LIVER ABSCESSES AND PERFORMANCE IN FEEDLOT CATTLE AS INFLUENCED BY DIETARY ROUGHAGE LEVEL AND TYLOSIN INCLUSION

BY

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SUMMARY

The focal interest of this study was the problem of liver abscesses that occurs in intensively fed beef cattle. The literature on metabolic disorders and diseases associated with feeding high concentrate diets to beef cattle was reviewed, with special emphasis on liver abscesses (Chapter 1). The antibiotic tylosin is generally included as a feed additive to curb liver abscesses, but has recently been banned as a feed additive in Europe. Whilst tylosin use is still permitted in South Africa, a long-term alternative to its use as a liver abscess control agent is needed. Previous research has shown a linear decline in liver abscesses as the roughage portion of high-concentrate finishing diets increases at the expense of concentrates. Unfortunately, animal performance and profits decline with such an increase in roughage inclusion, apparently due to the lower nutritive value of roughages relative to concentrates. However, if the nutritive value of roughages can be improved sufficiently, for instance by chemical treatment methods such as urea ammoniation, the detrimental effects of concentrate replacement may be at least partially alleviated. This will allow beef cattle finishing operations to use higher dietary roughage levels to reduce the incidence of liver abscesses, without severely compromising animal performance and economic returns.

Hence, this study was undertaken to examine: (i) the incidence of liver abscesses in feedlot cattle originating from three feedlots in Kwazulu-Natal province, South Africa (Chapter 2); (ii) the effect of dietary roughage level (20% or 40%), with or without tylosin (10 mg/kg feed) inclusion, on biological and economic performance of feedlot cattle, and the incidence of liver abscesses (Chapter 3); and (iii) the effect of dietary roughage level, with or without tylosin inclusion, on *in situ* degradation characteristics of dry matter (DM) and crude protein (CP) in dietary concentrates and roughage (either urea ammoniated or untreated), when incubated in the rumen (Chapter 4; dietary roughage levels and tylosin level as for Chapter 3). In the last chapter (Chapter 5), a general discussion of the outcomes of this study is presented.

The results of the survey show that the incidence and severity of liver abscesses in the feedlot beef cattle was high (25.4%), and there was a difference among the feedlots studied concerning the incidence of liver abscesses. The results of the feedlot experiment show that tylosin inclusion did not affect the performance and carcass characteristics of the steers.

Roughage level had an adverse effect (P<0.01) on growth rate and feed conversion ratio. However, average dry matter intake and carcass characteristics were not affected by roughage level. Roughage level and tylosin inclusion did not affect the cost of concentrate feed consumed, carcass income and margin over total feed cost, but cost of roughage consumed differed between roughage level and tylosin treatments (P<0.01).

In the degradability trial, inclusion of tylosin in the diet did not affect the DM and CP degradation of the untreated and treated veld hay in the rumen. In the concentrates incubated, tylosin affected the potential degradability (PD) of the DM and CP, and the rate of degradation (C) of CP. Roughage level only had a significant effect (P=0.05) on the effective degradability (ED) of CP of the incubated roughage. The CP content of the roughage (veld hay) was increased from 4.01 to 14.11 in the feedlot trial and to 13.10% in the degradability trial due to urea ammoniation. Urea ammoniation also resulted in a decrease of neutral detergent fibre and hemicellulose content of the roughage. However, the acid detergent fibre and lignin content increased due to urea treatment. The DM and CP degradability of veld hay was improved due to urea treatment.

In conclusion tylosin had no effect on performance of the steers and degradability of incubated veld hay. Urea treatment of veld hay increased CP content, decreased NDF and hemicellulose contents, and improved the degradability of DM and CP of veld hay in the rumen. Comparable results were found on performance and economical evaluation of beef steers by using either 20 or 40% of treated veld hay in feedlot finishing diets. The diets with 20% and 40% hay also responded similarly to the degradability of incubated hay. Therefore, the diet with 40% treated hay and 60% concentrate mixture (without tylosin) can be used as a strategic alternative to tylosin for combating liver abscesses in finishing cattle, without statistically significant loss in revenue.

Further research is necessary to study the most optimal level of treated hay in terms of performance of animals, incidence of liver abscesses and economical value. Further survey work on the incidence of liver abscesses in feedlot cattle, representative of South Africa (and not only KwaZulu-Natal) is also required.

