. Least Square Means test for average daily gain (ADG) of heifers subjected to factor B (growth promoter): placebo, monensin and oregano with 95% confidence intervals

All of the treatments had higher ADG during the first two weeks of the growth study ($ADG = 2.11 \pm 0.09$ kg/day) as seen in the higher gradient of the growth lines during the first two weeks (Figure 4.5). This higher growth rate might be due to some form of compensatory growth as the heifers were well adapted to concentrate supplements just before their first weighing at week 0 (Figure 4.5). From Weeks 2 to 6 extreme weather conditions, either very hot or rainy, might have contributed to the slower growth rate.



¹Ap = Apple placebo; Am = Apple monensin; Ao = Apple oregano; Mp = Maize placebo; Mm = Maize monensin; Mo = Maize oregano

Figure 4.5. Average heifer weights of each of the six treatments measured fortnightly during the study period

The fixed amount of concentrate supplied, increased from 4 kg/day to 5 kg/day in week 6. This increase had a slight increase effect on the ADG rate when compared to the previous 4 weeks (Weeks 2 to 6) as seen in the slope (Figure 4.5). The ADG of the all the treatments were, however, higher (1.49 ± 0.31 kg/day) during the first 6 weeks than the last four weeks (1.31 ± 0.05) (Table 4.5).

Table 4.5 ADG of heifers when 4 kg/day (week 0 to 6) and 5 kg/day (week 6 to 10) concentrate were supplemented respectively; total weight gain during study.

Treatment	ADG kg/day (weeks)		Body weight (kg)		
	0 to 6	6 to 10	Initial weight	End weight	Total weight gain
Ap	1.64	1.46	330.4	435.8	105.4
Am	1.59	1.36	332.1	431.9	99.8
Ao	1.56	1.37	321.3	421.5	100.2
Mp	1.28	1.27	322.4	407.3	84.9
Mm	1.59	1.21	326.2	423.3	97.1
Mo	1.25	1.18	334.6	416.5	81.9
Average	1.49	1.31	327.8	422.7	94.9

¹Ap = Apple placebo; Am = Apple monensin; Ao = Apple oregano; Mp = Maize placebo; Mm = Maize monensin; Mo = Maize oregano

It was, however, interesting to see that each of the apple pulp containing treatments had a higher average total gain (Ap = 105.4 ± 8.2 kg, Am = 99.8 ± 7.4 kg, Ao = 100.2 ± 4.8 kg) during the study period compared to the maize containing treatments (Mp = 84.9 ± 7.0 kg, Mm = 97.1 ± 6.6 kg, Mo = 81.9 ± 7.5 kg) (Table 4.5). It could

also be seen that the Mm treatment, which is most commonly used in South African pasture finishing systems, did perform better (but not significantly) than the Mp and Mo treatments.

There were no statistical differences between the carcass weights of the apple and maize containing concentrate supplements, with treatments having the following carcass weights: Ap = 225.5 ± 9.2 kg, Am = 221.8 ± 6.3 kg, Ao = 224.5 ± 7.5 kg, Mp = 214.6 ± 9.0 kg, Mm = 220.5 and Mo = 221.9 ± 6.5 . The reason why no differences in the carcass weights were detected might be because of the differences in the initial body weights of the treatment groups. Although the treatments were blocked according to body weight, the two missing values will be discussed in 3.2 (Animals, experimental design and treatments) caused the initial weights to differ slightly. Therefore, the differences in the “end weight” and accordingly the carcass weight of the treatment groups did not show significant differences. The individual carcass weights together with the “End weight” of each animal were used to calculate their dressing percentages.

4.9.3 Dressing percentages of heifers

All the experimental animals were slaughtered, except for the two missing value heifers as discussed in 3.2 (Animals, experimental design and treatments). ANOVA analyses of the dressing percentage results were done to ascertain whether any interaction occurred between “Energy source” and “Growth promoter”. The null hypothesis was that no interactions were present. According to the *P* value of 0.889 the null hypotheses could not be rejected. The LS means tests were then subjected to the main effects “energy” and “growth promoter”. The null hypotheses stated that there were no statistical differences between the treatments as pertaining to the dressing percentages. No evidence could be found to reject the null hypotheses with *P* values of 0.505 for “energy” (Table 4.6) and 0.240 for “growth promoter” (Table 4.7), respectively. Therefore no differences among treatments regarding dressing percentage were observed.

Table 4.6. Least Square Means for dressing percentage of heifers subjected to factor A (different energy sources): maize containing concentrate and apple pulp containing concentrate.

Current effect: $F(1,52) = 0.451, P = 0.505$					
Treatment ¹	Dressing % mean	Dressing % Std. Err.	Dressing % - 95.00%	Dressing % +95.00%	N
M	52.7	0.52	51.65	53.72	28
A	52.2	0.50	51.21	53.20	30

¹M = Maize; A = Apple pulp

Table 4.7. Least Square Means for dressing percentage of heifers subjected to factor B (different growth promoters): placebo, monensin and oregano concentrates.

