The effect of essential oils and calcified marine algae as natural alternatives to ionophore antibiotics on performance of feedlot cattle

by

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DECLARATION

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

E.F. Haasbroek

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SUMMARY

The effect of essential oils and calcified marine algae as natural alternatives to ionophore antibiotics on performance of feedlot cattle

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Ionophore antibiotic supplementation is standard practice in almost all feedlots in the USA, South Africa and many other countries due to its effectiveness to increase feed efficiency and modulate feed intake. Public concern over the emergence of antibiotic resistant bacteria and the consumers' demand for safe, high quality nutritious food has stimulated the search for natural alternatives to ionophores in ruminant diets. The objectives of this study were: (i) to compare the effect of a specific blend of essential oils (XTract X60 – 7065 (XTract)) and a rumen buffer (Acid Buf) to monensin and its effects on the performance of feedlot cattle under both experimental and commercial conditions (ii) to determine the effect of these feed additives on the health status of feedlot cattle and (iii) to determine whether Acid Buf can replace monensin as feed additive in high energy feedlot diets based on hominy chop.

For the experimental growth trial 180 Bonsmara type animals were blocked into two groups and then allocated to 6 pens with 10 animals each per treatment using a randomised complete block design. The basal diets (starter, intermediate finisher and final finisher) were the same for the Control XTract and Acid Buf; the only difference being the Control treatment was supplemented with monensin (21 – 33 mg /kg DM), the XTract treatment supplemented with XTract (1000 – 1200 mg /h /d) and the Acid Buf treatment supplemented with Acid Buf at 0,6% dietary DM. For the commercial trial, animals were blocked according to the same criteria but for each treatment there were 3 pens, standing 130 head of cattle per pen, therefore 390 animals

per treatment. The experimental pen trial was designed for evaluation of growth and the commercial pen trial for evaluation of health status and growth under practical feedlot conditions.

In the small pen trial there were no differences ($P > 0.05$) in DMI, FCR or ADG between treatments. In the commercial trial the XTract supplemented cattle had a higher EW (429.3 *vs.* 417.5 kg) and ADG (1.77 kg /d *vs.* 1.70 kg /d) ($P < 0.05$) compared to monensin supplemented cattle and the Acid Buf supplemented cattle tended ($P > 0.10$) towards a higher EW (425.3 *vs.* 417.5 kg) and ADG (1.74 *vs.* 1.70 kg /d) compared to monensin supplemented cattle.

The feed conversion ratios were 5.67 and 5.26 for XTract and monensin supplemented cattle and did not differ ($P = 0.26$). The feed conversion ratios were 5.22 and 5.26 respectively for Acid Buf and monensin supplemented cattle and did not differ ($P = 0.86$).

Treatments affected health parameters in the commercial pens with 78% healthy animals (not pulled) in the monensin supplemented animals compared to 82% for XTract and 66% for the Acid Buf supplemented animals ($P < 0.01$). Rumen damage occurred in 73% of monensin supplemented animals compared to 51% for the Acid Buf supplemented animals and only 24% of the XTract supplemented animals ($P < 0.01$). Differences in health parameters did not seem to affect the overall growth performance of the cattle, suggesting a relatively minor effect on performance.

Results from this large scale study should provide South African feedlot operators with sufficient information to make informed decisions on natural alternatives when the day comes that ionophores are placed on the banned list of ruminant feed additives. Further research, however, is needed on determining the optimal dose, dietary dependant responses, adaptation of rumen microbial populations and potential additive or synergistic effects when supplemented together with other rumen modifiers. Furthermore, the cost: benefit ratio should be determined under the prevailing conditions in different countries.

LIST OF ABBREVIATIONS

ADG	average daily gain
BRD	bovine respiratory disease
CCM	cold carcass mass
d	day
DMI	dry matter intake
EO	essential oils
EW	end weight
FCR	feed conversion ratio
g	gram
h	head
kg	kilogram
L	litre
mg	milligrams
mm	millimetres
N	nitrogen
SAS	Statistical Analysis System
S.E.	Standard Error
TMR	total mixed ration
VFA	volatile fatty acid

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CHAPTER 1

Introduction and motivation

Feed additives are defined as feed ingredients of a non-nutritive nature, that stimulate growth and/or improve efficiency of feed utilization, or that may be beneficial in some manner to the health or metabolism of the animal (Hutjens, 2008).

Antibiotic feed additives have been widely used in animal production for decades worldwide. Added in low doses to the feed of farm animals, they improve their growth performance and help to control metabolic and nutrition related disorders such as acidosis, bloat and laminitis (Dibner and Richards, 2005; Gaskins *et al*, 2002). Acute and chronic acidosis is conditions that follow ingestion of excessive amounts of readily fermented carbohydrates and are prominent production problems in feedlots (Owens *et al*., 1998). This might lead to decreased dry matter intake (DMI), decreased feed efficiencies and a decline in animal health. Furthermore, subclinical and acute acidosis results in significant financial losses. This statement is also true for other acute digestive disorders like red gut and bloat. Delayed digestive deaths like peritonitis and chronic bloats can also occur when acidosis is not managed properly.

However, due to the emergence of microbes resistant to antibiotics which are used to treat human and animal infections ("anti-microbial resistance"), the European Commission decided to phase out, and ultimately ban, the marketing and use of antibiotics as growth promoters in feed. Antibiotics will now only be allowed to be added to animal feed for veterinary purposes. This decision was based on opinions from the Scientific Steering Committee, an advisory committee to the European Commission, which recommended the progressive phasing out of antibiotics used for growth stimulation, while still preserving animal health. An EU-wide ban on the use of antibiotics as growth promoters in animal feed came into effect on January 1, 2006 (Official Journal of the European Union, 2003).

The EU has already banned antibiotics used in human medicine from being added to animal feed. The new Feed Additives Regulation completed measure with the total ban on antibiotics as growth promoters from January 1, 2006 as mentioned. On that date, the following 4 substances were removed from the EU Register of permitted feed additives:

- Monensin sodium used for cattle for fattening

- Salinomycin sodium used for piglets and pigs fattening
- Avilamycin used for piglets, pigs for fattening, chickens for fattening and turkeys
- Flavophospholipol used for rabbits laying hens, chickens for fattening, turkeys, piglets, pigs, calves and cattle for fattening

This measure is in line with the EU Commission's overall strategy to combat the threat to human, animal and plant health posed by anti-microbial resistance.

Despite the fact that ionophores represent the gold standard with regard to consistent responses in terms of significant increase in feed efficiency and controlling metabolic disturbances such as acidosis and bloat, consumer's demand for safe, high quality nutritious food has stimulated the search for natural alternative additives such as probiotics, enzymes, essential oils and organic acids. Furthermore the debate over the contribution of greenhouse gas emissions from enteric fermentation by livestock has also redirected research towards the development of natural modifiers of ruminal fermentation which has the capacity to reduce methane production (Calsamiglia, 2007). Therefore, recent research has been greatly focussed on exploiting plant bio actives, such as essential oils, as natural feed additives to improve rumen fermentation, decreasing methane production and reducing animal stress associated with digestive disorders like acidosis and bloat, and improving overall productivity (Patra, 2011).

Results from *in vitro* studies (Cardozo *et al*., 2004; Busquet *et al*., 2005, 2006) confirmed that the use of plant extracts and secondary metabolites can be beneficial as modifiers of ruminal fermentation, however, most research has been conducted with dairy cattle rumen fluid and dairy cattle diets, and results may not apply to beef cattle fed high concentrate diets because effects appear to be diet and pH dependent (Castillejos *et al*., 2005; Cardozo *et al*., 2005).

Therefore the objectives of this study were: (1) to determine the effect of either an essential oil blend (XTract) or a rumen buffer (Acid Buf) on the performance of feedlot beef cattle under both experimental and commercial scenarios at a large commercial feedlot and; (2) to determine whether a similar performance, relative to the performance of feedlot beef cattle supplemented with an ionophore, monensin sodium (monensin), could be achieved.

CHAPTER 2

The South African feedlot industry

2.1 Introduction

A feedlot is defined as: "An intensive animal production system that subjects an otherwise unmarketable calf to a process of intensive feeding and care, transforming it into high quality beef products" (Ford, 2012). Feedlots in South Africa and the rest of the world aim to produce a carcass with maximum amount of muscle, minimum amount of bone and the optimal amount of fat. Feedlots thus take a calf with minimum muscle and fat, transforming it into a desirable product that the consumer wants. The market demand (consumer) determines the acceptable live mass and fat content at which an animal will be slaughtered.

In this chapter an overview of the feedlot industry in South Africa will be given with emphasis on statistics, the industry operational structures, and the meat classification system and feedlot economics.

2.2 Brief overview and statistics of the feedlot industry in South Africa

2.2.1 Structure of the red meat industry in South Africa

The red meat industry structure is illustrated in Figure 2.1. The beef supply chain has undergone a significant amount of vertical integration over the years. The integration has mainly been stimulated by the feedlot industry where the majority of large feedlots have their own abattoirs. Some large feedlots also acquire their own retail outlets and distribute their products directly to the consumer. Presently, several wholesalers obtain live animals directly from farmers and feedlots for slaughter. The wholesaler determines at which abattoir the animals will be slaughtered, after which the carcasses are either distributed to retailers, or directly sold to the consumers. The abattoir industry consists of several subdivisions and may be associated with feedlots and the wholesale sector, while some are owned by municipalities, or primarily by farmers.

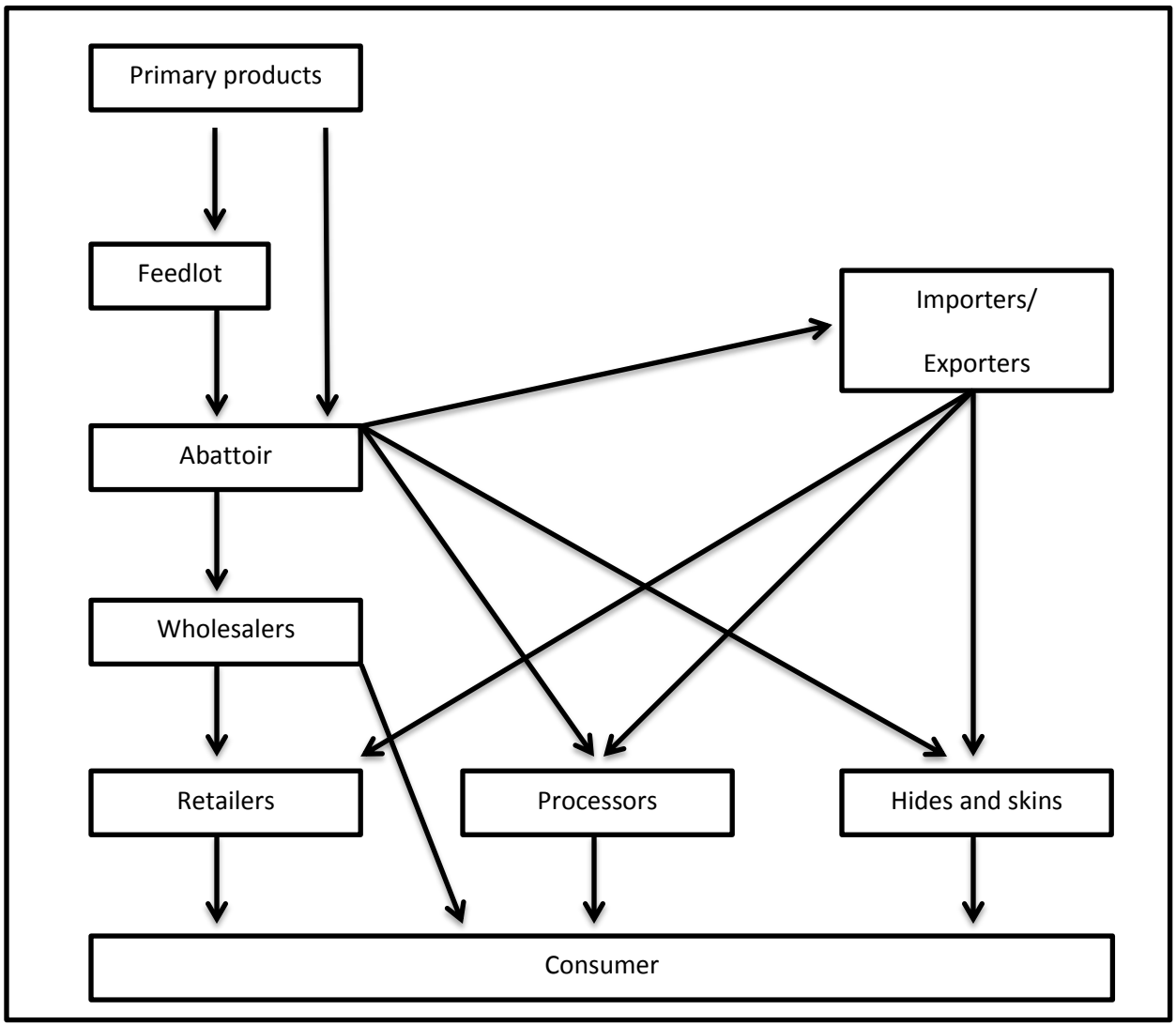


Figure 2.1 The red meat industry structure (Adapted from SAFA, 2003)

2.2.2 The feedlot industry

South African feedlots have the capacity to stand 500 000 head of cattle at any given time, and the throughput is approximately 1.7 million head of cattle per annum. The industry consists of 60 feedlots that can be found in all 9 provinces of South Africa. From all the beef produced in South Africa, 75 – 80% originates from the 60 commercial feedlots. The feedlot industry can be divided into 6 different categories according to their size. The categories include: farmer feeders (≤ 3000 head), small feedlots (3000 – 8000 head), medium feedlots (

8000 – 12 000 head), large feedlots (12 000 – 20 000 head), extra-large feedlots (20 000 – 30 000 head) and ultra large feedlots (≥ 30 000 head).

The live weight of cattle entering the feedlot is ± 235 kg and the cattle are fed to a weight of ± 450 kg for a period of approximately 125 days. The average carcass weight is ± 260 kg with 95% of the carcasses being A grade and the remainder AB grade. The dressing percentage achieved is 57.8%. During the 125 days growth period the mean average daily gain for cattle is 1.7 kg and the feed conversion ratio is approximately 5.5. Morbidities can range from 13% during the summer months, going up to 22% during the winter months and mortalities average around 0.8% (Ford, 2012).

2.3The South African beef carcass classification system

2.3.1 Age classification

In South Africa carcasses are classified according to age and fat class. Four different age groups are used in this system since meat tenderness is highly correlated with age. The four age groups are A, AB, B and C and are described in Table 2.1.

Table 2.1 The age classification used in the South African beef classification system.

Grade	Meaning	Approximate age
A	No permanent incisors	Birth to 18 months
AB	1 – 2 permanent incisors	19 to 24 months
B	3 – 6 permanent incisors	25 to 31 months
C	> 6 permanent incisors	More than 32 months

2.3.2 Fat classification

Fat classification was brought into the classification system because of health conscious consumers and because of the correlation between fat content and taste (juiciness). The amount of fat is indicated through a numbering system which ranges from 0 to 6. The number code was developed to inform the consumer about the thickness of the fat (Table 2.2). The fat thickness is

measured between the 10th and 11th rib and is done 50 millimetres from the median line of the cold, un-quartered carcass.

Table 2.2 The fat classification used in the South African beef classification system

Fat code	Meaning
0	No visible fat
1	Very lean (0.0 – 1.0 millimetre fat)
2	Lean (1.0 – 3.0 millimetre fat)
3	Medium (3.1 – 5.0 millimetre fat)
4	Fat (5.1 – 7.0 millimetre fat)
5	Moderately over fat (7.1 – 10.0 millimetre fat)
6	Excessively over fat (> 10.0 millimetre fat)

2.3.3 Colours used in the grading system

During the development of the system a colour code was also introduced. Four different colours are used to differentiate between the four different age groups. The colours are purple, green, brown and red.

Table 2.3 The colour codes used in the South African beef classification system

Class	Age	Roller mark colour
A	0 permanent teeth	Purple
AB	1 – 2 permanent teeth	Green
B	3 – 6 permanent teeth	Brown
C	> 6 permanent teeth	Red

In South Africa, consumers show a definite preference for younger more tender beef with a lean to medium fat class. That is why 95% of the carcasses sold are A grade with a fat classification of 2 or 3 (A2/A3 grade).

2.4 Feedlot economics

In terms of economics, there are two main concepts governing the viability and strategic management of a feedlot. The first is the beef to grain ratio, which is defined as "the amount in kilograms of grain that can be purchased per kilogram of beef income" (Ford, 2012). In South Africa the ratio is approximately 13:1, compared to American and Australian feedlots which operate at a ratio of 22:1 to 24:1. This indicates that South African feedlots are under more pressure than feedlots in other countries. South African feedlots are thus under more pressure to produce beef more efficiently since it is uneconomical to feed cattle below a ratio of 13:1.

The second concept consists of the purchase margin at which calves are purchased (calf purchase price vs. meat price) and feeding margin (feeding costs to produce 1 kg of meat vs. the price of 1 kg of meat). The calf purchasing margin, feeding margin and other expenses and incomes determine the feedlot's profit margin. The breakeven point for the feedlot is the point where the total input costs per kilogram beef produced is equal to the total amount of income per kilogram of beef sold. The input cost to produce the final carcass consists of several expenses during the lifetime of the animal at the feedlot. The main cost is the purchase price of the weaner calf (64.4%), followed by the price of feed (23.3%), overheads (6.7%), transport (2.43%), interest (2.27%), and mortalities (0.9%) (Ford, 2012). The income from selling carcasses, hides and offal as well as any other earnings amount to the total income.

The purchase price of weaner calves is typically influenced by the supply of weaners to the market and the demand for weaners from the market, but is also reliant on world trends, present and expected grain prices (Ford, 2012). Farmers that offer animals of the desired type (beef breeds) and required quality (between 200 and 230 kg) receive a premium from the feedlots. It should be noted that the South African feedlot industry is the only feedlot industry in the world where the final selling price of the carcasses being sold, is unknown at the time of purchasing the weaner calves (SAFA, 2003).

CHAPTER 3

Literature review: Feed additives in the feedlot

3.1 Introduction

There are many feed additives commercially available for ruminants, and in his publication "Feed Guide" Mike Hutjens summarised 24 different feed additives that can be used in dairy diets (Hutjens, 2008). Traditionally here in South Africa and abroad, ionophores has been the feed additive of choice for increasing feed efficiency of beef cattle. In this review the origins, mode of action and effects on animal performance of three different additives will be discussed, namely essential oils, buffers and monensin. Only those three additives were selected since the objective of this study was to investigate whether monensin can be replaced by essential oils or a rumen buffer and if the same results could be achieved by these natural alternatives to ionophores.

3.1.1 History of feed additives

In 1964, Pressman and co-workers reported a class of antibiotics that induced alkali ion permeability in mitochondria and other membranous systems. These antibiotics functioned as ionophores (ion carriers) to carry ions across lipid barriers as complexes soluble in the lipid phase of the membranes. The potential use of ionophores as probes of biological function, or as potential therapeutic agents, was recognized very early (Pressman, 1968; Reed and Lardy, 1972; Pressman, 1973; Reed, and Bokoch, 1982), but major economic importance was not forthcoming until the discovery of monensin in 1967 and the recognition of its potential in the poultry industry as a coccidiostat.