DECLARATION

The experimental work described in this thesis was carried out in the Department of Animal and Poultry Science, University of Natal, Pietermaritzburg, from January 2002 to September 2002, under the supervision of Dr. Nsahlai Ignatius Verla.

These studies represent the original work by the author and have not otherwise been submitted in any form for any degree or diploma to any university. Where use has been made of the work of others it is duly acknowledged in the text.

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Signed.............................. Date 10/02/2003

I Dr. Nsahlai, I.V., Chairperson of the Supervisory committee, approve release of this thesis for examination.

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CHAPTER ONE
GENERAL INTRODUCTION AND LITERATURE REVIEW

1.1 GENERAL INTRODUCTION

Roughages and concentrates contain carbohydrates that supply cattle with the energy needed for maintenance, growth, or production. The amount and quality of feed consumed and the digestion and conversion of carbohydrates to precursors of meat and milk synthesis largely determine feed efficiency. The difference between roughages and concentrates is arbitrary, but roughages usually include hay and straw, while concentrates include grains, oil seeds, and their by-products, as well as other by-products of the meat and fish industries (Lombard & Retief, 1969).

The use of high concentrate diets in feedlot enterprises has been shown to increase animal productivity and proved to be more economical than roughage-based diets. Roughage is low in nutritive value and it takes months for cattle to reach market weight. However, when cattle are offered starchy, low-fiber, grain-based diets, or when the animals are switched from high fiber grazing diets, this disrupts the buffering capacity of the rumen and increases acidity in the rumen. This leads to various digestive disorders such as acidosis, liver abscesses and bloat (Cheng & Hironaka, 1973; Clarke & Reid, 1974).

While the general evidence indicates that high cereal diets are the main predisposing causes for the digestive problems experienced in feedlot cattle, prevention by reducing the energy content of the diet makes no economic sense. The use of high roughage diets instead of high concentrate diets result in a serious reduction in rate of gain and feed conversion, and increased labour and other management costs. Therefore, feedlot producers counteract these problems by using feed additives such as ionophores, antibiotics and buffers.

Roughage has a great potential, as a feedstuff for ruminants. However, the digestibility and crude protein content of these materials are generally low. If roughages are to be used to meet the energy requirement of growing and lactating ruminants, their feeding value must be increased. Apart from agronomic and management strategies that minimize losses in nutritive value, such as early harvest, plant breeding and supplementation, the classical approach has been to treat roughages physically or chemically to increase digestibility and intake (Jackson, 1977). The chemicals used to improve the nutritive value of low quality roughage include sodium hydroxide, ammonia and urea (Horton, 1978; Klopfenstein, 1978; Hadjipanayiotou, 1982). The use of ammonia and urea has the additional advantage of increasing nitrogen content, which is especially important in areas where protein supplements are expensive. In addition urea is safe and relatively easy to handle, as compared to ammonia and sodium hydroxide (Cloete *et al.,* 1983).

OBJECTIVES OF THE STUDY

The main objectives of the study were to investigate the:

i. Incidence and severity of liver abscesses in feedlot beef cattle slaughtered at Cato Ridge abattoir;

ii. Effect of level of ammoniated roughage and tylosin phosphate on animal performance, the incidence of liver abscesses in feedlot cattle and degradation characteristics of experimental concentrates of the diets; urea ammoniated hay and untreated hay.

1.2 NUTRITIONAL DISORDERS ASSOCIATED WITH FEEDING HIGH CONCENTRATE DIETS: A REVIEW

1.2.1 INTRODUCTION

In feedlot cattle enterprises, the main objective is to attain maximum energy intake in order to achieve optimum production and growth performance. To achieve the objective, cattle feedlot enterprises incorporate high levels of grain during diet formulation. However, optimum level of utilization of concentrates remains a major challenge to the feedlot industry. It has been shown that by increasing the concentrate levels in the diet, feedlot cattle achieved high growth performance and carcass yields (White & Reynolds, 1969; Price *et al.,* 1978). The degree of improvement as a result of grain feeding varies as a function of quantity offered.