Current effect: $F(1,52) = 1.467, P = 0.240$					
Treatment ¹	Dressing % mean	Dressing % Std. Err.	Dressing % - 95.00%	Dressing % +95.00%	N
p	52.3	0.63	51.01	53.53	19
m	51.8	0.63	50.54	53.06	19
o	53.3	0.61	52.04	54.49	20

¹p = placebo; m = monensin; o = Origano

The fat classification of the carcasses was as follows: 3 x class 1, 47 x class 2 and 8 x class 3 (Table 4.8). No clear trends could be seen in the different fat classification frequencies among the different treatments. As a result of the fat classification it could be assumed that the ADG would have decreased further if the heifers were finished further and not slaughtered at the specific time (the heifers would have started to gain excess fat).

Table 4.8. Fat classification of the heifers in each treatment.

Treatment ¹	Fat classification			Total heifers
	class 1	class 2	class 3	
Ap	1	8	1	10
Am	0	9	1	10
Ao	1	7	2	10
Mp	0	8	1	9
Mm	1	8	1	10
Mo	0	7	2	9
Total	3	47	8	58

¹Ap = Apple placebo; Am = Apple monensin; Ao = Apple oregano; Mp = Maize placebo; Mm = Maize monensin; Mo = Maize oregano

4.10 Conclusion

The results obtained during this study indicated that feeding apple pulp as main energy source in a pasture supplement was more efficient than feeding maize as main energy source. When available, dried apple pulp can thus successfully replace maize in a pasture supplement. Growth promoters didn't affect results and it appears that either the placebo or oregano oil extract can replace monensin in a pasture supplement to finishing beef heifers without ill effects.

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CHAPTER 5

ECONOMICAL EVALUATION OF FINISHING EXPERIMENT; THE SOUTH AFRICAN APPLE INDUSTRY

5.1 Introduction

Meat consumption is projected to increase by 73% in 2050 (FAOSTAT, 2015). More cattle need to be finished in intensive finishing systems because of a restricted amount of available terrestrial biomass. At the moment livestock accounts for a fifth of all terrestrial biomass and from 2000 to 2050 it is expected that the global population of cattle will grow by about two thirds (FAOSTAT, 2015). These expected consumptions puts tremendous pressure on feed production systems to meet these demands.

The economical evaluation study was done to add the financial perspective and implications of the finishing study performed on the heifers. Factors that influence profitability of finishing systems include: management, price margin, feed margin, cost of feed, buying price of weaned calves and selling price of finished cattle (DARD, 2015). The economical focus of the study was on the feed cost and the feed margin (*ceretis paribus*) and not on the buying price and price margin.

Maize is the most commonly used energy source in South Africa and it was also used as base feed ingredient during this study. As South Africa is well known for its apple production, dried apple pulp was investigated as an alternative energy source to maize. South Africa is one of the world's major apple exporting countries with the Western Cape Province contributing 60% and more to these exports. Apples that are not exported are processed to juice concentrate and pulp.

5.2 Economical terms used in a beef finishing systems

As mentioned in the introduction, the cost and profit margin of finishing systems are determined by management costs, price margin, feed margin, cost of feed, buying price of weaned calves and selling price of finished cattle (DARD, 2015).

The price margin is the profit or loss of the farmer as a result of price increase or decreases from the time the animal is bought (cost price) to the time the animal is sold (sale price). It is calculated as follows: Price margin = Initial live mass x (sale price/kg - cost price/kg). Feed margin is determined by the amount of concentrate supplement or pasture consumed, and the growth results obtained. The feed margin is the profit or loss earned by a farmer as a result of average daily gain (ADG) in relation to the cost of dry matter intake (DMI) and is calculated as: Feed margin = Live mass gain x (sale price/kg - cost/kg gained). The variable feeding cost would therefore be determined by the feed margin and the feed cost. The feed ingredients used in a concentrate supplement determine the cost, with the availability of ingredients playing a major role in the price.

The cost of carbohydrate source used (usually maize, hominy chop, etc.) in relation to the beef price plays a significant role in the profitability of finishing systems. According to DARD (2015) a beef to maize ratio of more than 13:1 is needed to have a profitable cattle finishing business. The time period of finishing is also very important as the ADG decreases towards the end of feeding, therefore cattle have to be slaughtered before the cost per kg carcass gain is higher than the price per kg carcass earned (over finishing causing a negative feed margin).

Farmers usually buy cattle at a price per kg (live mass). They therefore have to estimate the dressing percentage in order to calculate the carcass price per kg. Dressing percentage differs between cattle, with lean animals having lower dressing percentages (49%) than very muscular animals (60%). The maturity level, fatness, sex, etc. have an influence on dressing percentage as discussed in 2.4.5.2 (Factors influencing the dressing percentage of cattle). Steers with a fat class of 2 or 3 will usually have a mean dressing percentage of between 54 and 56%.