Subsequently, it was discovered that ionophores also could improve feed conversion in ruminants such as cattle, thus adding further to their commercial value. Of the more than 100 ionophores that have been reported only three, monensin, lasalocid and salinomysin, have widespread commercial use.

Monensin, the most widely used ionophore was approved as feed additive for ruminants in the mid-1970's and since then has greatly improved the efficiency of beef production. Because of the cost effectiveness of ionophores, supplementation is standard practice in virtually

all feedlots in the USA, South Africa and many other parts of the world. Obvious exceptions are feeding programmes that produce 'natural' or 'organic' beef, for which alternative feed additive options are limited (DiLorenzo, 2011).

However, in recent years public concern over the use of antibiotics in livestock nutrition has increased due to the emergence of antibiotic resistant bacteria that may represent a risk to human health. The use of ionophores as a growth promoter therefore was banned in the EU at the beginning of 2006. The consumer's demand for safe, high quality nutritious food has stimulated the search for natural alternative additives such as probiotics, enzymes, essential oils, natural buffers, yeast products and organic acids. Furthermore, the debate over the contribution of greenhouse gas emissions from enteric fermentation by livestock has also redirected research towards the development of natural modifiers of ruminal fermentation which has the capacity to reduce methane production. Therefore, recent research has been greatly focussed to exploit plant bioactives, such as essential oils, as natural feed additives to improve rumen fermentation, decreasing methane production, reducing stress such as acidosis and bloat and improving overall productivity (Patra, 2011). There is also interest in the use of essential oils as an inhibitor of feed borne pathogens such as *E. coli* 0 157 : H7.

Recently, there has been a renewed interest in natural buffers, such as those extracted from marine algae and seaweed.

3.2 Essential oils

3.2.1 Origin and classification of essential oils

Essential oils (EO) are blends of secondary metabolites obtained from the plant volatile fraction. Essential oils are steam volatile or organic-solvent extracts of plants, commonly derived from herbs and spices. They are plant specific and are responsible for a plant's characteristic flavour, fragrance and colour. Essential oils can be extracted from many parts of a plant, including the leaves, flowers, stem, seeds, roots and bark. However, the composition of the EO can vary among different parts of the same plant (Dorman and Deans, 2000). For example, EO obtained from the seeds of coriander have a different composition from the essential oils of cilantro, which is obtained from the immature leaves of the same plant (Delaquis, *et al*., 2002). Chemical differences among EO extracted from individual plants, or different varieties of plants,

also exist and are attributed to genetically determined properties, age of the plant, and the environment in which the plant was grown.

The most important active compounds are included in 2 chemical groups: terpenoids (monoterpenoids and sesquiterpenoids) and phenylpropanoids. These 2 groups originate from different precursors of the primary metabolism and are synthesized through separate metabolic pathways. The terpenoids are the more numerous and diversified group of plant secondary metabolites with about 15,000 different compounds being described in the literature thus far (Gershenzon and Croteau, 1991). These compounds are characterized as deriving from a basic structure of 5 carbons (C_5H_8), commonly called isoprene units, and are classified depending on the number of these units in its skeleton. Within terpenoids, the most important components of essential oils of the majority of plants belong to the monoterpenoid and sesquiterpenoid families.

Phenylpropanoids are not the most common compounds of EO, but some plants have them in significant proportions. The term "phenylpropanoid" refers to compounds with a chain of 3 carbons bound to an aromatic ring of 6 carbons. Phenylpropanoids derive mainly from the amino acid phenylalanine which is an aromatic amino acid, synthesized by the shikimate metabolic pathway, which is only functional in microorganisms and plants (Sangwan *et al*., 2001).

3.2.2 Mode of action of essential oils

The antimicrobial activity of most essential oils is similar to that of ionophores in the sense that gram positive bacteria are selectively inhibited. Similar to ionophores, the hydrophobic natures of the essential oils allow their interaction with the bacterial membrane altering the transport of ions across the membrane. A similar effect to ionophores in terms of ruminal VFA profile can be expected, i.e. a reduction in the acetate: propionate ratio. This is sometimes, but not always the case, since the effects of essential oils are dependent on the type of diet, ingredients used and the type and dose of essential oil (DiLorenzo, 2011). Addition of horseradish, garlic oil and cinnamaldehyde resulted in beneficial reductions in the acetate: propionate ratio (Busquet *et al*., 2006) while studies with eugenol resulted in lower propionate concentrations (Castillejos *et al*., 2006). One of the challenges with essential oil research is that microbes can adapt to essential oils, and therefore short-term *in vitro* studies that have been used mostly in published literature, cannot always be extrapolated to the *in vivo* situation. Studies

reported by Benchaar *et al*. (2008) showed that anise, capsicum, cinnamon, clove, dill, garlic, eugenol and cinnamaldehyde reduced amino acid deamination considerably. This is similar to the effect of ionophores which inhibit hyper-ammonia producing bacteria such as *Clostridium sticklandi* and *Peptostreptococcus anaerobius*. However, the nature of the diet can play an important role since the effect on AA deamination was far more pronounced when low protein rather than high protein diets were fed (Wallace, 2004).

Essential oils have been identified as a feed additive that can play an important role in greenhouse gas mitigation strategies. Some essential oils, specifically garlic, are effective in reducing methane production in the rumen. Reductions of up to 70% by garlic oil have been reported (Adesogan, 2009). These reductions exceed those achieved by monensin since they were attributed to direct inhibition of methanogenic bacteria rather than to inhibition of precursors of methane (Adesogan, 2009). Results from others, using thymol, clove or fennel extracts also showed reduced methane production, but also reduced propionate concentrations (Patra, *et al*., 2005). As is the case with other rumen fermentation parameters, the results achieved on methane reduction using essential oils are not consistent. A commercial blend of essential oils did not show a decrease in methane production, despite a decreased digestibility of all nutrients (Bauchemin and McGinn, 2006).

It has been shown that essential oils can inhibit several food-borne pathogens such as *E. coli*, *S. aureus* and Salmonella spp. but the broad spectrum antimicrobial activity of the essential oils makes it difficult to use them to specifically target pathogens within the digestive tract. The essential oils with the highest potency against pathogens are carvacrol, oregano and thyme oils. The extent to which essential oils escape the rumen and inhibit pathogens in the lower digestive tract has not been investigated at all (Benchaar, *et al*., 2007). There are a number of EO products available, some having different combinations and levels of EO's. In the following section, the three EO's that were supplemented in this study by means of the additive XTract 7065 (Pancosma Geneva, Switzerland) will be discussed in more detail.

3.2.2.1 Capsaicin

Capsaicin is an EO that is found in hot peppers *Capsicum annum* ssp. Capsaicin is a carotenoid that belongs to the tetraterpenoid group that has the following chemical name, 8-methyl-*N*-vanillyl-6-nonenamide and structure $C_{18}H_{27}NO_3$ (Cichewicz and Thorpe, 1996).

Capsaicin is the main component of capsicum oil (10 to 15%). When capsicum oil was supplied to an in vitro culture of rumen fluid from dairy cattle fed a 60:40 alfalfa hay:concentrate diet, the effects in short- and long-term fermentations have been negligible (Cardozo *et al*., 2004; Busquet *et al*., 2005c). The lack of effect could be explained by the low number of oxygen molecules in capsaicin, which are directly related to the antimicrobial activity of terpenes, thus the higher the number of oxygen molecules, the better its antimicrobial activity (Griffin *et al*., 1999; Dorman and Deans, 2000).

Cardozo *et al*. (2005) demonstrated that the effects of capsicum oil were different in an *in vitro* system with rumen fluid from beef cattle fed a 10:90 straw: concentrate diet. They reported that at pH 7.0, even at moderate doses, total VFA and ammonia N concentrations were reduced and the acetate-to-propionate ratio was increased. In contrast, at a lower pH of 5.5, capsicum oil reduced the ammonia N concentration, increased total VFA production and the propionate proportion, and reduced the acetate proportion and acetate-to-propionate ratio. Therefore one can conclude that although there seems to be little benefit for the use of capsicum oil for dairy cattle diets, its effects on high-concentrates such as in feedlot diets, which are characterized by low pH values, suggest that nutrient utilization in the rumen may be improved.

3.2.2.2 Cinnamaldehyde

Cinnamaldehyde is chemically known as 3-fenil-2-propenal phenol and the chemical structure is C_9H_8O. Cinnamaldehyde is a phenylpropanoid with antimicrobial activity, and is the main active component of cinnamon oil (*C. cassia*), accounting for up to 75% of its composition. In a continuous culture experiment, Cardozo *et al*. (2004) were the first to suggest that cinnamon oil (0.22 mg/L of rumen fluid) modified the N metabolism of rumen microorganisms by inhibiting peptidolysis. They also found the effect on VFA concentrations to be negligible. When higher doses (3,000 mg/L) of cinnamon oil and cinnamaldehyde were tested by Busquet *et al* (2006), a decrease in total VFA and ammonia N concentrations were found. It was also found that cinnamaldehyde had stronger effects compared with cinnamon oil.

Effects on the proportions of individual VFA were different, and although cinnamon oil increased acetate without affecting the molar proportions of propionate or butyrate, cinnamaldehyde on the other hand increased propionate without affecting the acetate and butyrate proportions. These results suggest that, although cinnamaldehyde is the main and most

active component found in cinnamon oil, other EO's within cinnamon oil may interact with cinnamaldehyde, although cinnamaldehyde resulted in a more desirable fermentation profile.

The effects of cinnamaldehyde found on N metabolism were inconsistent. Although some studies reported changes in N metabolism (Cardozo *et al*., 2004; Busquet *et al*., 2005c), other studies found no effects (Busquet *et al*., 2005a). Results indicate that cinnamon oil and cinnamaldehyde have the potential to improve nutrient utilization in the rumen, but in beef production systems, the effects may be more relevant in feeding conditions that favor low ruminal pH.

3.2.2.3 Eugenol

Eugenol chemically known as 4-allyl-2-methoxyphenol and chemical structure $C_{10}H_{12}O_2$, is a phenolic compound with a wide-spectrum antimicrobial activity against both gram-positive and gram-negative bacteria. It is one of the main active components found in clove buds (*Eugenia caryophyllus* or *S. aromaticum*) and it is also found in cinnamon oil (*C. cassia*), accounting for up to 85 and 8% of these oils, respectively.

In a continuous culture study, low doses of clove bud oil (2.2 mg/L) resulted in lower molar proportions of acetate and branched-chain VFA (BCVFA) and a higher molar proportion of propionate (Busquet *et al*., 2005c). It was also found that clove bud oil affected N metabolism, increasing peptide N and numerically decreasing amino acid (AA) N concentrations, suggesting that it decreased the peptidolytic activity of microbes in the rumen. In an in vitro batch culture dose-response study, Busquet *et al*. (2006) confirmed that clove bud oil affected rumen fermentation, reducing total VFA and ammonia N concentrations and showing a linear increase in the molar proportion of propionate and a quadratic effect on the molar proportions of acetate and butyrate.

3.2.3 Effects on animal performance

Most *in vivo* studies on supplementation of essential oils have been done in dairy cattle showing limited or no responses (DiLorenzo, 2011). Results of studies on the effects of essential oils in beef cattle diets are limited. A recent study reported by Yang *et al*. (2010) investigated the effect of 3 doses of cinnamaldehyde or monensin on feedlot performance. None of the performance parameters were affected apart from an increase in feed intake in steers fed

the cinnamaldehyde diet compared to the control diet for the first 28 days of the feeding period. An increase in feed efficiency was reported by Meyer *et al*. (2009) after supplementing steers with tylosin and a blend of essential oils (thymol, eugenol, vanillin, and limonene). No effects, however, were found when the blend was fed without tylosin. The proper doses of essential oils are important since high doses of cinnamaldehyde (180 mg /d) and eugenol (90 g /d) in beef cattle and high doses of cinnamaldehyde (500 mg /d) in dairy cattle reduced intake (Patra, 2011). In contrast, addition of capsicum oil (1 g /d) of extract containing 15% capsaicin stimulated intake and rumen fermentation (Cardozo *et al*., 2006). Chaves *et al*. (2008) reported that cinnamaldehyde (0.2 g /d) did not affect growth of sheep fed maize based diets, but higher ADG (254 *vs*. 217 g /d) was observed when cinnamaldehyde or juniper berry EO was added to a barley based diet at the same concentration. It therefore, appears that the effect of essential oils on growth performance is diet dependant (Patra, 2011).

The additive, synergistic and/or antagonistic effects of different combinations of essential oils have been reported previously (Calsamiglia *et al*, 2007). Many commercial products have combined one or more essential oils, but limited information is available on potential synergies among them. Research in this area is urgently needed since some essential oils have their greatest effects on either modulation of intake, changing VFA profiles, reducing deamination of amino acids or inhibiting methanogenic bacteria. To achieve your goal for supplementing essential oils, this type of information is urgently needed.

3.2.4 Essential oil residues in meat and milk

Little information is available on the transfer of essential oils into animal products. There is evidence that essential oils can be absorbed from different parts of the digestive tract, thus the potential of residues in animal products cannot be excluded (Benchaar and Greathead, 2011). Studies by Tornambe *et al*. (2006) have shown transfer of terpenes in forages to milk of grazing cows and these essential oils can modify organoleptic properties of dairy products. Essential oils have an antimicrobial activity against Gram negative and Gram positive bacteria. Several Gram positive bacteria are involved in ruminal biohydrogenation of dietary fatty acids, therefore essential oils could lower biohydrogenation of fatty acids. No change in the milk fatty acid profile was reported by Benchaar *et al*. (2007) after supplementation of 759 mg of MEO (Crina®) supplement containing cresol, resorcinol, thymol, guaiacol and eugenol.

Supplementing the same mixture at 2 g /d increased the concentration of CLA, a health promoting fatty acid in milk. The impact of essential oils on sensory quality of poultry meat is regarded as minor (Vogt and Rauch, 1991) and essential oils in poultry tissue can be consumed by humans. Hernandez *et al*. (2010) reported no effect of clove essential oil on poultry meat fatty acid profile, oxidation was not affected, shear force and firmness as well as microbiological quality. No research could be found on the effect of EO on meat quality of feedlot animals. It should be emphasized that the EO compounds thymol, carvacrol, cinnamaldehyde and ionone have been given GRAS status by the Flavor and Extract Manufacturers Assoc. and the FDA. Animal product residues should not be a concern when following EO products dosing recommendations.

3.3 Buffers

3.3.1 Why supplement buffers

Buffers are traditionally used in dairy rations as compounds that neutralize excess acid within the animal's digestive system. Buffers supplement the dairy cow's natural buffers that occur in saliva and increase her ability to overcome the harmful effects of too much acid production.

Technically speaking, buffers and alkalinizer differ from each other. A buffer maintains the acidity level, or pH, within a narrow range when either an acid or a base is added. Examples of commonly used buffers are sodium bicarbonate and sodium sesquicarbonate. An alkalinizer raises the pH in direct proportion to the amount added. Magnesium oxide and magnesium hydroxide are good examples of an alkalinizer. Both buffers and alkalinizer are important for neutralizing excess acidity and both are called buffers in common usage.

As mentioned above, buffers are included in ruminant diets to regulate rumen pH to levels that favor the activity of cellulolytic microbes (pH 6 – 7). This pH range is important for dairy farmers because too much acidity can reduce feed intake, decrease ration digestibility, lower milk production and decrease butterfat production by the dairy cow.

Diets for feedlot animals are usually rich in readily fermentable carbohydrates which are generally responsible for creating acidic conditions and also for the increase in lactic acid formation. When fed at high levels these conditions are detrimental to the cellulolytic microbes,

and in most case also to the well-being of ruminants. Overfeeding of concentrates or poor adaptation to high concentrate diets could cause a decrease in food intake and will predispose the animal to digestive disturbances like bloat, acidosis, red gut and laminitis. Secondary problems which could arise are ruminitis, peritonitis, ketosis and liver abscesses which could all potentially cause an increase in mortalities.

Bicarbonate is the dominant natural ruminal buffer and sodium bicarbonate is the buffer traditionally added to diets in ruminant nutrition to moderate ruminal pH. In the literature, however, there are contradictory responses of variables measured to the addition of buffers, and confusion in the interpretation of results (Russell and Chow, 1993). For instance, the addition of up to 5% bicarbonate in high-concentrate rations improved dry matter intake (DMI) in growing cattle (Nicholson *et al*., 1963; Wise *et al*., 1965; Zinn, 1991) but 5% bicarbonate depressed DMI in dairy cows (Emery *et al*., 1964). Ruminal pH has also been ameliorated in some studies (Nicholson *et al*., 1963; Okeke *et al*., 1983; Zinn, 1991), but no effects have been reported in many others (Thomas and Hall, 1984; Leventini *et al*., 1990). This fact could be the result of the different variables affected by buffer addition and interactions between them, such as intake level, ruminal fermentation and passage rates, water consumption and blood biochemistry (Erdman, 1988).

3.3.2 Mode of action

Buffers are weak acids or alkalis that resist changes in H^+ concentration or pH and are added to diets to complement the buffering effect of saliva or neutralize ruminal acidity (Adesogan, 2009). Both buffers and alkalinizers have been proposed to prevent and control metabolic disturbances such as acidosis and bloat. Buffers are substances which, once added to a solution, necessitates an increase in the amount of acid added to the solution to achieve a change in pH. Examples of buffers are sodium bicarbonate, sesquicarbonate, limestone and sodium bentonite. Alkalinizers are substances that once added to a solution, cause the pH to increase. The most common alkalinizer used in ruminant diets is magnesium oxide. Higher pH values facilitate fibre digestion, and therefore increase the acetate: propionate ratio. In addition certain buffers increase ruminal osmolality and therefore increase ruminal fluid outflow rate which is associated with less propionate production, but increased milk fat synthesis (Adesogan, 2009).

A classic buffer is a combination of a weak acid and its conjugate salt; for instance, carbonic acid (H_2CO_3) and sodium bicarbonate ($NaHCO_3$), or even calcium carbonate. What happens when one titrates this combination with the (strong) acid of your choice? Well, in any buffer system, the boost in [H^+] increases the reaction rate H^+ + salt => weak acid and takes some H^+ out of circulation. Of course, as it does so, it increases weak acid concentration, so the reverse reaction rate starts to increase until you get a new equilibrium. Similarly, titration with a strong base decreases the H^+ + salt => weak acid rate, and so (since the weak acid dissociation is still happening), the weak acid => H^+ + salt adds some H^+ to the solution. Thus the pH changes less than it would if one titrated pure water - it's buffered.
(www.amrclearinghouse.org/Sub/AMDbasics/buffering.htm)

3.3.3 Acid Buf characteristics

Soluble buffers like Sodium Bicarbonate have been used extensively in ruminant nutrition for many years but the effects on rumen pH, DMI and milk yield are inconsistent (Bach, 2008). Furthermore, in some cases benefits are short lived and problems resulting from their inability to buffer against an on-going production of acids in the rumen were recognized during the mid 90's. Slow release buffers such as Acid Buf (Celtic Sea Minerals, Strand Farm, Currabinny, Carrigaline, Co. Cork, Ireland.) are relatively new to the market place and present a sustained/slow release buffering action that occurs as the acid is produced in the rumen. This slow release action also means that the buffering activity of Acid Buf will not be exhausted as rapidly as that of sodium bicarbonate. The lower the rumen pH the more Acid Buf is ionized and released into the rumen and this also means the higher the buffering capacity.