Preston & Willis (1974) observed improved live weight gain when 80-85% of the roughage diet was replaced with concentrates; which they attributed to an improvement in feed efficiency. However, studies of Jensen *et al.* (1954b) and Huntington (1988) have associated high levels of concentrate diets in cattle enterprise with many metabolic disorders, such as bloat, acidosis, rumenitis, parakeratosis and liver abscesses; all of which can lead to reduced cattle performance and death in extreme cases (Kreikemeier *et al.,* 1990; Loerch, 1991).

1.2.2 BLOAT

There are two kinds of bloat, pasture bloat and feedlot bloat. Pasture bloat is associated with grazing of legumes or lush grass (Clarke & Reid, 1974; Preston & Willis, 1974) and feedlot bloat occurs in cattle fed diets that contain more than 50% grain and it is observed most often when cattle are being shifted from low-grain to high grain diets (Cheng & Hironaka, 1973; Ramsey *et al.*, 1997) without proper adaptation. Grain bloat is similar to legume bloat in that both types produce excessive foaming of ruminal digesta. In legume bloat, although ruminal microorganisms contribute to foaming, the primary foaming agents are derived from plants. In grain bloat the major source of foaming agent is bacterial slime that traps fermentation gas thus forming foam (Bartley *et al.*, 1975).

1.2.2.1 Causes

Bloat is a ruminal dysfunction that results from accumulation of excessive gas (CO_2 and CH_4) in the rumen (Cheng *et al.*, 1998). Normally, the majority of rumen gases resulting from fermentation is eliminated via eructation (Cheng *et al.*, 1998). Bloat occurs when ruminants are unable to remove excess gas via eructation (belching). The eructation sequence is initiated by the presence of free gas in the dorsal sac of the rumen. Thus, if ruminal conditions prevent normal contractions from occurring in the reticulo-rumen or if a movement of free gas through the cardia or esophagus is obstructed, bloat occurs (Clarke & Reid, 1974). If the gas present in the rumen is in the form of small bubbles that became mixed within the feed, a frothy mixture of gas and feed will result. The animal is not able to get rid of the excess gas because gas does not separate from the feed. As gas accumulates, the expanding rumen exerts pressure on the diaphragm and lungs, impairs respiration, and ultimately leads to death (Bartley *et al.*, 1975).

The incidence of feedlot bloat is higher in Holstein cattle than beef cattle; perhaps this is attributable to the greater feed intake or increased time to finish of Holsteins (Vogel & Parrot, 1994, cited by Cheng *et al.*, 1998). Death is the most visible economic loss associated with feedlot bloat, but the financial losses incurred with culling and treatment of bloat-prone animals and lost production in surviving cattle likely are even costlier (Clarke & Reid, 1974).

1.2.2.2 Symptoms

Bloat is characterized by an accumulation of gases (primarily CO_2) within the reticulo-rumen. Swelling occurs first and most prominently at the left flank above the rumen, then later on the right side of the animal (Essig, 1988). Other symptoms of bloat include kicking of the abdomen, staggering gait, vomiting, frequent urination and defecation, labored breathing with nostrils dilated, extended tongue and eventually collapse, followed by death (Bartley *et al.*, 1975; Essig, 1988) in extreme situations.

1.2.2.3 Prevention

Bloat can be treated by compounds such as polaxalene or antifoaming agents such as vegetable oil, mineral oil, paraffin, lard or turpentine (Essig, 1988). However, it is far more profitable to use management strategies to reduce its incidence. Quantity of roughage in the ration, grain processing techniques, type of cereal grains, use of feed additives (e.g. ionophores; Bartley *et al.,* 1983; Nagaraja & Wolfrom, 1993), and feeding management practices (Cheng *et al.,* 1998) have been found to prevent or reduce the incidence of bloat in feedlot cattle enterprises.

1.2.3 ACIDOSIS

Acidosis refers to the syndrome in ruminants, which is brought about by excessive ingestion of feeds, rich in readily available carbohydrates, such as starch and sugar. There are two main types of acidosis, namely acute and sub-acute acidosis with the latter being more difficult to diagnose than the former (Slyter, 1976; Huntington, 1988). Acute acidosis was found to be life threatening due to impairment of absorption associated with the disorder (Huntington & Britton, 1979). The major response of animals suffering from sub-acute acidosis is reduced feed intake with an accompanying reduction in performance (Slyter, 1976; Fulton *et al.,* 1979; Huntington, 1988; Stock & Britton, 1996). Acidosis has also been implicated in low milk fat syndrome in dairy cattle (Stock & Britton, 1996).