5.3 Methods and results of growth study

Sixty Bonsmara heifers were finished on irrigated pastures. They were blocked according to initial weight and then divided into six treatments according to a 2 x 3 factorial design. All concentrate supplements were formulated to have iso-nutrient values, with three treatments mainly containing a starch energy source (maize) and three mainly containing non-starch energy source (apple pulp). Each of the three treatment groups received different supplements that contained the following potential growth promoters: placebo, monensin or oregano oil extract. Treatments were designated as Apple placebo (Ap), Apple monensin (Am), Apple oregano (Ao), Maize placebo (Mp), Maize monensin (Mm) and Maize oregano (Mo).

During the first 42 days of the growth study, all heifers received an average of 4 kg of supplement (“as is” basis) per day. From day 43 until day 66 (the last day of the study) each heifer received 5 kg (“as is”) of the supplement per day. Fresh drinking water and pasture were available *ad libitum* for the duration of the trial. The heifers were weighed every fortnight in order to determine their average daily gain (ADG). The following ADGs were obtained from the different treatments; Ap = 1.60 kg/day, Am = 1.51 k/day, Ao = 1.52 kg/day, Mp = 1.29 kg/day, Mm = 1.47 kg/day and Mo = 1.24 kg/day.

5.4 Costs and revenue summary of growth study

A Table was used to summarise all the financial factors that had an influence on the net income over feeding cost. A few assumptions were made in order to calculate the “net income over feeding cost”. As the focus of the study was to evaluate the financial impact of the treatment groups during the 66 days, an assumption was made that dressing percentage and price would have been the same if the heifers were slaughtered on the first day of the experimental study (price margin = 0). There fore only the carcass weight gain and cost of the weight gain were calculated to determine the “net income over feeding cost” for the specific time period. All the parameters included in the table are discussed beneath.

Table 5.1. Summary of the growth study in financial terms

Parameters ¹	Non-starch energy source ²			Starch energy source		
	Ap	Am	Ao	Mp	Mm	Mo
Concentrate cost (R/Ton)	3187.75	3208.75	3194.05	3316.75	3337.75	3323.05
Concentration intake/heifer (kg)	288	288	288	288	288	288
Pasture cost (R/kg) DM	1	1	1	1	1	1
Pasture DMI/ heifer (kg/day)	4.52	4.17	4.7	4.23	4.7	4.64
Total feed input cost/heifer	1216.39	1199.34	1230.09	1234.4	1271.47	1263.28
Avg weight gain/heifer (kg)	105.4	100.2	99.8	84.9	96	81.9
Avg dressing percentage/heifer	51.83	53.23	51.53	52.71	52.07	53.28
Beef price (R/kg)	32.75	32.75	32.75	32.75	32.75	32.75
Net beef income/heifer (R)	1789.09	1746.76	1684.23	1465.58	1637.08	1429.08
Net income over feed cost (R/heifer)	572.7	547.42	454.14	231.18	365.6	165.81

¹Measured during research

²Ap - Apple placebo; Am - Apple monensin; Ao - Apple oregano; Mp - Maize placebo; Mm - Maize monensin; Mo - Maize oregano

The prices of the different concentrates delivered on the experimental farm were: R3288.25 /ton for the starch based and R3159.25 /ton for the non-starch based concentrates. The different premixes still had to be added to this price. Prices of the premixes were: R9.50 /kg for the placebo, R16.50 /kg for the monensin and R11.60 /kg for the oregano premix (FeedPharm, 5 Crompton Street, Strand, Capetown, 7140), 3 kg of premix were used per ton of concentrate.

The total concentrate intake was calculated according to the 42 day restricted 4 kg/day and 24 day restricted 5 kg/day intake levels. The pasture cost was R1 /kg DM (2015, Prof R. Meeske, Specialist scientist, 082 9084 110). The DMI per heifer were calculated according to the falling plate meter (FPM) measurements and regressions formulated to predict a DMI per paddock as seen in 3.3.6 (Pasture measurement). The weight gain and dressing percentage were obtained according to data collected in 3.5.2 (Growth rate of heifers) and

3.5.3 (Dressing percentages). Roelcor abattoir (Roelcor abattoir Malmesbury, Western Cape, South Africa, 021 851 2694) offered a price of R 32.75 /kg for A-class beef on the 17 November 2014.

All the above information was used to calculate the total feed input cost and the net beef income. According to the two assumptions (same dressing percentage and price/kg carcass at the beginning and end of trial) net income over feeding cost of treatments could be calculated by subtracting total feeding cost from the net beef income (Table 5.1). The average net income over feeding cost of the non-starch (apple pulp) concentrate treatments were R524.75 /heifer. While the average net income over feeding cost of the starch based (maize) concentrate were R254.20 /heifer *ceretis paribus*. According to these calculations the farmer would have gained more than double the net income over feeding cost if he/she used the non-starch containing energy source rather than the starch containing energy concentrate supplements.