Acid Buf is the skeletal remains of the seaweed *Lithothamnium calcareum*, harvested off the Irish and Icelandic Coast. Chemically it is almost 95% ash. The 3 major minerals that make up Acid Buf are Calcium (30%), Magnesium (5.5%) and Potassium (0.7%). The rest of the product is made up of other minerals that range from 0.1 to 500 ppm (Boron, Cobalt, Copper, Iodine, Iron, Manganese, Molybdenum, Selenium and Zinc). The product has been shown to possess a honeycomb structure, providing over ten times the surface area of that from an equivalent weight of limestone. The reactivity of the product is also increased by its molecular lattice structure, the calcium carbonate existing as a mixture of calcite, aragonite and vaterite. Calcite makes up 65%, aragonite 23% and vaterite 12 % of Acid Buf compared to the stable

calcite form only found in limestone. The honey comb structure does not absorb acid. It merely increases the surface area, to create a greater exposure for a chemical acid neutralization reaction to occur. Ionized Ca and Mg from Acid Buf are totally solubilized and are made bio-available at a rumen simulated pH of 5.5 over an extended period (CSM, Acid Buf technical brochure).

3.4 Ionophores

3.4.1 Chemistry and mode of action

Ionophores are lipophilic compounds that are toxic to many bacteria, protozoa fungi and higher organisms (Russell and Strobel, 1989). Ionophore molecules are diverse in chemical structure but have in common several oxygen atoms spaced throughout the molecule. The position of the oxygen atoms creates a cavity to entrap a cation (Pressman,1976). Ionophores have polar and nonpolar regions that enhance interaction with membranes after cation entrapment. Carboxylic acid polyether ionophores were originally developed to improve the production performance of cattle by changing ruminal fermentation patterns. Ionophores, in general, share a common mode of action, but some differences do exist, for example cation specificity and different capacities to achieve effective rumen concentrations (potency) amongst these molecules (McGuffey *et al*., 2001).

The primary way in which ionophores modify rumen fermentation is by decreasing the ruminal population of gram positive bacteria relative to that of the population of gram negative bacteria. Gram positive bacteria do not possess the complex outer cell wall of gram negative bacteria and the associated lipopolysaccharide layer with its protein channels that have a size exclusion limit that is impermeable to ionophores. Ionophores therefore can successfully penetrate the outer membrane of gram positive bacteria and rapidly and repeatedly cause efflux of intracellular K^+ from the cell and an influx of extracellular protons (Na^+ and H^+). In order to counteract the resulting acidity, and the depletion of K^+, which inhibits protein synthesis, ATPase pumps are activated to eject the protons but this depletes energy reserves for bacterial growth. This energy spilling cycle is a futile process to maintain the ion gradient and eventually the cytoplasmic acidity culminate in cell death (McGuffey *et al*., 2001; Adesogan, 2009).

Ionophores often lead to a decrease in acetate to propionate ratio because gram positive bacteria are mostly acetate producers and gram negative bacteria are mostly propionate and

succinate producers (Nagaraja *et al*., 1997). This reduction in acetate to propionate ratio improves efficiency of energy utilisation. Furthermore ionophores, like monensin, can decrease methane production by up to 30% (Russell and Strobel, 1989) through inhibiting bacteria that provides precursors of methane (H_2 and formate) rather than directly inhibiting methanogens. In addition, ionophores often increase postruminal supply of protein and peptides through reduced peptidolysis and amino acid deamination (McGuffey *et al.,* 2001).

3.4.2 Effects on animal performance and health

Supplementation with monensin often results in a decrease in feed intake by feedlot steers, leading to an improvement in feed efficiency in the order of 7.5% versus control animals (Goodrich *et al*., 1984). In a summary of a number of studies, improvements in feed efficiency in feedlot cattle were 5.6%, 7.5% and 8.1% when supplementing laidlomycin propionate, lasalocid and salinomycin respectively (DiLorenzo, 2011).

Ionophores have been effective in decreasing counts of lactate producing bacteria and increasing pH in steers during the transition period to a high grain diet. Coe *et al*. (1999), however, reported that once steers were adapted to the high concentrate diet after 21 d no effects on pH were detected. It appears that the greatest effect of ionophores on prevention of acidosis is achieved by modulation of feed intake, rather than modification of rumen fermentation and pH regulation (Salinas-Chavira *et al*., 2009).

A meta-analysis involving 77 dairy cow studies showed that dry matter intake, milk fat and protein contents were reduced by 2, 3 and 1% respectively, while milk yield, feed efficiency and protein yield were each increased by about 2% (Adesogan, 2009). Monensin has been reported to have a benefit to cost ratio of 5:1 when added to dairy cow diets (Hutjens, 2008).

CHAPTER 4

Materials and methods

4.1 Small pen and commercial pen trial

The study was conducted in two phases, namely a trial under experimental conditions (small pen trial) and under commercial conditions (commercial pen trial). The study was conducted at the largest privately owned feedlot in South Africa, namely Karan Beef, (Vaaldam Road, Heidelberg, South Africa), with a standing capacity of 120 000 head. The study was approved by the Ethics committee of the University of Pretoria

4.2 Experimental design, treatments, diets and sampling

4.2.1 Experimental design and treatments

The experimental design was a randomised complete block design with three experimental treatments:

(i) Basal diet supplemented with monensin (Control)

(ii) Basal diet supplemented with EO's (XTract)

(iii) Basal diet supplemented with a buffer (Acid Buf)

A monensin supplemented diet was used as the control group since it is standard practice in all large commercial feedlots in South Africa and numerous feedlots in the USA. A negative control without monensin was not an option due to the high risk of mortalities or animals developing digestive disorders like red gut, acute acidosis, bloat or delayed digestive disorders like peritonitis.

For the small pen trial a homogenous group of 180 Bonsmara type animals were selected. The cattle were blocked into two groups, based on sex (only males, bulls and steers) and body weight (200 – 250 kg). Within each of the three treatment groups of 60 animals each, the cattle were randomly allocated to 6 pens of 10 animals each. The bulls were first allocated to the pens and thereafter the steers; each pen therefore had the same number of bulls and steers.

The production parameters measured were average ADG, FCR and DMI per pen, CCM and dressing percentage.

The commercial pen trial was designed primarily to measure digestive morbidity and mortality but also to measure the production parameters as in the small pen trial. In addition other health parameters such as lung and rumen scoring were also performed. For the commercial pen trial all the different breeds normally purchased by the feedlot were considered. The feedlot does not group the animals together according to breed. They only spilt the males and the females from each other. For this reason it was decided to keep the standard the same for the commercial pen trial and not to group the animals according to breed. The breeds ranged from indigenous (Nguni) to European breeds (Angus) and from early maturing (Nguni, Afrikaner) to late maturing (Limosine) breeds. The cattle were blocked into two homogenous groups based on weight (between 200 and 250 kg) and on sex (only males, both bulls and steers). Within each group the animals were randomly placed into 3 pens holding 130 head of cattle, therefore 1170 cattle were used in the commercial pen trial (390 per treatment). For the purpose of the commercial pen trial, 3 pens each holding 130 head of cattle, were used per treatment. Examples of the indigenous types of cattle used in the trial are shown in Figures 4.1 to 4.3.

Figure 4.1 Afrikaner

Figure 4.2 Drakensberger

Figure 4.3 Nguni

Figure 4.4 is an example of the Bonsmara cattle used in the small pen trial. Figure 4.5 is an example of the small pens used for the trial and figure 4.6 and 4.7 are examples of the commercial pens used for the trial showing a mix of different breeds.

Figure 4.4 Bonsmara

Figure 4.5 Top view of small pens used for the trial

Figure 4.6 Photo of the commercial pens.

Figure 4.7 Photo of the commercial pens.

4.2.2 Processing of animals

All the animals used in the trial were processed according to the feedlot protocol on "Arrival and processing of new animals". All the animals were vaccinated against Botulism, Bovine rhinotracheitis, Bovine virus diarrhoea (BVD Type 1), Parainfluenza 3 and Bovine respiratory syncytial virus. A hormonal implant which is standard practise at the feedlot was also administered. All the animals at the feedlot receive a 6 digit ear tag which is coloured. The colour of the tag along with the first of the 6 digits determine the month in which the animal was processed. The 6 digits on the ear tag are also used for traceability purposes. The number allows the manager to trace the animal back to the region of origin, its processing mass and treatment history.

4.2.3 Experimental diets

The diets for the three different treatments were formulated to be isocaloric and isonitrogenous with the only difference being the additive added to the diet (XTract, Acid Buf or monensin). Due to confidentiality only the feed, premix and pre-pack ingredients can be published, but not the complete formulations (Tables 4.1 – 4.3). The animals had *ad lib* access to feed and water during all times. The feed was fed 3 times per day by dividing the daily feed assignment accordingly, 30% for the 1st feeding, 30% for the 2nd feeding and 40% for the 3rd feeding. The diet fed was a high energy diet based on hominy chop as the primary energy source. Hominy chop is a by-product produced from the wet milling of maize and is sometimes referred to as hominy feed. Feed refusals from the previous day were weighed back the following day before the 1st feeding at the small pens. Feed refusals at the commercial pens were not weighed back due to the time constraints involved with getting to the commercial pens before the feed cars.

Four different diets were fed during the production phase namely a starter, intermediate, finisher and final finisher diet (Table 4.1). The difference between the 4 diets was the amounts of additive added and the roughage: concentrate ratio. The 4 different diets were a starter diet (largest percentage of roughage and lowest concentration of additive), intermediate diet, finisher diet and final finisher diet (lowest percentage of roughage and highest concentration of additive). The finisher and final finisher diets contained the same amounts of raw materials, the only

difference being that Zilmax® (Intervet South Africa, Isando, South Africa) was added to the final finisher diet.

The starter diet was fed for 20 days which was followed by a transition of 3 days from starter to intermediate diet. The intermediate diet was fed for 10 days which was followed by a transition of 3 days from the intermediate diet to the finisher diet. The finisher diet was fed for 50 days whereafter no transition period occurred from the finisher diet to the final finisher diet. The final finisher diet contained the Zilmax and was fed for a period of 30 days. After the 30 days on the final finisher diet, a withdrawal period of two days was allowed for the withdrawal of Zilmax. During the withdrawal period the animals received the finisher ration.

Table 4.1 Composition of the four different diets fed during the different production phases

Ingredient	Starter	Intermediate	Finisher	Final Finisher
Eragrostis curvula hay	*	*	*	*
Wheat straw	*	*	*	*
Bagasse meal	*	*	*	*
Hominy chop	*	*	*	*
Gluten 20	*	*	*	*
Wheat bran	*	*	*	*
Cottonseed meal	*	*	*	
Whole cottonseed	*	*	*	*
Premix	5.86%	5.86%	6.0%	6.0%
Molasses	*	*	*	*
Water		*	*	*

The active ingredient in Zilmax® is zilpaterol hydrochloride. This is a non-steroidal growth stimulant for improved body mass gain and feed conversion in feedlot cattle. From a pharmacological point of view, zilpaterol hydrochloride is classified as a beta-agonist. Under beta-agonists, some are classified as repartitioning agents. Zilmax® is classified as a repartitioning agent because it acts directly on the metabolism of fat and muscle tissue. It causes the muscle and fat cells to modify their normal utilization of nutrients and energy. This causes an increase in muscle tissue and a decrease in adipose tissue.

The XTract and Acid Buf premix batches were mixed using a ribbon mixer and after mixing were loaded into a bunker. One batch totalled an amount of 990 kg. The two treatment batches were bagged in 20kg bags and added to the ration by hand. The control premix batch was made in the same way as the two treatments but was kept in a bin and was added automatically to the ration. As soon as one 990 kg batch was finished, a new batch was made.

The ingredients used to make the premix of the four different diets and the percentages of pre-pack per premix are presented in Table 4.2.

Table 4.2 Premix composition of the four diets fed during the different production phases

Ingredient	Starter	Intermediate	Finisher	Final Finisher
Hominy chop	*	*	*	*
Feed grade lime	*	*	*	*
Feed grade urea	*	*	*	*
Potassium chloride	*			
Availa-Zn 100	*	*	*	
Salt	*	*	*	*
Starter pre-pack	1.62%			
Intermediate pre-pack		1.62%		
Finisher pre-pack			1.41%	
F/Finisher pre-pack				1.41%

The pre-packs are custom made for Karan Beef by DSM in Isando, South Africa. Due to this and as stated in the protocol, no information on the percentage inclusion of raw materials and also on the premix and pre-pack composition can be made public due to it being proprietary information (Table 4.3).

Table 4.3 Pre-pack composition of the diets fed during the different production phases

Ingredient	Starter	Intermediate	Finisher	Final Finisher
Vitamin A	*	*	*	*
Vitamin E	*	*	*	
Manganese	*	*	*	*
Zinc	*	*	*	*
Copper	*	*	*	*
Cobalt	*	*	*	*
Iodine	*	*	*	
Selenium	*	*	*	
Limestone carrier	*	*	*	*
Monensin / XTract / Acid Buf	*	*	*	*
Zilmax®				*

To differentiate between the two treatments and the control, plastic markers were added to the treatments. The XTract diet contained blue plastic makers and the Acid Buf contained orange plastic markers. The pellets were added to the premix when it was mixed in the ribbon mixer. The pellets were added to ensure that the treatment animals received the correct feed. No plastic pellets were added to the control diet. This is illustrated in Figure 4.8 showing the blue plastic markers added to the XTract feed.

Figure 4.8 Photo with feed containing the blue marker pellets

The starter diet and intermediate diet were formulated to supply 1000 mg /h /d of XTract and the finisher and final finisher diets 1200 mg /h /d. The amount of XTract added to the pre-packs was formulated using historical feed intake data on an "As is" basis obtained from the feedlot for March to June from 2008 to 2010 (Table 4.4). This resulted in 158 mg /kg, 100 mg /kg, 116 mg/kg and 115 mg /kg for the starter, intermediate, finisher and final finisher diets respectively.

All four diets for the Acid Buf treatment contained the same percentage of Acid Buf. Celtic Sea Minerals recommended that the Acid Buf should total 0.6% of the ration on a DM basis. The inclusion levels of monensin were 21 mg /kg, 27 mg /kg, 33 mg /kg and 33 mg /kg for the starter, intermediate, finisher and final finisher diets respectively.

Table 4.4 Actual Feed Intake history ("As is" basis kg /h/d) (± 82% DM)

Diet	Period	Aver intake /day (kg /d)	Aver intake /period (kg /d)
Starter diet	March '08	6.1	6.3
	March '09	6.4	
	March '10	6.3	
Intermediate diet	March '08	10	10
	March '09	9.8	
	March '10	10.3	
Finisher diet	April '08 - May '08	10.4	10.3
	April '09 - May '09	10.2	
	April '10 - May '10	10.4	
F/Finisher diet	June '08	10.2	10.4
	June '09	10.5	
	June '10	10.6	

According to the information in Table 4.4 the amount of XTract and Monensin was calculated to be added to a 25 kg bag of pre-pack and the amount of Acid Buf to be added to the premix. Based on the same historical data the formulation was adjusted for the amount of pre-pack mixed into the premix. Working on the same historical data the formulation was made for the amount of pre-pack containing only vitamins and minerals going into the pre-pack for the Acid Buf premix.

4.2.4 Sample collection and analysis

Feed samples were taken during the trial on predetermined dates. Two samples were taken for the starter diet, two for the intermediate diet, three for the finisher diet and three for the

final finisher diet. No samples were taken from the feed refusals that were weighed back each morning. This was done in accordance with the normal practise at the feedlot. Feed bunks are assigned in such a way as to leave just enough feed until the first feeding the next morning.

Feed samples were taken during the first feeding on sampling days. Sampling was done by taking grab samples at different places in the feed bunk. The sampling was done at the small pens and the grab samples were taken from each of the 6 small pens. The grab samples were pooled to make one sample of approximately 1 kg. The reason for taking grab samples were that the feed was very dense and separation occurred when samples were taken in other ways. Directly after sampling, the samples were sealed in an air tight zip lock bag and were frozen at -18 °C in a chest freezer. The samples from different days were not pooled together. Each sample was analysed separately and the analysed values were averaged together.

Samples were analysed for DM, CP using a Leco analyser, EE, Ash, Ca and P (AOAC, 2000), IVOMD (Tilley & Terry, 1963), NDF (Robertson & Van Soest, 1981), Gross energy (1000 Modular calorimeter). Samples were also analysed for starch content following the procedure of AOAC (1984), procedure 996.11. The chemical analyses differed very little from the values obtained using the Karan Beef formulation program and data base.

4.2.5 Feed bunk management

The feed bunk assignments at the commercial pens were done by an experienced section manager while the feed bunk assignments at the small pens were done by the researcher.

4.3 Scoring systems

4.3.1 Lung and rumen scoring

On the day of slaughter lung and rumen scores were performed on most of the animals at the abattoir. This was done by means of a simple scoring system. The scoring system for the lungs was done by using different codes (Verwoerd, D. Personal communication, 2011) as described in Table 4.5. The lung scoring was done to determine if the different treatments had any effect on the morbidity of the animals with regards to lung infections.

Table 4.5 The lung scoring system that was used for both the small pen and commercial pen studies.

Percentage of lungs affected	Code
0%	0
< 25%	1
25 - 50%	2
> 50%	3

The rumen scoring was done on the basis of assigning the rumen with the carcass number and then tagging the rumen. After the rumens were tagged they were opened, the contents removed and the rumens washed. Rumen scoring was based on the observation of a damaged or no-damaged rumen wall. Rumen scoring was done to determine if the rumen damage had any effect on the animal's growth and also to determine if any treatment contributed to more affected rumen areas. Different types of rumen damage are illustrated in Figures 4.9 to 4.11.