Acidosis commonly leads to a half dozen other conditions and causes significant economic losses to producers through deaths, wasted feed, delayed marketing, and costs of treatments, and to packers through condemnations of rumens and livers (Jensen & Mackey, 1965). Several acidosis-related problems (Stock & Britton, 1996) occurring in the feedlot are: sudden death syndrome, polioencephalomalacia -"brainers" (polio), founder, rumenitis, liver abscesses, malabsorption, clostridial infections and off-feed or reduced feed intakes.

1.2.3.1 Causes

Acidosis results from excessive ingestion of concentrate diets that are readily fermentable in the rumen (Elam, 1976; Slyter, 1976; Stock & Britton, 1996; Owens *et al.*, 1998). It is a common occurrence when ruminants accidentally gain access to a barn where cereals are stored or when ruminants previously on roughage diets are suddenly introduced to a large quantity of concentrates as a sole or supplementary diet (Elam, 1976; Owens *et al.*, 1998). Acidosis results in a sharp increase and large production of volatile fatty acids (VFAs) especially lactic acid (Uhart & Carroll, 1967; Brake & Hutcheson, 1996).

In typical feedlot diets, grain is the single most important factor affecting acidosis. While high-grain diets are generally predisposing to acidosis, some grains are worse than others. Wheat is generally considered the worst grain as far as development of acidosis is concerned. Milo, sorghum, and corn diets are also highly conducive to the occurrence of acidosis, while barley is observed to be the least predisposing to acidosis (Elam, 1976). This difference may be attributed to the fact that rate and extent of fermentation of wheat are greater than those of barley, sorghum, or corn (McAllister *et al.,* 1990). Furthermore, between 80 and 90% of the starch in wheat and barley is digested within the rumen; this value ranges from 55 to 70% for sorghum and corn (Nocek & Tamminga, 1991).

Processing of grain increases the rate and extent of ruminal starch digestion and reduces the amount of starch available for digestion in the small intestine. Typically grains are ground, cracked, flaked, or steam-rolled to disrupt the pericarp and provide microorganisms access to the nutrient-rich components of the endosperm (Cheng *et al.,* 1998). These processing methods increase starch availability and the propensity for acidosis (Owens *et al.,* 1998).

The pathogenesis of acidosis involves a series of biochemical changes in the rumen and blood. Cattle accustomed to eating grass, hay, or other cellulosic feeds possess a ruminal microflora of cellulolytic gram-negative bacteria. Following engorgement on starch-rich feed, amylolytic gram-positive *Streptococcus bovis* and *Lactobacilli* rapidly multiply and replace the gram-negative bacilli (Jensen & Mackey, 1965; Mann, 1970). The amylolytic gram-positive *Streptococcus bovis* and *Lactobacilli* rapidly flourish in cattle consuming high grain diets, and lactic acid becomes a principal fermentation end product. These microbial species use excessive amounts of readily fermentable carbohydrates to over-produce lactic acid and VFAs. The combination of lactic acid and VFAs reduces ruminal pH and the rapid production of lactic acid quickly overcomes the buffering capacity in the rumen (Brake & Hutcheson, 1996). The fall in ruminal pH is generally accompanied by a decrease in protozoal concentration; an increase in the percentage of *Entodinium* species and in some instances a complete disappearance of the protozoa (Latham *et al.*, 1971; Lyle *et al.*, 1981). The excessive production and accumulation of L (+) and D (-) lactic acid lead to ruminal acidosis, which consequently destroys the normal microbial population of the rumen and produces potentially toxic metabolites (Nagaraja, 1995).

Stock & Britton (1996) attributed the loss of appetite associated with acidosis to the inhibiting tendency of lactate on intake. The highly acidic condition in the rumen also results in corrosion and damage of the rumen wall (rumenitis) (Brake & Hutcheson, 1996). Rumenitis can be aggravated by the presence of foreign objects in the feed or feeding very coarse feed (Jensen *et al.*, 1954b). The highly acidic rumen digesta during acidosis has been reported to be responsible for parakeratosis i.e. peeling of rumen papillae; resulting in microbial invasion of the rumen wall (especially by *Fusobacterium necrophorum*), impaired nutrient absorption and high incidence of liver abscesses (Cheeke, 1991).