It is important to mention that the relative purchase price of maize and apple pulp will have a great influence on the outcome of the financial summary in this study. Apple pulp and maize formed 50% of both concentrates used in this study, implying that the price of either would have a significant effect on the cost of the supplements. All the input and output costs are variable and have a huge influence on the net income over feeding cost. As maize is generally used as feed ingredient, the apple pulp industry needs to be investigated to evaluate the possibility of apple pulp as sustainable feed source and to look at the relative prices between these two feed ingredients.

5.5 Overview of apple production in South Africa

South Africa can cultivate a variety of fruits due to its diverse weather and climate conditions. South Africa is a globally well-known producer and exporter of apples (Jafta, 2014). Due to the Mediterranean climate in the Western Cape Province it contributes to a major portion (more than 60%) of the total apple production in South Africa, the specific regions are: Groenland, Ceres and Villiersdorp (Hortgro, 2014). Other regions include the Langkloof West in the Eastern Cape and also small areas in the Northern Cape, Free State, KwaZulu-Natal and Mpumalanga (Table 5.2). The total production area for apples during 2014 was 22 443 hectares with the four main producing regions being responsible for 89% of the total hectares planted in South Africa. All of these producing areas are export driven and have relative high packing percentages, depending on the weather and climate.

Table 5.2 Apple production areas in hectares during 2012

District	Number of trees	Area (Ha)
Ceres	8 884 650	6 724
Groenland	7 424 929	5 819
Langkloof East	4 249 975	4 191
Velliersdorp / Vyeboom	4 246 462	3 707
Langkloof West	606 689	534
Free State	724 259	489
Southern Cape	600 528	411
Piketberg	467 455	337
Klein Karoo	257 350	271
Mpumalanga	263 872	187
Somerset West	297 157	133
Worcester	64 078	35
Wolseley / Tulbagh	24 616	22
Northern Province	20 140	20
Eastern Cape	3 739	15
Stellenbosch	20 869	15
Paarl	13 163	11
Franschhoek	3 036	2
Total	28 172 967	22 925

Source: Hortgro, 2014

5.6 Total apple production and projection in South Africa

Apple production have surpassed 5.2 million tons during 2014 in the Southern Hemisphere, South Africa has contributed 15% of this total (BFAP, 2015). The Southern Hemisphere production is projected to expand by 5% to 5.5 million tons during the 2015 season (WAPA, 2015). Apple production in South Africa has grown consistently from 2006, reaching a 41% expansion in 2014. The apple bearing area in South Africa has expanded by 11% during this period. It can be assumed that the bulk of production increase was attributed to yield improvements (BFAP, 2015). Although further expansion are constrained by climatic conditions, water availability and chilling requirements, production is still projected to sustain an upwards trend due to continuous technological innovations. By 2024, apple production is projected to be more than 950 thousand tons which is an expansion of about 16% during the next decade (Figure 5.1).

The South African apple industry is more stable in the long run than the short run. Weather conditions have the biggest contribution to the amount and quality of apple production in the short run. One of the main reasons why the industry output is more stable over the long term is because of the long productive life time of the orchards. The high establishment cost per hectare causes the break even points to be reached many years

after the orchards had been established. According to Hortgrow (2014), 31% of South African orchards are between 0 and 10 years of age, 38% between 11 and 25 years and 34% older than 25 years.