Figure 4.9 A rumen wall showing 3 stars

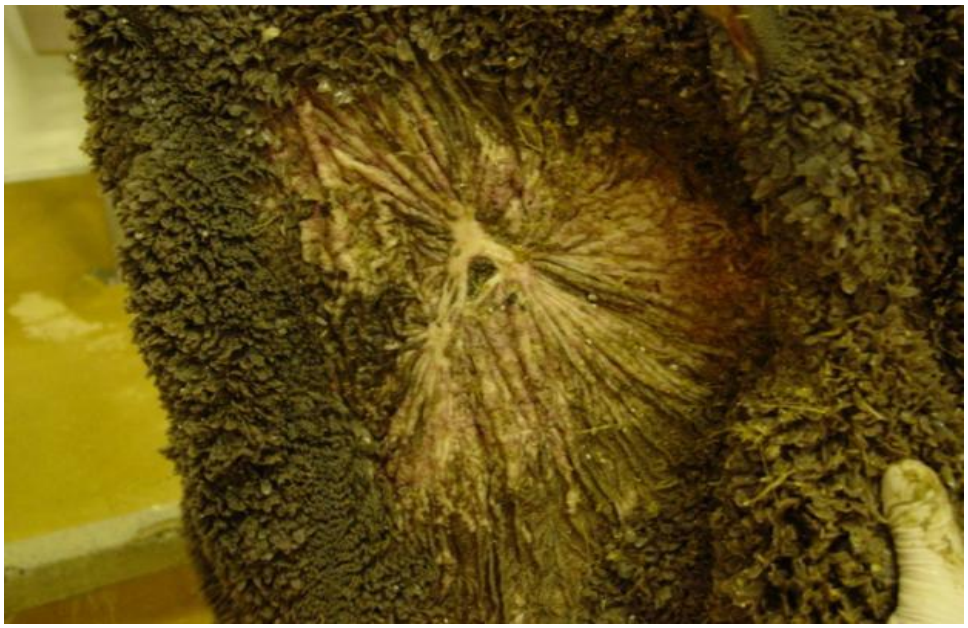


Figure 4.10 A rumen wall showing 2 active star regions

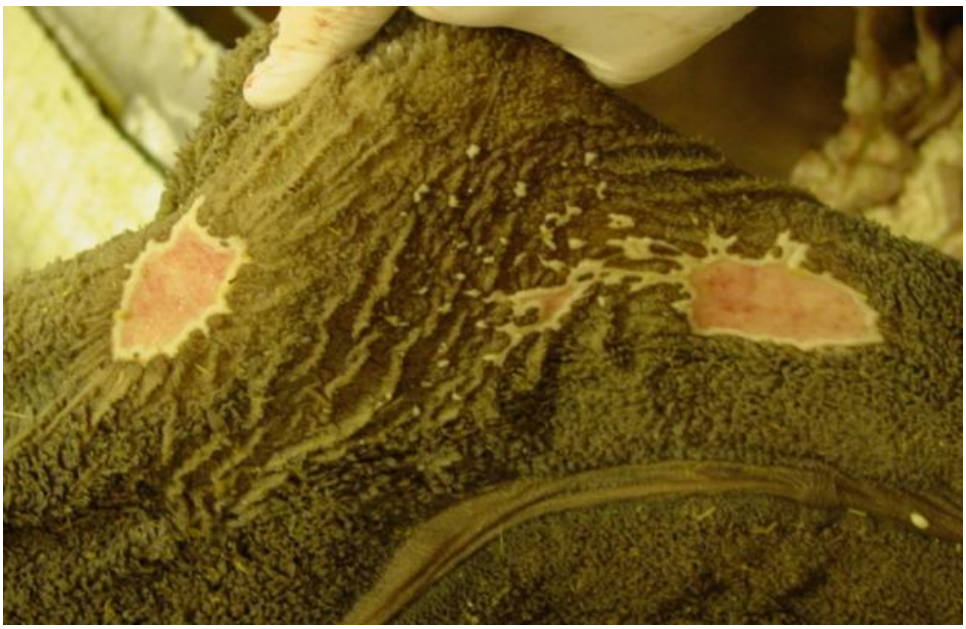
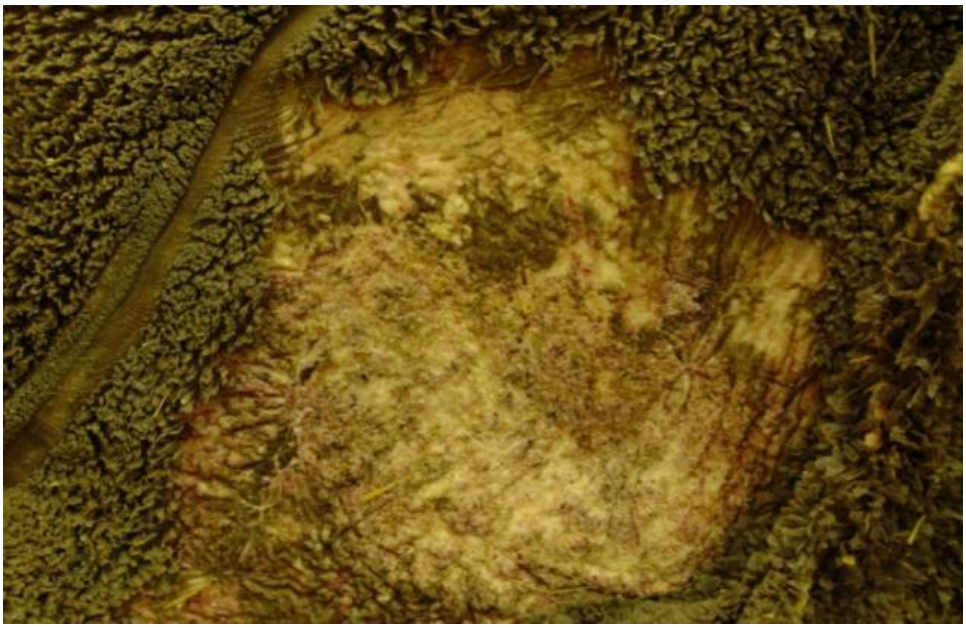


Figure 4.11 A rumen wall showing an inflamed area



4.4 Animal morbidities and mortalities

The commercial pen trial was used to determine the effect of digestive morbidity and mortality with regards to the different treatments. At the same time all the animals pulled (permanently removed from the pen) for reasons such as lung disease, cripples, bullying injury, etc. were also recorded. A post-mortem evaluation was done on each animal that died to determine the cause of death.

Each morning the pens (both small and commercial pens) were walked by hospital staff to look for sick animals. If a sick animal was identified by the staff, its ear tag number was written down and the animal was pulled from the pen. Animals that were pulled were all grouped together in a hospital pen where they received a hospital ration, hay and water *ad lib*. After 3 hours, all the animals that were pulled during the morning pull session were evaluated by the section manager who took a decision on whether an animal should be treated or not by means of a visual evaluation. All the animals that were treated were removed from the trial.

During the visual evaluation of potentially sick animals, the section manager made the following observations:

Did the animal eat before the visual evaluation (for pneumonia)?
Is the animal's nose wet (for pneumonia)?
Does it look like the animal groomed itself (for pneumonia)?
Does the animal show signs of laboured breathing (for pneumonia)?
What does the animals gait look like, is it struggling to walk/run or does it walk/run with ease (for cripples)?
What does it smell like when the animal walks/runs by when it is evaluated, can flies be seen around the tail and anus (for enteritis)?

4.5 Statistical analysis

One-way analysis of variance (ANOVA) was applied to all production data except DMI and body weight to test for differences between the two treatment effects, Control and XTract

(Snedecor & Cochran, 1980). The pens were regarded as the experimental unit for all parameters except rumen, lung and health parameters. Animals in the small pens study were blocked according to starting weight, whereas animals from the commercial pen study were randomly allocated to the different treatments. Day, treatment and the day x treatment interaction were specified as fixed effects. In addition, Linear mixed model repeated measurements analysis was used to analyze DMI and BW as dependent variables specifying pen, day and the pen x day interaction as random effects. Predicted means were separated using Fisher's protected least significance difference test (LSD) at the 5% level. In all tests significance was declared at $P < 0.05$ and tendencies at $P < 0.10$. Row by column chi-square testing was applied to all categorical (health and rumen) data. Data were analysed using the statistical program GenStat® (Payne *et al*., 2011). Chi-square analyses were used for the lung and rumen scores. Chi-square is a statistical calculation used to test how well the distribution of a set of observed data matches a theoretical probability distribution. The calculated value is equal to the sum of the squares of the differences divided by the expected values.

CHAPTER 5

Small pen trial

Results and discussion

5.1 Introduction

In this chapter the results of the small pen trial will be discussed. These will include performance data with regards to end weights achieved, average daily gains, feed conversion ratios, cold carcass mass, dressing percentage and dry matter intake. For the performance data each pen was considered as an experimental unit. The feed analysis will also be discussed and will be applicable to the commercial pen trial as well, which will be discussed in the following chapter, chapter 6.

In this chapter no health data will be discussed as the small pen trial's focus was primarily on growth. The health data of the commercial pen study will be discussed in chapter 6.

5.2 Chemical feed analysis

The chemical analysis of the feed was done at the University of Pretoria's Nutrilab. Table 5.1 presents the chemical analysis of the four different rations fed to the trial animals. The experimental rations and their chemical analysis are very similar to the rations normally fed at Karan Beef.

Table 5.1 Chemical composition of the experimental diets (% DM)

Nutrient	Unit	Starter Diet	Intermediate diet	Finisher diet	F/Finisher diet
DM	%	82.03	82.00	80.55	82.05
Roughage	%	8.88	7.78	7.07	5.57
ME[1]	MJ/kg	10.60	11.72	11.57	11.40
IVOMD	%	71.1	79.7	74.10	75.80
Starch	%	30.99	34.49	34.09	34.10
CP	%	13.69	13.10	13.29	13.44
NDF	%	31.94	31.82	34.70	35.33
EE	%	6.67	6.63	7.69	7.47
Ash	%	6.33	5.98	6.49	6.53
Ca	%	0.79	0.85	0.74	0.79
P	%	0.55	0.53	0.51	0.52
Ca:P		1.40:1	1.50:1	1.47:1	1.53:1

[1]ME = 0.82 x (GE x IVOMD) (Robinson et al., 2004)

5.2.1 Daily feed intake pattern

The daily feed intake ("As is" basis) of the animals receiving the different diets are shown in Figures 5.1 to 5.3.

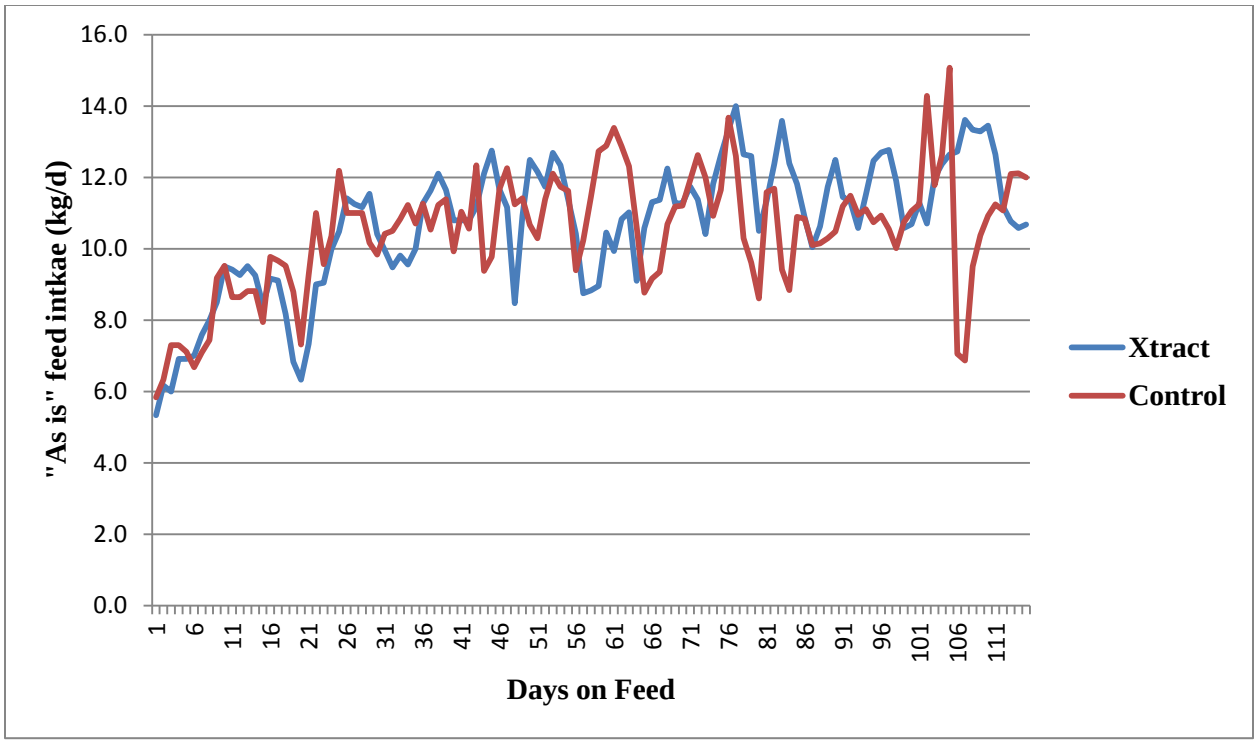


Figure 5.1 Daily feed intake patterns for animals fed the control compared to XTract

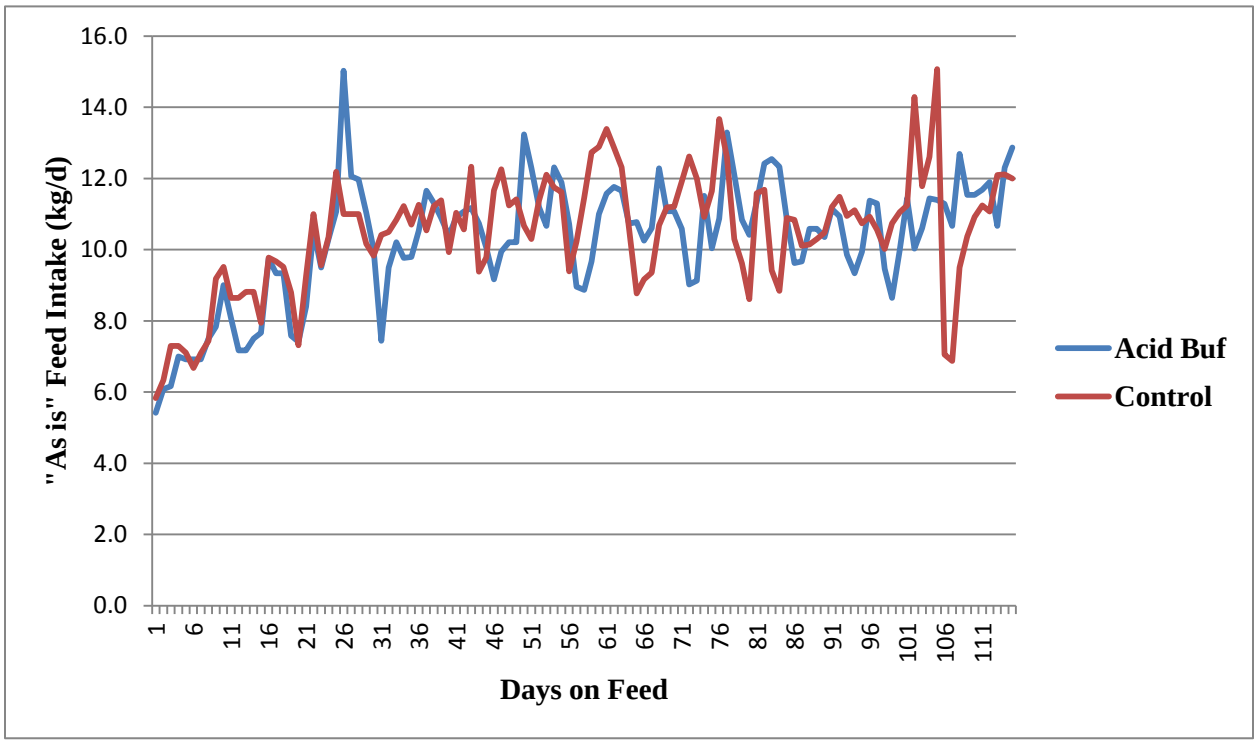


Figure 5.2 Daily feed intake patterns for animals fed the control compared to Acid Buf

The large daily variation in DMI can be ascribed to the small number of animals per pen where a low/high daily feed intake of one animal can have a significant impact on the daily average feed intake of the pen. The feeding procedure followed at the feedlot also complicated matters in the sense that feed leftovers were not removed and bunk scoring was used with codes to either supply more feed or cut back on the day's feeding.

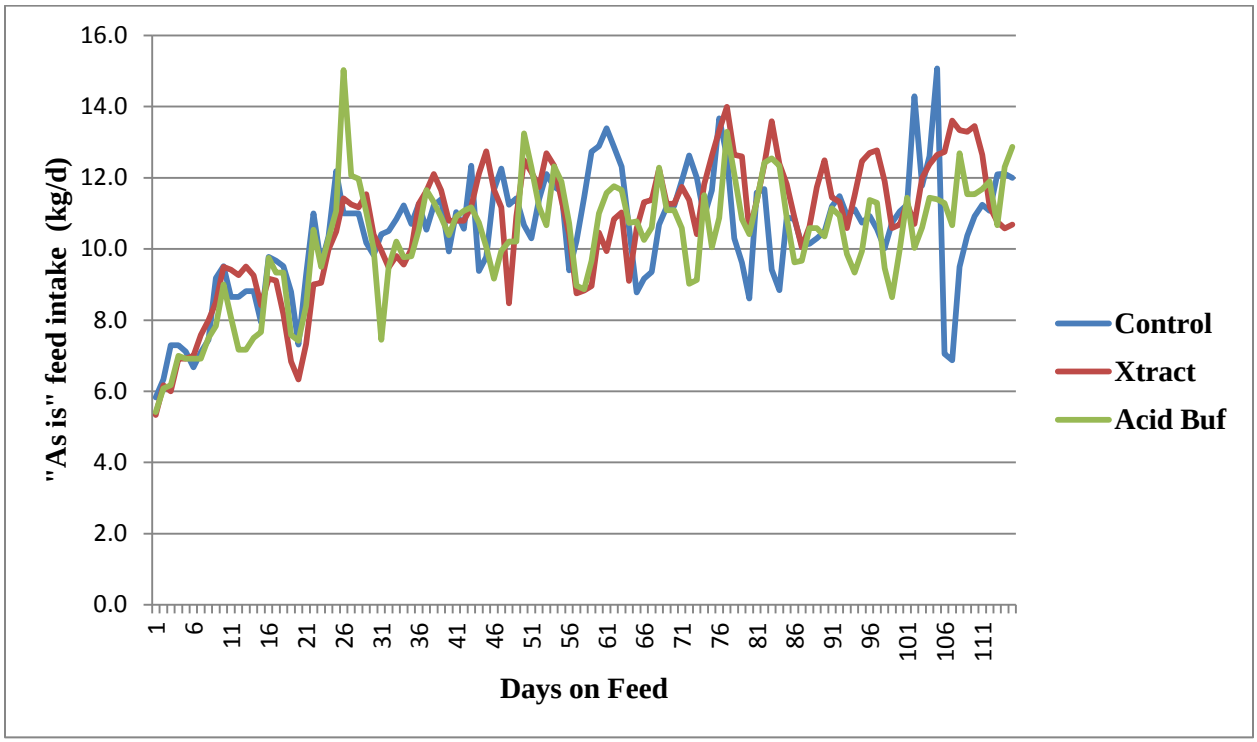


Figure 5.3 Daily feed intake variation for animals fed the three treatments

For the feed bunk assignment a coding system is used by the feedlot. The system works by assigning the bunks a score between 0 and 5 where 0 is an empty or slick bunk and 5 is overfull. Feed is thus increased when the bunk score is 0 and cut back by using 1 to 5. Assigning a 1 cuts back on 50 kg of the previous day's feed, 2 cuts back 100 kg, 3 cuts back 300 kg, 4 cuts back 700 kg and 5 cuts back 1500 kg. Values between the amounts can also be used to cut back on the previous day's feed.