1.2.3.2 Symptoms

Symptoms of acidosis include: loss of appetite (Slyter, 1976; Fulton *et al.*, 1979; Huntington, 1988; Stock & Britton, 1996), diarrhoea, dehydration, hemoconcentration, poor coordination and death in extreme cases (Elam, 1976; Huber, 1976). Physiological symptoms comprise: low rumen, blood and urine pH (Jensen & Mackey, 1965; Uhart & Carroll, 1967; Stock & Britton, 1996); high rumen osmolality, reduced rumen gram negative bacteria and protozoa count (Jensen & Mackey, 1965); increased rumen gram positive bacteria count (Elam, 1976);

damage to the rumen wall (rumenitis) and liver abscesses (Jensen & Mackey, 1965). Clinical diagnosis of acidosis depends on measurements of ruminal or blood acidity; with ruminal pH of 5.6 and 5.2 often being used as respective benchmarks for chronic and acute acidosis respectively (Cooper & Klopfenstein, 1996, cited by Owens *et al.*, 1998). The low ruminal pH is the result of the production of large quantities of volatile fatty acids as well as other acids (such as lactic) and the weaker buffering power of concentrates compared with that of forages in pH range of 6.0 to 4.0 in the rumen (Slyter, 1976).

1.2.3.3 Prevention

In feedlot cattle, acidosis problems are usually encountered under the following circumstance: when cattle are starting on feed, when they are graduating to higher concentrate rations, during changes in weather, during long periods on finishing diet and when cattle are extremely hungry due to feeding problems or errors (Elam, 1976). Hence, the control measures of acidosis centre on management techniques, including gradual adaptation of cattle to diets high in rapidly fermented carbohydrates, close monitoring of daily feed intake of rations high in readily-fermentable carbohydrates (RFC) and of animals' condition, provision of fresh feed and water daily and the use of ionophore feed additives like monensin and lasalocid (Huntington, 1988; Owens *et al.*, 1998).

Brent (1976) suggested that rapid changes in the levels of concentrate fed to cattle early in the feeding cycle might result in a rumenitis that can predispose cattle to liver abscesses, laminitis, and other problems throughout the feeding period. Ionophores, such as monensin and lasalocid, inhibit lactate producing ruminal bacteria and can help ameliorate the adverse effects of ruminal acidosis during adaptation of feedlot cattle to high-grains diets (Dennis *et al.,* 1981a, b; Nagaraja *et al.,* 1981, 1982, 1986).

Including monensin in the diet has reduced the incidence of death due to digestive disorders in feedlot cattle (Parrott, 1993 and Vogel, 1996, both cited by Owens *et al.*, 1998). This reduction is due to inhibition of certain lactate-producing bacteria, maintaining favourable ruminal pH and reduced daily variation in feed intake (Burrin & Britton, 1986; Burrin *et al.*, 1988).

1.2.4 LIVER ABSCESSES

Most feedlots use high concentrate levels in finishing diets to achieve higher growth performance. However, the main constraint with the use of high levels of concentrate in diets, especially in beef cattle enterprise, is the high incidence of condemned livers resulting from liver abscesses (Jensen *et al.*, 1954a). Many studies (Harvey *et al.*, 1968; Foster & Wood, 1970; Brent, 1976; Gill *et al.*, 1979; Zinn & Plascencia, 1996) have shown that the incidence and severity of liver abscesses increase as diet roughage level decreases. However, replacing dietary concentrate with high levels (> 20%) of roughage depresses growth rate, which Bartle *et al.* (1994) and Zinn *et al.* (1994) ascribed to a reduction in digestibility of the diet.

Liver abscesses are pus-filled capsules varying in thickness and size and could range from less than one cm to over 15 cm in diameter (Figure 1.1). Small, medium and large abscesses seldom exhibit any clinical signs (Nagaraja & Chengappa, 1998) and can only be physically confirmed during dressing.