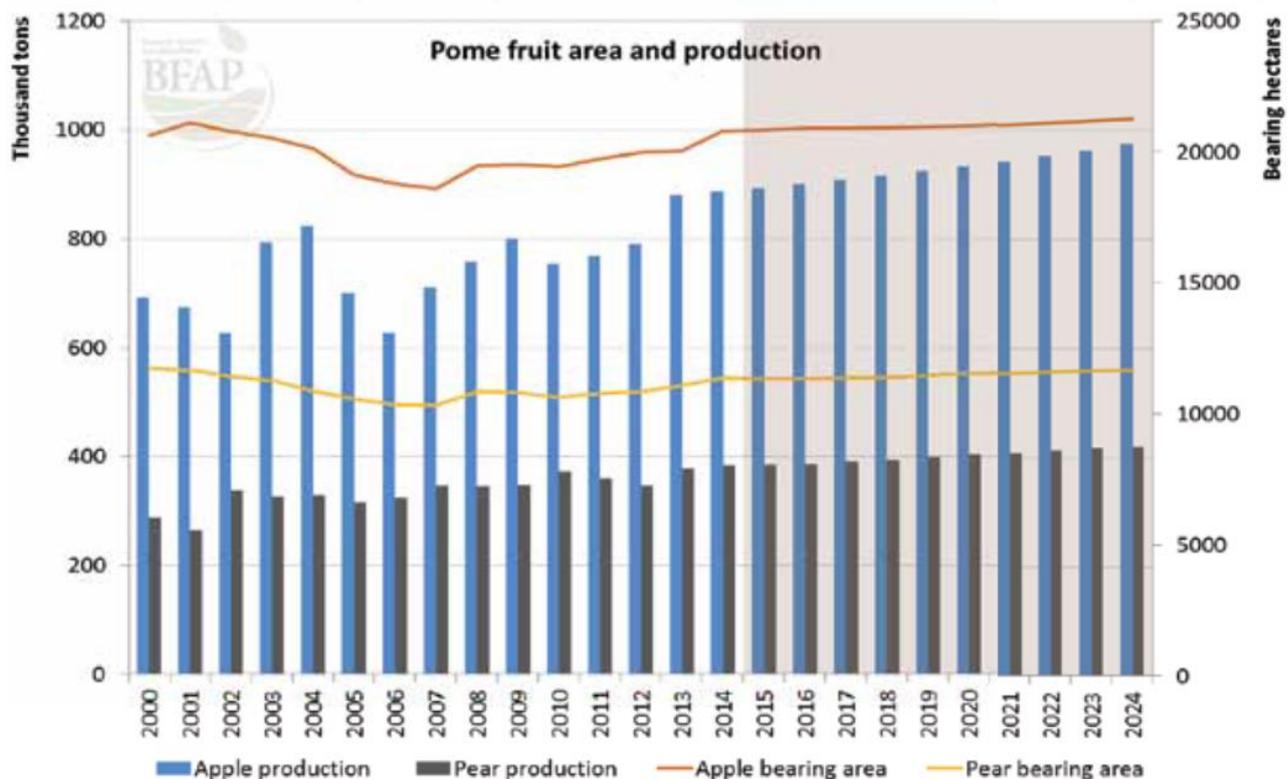


Figure 5.1. Total production and bearing hectares of South African apple and pear industry (BFAP, 2015)

5.7 Marketing distribution of the South African apple industry

In South Africa, apples are mainly produced for the export market. Climate conditions play an important role in the quality of the apples and therefore also on the production distribution as only high quality apples are exported. When measured with the Relative Trade Advantage (RTA) framework, South Africa is one of the most competitive apple exporters in the world. From 1990 to 2011 South Africa is only outranked by Chile in the Southern Hemisphere, while outperforming countries in the Northern Hemisphere, such as Spain, Italy and France (BFAP, 2014). Factors such as relative currency depreciation, strong import demand from Europe and prime apple production climates in South Africa lead to an all-time high of 47% of the total production entering the export market. This exporting share of total production decreased to 37% in 2014 mainly due to reduced quality. Over the next ten years the production entering the exporting market is projected to remain at 42% if normal climate conditions are assumed. The processed and dried fraction is also projected to stay at about 30% (Figure 5.2). Therefore, the total amount of processed apples (tons) will increase as the portion of processed apples is projected to be consistent (30%) and the total amount of apple production is projected to increase.