5.3 Growth performance

5.3.1 Effects of the three different treatments on starting weight, end weight, cold carcass mass and dressing percentage

Table 5.2 presents the means of the starting weight (kg), end weight (kg), CCM (kg) and dressing percentage of the animals receiving the three different treatments. The mean starting weight for the control group was 227.4 kg, with a minimum weight of 186 kg and a maximum of 250 kg. For the XTract group the mean was 226.4 kg, with a minimum weight of 206 kg and a maximum weight of 246 kg. The Acid Buf group had a mean weight of 226.6 kg, with a minimum weight of 204 kg and a maximum weight of 250 kg. No differences (P = 0.44) were observed when comparing the starting weight of the three treatments.

For the end weight, the mean for the control group was 439.9 kg with the minimum weight being 373 kg and the maximum weight being 506 kg. For the XTract group the mean end weight was 429.7 kg, with a minimum weight of 365 kg and a maximum weight of 513 kg. The Acid Buf group had a mean weight of 448.2 kg, with a minimum weight of 370 kg and a maximum weight of 566 kg. The end weight (P = 0.04) was higher for the control and the Acid Buf treatment groups when compared to the XTract treatment group. The animals that received the Acid Buf had a 1.852% increase in end weight when compared to the control and XTract treatment groups.

The mean cold carcass mass for the control group was 258.7 kg with a minimum of 213 kg and a maximum of 304 kg. For the XTract group the mean cold carcass mass was 252.2 kg, with a minimum of 185 kg and a maximum of 300 kg. For the Acid Buf group the mean cold carcass mass was 263.0 kg, with a minimum of 213 kg and a maximum of 339 kg. The cold carcass mass of animals fed the control and Acid Buf treatments tended to be higher than animals fed the XTract treatment. When comparing the cold carcass mass of animals that received Acid Buf to the control animals, the Acid Buf animals showed a 1.662% increase in cold carcass mass. The XTract animals showed a 2.513% decrease in cold carcass mass when compared to the control.

The dressing percentage was calculated by using the end weight. The mean dressing percentage for the control group was 58.4 %, with a minimum percentage of 55.3 % and a maximum of 64.1 %. For the XTract group the mean was 57.6 %, with a minimum dressing

percentage of 48.0 % and a maximum of 61.7 %. For the Acid Buf group the mean dressing percentage was 58.1 %, with a minimum of 51.8 % and a maximum of 61.9 %. No differences (P = 0.15) were observed between the dressing percentages of the three treatments.

Table 5.2 A comparison of starting weight, end weight, cold carcass mass and dressing percentage of animals as affected by the three different treatments.

Parameter	n	Control	XTract	Acid Buf	P-value	S.E
Starting weight (kg)	6	227.4	226.4	226.6	0.44	1.57
EW (kg)	6	439.9^{ab}	429.7^{a}	448.2^{b}	0.04	9.41
CCM (kg)	6	258.7^{ab}	252.2^{a}	263.0^{b}	0.08	7.56
Dressing %	6	58.4	57.6	58.1	0.15	0.66

$^{a, b}$ – Row means with different superscripts differ (P < 0.05)
CCM – Cold Carcass Mass, EW – End Weight, n – number of pens, S.E. – Standard Error

5.3.2 Growth curves

A graphic illustration of the daily live weight gain of the animals receiving the three different treatments is shown in Figure 5.4 to 5.6. The animals were weighed on predetermined dates to monitor their growth and all animals fed the three treatments were weighed on the same dates. This was done in accordance with the protocol that stated if a treatment was 10% below the weight of the control group the treatment would be terminated. Table 5.3 presents the weights of animals fed the three treatments on the day they were weighed. Table 5.3 also represents the mean weights from which the growth curves were drawn.

Table 5.3 Mean body weights of the experimental animals when weighed on predetermined dates

Day	Control (kg)	XTract (kg)	% difference (XTract *vs.* Control	Acid Buf (kg)	% difference (Acid Buf *vs.* Control)
0	227	226	0.441	227	0.000
16	269	263	2.230	265	1.487
43	314	309	1.592	310	1.274
63	355	346	2.535	353	0.563
91	406	399	1.724	403	0.739
118	443	440	0.682	456	2.935*

* - Superscript means an increase in percentage above the Control

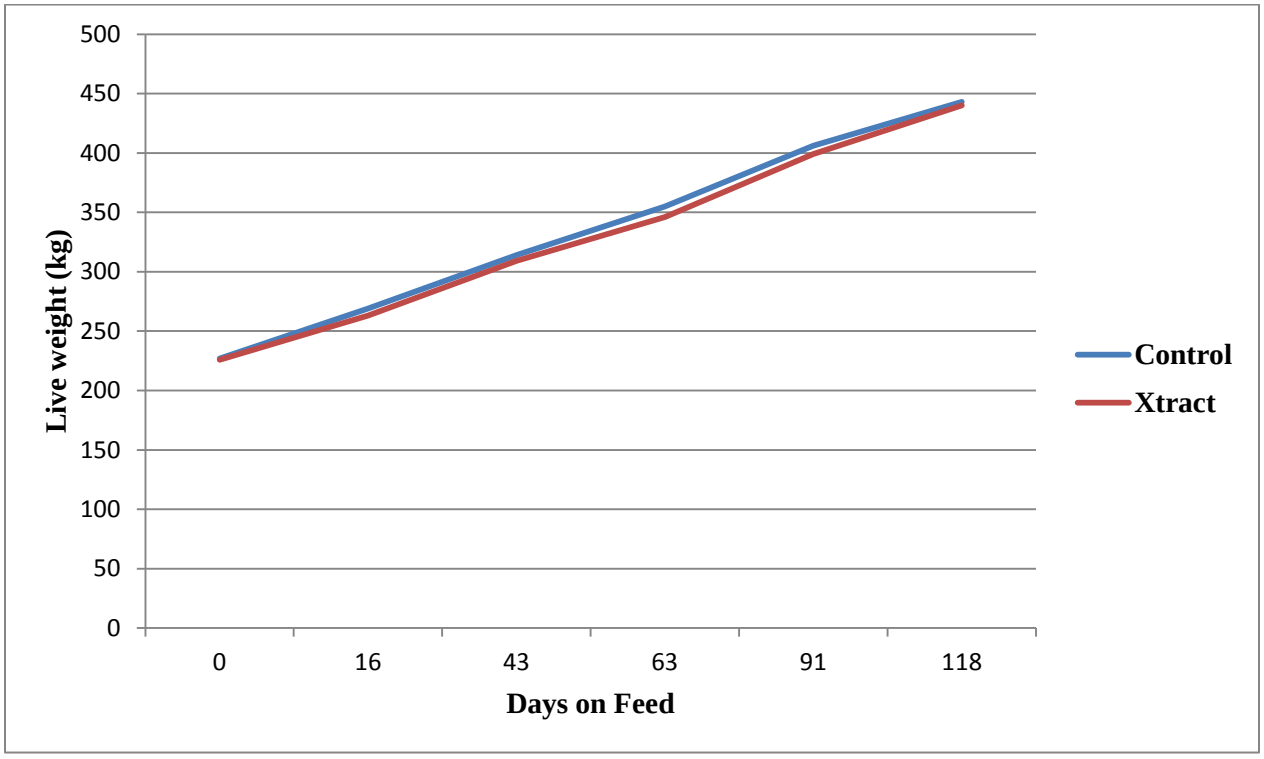


Figure 5.4 Growth of animals receiving the control treatment compared to the XTract treatment group

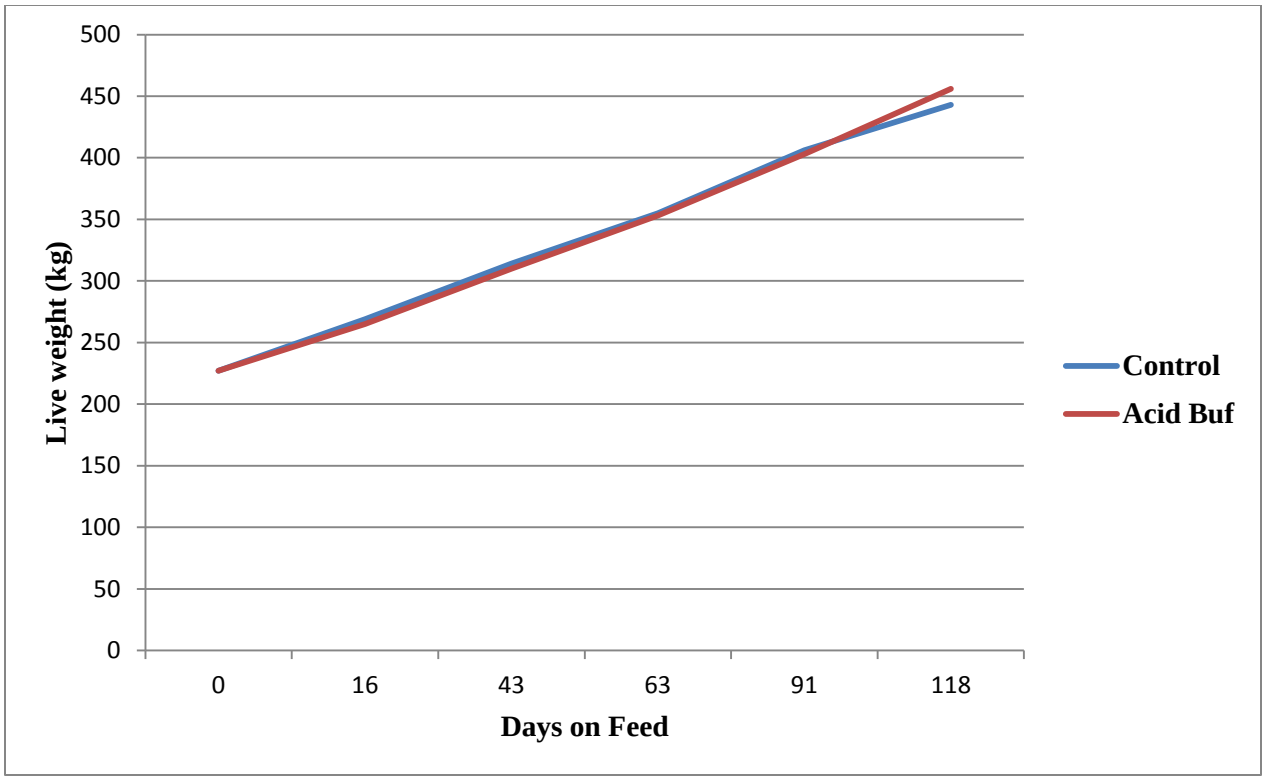


Figure 5.5 Growth of animals receiving the control treatment compared to the Acid Buf treatment group

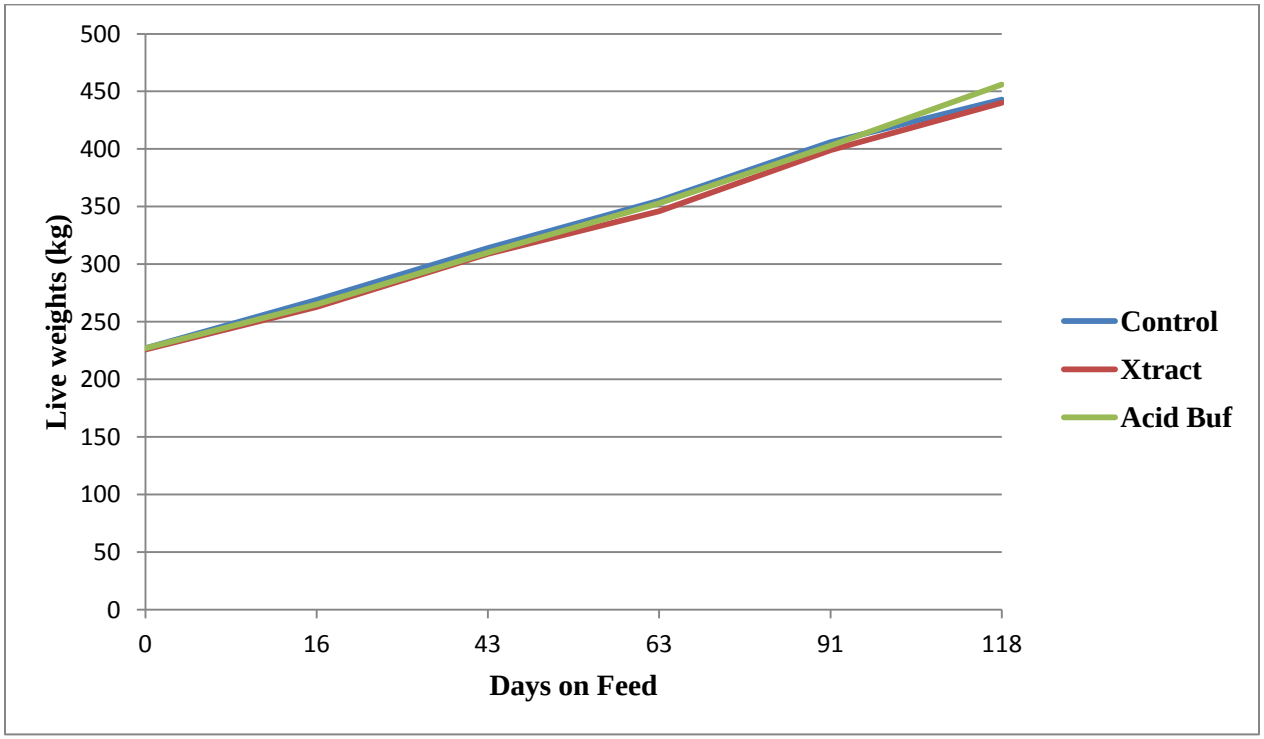


Figure 5.6 Growth of animals receiving the control treatment compared to the XTract and Acid Buf treatment groups

Visual observation of the three figures suggested minor differences in live weight between animals fed the experimental treatments.

5.3.3 Effect of experimental treatments on dry matter intake, feed conversion and average daily gain

Table 5.4 presents the dry matter intake and growth performance parameters for the animals fed the three different treatments. The means of the dry matter intake, feed conversion and average daily gain is for the entire period and is thus the mean of the four different rations combined.

There were no differences in dry matter intake ($P < 0.05$) between treatment animals. The mean dry matter intake for the control group was 8.66 kg, for the XTract group 8.87 kg and for the Acid Buf group 8.49 kg.

Differences were found in feed conversion between the experimental treatment groups ($P < 0.05$). Animals fed the Acid Buf diet had a better feed conversion of 4.51 kg feed/ kg gain compared to animals fed the control treatment. Animals fed the XTract treatment had a lower feed conversion of 4.94 kg feed/ kg gain compared to the animals fed control treatment.

Average daily gain did not differ between the treatment groups ($P > 0.05$) and varied between 1.79 kg/d (XTract) and 1.89 kg/d (Acid Buf).

The days on feed differ between treatments because not all the animals selected for the trial were processed on the same day.

Table 5.4 A comparison between the feed associated parameters, dry matter intake, feed conversion ratio, average daily gain and days on feed between the treatments.

Parameter	n	Control	XTract	Acid Buf	P-value	S.E.
DMI (kg)	6	8.660	8.865	8.490	0.38	0.1872
FCR (DM)	6	4.73^{ab}	4.94^{a}	4.51^{b}	0.03	0.248
ADG (kg)	6	1.82	1.79	1.89	0.16	0.08
Days on feed	6	118.9	119.7	122.3	*	*

$^{a, b}$ – Row means with different superscripts differ ($P < 0.05$)
DMI – Dry matter intake, FCR – Feed conversion ratio, ADG – Average daily gain, n – number of pens, S.E. – Standard Error

In the small pens DMI was not affected by treatment. There are mixed results on the effects of EO's on DMI and it appears to be dependent on the dose, type of diet and the type of EO. In a study involving 1468 yearling steers there were no differences in DMI of steers fed either 1.0 g /d of different EO mixtures or different combinations of monensin (300 mg /d) and Tylosin (90 g /d). However, an EO mixture of cinnamaldehyde (180 mg /d) and eugenol (90 mg /d) in beef cattle diets (Cardozo *et al*., 2006) and high doses of cinnamaldehyde in dairy cattle diets (Busquet *et al*., 2003) negatively affected DMI. In contrast, Cardozo *et al.* (2006) reported that supplementation with capsicum oil in concentrate based beef diet stimulated intake and rumen fermentation.

5.4 Mortalities

Out of all the animals selected for the trial, only three mortalities were recorded. Two of the animals from the XTract treatment died and only one from the control treatment. There were no mortalities amongst animals receiving the Acid Buf treatment. The post mortems done by the veterinarian revealed that the control animal died of bloat and one of the XTract animals was a chronic bloat with the other animal's post mortem diagnosis indicating black quarter.

CHAPTER 6

Commercial pen trial

Results and discussion

6.1 Introduction

In this chapter the results of the commercial pen trial will be discussed. This will include performance data with regards to end weights achieved, average daily gains, feed conversion ratios, cold carcass mass, dressing percentage and dry matter intake. For the performance data the pen was taken as a unit and for the health data the individual animal was taken as a unit. The feed analysis was discussed in the previous chapter and will thus not be discussed here again. The daily feed intake pattern will be shown in this chapter for the commercial pens.

The focus of the commercial pens was on digestive disorder. The other health parameters like the lung scoring and the rumen scoring will be discussed during this chapter as well as mortalities that occurred. The chapter concludes with findings from other trials.

6.2 Daily feed intake pattern

The line charts presented in Figure 6.1 and 6.2 represent the average feed intake on an "As is" basis per animal per day for the trial period. The three different line charts presents the feed intake for the Control *vs.* XTract (Figure 6.1) and Control *vs.* Acid Buf (Figure 6.2) Control *vs.* XTract *vs.* Acid Buf (Figure 6.3)

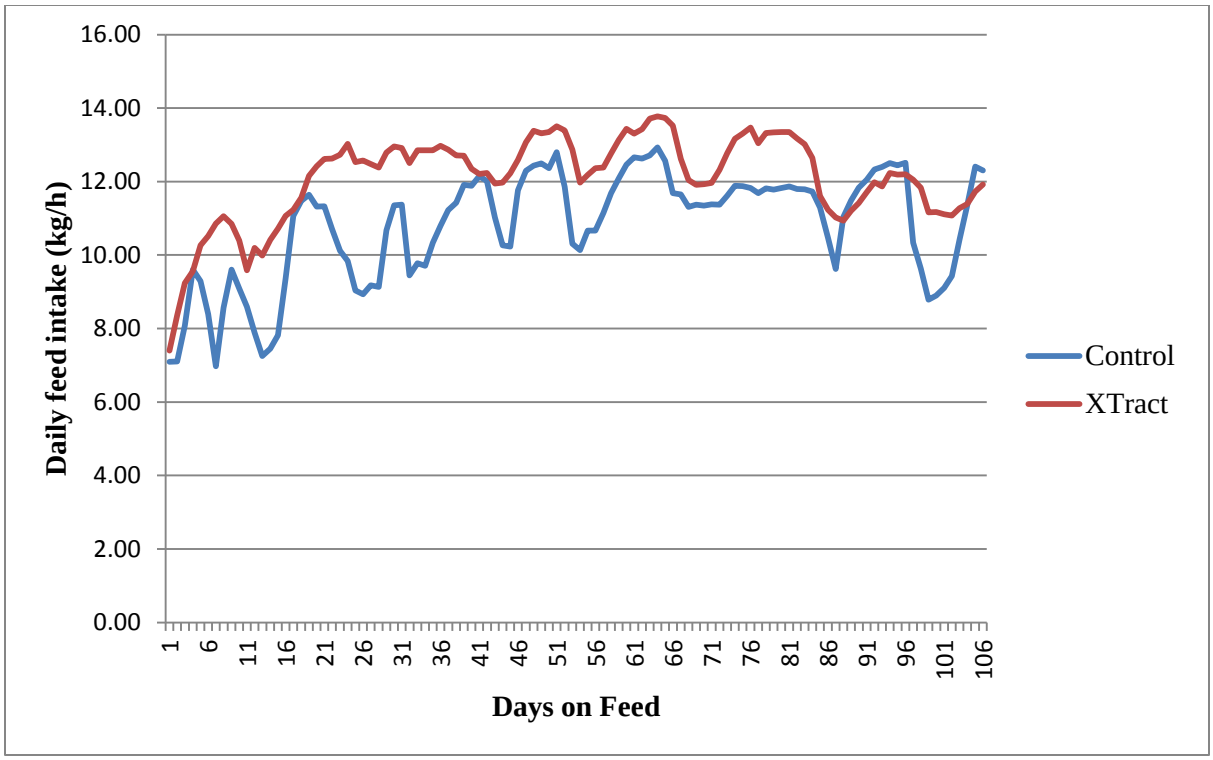


Figure 6.1 "As is" feed intake pattern for the Control treatment and XTract treatment.