1.2.4.1 Causes

Liver abscesses belong to a disease complex known as acidosis-rumenitis-liver abscess (Jensen *et al.*, 1954a). Liver abscesses are secondary to acidosis-rumenitis and have been reported to be associated with the consumption of high concentrate diets and also with an abrupt increase in the intake of a high-energy feed (Dinusson *et al.*, 1964; Haskins *et al.*, 1967). Rumenitis resulting from acidosis generally is accepted as the predisposing factor to the on-set of liver abscesses (Smith, 1944; Jensen *et al.*, 1954a, b; Tan *et al.*, 1996).

When cattle consume too much starch (primarily grain) within a short period of time or when cattle are suddenly changed from a high roughage diet to high concentrate diet without adequate adaptation, this results in a rapid production and absorption of acids from the rumen. Ruminal lactic acidosis damages the rumen wall. The ruminal wall can also be physically damaged by the penetration of foreign objects. The damaged ruminal wall becomes susceptible to invasion and colonization by *Fusobacterium necrophorum*, which probably originates from the ruminal contents. After colonization has occurred, *Fusobacterium necrophorum* either gains entry into the blood or cause ruminal wall abscesses, which subsequently shed bacterial emboli to the portal circulation. Bacteria from the portal circulation are filtered by the liver, leading to infection and abscess formation (Nagaraja & Chengappa, 1998, Figure 1.1)

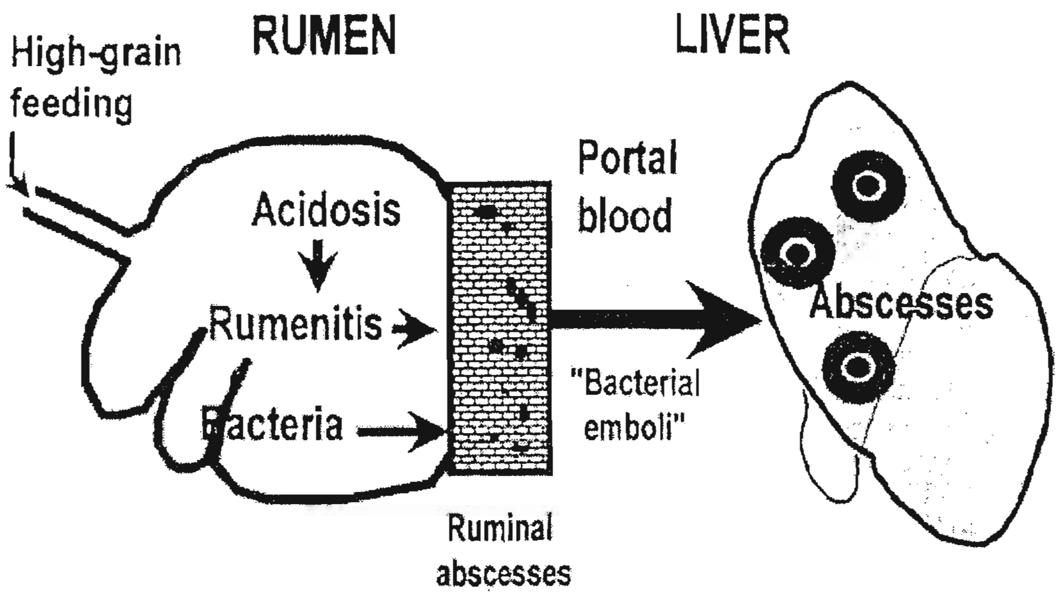

Figure 1.1 Pathogenesis of liver abscesses in cattle fed a high-grain diet (Nagaraja & Chengappa, 1998).

Previous studies (Scanlan & Hathcock, 1983; Nagaraja & Chengappa, 1998) on liver abscesses have shown that liver abscesses were due to *Fusobacterium necrophorum* alone or in association with other bacteria like *Actinomyces pyogenes*, previously named *Corynebacterium pyogenes*. Other pathogens isolated from liver abscesses include *Staphylococcus* and *Streptococcus* species (Lechtenberg *et al.*, 1988). The fact that the main energy substrate of *Fusobacterium necrophorum* is lactate (Lechtenberg *et al.*, 1988) probably explains a previous conclusion (Scanlan & Hathcock, 1983; Nagaraja & Chengappa, 1998) that the bacterium is responsible for liver abscesses. *Fusobacterium necrophorum* is a gram negative, non-motile, non-sporulating, rod-shaped (pleomorphic) bacterium (Langworth, 1977). Several toxins have been implicated as virulence factors in the pathogenesis of *Fusobacterium necrophorum* infections. Amongst these, leukotoxin and endotoxic lipopolysaccharides are believed to be the major virulence factors involved in *Fusobacterium necrophorum* infection (Tan *et al.*, 1996).