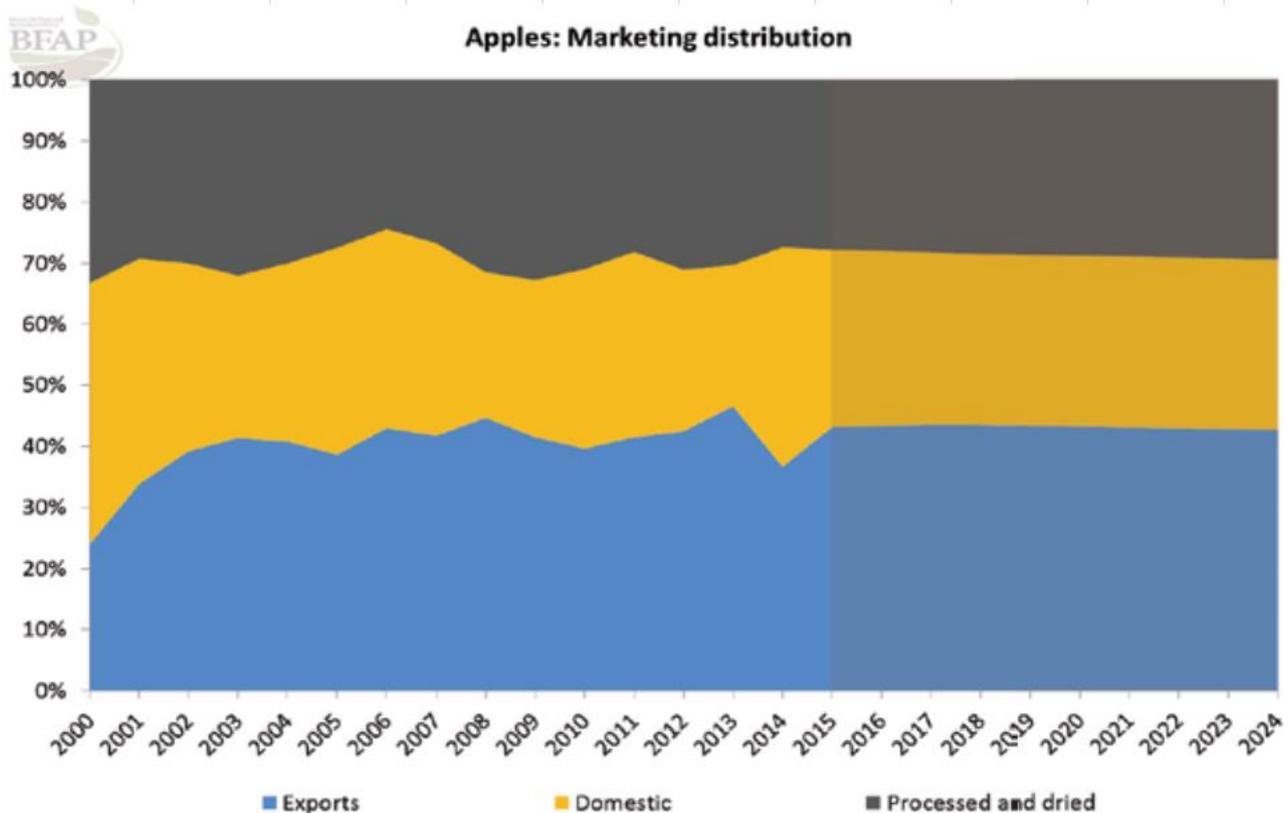


Figure 5.2. Marketing distribution of South African Apples (BFAP, 2015)

5.8 Overview of the apple pulp industry in South Africa

Processing of apples consists of canning, drying and juice manufacturing. There are six manufacturers of juice in South Africa (2015, Fred Mosterd, Director of processing, Elgin Fruit Juices, 084 624 7964). Apple pulp is a by-product of the apple juice industry and the amount of apples being used for juice is dependent on the quality of the exporting apple industry. When South African farmers have high exporting quality and quantities, fewer apples are available for the juice industry, in which case concentrated apple juice will be imported. It is therefore difficult to estimate the growth of the apple pulp industry.

Elgin Fruit Juices at Grabouw in the Western Cape is the only apple juice manufacturer in South Africa that dries their apple pulp. Each of the other juice producers sell wet apple pulp to nearby consumers which is mainly used for animal feeding purposes, compost manufacturing and also the generation of electricity (2015, Fred Mosterd, Director of processing, Elgin Fruit Juices, 084 624 7964). The other juice producers possibly believe that the extra risk and labour costs exceed the benefits of the value adding drying process. Three main reasons are responsible for the trend, namely: the high cost of drying without a high enough premium for the dried product. Secondly, there is currently not a well-established market for dried apple pulp. Lastly, the volatility in the industry because of apple pulp being only a by-product.

Table 5.3. Apple production and distribution to the different markets in South Africa from the year 2006 to 2014

Year: Oct-Sep	Total production (Tons)	Local Market (Tons)	Export Volume (Tons)	Processed Volume (Tons)	Dried Fresh Volume (Tons)	Change in total production (%)
2005/2006	627091	204123	266413	153033	250	-10%
2006/2007	710172	223552	296776	188624	1220	13%
2007/2008	757680	180480	338647	236833	1720	7%
2008/2009	800803	205808	332684	261191	1120	6%
2009/2010	753167	221131	298574	232473	990	-6%
2010/2011	768125	231285	318993	216257	1590	2%
2011/2012	790636	209198	335827	244427	1110	6%
2012/2013**	908240	203181	434663	267436	2960	12%
2013/2014**	792549	210303	339321	239765	3160	-13%
Average crop distribution (%)		27.80%	42.70%	29.20%	0.20%	

5.9 Processing of dry apple pulp

Elgin Fruit Juices is the only drying facility in South Africa. They receive apples mainly during the harvesting season, but store the apples in wooden crates in order to produce throughout the year. Each ton of apples delivers approximately 815 L of juice, which means that 185 kg/ton wet apple pulp can be produced. After the juice has been extracted the wet pulp has a DM content of about 65 to 70%. After drying, a total mass of 42 kg/ton dry apple pulp is produced (Mirzaei-Aghsaghali & Maheri-Sis, 2008). After the drying process, apple pulp has a DM content of between 86 and 90%. During the drying process, the wet pulp is blown through a large round oven in a zig-zag pattern. The oven has a temperature of up to 500°C. The drying process is expensive, as the heat source is coal which has to be transported from the northern parts of South Africa. After the drying process, the pulp goes through a cooling process to prevent heat damage (2015, Fred Mosterd, Director of processing, Elgin Fruit Juices, 084 624 7964). After cooling, the dried pulp is stored in bunkers from where it can be distributed. Compared to juice producers that only sell wet pulp, drying facilities require additional labour, management and maintenance costs.