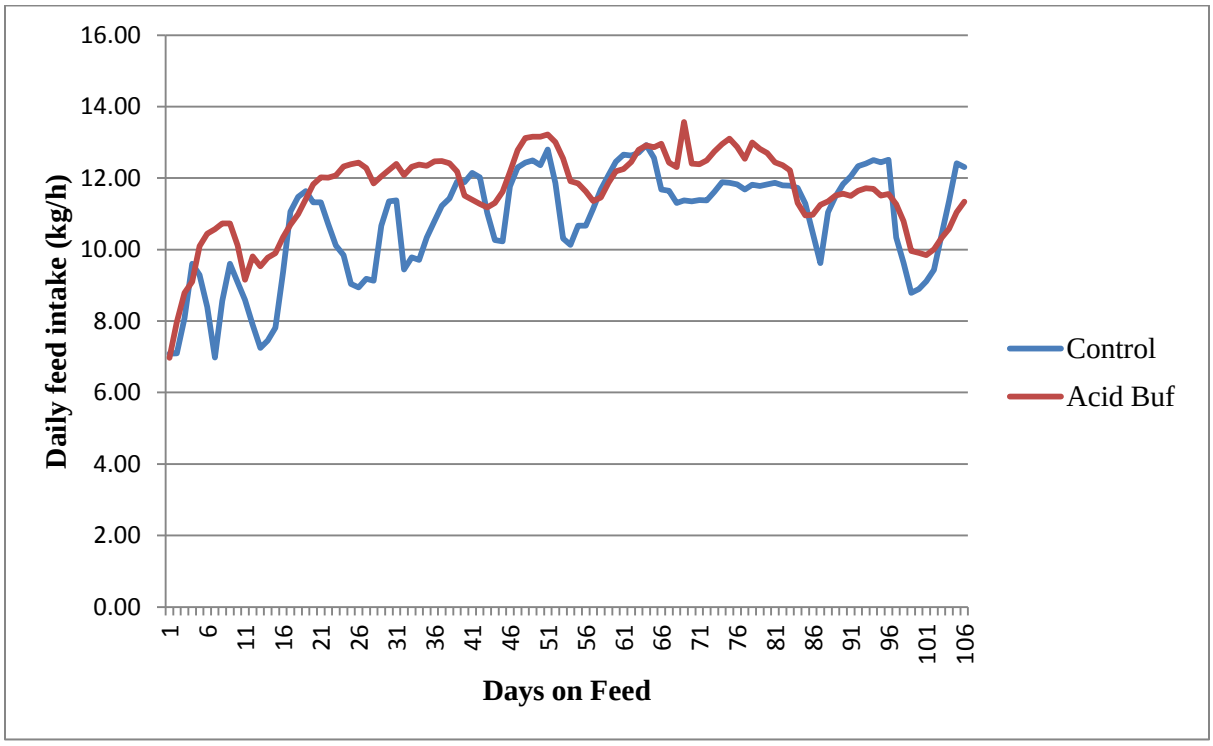


Figure 6.2 "As is" feed intake pattern for the Control treatment and Acid Buf treatment.

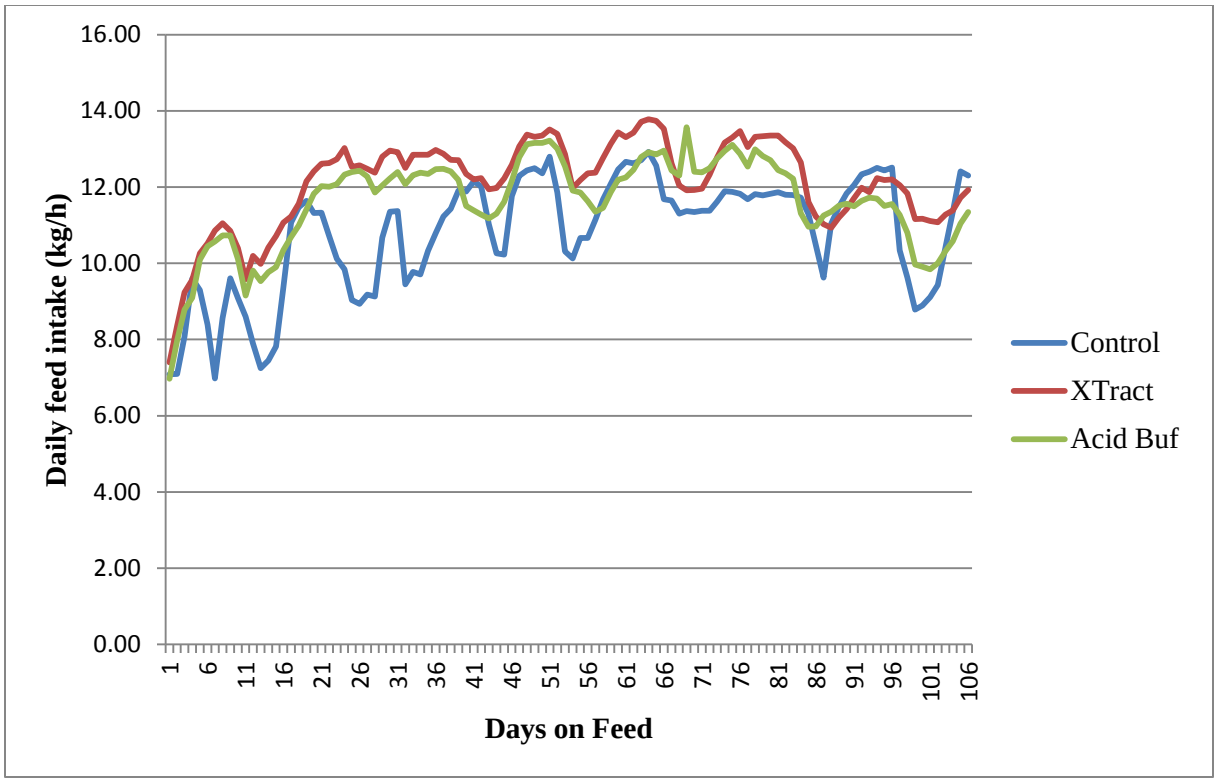


Figure 6.3 Daily feed intake variation for the three treatments.

The commercial pens show less daily variation in feed intake than the small pens. This is due to a higher number of animals per pen and also if an over feeding occurred, one wouldn't see it as one would with the small pens. The bunk checks were done the same as for the small pens, assigned to be slick before the first feeding.

From the blue line representing the Control treatment; one can see what the feedlot calls a roller coaster. During the first 67 days the Control treatment has a more variable daily change in intake when compared to the other two treatments as can be seen from figure 6.3. The first decrease in feed intake for XTract and Acid Buf occurs at day 11. On this date the animals were revaccinated and a decrease in feed intake did occur after revaccination. For the control group revaccination took place on day 13 and a drop in feed intake also occurred. The drop for the two treatments was from 10.11 to 9.15 kg/h for Acid Buf and 10.40 to 10.19 kg/h for XTract compared to the Control which dropped from 7.89 to 7.25 kg/h.

6.3 Growth performance

6.3.1 Effects of the three different treatments on growth

Table 6.1 presents the means of the Starting weight (kg), CCM (kg), Dressing percentage on End weight (kg) of the three different treatments. The mean starting weight for the control group was 225.6 kg with a minimum weight of 201 kg and a maximum weight of 250 kg. For the XTract group the mean was 225.4 kg, with a minimum weight of 201 kg and a maximum weight of 250 kg. The Acid Buf group had a mean weight of 222.7 kg, with a minimum weight of 201 kg and a maximum weight of 250 kg. No differences (P = 0.17) were observed in the Starting weight of the three treatments.

Cold Carcass Mass mean for the Control group was 242.7 kg with a minimum of 184.0 kg and a maximum of 313.0 kg. For the XTract group the mean Cold Carcass Mass was 247.3 kg, with a minimum of 160.0 kg and a maximum of 352.0 kg. For the Acid Buf group the mean Cold Carcass Mass was 245.9 kg, with a minimum of 159.0 kg and a maximum of 328.0 kg. The XTract and the Acid Buf tended (P = 0.26) to be higher than Control. When Comparing the CCM of the Control to XTract, XTract showed a 1.895% increase in CCM. Acid Buf showed a 1.319% increase in CCM when compared to the Control.

The Dressing percentage was calculated by using the End Weight. The mean Dressing percentage for the Control group was 58.1 %, with a minimum percentage of 51.5 % and a maximum of 64.5 %. For the XTract group the mean was 57.57 %, with a minimum Dressing percentage of 48.6 % and a maximum of 62.0 %. For the Acid Buf group the mean Dressing percentage was 57.83 %, with a minimum of 51.2 % and a maximum of 63.4 %. No differences (P = 0.52) were observed between the Dressing percentages of the treatments. Both the treatments showed a decrease in dressing percentage when compared to the control. XTract had a 0.91% decrease and Acid Buf a 0.46% decrease in dressing percentage.

For the End Weight, the mean for the Control group was 417.5 kg with the minimum weight being 328 kg and the maximum weight being 515 kg. For the XTract group the mean End Weight was 429.3 kg, with a minimum weight of 325 kg and a maximum weight of 533 kg. The Acid Buf group had a mean weight of 425.3 kg, with a minimum weight of 346 kg and a maximum weight of 553 kg. The End Weight (P = 0.02) was higher for XTract and the Acid Buf

when compared to the Control. Acid Buf had a 1.868% increase in End Weight when compared to the Control and XTract had a 2.826% increase in End Weight.

Table 6.1 A comparison of starting weight, end weight, cold carcass mass and dressing percentage between the three different treatments.

Parameter	n	Control	XTract	Acid Buf	P-value	S.E.
Starting weight (kg)	3	225.6	225.4	222.7	0.17	1.80
EW (kg)	3	417.5[a]	429.3[b]	425.3[b]	0.02	3.55
CCM (kg)	3	242.7	247.3	245.9	0.26	3.15
Dressing %	3	58.1	57.57	57.83	0.52	0.54

[a, b] – Rows means with different superscripts differ ($P < 0.05$)
CCM – Cold Carcass Mass, EW – End Weight, n – number of pens, S.E. – Standard Error

6.3.2 Growth curves

Figure 6.4, 6.5 and 6.6 present the growth of the animals throughout the trial period. Figure 6.4 presents the Control *vs.* the XTract treatment and figure 6.5 presents the Control *vs.* the Acid Buf. Figure 6.6 presents the three treatments compared to each other. As with the Small pen trial, the animals were weighed on predetermined dates to track their growth. Thirty animals from each treatment were randomly selected by the hospital team to weigh. This was done in accordance with the protocol that stated if a treatment was 10% below the weight of the Control group the treatment would be terminated. Table 6.2 presents the weights of the three treatments on the day they were weighed. Table 6.2 also represents the mean weights from which the growth curves were drawn.

Table 6.2 Mean weights of the treatments on predetermined dates

Day	Control (kg)	XTract (kg)	% difference (XTract *vs.* Control	Acid Buf (kg)	% difference (Acid Buf *vs.* Control)
0	226	225	0.442	223	1.327
15	255	258	1.176*	252	1.176
43	304	308	1.316*	296	2.597
63	331	344	3.927*	342	3.323*
91	379	394	3.958*	392	3.430*
114	418	429	2.632*	425	1.675*

* - Superscript means an increase in percentage above the Control

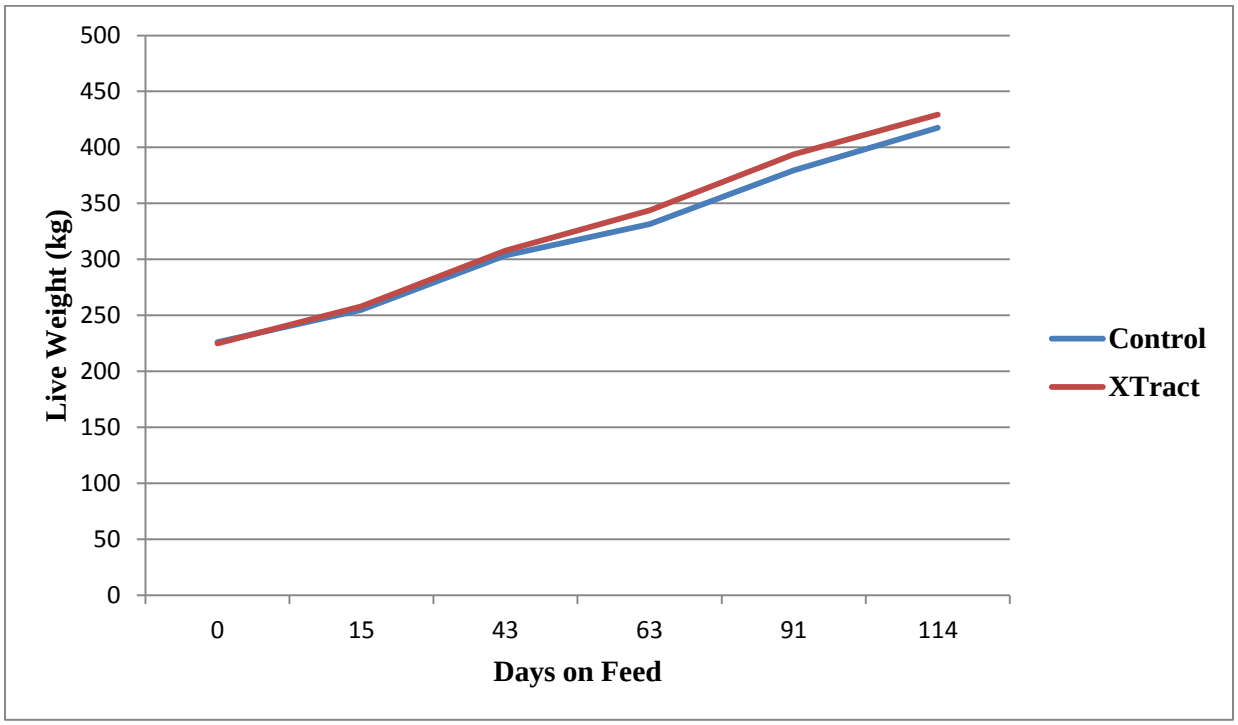


Figure 6.4 Growth of the Control treatment compared to the XTract treatment

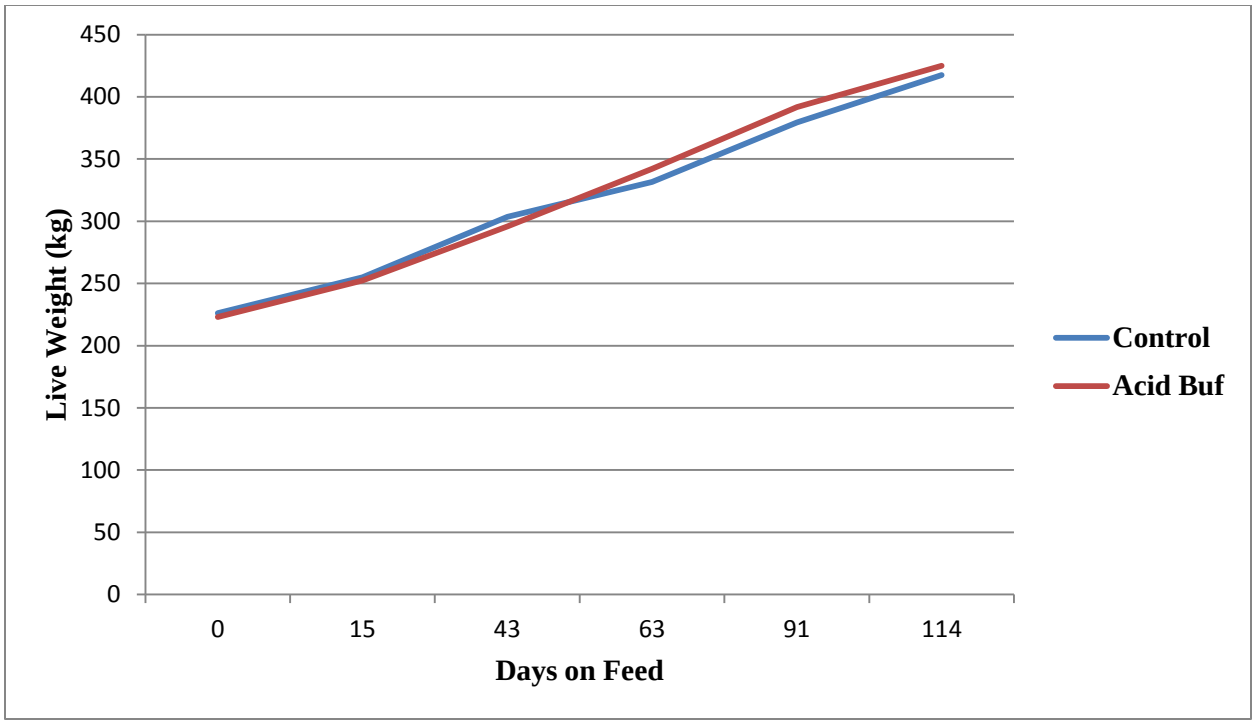


Figure 6.5 Growth of the Control treatment compared to the Acid Buf treatment

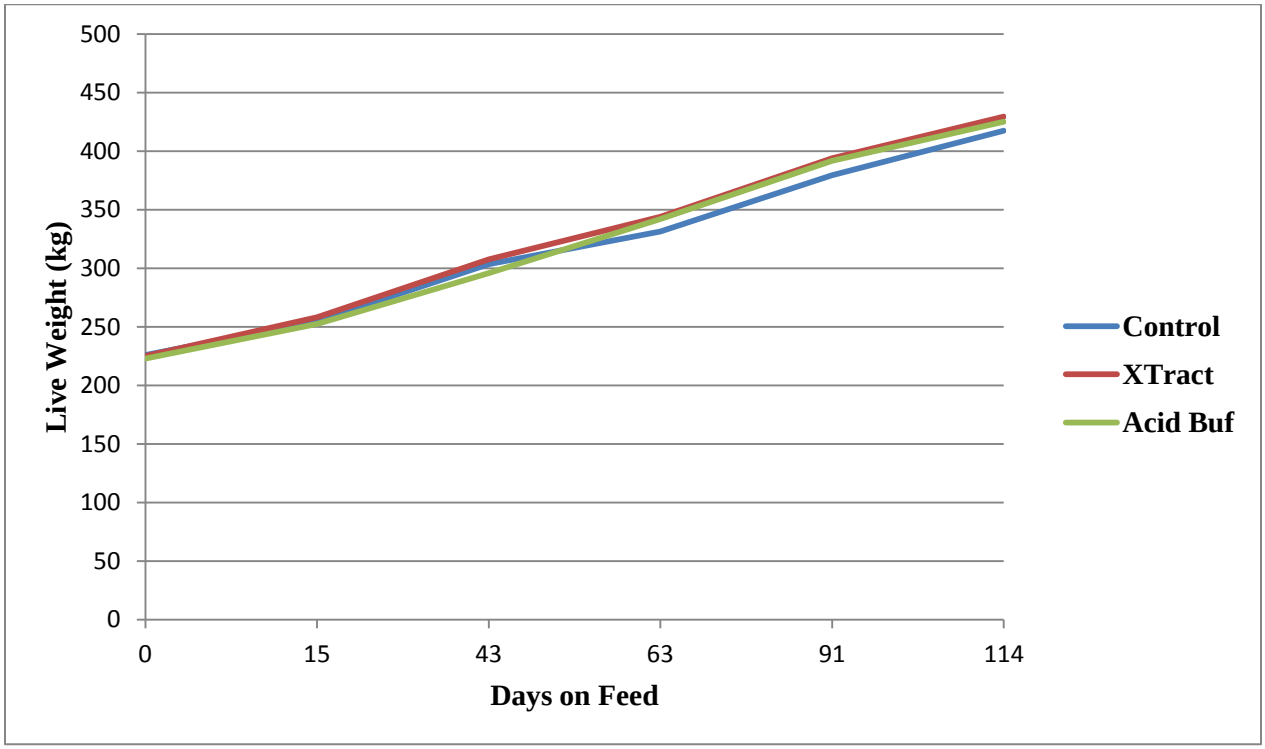


Figure 6.6 Growth of the Control treatment compared to the Acid Buf treatment

6.3.3 The effect of feed associated parameters between the three different treatments

Table 6.3 presents the feed parameters for the three different treatments. The means of the DMI, FCR and ADG is for the entire period and is thus the average of the four different rations combined.