1.2.4.2 Incidence

Liver abscesses occur worldwide in all cattle types offered excessive concentrate diets (Dinusson *et al.*, 1964; Haskins *et al.*, 1967; Nagaraja & Chengappa, 1998) or very little roughage (Elam, 1976). However, it is highly pronounced in feedlot cattle and most common in the United States of America, Canada, Europe, Japan, and South Africa (Nagaraja *et al.*, 1996a).

In beef cattle, liver abscess formation occurs during the first third of the fattening period, during which beef cattle are still adapting to concentrate diets (Jensen & Mackey, 1965). Susceptibility to liver abscesses depends on levels of roughage replacing the concentrate component of the ration (Figure 1.2), duration of feeding, cattle types and breed. Holstein cattle were reported to be more susceptible than other cattle breeds; Hicks *et al.* (1994) attributed this to a long duration of exposure to high levels of concentrate feeding and to high dry matter intake (DMI) of Holsteins. The high DMI of steers relative to that of heifers was also used to explain the higher incidence of liver damage in steers when compared with heifers (Dehaan *et al.*, 1995, cited by Nagaraja & Chengappa, 1998). Besides, heifers are finished earlier than steers, thus the duration of exposure to concentrates is shorter for heifers relative to steers.

There is a wide variation in the incidence of liver abscesses in feedlot cattle which can range from as low as 1 or 2% to as high as 90 or 95% in specific groups of grain-fed cattle (Nagaraja *et al.*, 1996b). Generally the incidence of liver abscesses averages from 12 to 32% in most feedlots (Brink *et al.*, 1990).

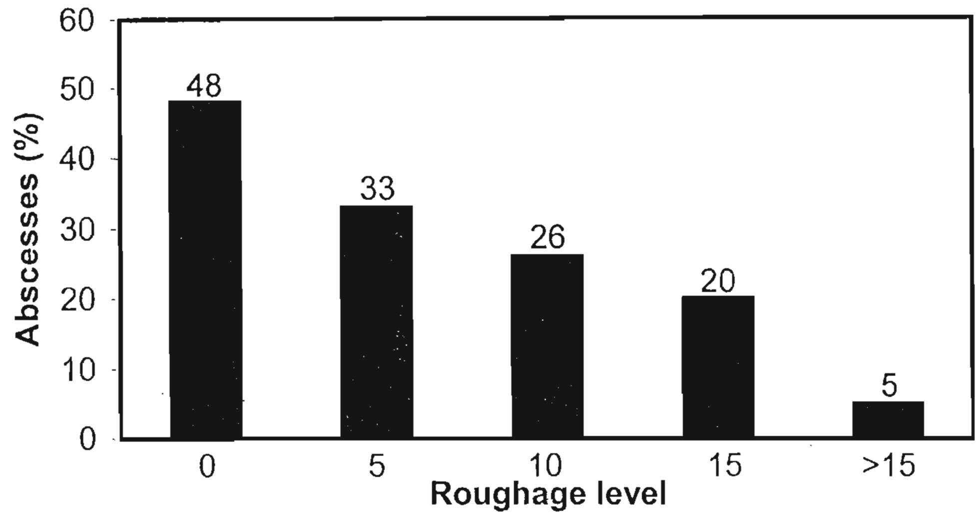

Figure 1.2 The effect of dietary roughage level on the incidence of liver abscesses in grain-fed cattle (Nagaraja *et al.,* 1996b).

1.2.4.3 Economic implications

Economic losses attributable to liver abscesses in feedlot cattle include reduced growth performance due to low feed intake and poor feed efficiency (Table 1.1; Foster & Wood, 1970; Brown *et al.,* 1973,1975; Brink *et al.*, 1990; Nagaraja & Chengappa, 1998); condemnation of livers, and mortality in extreme cases (Jensen & Mackey, 1965; Nagaraja & Chengappa, 1998). Cattle with liver abscesses had lower dressing percentage and fetched lower earnings than liver abscess-free cattle (Powell *et al.,* 1968; Foster & Wood, 1970; Montgomery, 1985). Cattle with severe liver abscesses (A+) also may require more carcass trimming because of adhesion of abscesses to the diaphragm and surrounding organs (Montgomery, 1985; Brink *et al.,* 1990).