5.10 Chemical composition of apple pulp for ruminant use

The nutritive value of apple pulp (AP) is variable. It depends on husbandry practices of the orchards, apple maturity, natural variation between apples and the extraction process that is used to make juice (Kennedy *et al.*, 1999). According to Carson *et al.* (1994), the CP of AP can vary between 19 and 65 g/kg on a DM basis. Singhal *et al.* (1991) and Wolter *et al.* (1980) reported NDF values of 300 to 482 g/kg DM and ADF values of 250 to 420 g/kg DM. The ME content of apple pulp can vary between 7.77 and 9.1 MJ/kg DM (Givens & Moss, 1990). According to the NRC (2001), the mean protein degradability is 68.4%. The following results (Table 5.4) were obtained from analyses done on the AP that was used in the current study:

Table 5.4. Nutrient values of dried apple pulp as analysed according to methods used in Chapter 3.5.1

¹ Parameters (g/kg)	Dried apple pulp
CP	63.7 ± 175
ME (MJ/kg)	11.61 ± 0.48
NDF	424.0 ± 4.64
OM	973.9 ± 1.74
EE	55.0 ± 0.94
Calcium	1.25 ± 0.03
Phosphorus	1.50 ± 0.05

¹ CP - Crude Protein; ME - Metabolizable Energy; NDF - Neutral Detergent Fibre; OM - Organic Matter; EE - Ether Extract; Ca - Calcium; P - Phosphorous.
± - Mean and standard error

5.11 Advantages and disadvantages of dried apple pulp as feeding source

Apple pulp as by-product energy source has two important advantages, firstly it can reduce dependence of livestock on grain (being a human consumed commodity) and secondly it can eliminate the cost of waste management programs. Both factors became important in recent years especially in developed countries as human population and the amount of food by-products have increased (Bampidis & Robinson, 2006).

When fed to ruminants, apple pulp offers many advantages as a raw material, especially when dried. Firstly it can be stored for long periods without getting mouldy. Secondly, it can be mixed with any other feed sources, making it comparable to any other commercially used raw material. The nutritional value of apple pulp is such that it has a relatively low metabolizable energy and crude protein content compared to maize while it has a higher neutral detergent fibre content. Apple pulp containing concentrates may therefore have a lower risk for causing acidosis in ruminants. However, other feeding raw materials which contain a higher crude protein and metabolizable energy content (for example canola or soya oilcake) have to be added in order to produce a high quality concentrate that meets protein requirements. Mould *et al.* (1983) found that concentrates containing sugar (sucrose) result in higher rumen pH values than concentrates containing starch.

5.12 Investigation of expansion in the dried apple pulp market

When investigating a market for dried apple pulp, the main factors affecting expansion in the industry would firstly be the ability to supply consistently throughout the year. Supply throughout the year will most probably be attainable if sufficient quantities of apples can be stored in order to continue pulp production during the non-harvesting season. Secondly, the cost of constructing a drying facility and the location of the facility will play a major role as apple pulp is a bulky product. According to Webber's triangle, it would be wise to investigate the construction of drying facilities near the production areas. Therefore, further investigation would be appropriate in the following three apple producing regions: Ceres, Langkloof East and Villiersdorp (Table 5.2). According to Webber's triangle it is, however, just as important that the product (dry apple pulp) has to be consumed near the production area. This investigation would therefore typically be for consumers in the Western Cape as they

would have a lower transport differential for apple pulp compared to maize that has to be transported from the northern parts of South Africa.

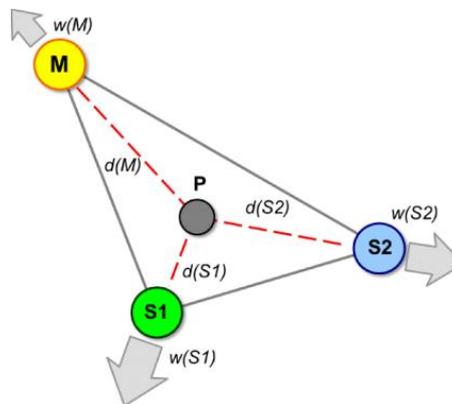


Figure 5.3. Weber's location triangle (WLT, 2015)

According to Weber's location triangle three factors (transport cost, labour cost and agglomeration economies) influence industrial location, but transportation is the most important element of the model. Figure 5.3 illustrates the issue of minimizing transport cost with dried apple pulp $w(M)$ tons to be sold at market M and $w(S1)$ and $w(S2)$ tons of processing apples (input materials), respectively from S1 and S2 (WLT, 2015). Weber developed a material index which is simply the ratio of the weight of inputs delivered and output obtained. According to this index, the apple pulp producers have to be near the production areas as the ratio is > 1 . Transportation cost of feed sources such as dried apple pulp is still a big expense because of its bulkiness. The transportation cost has to be minimized in order to get an economical advantage.

5.13 Conclusion

The reason why this chapter was included was to confirm whether apple could be used in an economic way to replace maize (at least partly) in pasture based beef production systems in the Western Cape. The two main aspects of this study was to firstly see if apple pulp could be used successfully in pasture finishing systems, pertaining to the ADG of the different treatments used in the experiment. Secondly, to give an overview of the apple industry and more specific the apple pulp industry in the Western Cape as it might have an effect on the feed ingredient supply.