The DMI showed no differences (P = 0.06) between treatments, only numerical differences were found. The mean DMI for the Control was 8.97 kg, for XTract 10.05 kg and for Acid Buf 9.07 kg. Both the XTract and Acid Buf tended to be higher than the Control. The Acid Buf treatment had a 1.103% increase in DMI when compared to the Control and XTract had a 10.746% increase in DMI when compared to the Control treatment.

FCR had no differences (P = 0.23) between treatments when compared to each other. The Control treatment had an FCR of 5.26, XTract 5.67 and Acid Buf had a FCR of 5.22. When comparing XTract and Acid Buf to the Control, XTract's FCR was reduced by 7.795% and Acid Buf had an improvement of 0.760% in FCR when compared to the Control.

ADG showed no differences (P = 0.06) between the treatments and only numerical differences were found. The ADG for the Control was 1.70 kg/d, for XTract 1.77 kg/d and for Acid Buf it was 1.74 kg/day. XTract tended to increase ADG by 3.955% when compared to the Control and Acid Buf tended to increase by 2.299% when compared to the Control.

The days on feed differ between treatments because not all the animals selected for the trial were processed on the same day.

Table 6.3 A comparison between the feed associated parameters, dry matter intake, feed conversion ratio, average daily gain and days on feed between the treatments.

Parameter	n	Control	XTract	Acid Buf	P-value	S.E.
DMI (kg)	3	8.97[a]	10.05[b]	9.07[a]	0.06	0.28
FCR (DM)	3	5.26	5.67	5.22	0.23	0.31
ADG (kg)	3	1.70[a]	1.77[b]	1.74[ab]	0.06	0.03
DOF (day)	3	113.1	115.0	116.6	*	*

[a, b] – Row means with different superscripts differ (P < 0.05)
DMI – Dry matter intake, FCR – Feed conversion ratio, ADG – Average daily gain, n – number of pens, S.E. – Standard Error

In grain fed animals ionophores generally depress feed intake, body weight gain is increased or unaffected and feed efficiency (feed/gain) is improved. Summaries by Goodrich *et al*. (1984) and Raun (1990) have shown that monensin increased feed efficiency by 5.6 – 7.5%, increased ADG by 1.6 – 1.8% and decreased DMI by between 4 and 6%. The diets fed in this trial contained high levels of hominy chop which has a higher ruminal starch fermentation rate than dry rolled maize often used in feedlot diets. The cattle in our study were perhaps challenged more, compared to cattle fed the average US feedlot diet and it could be speculated that the increase in performance compared to a monensin free diet, in our study, could be at the upper range of results of the USA studies mentioned above.

In a recent study Yang *et al*. (2010) compared a control, monensin (330 mg /d) and three doses of cinnamaldehyde (400, 800 or 1600 mg /d) in a diet containing 86% barley grain. Dry matter intake responded quadratically (P = 0.03) to cinnamaldehyde supplementation with 13% more feed consumed for steers fed the cinnamaldehyde compared to the control diet over the first 28 days of the study. A similar effect on DMI during the first 35 days was observed in the commercial pen trial. Apart from overall DMI of the XTract supplemented animals being higher, the intakes, during weeks 1, 2, 4 and 5 were higher (P < 0.05) compared to monensin supplemented animals (Fig. 6.3). The first month in a feedlot is of extreme importance since the rumen has to adapt and getting animals to change over from the starter to the intermediate and finisher rations and might prove to be the difference between a profit and a loss scenario.

Capsicum, which is one of the three plant extracts in XTract, is perhaps responsible for controlling feed intake behaviour. In an *in vitro* study Cardozo *et al*. (2005) reported that capsicum oil in high concentrate low pH diets improved general rumen fermentation and nutrient utilization. In a study with steers, results from Cardozo *et al*. (2006) suggested that capsicum oil stimulated peptidolysis which enhances microbial protein synthesis and flow to the small intestine. In addition capsicum oil increased DM and water intake. This was also found in studies with rats and humans (Zafra *et al*., 2003; Calixto *et al*., 2000). Similar results were also reported by Fandino *et al*. (2006). Capsicum therefore appears to stimulate DMI through a combination of ruminal effects and indirectly through higher water intake. From Figure 6.3 it also appears that the daily variation in feed intake, especially during the first 7 weeks, is less in XTract supplemented animals compared to monensin. It is well known that many feedlotters insist on monensin, not so much for preventing metabolic disorders, but more for its role in modulating feed intake.

Few studies on the effects of EO's on animal performance have been reported (Calsamiglia *et al*, 2007; Adesogan, 2009; Patra, 2010). Benchaar *et al*. (2006) found no difference in the ADG of cattle fed a silage based diet supplemented with either monensin or two levels of an EO mixture. Similarly, Chaves *et al*. (2008) found no effect of carvacrol or cinnamaldehyde on growth performance of sheep when fed a maize or barley based diet. This is in agreement with our small pen study where treatment did not affect either FCR or ADG ($P > 0.10$).

In the commercial pen study which represents the real time practical feedlot conditions, the DMI, tended to ($P=0.09$), and carcass end weight and ADG were higher ($P < 0.05$) for XTract supplemented animals, suggesting that XTract can be used as a natural alternative to ionophore antibiotics. A meta - analyses done by Bravo *et al* (2010) which included 15 trials, reported an improvement in body weight gain and gain to feed ratio. Although speculative, these effects could be through capsicum oleoresin decreasing the acetate: propionate ratio and increasing intake (Cardozo *et al*. 2006) together with cinnamon oil and cinnamaldehyde increasing total VFA and reducing acetate: propionate ratio (Cardozo *et al*, 2005). In addition eugenol has been reported to increase molar proportions of propionate and decrease ruminal ammonia and ruminal peptidolytic activity, thereby increasing energy and protein utilization in

the rumen. Further research is urgently needed on the additive/synergistic effects between different EO's.

Due to the commercial conditions and the large number of animals, emphasis should be placed on the health data from the commercial trial. The percentage of XTract supplemented animals pulled and treated for respiratory problems was numerically lower than the control animals. Although essential oils have antimicrobial properties, the EO's were fed at low levels in this study and it could therefore be speculated that the essential oils would rather have played a role as immune modulator, thereby stimulating an immune response that addresses health problems (Lee *et al*, 2011) (Table 6.4).

No scientific publications could be found on the supplementation of Acid Buf to feedlot cattle, making this large scale feedlot study quite unique. Similarly for dairy cattle the only published scientific study is the abstract by Cruywagen *et al*. (2007). In the discussion, therefore, we have to refer to other buffers like sodium bicarbonate (SB) when comparing results to monensin supplemented cattle.

Despite the variability in response to SB in research studies, buffers are routinely added to commercial cattle diets to maintain a more stable rumen and as a precautionary measure in the prevention of acidosis (Beachemin *et al*., 2006). Ruminal acidosis, followed by rumenitis, laminitis and liver abscesses may result from rapidly adapting cattle to high concentrate diets. Enhanced performance during adaptation to high grain diets with buffer supplementation has been documented (Nicholson *et al*., 1963; Huntington *et al*., 1977), but Zinn and Borques (1993) reported no effects of SB (0.75% of DM) on feedlot performance of steers fed high grain diets.

The effects of SB on rumen pH in feedlot cattle have also been inconsistent. Boener *et al*. (1987) and Zinn (1991) observed an increase in rumen pH after 0.75 – 1.0% DM supplementation of SB. On the contrary, Russel *et al*. (1980) and Haaland and Tyrell (1982) found up to 2% SB inclusion had no effect on ruminal pH of feedlot steers. When interpreting results, the composition of the basal diet is in many cases a good indicator of whether a response could be expected. In the study by Zinn (1991) the basal diet contained 12% roughage and 74% maize while in the study of Haaland and Tyrell (1982) the basal diet contained 35% maize silage and only 55% maize. Based on the basal diets, a positive response with the Zinn (1991) study could have been predicted.

In our study the finisher diet only contained 6% grass hay and 9% molasses meal. It can be assumed that the roughage contribution of molasses meal is 50%, and that the diet only contained 10.5% roughage. Based only on the diet composition, it is reasonable to expect a positive response when compared to a control diet. Unfortunately in this study a control diet (no supplement) was not an option due to the high risk of mortalities and the resulting financial implications. In this study the control diet was the monensin supplemented diet as mentioned, since monensin is included in the diets fed at all the large commercial feedlots in South Africa. Monensin therefore is the golden standard against which all other feed additives are compared.

The FDA approved the ionophore monensin as a feed additive for cattle in 1976, although it is currently banned in Europe (Conzalez *et al*., 2012). Goodrich *et al*. (1984) reviewed the effects of monensin on the performance of close to 16 000 feedlot cattle and found treated cattle gained 1.6% faster, consumed 6.4% less feed and had a 7.5% greater feed efficiency than un-supplemented cattle. In another summary of 24 US trials, monensin supplemented at 154 mg /d increased gain by 13.5% (Goodrich *et al*., 1984).

When individual study results obtained with SB or monensin supplementation is compared, the responses are sometimes remarkably similar. Lofgreen (1976) observed a 7% increase in ADG of cattle supplemented with 0.75% SB in a steam rolled barley based diet containing 90% concentrate. Brenthour *et al*. (1986) reported an 11.6% increase in ADG by the addition of 1.05% SB to finely rolled wheat and sorghum based finisher diet.

There were no differences between treatments for any of the parameters measured in the small pens (Table 5.2) and in the commercial pens (Table 6.3), only end weight and ADG tended ($P < 0.10$) to be higher for Acid Buf supplemented cattle. Looking at the performance results in totality, it suggests that both monensin and Acid Buf supplementation resulted in a similar feedlot performance. This is supported by other results discussed above where there were also similarities in the increased performance of feedlot cattle supplemented with either SB or monensin when compared to a control diet.

6.4 Health parameters

For the health parameters the main focus was on digestive disorders and mortalities due to digestive problems. The three main digestive disorders focused on were free gas bloat, frothy bloat and acidosis. When animals were pulled for one of the above, they were treated and went

back to their original pens. They were also logged on to the feedlot's data base so that they could be checked again when they were pulled.

For animals that showed signs of pneumonia, they were pulled from the pens, treated and were out of the trial. These animals were also logged on to the data base and it is from this data base that the number of healthy and sick animals' data was collected.

6.4.1 Animals pulled during the trial

During the trial animals were pulled on a daily basis for showing signs of being sick. Table 6.4 is a summary of the percentage of animals being healthy and animals showing signs of being sick. The percentage of healthy vs. sick animals was significant when compared to each other. The Control treatment had 319 animals which fit the criteria for the corrected weight group. Of the 319 animals 78.1% were healthy and 21.9% were considered sick. For XTract, 344 animals fitted the criteria with 82.3% being healthy and 17.7% considered sick and for the Acid Buf group, 352 animals fitted the criteria with 65.8% being healthy and 34.2% considered sick.

Table 6.4 Percentage of healthy and sick animals per treatment

Treatment	n	Parameters		P - value	χ^2
		Health (%)	Sick (%)		
Control	319	78.1	21.9		
XTract	344	82.3	17.7	< 0.01	27.9
Acid Buf	352	65.8	34.2		

6.4.2 Reason animals were pulled

The two main signs showed by animals in terms of being sick were signs of digestive disorders and pneumonia. Table 6.5 shows the percentages of animals pulled. The percentages between treatments showed differences ($P < 0.01$). For the Control treatment 78.1% of the animals were healthy with 6.0% showing signs of digestive disorder, 15.7% signs of pneumonia and 0.3% were classified under "Other". For XTract, 82.3% were healthy, 5.8% showed signs of digestive disorders, 9.9% signs of pneumonia and 2.0% were classified under "Other". Acid Buf

had the lowest percentage of healthy animals with 65.8%. Acid Buf also had the highest percentage of signs of digestive disorders at 10.8%, pneumonia at 21.1% and Other at 2.3%.

Results on the health data (Table 6.4) is difficult to interpret in the sense that monensin supplemented cattle appeared to be more healthy with less pulls (21.9% *vs.* 34.4%) ($P < 0.01$).

Table 6.5 Percentage of animals pulled per treatment

Treatment	n	Parameters				P - value	χ^2
		None (%)	Digestive (%)	Respiratory (%)	Other (%)*		
Control	319	78.1	6.0	15.7	0.3		
XTract	344	82.3	5.8	9.9	2.0	< 0.01	32.9
Acid Buf	352	65.8	10.8	21.1	2.3		

* - Superscripts indicates percentage of animals treated for injuries, cripples, abscesses and eye infections

Table 6.6 presents the lung scores of the different treatments done by the feedlot veterinarian. The percentages between the different scores showed differences ($P < 0.01$). Out of Table 6.6, XTract had the best lung scores with 62.9% of the animals having no visual lung damage. The Control had 59.6% scoring 0 and Acid Buf had 49.2% scoring 0.

Table 6.6 Lung scoring percentages per treatment

Treatment	n	Parameter				P - value	χ^2
		Lung score					
		0	1	2	3		
Control	268	59.6	27.0	10.0	3.4		
XTract	299	62.9	27.2	6.6	3.3	< 0.01	15.62
Acid Buf	243	49.2	35.4	13.1	2.3		

Several researchers, however, examined the antimicrobial activities of a variety of oils and oil compounds against *Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes,* and *Salmonella enteric* strains as well as some of the factors that may influence these activities (Patra, 2010). Activity levels of 96 essential oils and 23 oil compounds were evaluated in the study reported by Friedman *et al.* (2002). In their study they have shown that

many plant essential oils and many compounds isolated from plants are bactericidal against multiple strains of *C. jejuni*, *E. coli* O157 and O157: H7, *L. monocytogenes,* and *S. enterica,* including strains associated with food borne outbreaks, human illness, and recent food isolates. One can thus speculate that the three essential oils in XTract had the same bactericidal effect on the organisms that cause lung disease and this could also explain the lower percentage of total pulls and pulls for respiratory problems when compared to animals only supplemented with monensin (Table 6.5). However, much more research with a large number of animals are needed on this aspect before definite conclusions can be drawn.

Table 6.7 presents the rumen score percentages for the treatments from the commercial pens. Rumens were scored visually by looking at the damage as was explained in Chapter 4. All the types of damage were combined and only two categories were chosen. If the rumens were damaged they were classed under Yes and for no damage under No. As can be seen from Table 6.7, the Control had 72.9% damaged rumens versus 27.1 being healthy with no visual damage. XTract had 23.7% damaged rumens with 76.3% showing no visual damage and Acid Buf had 50.8% damaged rumens with 49.2% of the rumens scored showing no visual damage.

Table 6.7 Rumen scoring percentages per treatment

Parameter					
		Rumen Damage			
Treatment	**n**	**Yes (%)**	**No (%)**	**P - value**	**χ^2**
Control	223	72.9	27.1		
XTract	256	23.7	76.3	< 0.01	109.6
Acid Buf	255	50.8	49.2		

Rumen damage was 48% lower for animals supplemented with XTract compared to the monensin supplemented animals (Table 6.7). A possible reason for the decrease in rumen damage might be through a more constant and less variable feed intake pattern by the XTract supplemented animals especially in the commercial pens. This is supported by other research (Calsamiglia *et al*., 2007). Constant feed intake leads to a more favourable rumen environment causing less variation in the rumen microbial population and a more constant production of volatile fatty acids. Thus the periods of high concentrations of total VFA and lactic acid

accumulation will be reduced and, together with potentially less time below pH 5.6, will probably lead to less rumen damage together with better feedlot performance.

With regard to rumen score (Table 6.7) only 50.8% rumens were damaged in Acid Buf supplemented cattle compared to the 72.9% of the monensin group ($P < 0.01$). Results suggest that monensin had more of a generalised effect on improving health while the role of Acid Buf is more concentrated on improving rumen health. Nevertheless, differences in health parameters did not affect the growth performance of the cattle, suggesting a relatively minor effect on performance.

6.5 Mortalities

Six mortalities occurred at the commercial pen trial. One mortality was recorded for the Control treatment group, two for the XTract treatment group and three for the Acid Buf group. The post mortem for the animal from the Control group showed pneumonia as the cause of death. The post mortems for the XTract animals showed both died of pneumonia with one animal also having lung abscesses. For the three animals from the Acid Buf group, the post mortems showed red water and bloat as the causes of death. The third animal showed signs of frothy bloat and was sent to the abattoir as an emergency slaughter.

CHAPTER 7

Economical evaluation of the different feed additives

7.1 Introduction

Feed additives are used by the feedlot industry to either stimulate growth, improve efficiency of feed utilization or because they may in some manner be beneficial to the health or metabolism of the animal. These additives however increase the cost of the feed. An economical evaluation on products like feed additives are difficult due to the many factors that play a role in determining if the products are economical.

Some of the factors include the price of the product, in this case the additive, the price of the basal feed and the day to day variation in the feed cost, the price at which the cattle was bought, the price at which the meat is sold and the treatment costs of sick animals, only to name a few. It is thus a combination of the above mentioned factors that determines whether a product is or is not economical.

In this chapter the three different additives in terms of how economical they are will be discussed. Only data from the commercial pen trial will be discussed here as it better reflects what happens in the commercial environment.

7.2 Cost of the basal diet

The ration cost varied from time to time. The cost variation was kept to a minimum by the inclusion of hominy chop. Thus when a variation in cost is observed, it is due to the change in price of the hominy chop. All the other raw material costs were constant due to long term contracts that kept the raw material prices the same. The price of the vitamin and mineral pre-packs and the Zilmax were constant as contracts for these materials are signed from year to year which keeps the price the same for the year.

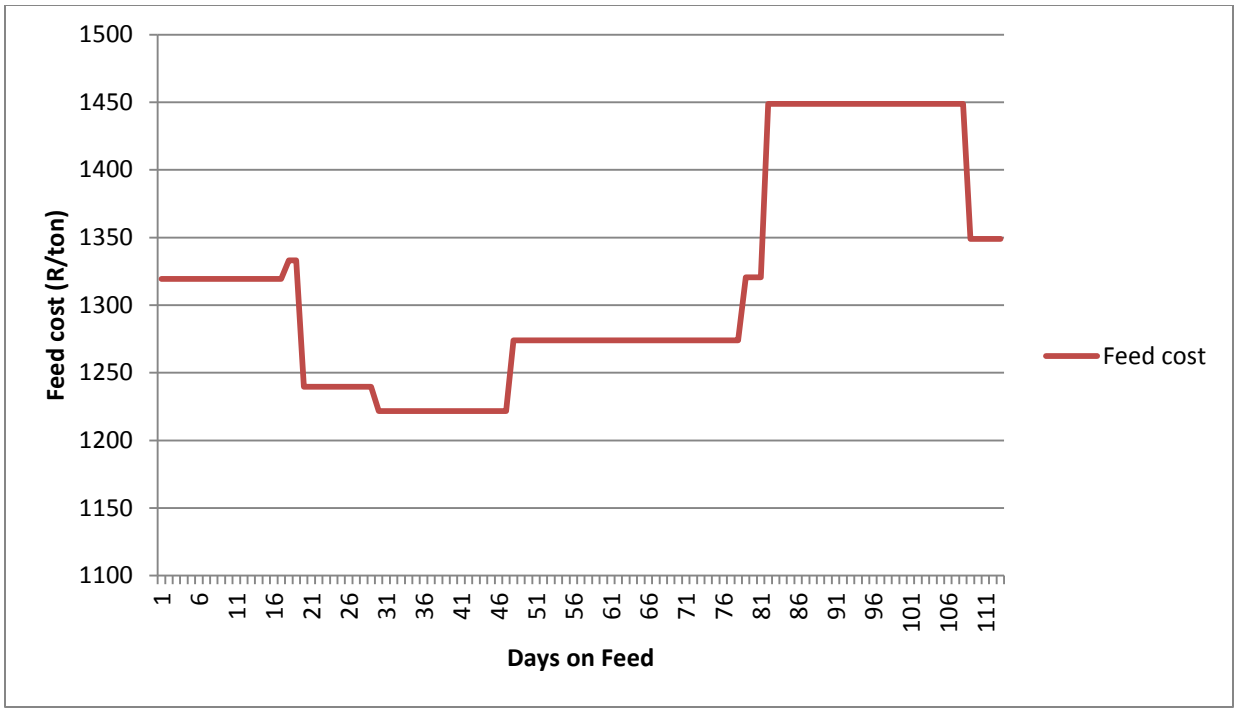


Figure 7.1 Cost of the feed over the entire feeding period expressed in Rand per ton.

As can be seen from the above figure, the cost of the feed varied from time to time. This is due to the cost of the Hominy chop that varied, with all the other raw material being constant. The starter diet varied between R 1,319.35 per ton, for 17 days and R 1,333.01 per ton for 2 days. The intermediate diet was constant at R 1,239.60 per ton for the 10 days. The finisher diet for the first 18 days of the finisher period was R 1,221.69 per ton, for the next 31 days R 1,273.92 and for the last 3 days R 1,320.46 per ton. The final finisher diet was R 1,448.72 per ton for the first 27 days and R 1,348.86 for the last 2 days followed by a withdrawal period of 3 days at R 1,348.68 per ton.

Table 7.1 Total cost of basal diet as determined by the price of hominy chop

Ration	Days on ration	Cost of ration
Starter	17	1319.35
Starter	2	1333.01
Intermediate	10	1239.6
Finisher	18	1221.69
Finisher	31	1273.92
Finisher	3	1320.46
Final finisher	27	1448.72
Finisher	5	1348.86

Table 7.2.1 Cost of the basal diet for the control group without the cost of the additive monensin

Ration	Days on ration	Cost of ration (R/ton)	Total amount fed (ton)	Cost (R)
Starter	17	1319.35	36.175	R 47,727.49
Starter	2	1333.01	4.970	R 6,625.06
Intermediate	10	1239.6	33.030	R 40,943.99
Finisher	18	1221.69	57.890	R 70,723.63
Finisher	31	1273.92	107.261	R 136,641.93
Finisher	3	1320.46	10.415	R 13,752.59
Final Finisher	27	1448.72	87.575	R 126,871.65
Finisher	5	1348.86	13.265	R 17,892.63
			Total	**R 461,178.97**

Table 7.2.2 Cost of the basal diet for the XTract group without the cost of the additive

Ration	Days on ration	Cost of ration (R/ton)	Total amount fed (ton)	Cost (R)
Starter	17	1319.35	48.850	R 64,450.25
Starter	2	1333.01	7.170	R 9,557.68
Intermediate	10	1239.6	40.850	R 50,637.66
Finisher	18	1221.69	76.045	R 92,903.42
Finisher	31	1273.92	127.945	R 162,991.69
Finisher	3	1320.46	12.625	R 16,670.81
Final Finisher	27	1448.72	104.690	R 151,666.50
Finisher	5	1348.86	18.610	R 25,102.29
			Total	**R 573,980.30**

Table 7.2.3 Cost of the basal diet for the Acid Buf group without the cost of the additive

Ration	Days on ration	Cost of ration (R/ton)	Total amount fed (ton)	Cost (R)
Starter	17	1319.35	39.480	R 52,087.94
Starter	2	1333.01	5.995	R 7,991.40
Intermediate	10	1239.60	35.235	R 43,677.31
Finisher	18	1221.69	61.845	R 75,555.42
Finisher	31	1273.92	108.470	R 138,182.10
Finisher	3	1320.46	11.195	R 14,782.55
Final Finisher	27	1448.72	89.500	R 126,660.44
Finisher	5	1348.86	17.010	R 22,944.11
			Total	**R 481,881.27**

7.3 Determining inclusion levels

Historical feeding data was used to try and predict the amounts of each ration that was fed to the cattle. Historical data for the months that the trials would take place were used and a three year average was taken as can be seen from Table 7.3.

Table 7.3 The actual feed intake ("As is" basis ± 82% DM) history for the four different rations for a three year period (kg/h/d)

Diet Period				Average Intake of diet (kg/h/d)			
Start	**Intermediate**	**Finisher**	**Final finisher**	**Starter**	**Intermediate**	**Finisher**	**Final finisher**
March 2008	March 2008	April and May 2008	June 2008	6.1	10.0	10.4	10.2
March 2009	March 2009	April and May 2009	June 2009	6.4	9.8	10.2	10.5
March 2010	March 2010	April and May 2010	June 2010	6.3	10.3	10.4	10.6

From this actual feed intake history on an "As is" basis, the amounts of XTract and monensin sodium that needed to be included into the vitamin and mineral pre-packs were calculated. As the pre-pack formulation and make up is confidential, only the final XTract and monensin sodium intakes will be discussed.

7.4 Cost of the additives

7.4.1 Cost and inclusion of Rumensin

As the trial was conducted at a commercial feedlot, the cost of the monensin cannot be compared to the cost of the XTract. The percentage discount is too high; therefore the cost before discount will be used in the evaluation.

The cost of monensin at the time of the trial was R 119/kg. According to the inclusion levels the amounts per feeding period and also the price per head per day was calculated. Table 7.4.1 presents the amount of monensin sodium per kilogram ration and also the cost of the additive per kilogram ration fed. Rumensin 20 was used, which contained 20% of the active

ingredient monensin sodium. Table 7.4.2 presents the amounts of monensin sodium within the different rations.

Table 7.4.1 Monensin inclusion and cost over the different feeding periods

	Rumensin	
Period	**g/kg Ration**	**R/kg Ration**
Starter diet	0.103	0.012257
Intermediate diet	0.132	0.015708
Finisher diet	0.164	0.019516
Final finisher diet	0.164	0.019516

When the total amount of feed was calculated and averaged over the number of animals, a total of 0.1798412 kg Rumensin per animal over the entire feeding period was found. Taking the cost into consideration, it equates to a total of R 21.40 over the feeding period.

Table 7.4.2 Monensin sodium in the different diets

Period	Rumensin 20 (g/kg)	Monensin Sodium (g/kg)
Starter diet	0.103	0.0206
Intermediate diet	0.132	0.0264
Finisher diet	0.164	0.0328
Final finisher diet	0.164	0.0328

7.4.2 Cost and inclusion of XTract

The cost of XTract at the time of the trial was R 250/kg. According to the inclusion levels, the amounts per feeding period and the price per head per day was calculated. In Table 7.5 is shown the amount of XTract per kilogram ration and also the cost of the additive per kilogram ration fed.

Table 7.5 XTract inclusion and cost over the different feeding periods

	XTract	
Period	**g/kg Ration**	**R/kg Ration**
Starter diet	0.158730	0.039683
Intermediate diet	0.100000	0.025
Finisher diet	0.116505	0.029126
Final finisher diet	0.115385	0.028846

When the total amount of feed was calculated and averaged over the number of animals, a total of 0.1581432 kg XTract per animal over the entire feeding period was supplemented. Taking the cost into consideration, it equates to a total of R 39.54 over the feeding period.

7.4.3 Cost and inclusion of Acid Buf

The cost of Acid Buf at the time of the trial was R 6.09/kg. According to the inclusion levels, the amounts per feeding period and the cost per head per day were calculated. In Table 7.6 is shown the amount of Acid Buf per kilogram ration and also the cost of the additive per kilogram ration fed.

Table 7.6 Acid Buf inclusion and cost over the different feeding periods

	Acid Buf	
Period	**g/kg Ration**	**R/kg Ration**
Starter diet	6	0.03654
Intermediate diet	6	0.03654
Finisher diet	6	0.03654
Final finisher diet	6	0.03654

When the total amount of feed was calculated and averaged over the number of animals, a total of 7.60 kg Acid Buf per animal over the entire feeding period was supplemented. Taking the cost into consideration, it equates to a total of R 46.29 over the feeding period.

7.4.4 Total Cost of the Additives

As mentioned above, the cost of monensin was R 21.40 per head over the feeding period, for XTract R 39.54 per head over the period and for Acid Buf R 46.29 per head over the feeding period. To calculate the total cost of each additive the number of animals slaughtered per trial was multiplied by the costs mentioned above. Table 7.7 presents the total feed additive costs of each treatment.

Table 7.7 Total cost of each additive

Additive	n	Cost per animal	Total cost
Rumensin	249	R 21.40	R5,328.60
XTract	283	R 39.54	R 11,189.82
Acid Buf	231	R 46.29	R 10,692.99

7.5 Total amount of meat produced

To calculate the total amount of meat produced per treatment, the processing weight of all the animals slaughtered was subtracted from the EW. At the time when the animals were slaughtered the meat price was R 26/kg carcass.

7.5.1 Amount of meat produced for the per treatment

In Table 7.8, is shown the total weight of the processed animals per treatment and the total weight of the carcasses per treatment. The animals used per treatment were those that fitted the weight profile and that were slaughtered on the dates set aside for the different treatments.

Table 7.8 Total processing and carcass weight per treatment of all animals (kg) for the three different treatments

	Treatment		
	Control	**XTract**	**Acid Buf**
N	249	283	231
Processing weight (kg)	56,363	63,881	51,425
End weight (kg)	104,020	120,862	98,449
Weight gain (kg)	47,657	56,981	47,024
Cold Carcass Mass (kg)	60695	69769	57047

7.5.2 Value of the carcass

To calculate the value of each carcass the price paid per weaner (R/kg) was calculated and then subtracted from the EW, which was the weight of the carcass that was sold at R 26/kg. During the period when the trial began the price paid per weaner was R 17.78/kg. In Table 7.9 is presented the total Rand values for the weaners paid and the total value of the carcasses per treatment.

Table 7.9 The totals paid per treatment and total value of carcasses for the three different treatment

	Treatment		
	Control	**XTract**	**Acid Buf**
Process weight x R 17.78/kg	R 1,002,134.14	R 1,135,804.18	R 914,336.50
Cold Carcass Mass x R 26.00	R 1,578,070.00	R 1,813,994.00	R 1,483,222.00
Value of carcasses	R 575,935.86	R 678,189.82	R 568,885.50

From the above table the total amount of feed per treatment and the value of the additives need to be subtracted. The control treatment was taken as the bench mark, thus a value above the

value of the control treatment was taken as a profit and a value below the control treatment as a loss.

7.6 Profit or loss calculation

To determine if any profits or losses were incurred, all the above mentioned tables need to be combined. Once combined, grand totals for each treatment will be found; this grand total needs to be divided by the number of animals per treatment slaughtered to then calculate a profit/loss. Table 7.10 presents all the costs incurred and the value of the carcasses sold divided by the number of animals slaughtered.

Table 7.10 Economic evaluation of the effect of supplementing different feed additives to feedlot animals

Total costs incurred	Control	XTract	Acid Buf
Basal diet	R 461,178.97	R 573,980.30	R 481,881.27
Additive cost	R5,328.60	R 11,189.82	R 10,692.99
Animal purchases	R 1,002,134.14	R 1,135,804.18	R 914,336.50
Total cost	R 1,468,641.71	R 1,720,974.30	R 1,406,910.76
Carcass value	R 1,578,070.00	R 1,813,994.00	R 1,483,222.00
Carcass value minus total cost	R 109,428.29	R 93,017.70	R 76,311.24
Number of animals	249	283	231
	R 439.47	R 328.69	R 330.35
Control minus other treatments	**R 0.00**	**- R 110.78**	**- R 109.12**

From the economic evaluation in Table 7.10 it can be concluded that the XTract and Acid Buf treatment groups were R 110.78 and R 109.12 less profitable respectively compared to the control treatment group. The cost: benefit ratio, however, was still favourable for XTract and Acid Buf, regardless of the fact that the profit was less when compared to the monensin supplemented animals.

For the control treatment the benefit was R 439.47 and the cost was R 21.40, realising a benefit to cost of 20.54: 1. For the XTract treatment the benefit was R 328.69 and the cost was R 39.45, realising a benefit to cost 8.31:1. For the Acid Buf treatment the benefit was R 330.35 and the cost was R 46.29, realising a benefit to cost of 7.14:1.

Although debatable, a guideline is that an additive should return R 2.00 or more for every R 1.00 invested in order to cover for non-responsive animals or commercial field conditions that could minimise the expected response. All three additives exceeded the ratio of 2:1.

According to Hutjens (2008) monensin has a benefit to cost of 6 – 10:1, essential oils 7:1 and buffers 4:1. The benefit to cost worked out for XTract is close to what is reported by Hutjens. One of the reasons for the difference in the benefit to cost for monensin and the buffer could be the price at which it was purchased.

What is not included in the calculation is the cost of treatment of sick animals pulled during the trial. The medicine cost is not a fixed amount per head treated as the treatment is weight dependant. The cost to benefit ratios calculated above, therefore, should be lowered if treatment costs are included.

CHAPTER 8

Conclusions and Recommendations

Results from this study have shown that both essential oils (XTract) and calcified marine algae (Acid Buf) may prove to be suitable natural alternatives to replace ionophore antibiotics in feedlot diets. In the commercial pens XTract supplementation increased DMI, especially during the first 5 weeks, as well as increasing ADG and EW achieved ($P < 0.05$) when compared to monensin supplementation. Acid Buf affected feedlot performance to the same extent as monensin, with only minor differences in some parameters.

The improved health status, especially the 48% lower incidence of rumen damage in XTract supplemented cattle ($P < 0.01$) probably contributed to the better performance observed. These relatively small differences did not impact on feedlot performance.

Results from this large scale study should provide South African feedlotters with sufficient information to make an informed decision on natural alternatives when the day comes that ionophores are placed on the banned list of ruminant feed additives. Further research, however, is needed on determining the optimal dose, dietary dependant responses, adaptation of rumen microbial populations to essential oils and the potential to inhibit food borne pathogens in the lower intestinal tract. Furthermore, the benefit: cost ratio should be determined under the prevailing conditions in different countries.

CHAPTER 9

Critical Evaluation

Conducting trials at commercial feedlots is difficult and a lot of planning is needed. Having good knowledge of how the particular feedlot operates on a daily basis will be an advantage to the researcher. This will help during the planning and protocol phase of the trial and also when it would be best to collect data such as weighing of animals, when feed refusal weigh backs should be done, when feed samples should be taken and so on.

Having prior knowledge of how feed bunk assignments are done will also help if feeding trial needs to be conducted. Knowing how the feeding schedule works can help one to make decisions on how much to feed each pen per day.

The trials were conducted at two different sections in the feedlot. This meant that two different managers and two different hospital teams managed the cattle. Performing the trial at one section would have been better as the same people would have managed and cared for the animals and this would have made the data capturing easier.

The rumen and lung scoring is also difficult to interpret, as there is no benchmark with which to compare the data.

By feeding the small pens with bags, made up to 10 kg, would have helped in reducing the variation in feed intake. It would also be more accurate than the mixer wagons used.

Having experience in animal health would also be to an advantage. To know what signs to look for when pulling sick animals would help in making a decision on how to treat the animals in the best possible way.

To help with the economical evaluation, it would be wise to feed the animals the same treatment diets in the hospital pens. This would also assist in determining if the additives had an effect on health after treatment. This could be done by determining the number of repulls per treatment after the animals were treated and discharged from the hospital program.

It would also be beneficial to keep the animals from the different treatments separate after hospitalisation as this would help to determine the cost of sick animals per treatment better.

The trial was conducted during autumn and the beginning of winter. It would be interesting to see what effect different seasons would have on the response to supplementation.

Furthermore, weight groups with shorter and longer standing periods and the inclusion of heifers in the trial should be considered.

For different diets it could help to have some of the animals cannulated. This can help by taking samples from the rumen to be analysed for VFA's, pH and microbial population analysis. It could also help if cameras were setup to monitor feed intake patterns. By monitoring the feed intake pattern in terms of time spent at the feed bunk an intake graph can be drawn and may help to explain the severity of rumen damage, growth and it may also help to identify sick animals.

During this trial only one level of Acid Buf was evaluated and only two different levels of the XTract. More information is needed on different supplementation for the four different diets fed during the production trial in order to establish the optimum supplementation strategy.

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