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CHAPTER 6

GENERAL CONCLUSION AND RECOMMENDATION

The first aim of the study was to evaluate an alternative energy source to maize. The alternative had to be economically viable and continuously available. Apple pulp, which is a readily available product, especially in the Western Cape of South Africa, was therefore investigated. The two iso-nutrient feed supplements were therefore compared in a growth study which was conducted on pastures with restricted amounts of concentrate supply. Within these two supplements, different growth promoters were included to form a 2 x 3 factorial design growth study. The second aim of the study was to determine if any differences could be found between the different feed additives with growth promoting activity.

The ADG was used as parameter to compare the different treatments. The results obtained in Chapter 5 showed that there were no interactions in ADG between the two factors (energy sources and growth promoters) used. The main effects could therefore be interpreted. The heifers that received the non-starch (A) containing energy concentrate had a higher ADG than those receiving the starch energy (M) containing supplement ($P = 0.0196$). No statistical differences were found between the treatments that received the placebo growth promoter, monensin or the oregano oil extract ($P = 0.573$).

As the carcass is the final product of a growth study, the heifers were all slaughtered and dressing percentages were obtained. The analyses of the dressing percentage data showed that no interactions between the treatments occurred. The main effects could therefore be interpreted and no differences between the energy or growth promoter treatments were found. According to this study, it is suggested that no growth promoters need to be included in the concentrates. Further studies could be done to optimize the inclusion levels of monensin and oregano oil extract. Also, further studies with more experimental animals could be done, as more than 20 animals per growth promoter treatment may have a higher possibility to obtain significant differences.

The pastures consumed during the study played an important role in the nutrient intake of the heifers. According to the FPM readings and calibration, animals in all the treatment groups consumed an average of 4.5 kg of pasture DM per day during the study period. The pasture consumed during the study period had a relatively high content of structural components, with high levels of NDF and ADF. The pasture was therefore not as highly digestible as expected and can only be classified as a average quality pasture. The maize and apple based supplements were also analysed separately and results obtained showed that they had similar nutrient values. With the high NDF values, the restricted amount of concentrate supplement provided and the good adaption periods, no signs of acidosis were observed. No other diseases or discomforts (except for heat stress due to extreme temperatures) were detected during the study period.

When looking at the study from a financial perspective, it is clear that the apple pulp containing supplements were firstly cheaper to produce per ton than the maize based ones, when formulated on an iso-nutrient base, and secondly, that they performed better, resulting in a higher ADG with the same restricted amounts supplied to all treatments. Therefore, it is suggested that apple pulp can be used as an alternative energy source (in the current economic situation) with inclusion levels of up to 50% in a concentrate supplement for beef animals finished on cultivated pastures. The study also investigated the short and long-term availability of apple pulp and it was found that there are seasonal differences depending on the weather as it influences exporting qualities. Over the long term, however, the apple pulp industry will not disappear overnight because of the high input cost of orchard establishment and also the long lifespan of an apple tree. Further studies can therefore be done to investigate possible dried apple pulp markets and evaluate if it would be feasible for other pulp producers to build drying facilities. Further studies can also be done to investigate the possibility of the fruit industry to dry some of their by-products for the cattle industry

CHAPTER 7

CRITICAL EVALUATION

7.1 Pasture

As mentioned in 2.2.6 (Measuring pasture intake) the falling plate meter (FPM) has some disadvantages. The improved model (rising plate meter or RPM) should be used in further studies and despite some other disadvantages, the RPM improves the following aspects of the FPM: the plate is not dropped onto the pasture canopy, so the plate does not travel different distances before it hits the pasture canopy at different velocities. The RPM uses the vertical dispersion of pasture pushing up the plate. A consistent spring is used to determine the density of the pasture and not gravity. The reason for the use of the FPM was because of the unavailability of a RPM at the time of the study.

Fractioning of the different grass species could have been conducted but would have been very difficult, especially when the different grass species were not at a seed production stage. The pasture samples that had to be analysed had to be frozen first before it could be dried at a later stage for analyses because there were no drying facilities on the experimental farm.

One grazing cycle was not completed before the growth experiment started, therefore the pastures were not 24 to 28 days of age during the first grazing cycle. The pasture of all treatments was, however, the same age but not the desired age of 21 to 28 days during the first grazing cycle.

7.2 Concentrate supplements

The study mainly refers to the differences obtained because of differences between the starch (M) and non-starch (A) factors, but the inclusion levels of the different protein sources (soya oilcake and canola oilcake) could have had a contributing effect on the results obtained. Further studies could therefore be done to evaluate the inclusion levels of different protein sources.

More animals per treatment would contribute to more accurate statistical differences between the different growth promoter treatments. Therefore, it is suggested that treatments with more than 20 experimental animals per group would have to be conducted to yield more accurate results. However, due to financial and labour restrictions the experiment could not have been done with more than 60 heifers in total.