The reported effects of liver abscesses on animal performance have ranged from no effect (Wieser *et al.,* 1966; Harman *et al.,* 1989) to a depression in daily gain of as much as 11% and a decrease in feed efficiency of up to 9.7% (Brink *et al.,* 1990). These effects are evident primarily for cattle with the most severe abscesses (based on size and number) generally referred to as A+ (based on a scale of O, A-, A, and A+; Brown *et al.,* 1975); liver abscesses in the A- or A category have no measurable impact on performance of feedlot cattle (Brown *et al.,* 1975; Brink *et al.,* 1990).

Table 1.1 Relationship between severity of liver abscesses and performance and carcass yields in feedlot cattle (from Nagaraja & Chengappa, 1998).

	Liver abscesses score[1]			
Item	O (%)	A- (%)	A (%)	A+(%)
Brink *et al.,* 1990				
No. of steers (% of steers)	405(71.5)	52(9.2)	37(6.5)	72(12.7)
Daily feed intake, kg DM	8.39^{c}	8.27^{c}	8.42^{c}	7.96^{d}
Daily gain, kg	1.27^{c}	1.23^{c}	1.24^{c}	1.15^{d}
Gain/DMI	0.151^{c}	0.149^{c}	0.145^{c}	0.130^{d}
Montgomery, 1985				
No. of steers (% of steers)	1166(80.6)	164(11.3)	45(3.1)	72(5.0)
Live weight, kg	490^{c}	480^{c}	473^{c}	442^{d}
Hot carcass weight, kg	310^{c}	302^{c}	300^{c}	274^{d}
Dressing percentage	63.3^{c}	62.8^{c}	62.7^{c}	61.7^{d}
Fat thickness, cm	1.10^{c}	1.10^{c}	1.13^{c}	0.98^{d}
USDA yield grade	2.54	2.46	2.47	2.40
USDA quality grade[2]	2.27	2.31	2.40	2.23
Trim due to abscesses, % of carcass weight	0.0214^{c}	0.0205^{c}	0.0424^{c}	0.4538^{d}

[1]O = no abscesses; A- = one or two small abscesses or scars; A = two to four small, well-organized abscesses; A+ = one or more large or multiple, small, active abscesses with or without adhesions.

[2]Choice = 3; Good = 2.

[ab]means in the same row with different superscripts differ ($p<0.05$).

1.2.4.4 Prevention

The control of liver abscesses in feedlot cattle generally depended on the use of antimicrobial compounds (Nagaraja & Chengappa, 1998). *Fusobacterium necrophorum*, one of the bacteria responsible for liver abscesses has been reported (Nagaraja *et al.*, 1998) to be susceptible to some antibiotics such as penicillins, tetracyclines (chlortetracycline and oxytetracycline), lincosamides (clindamycine and lincomycin) and macrolides (tylosin and erythromycin). However, not all antibiotics are approved for use in feedlot cattle diets. The antibiotics bacitracin methylene disalicylate, chlortetracycline, oxytetracycline, tylosin, and virginiamycin are approved for prevention of liver abscesses in feedlot cattle (Nagaraja *et al.*, 1999). These antibiotics differ in their inhibitory effect on *Fusobacterium necrophorum* and *Actinomyces pyogenes* and their effectiveness in preventing liver abscesses, but generally bacitracin is the least effective and tylosin is the most effective of the five antibiotics (Haskins *et al.*, 1967; Brown *et al.*, 1973; Potter *et al.*, 1985; Vogel & Laudert, 1994; Rogers *et al.*, 1995). These antimicrobial compounds are believed to inhibit the growth of *Fusobacterium necrophorum,* primarily in the rumen and possibly in the liver, if they can be absorbed from the gut (Nagaraja & Chengappa, 1998).

Flint & Jensen (1958) originally proposed the most positive approach of preventing liver abscesses. These workers reported that giving 70 mg chlortetracycline daily considerably reduced, although did not completely eliminate the incidence of liver abscesses. This was confirmed by several workers (Table 1.2). Chlortetracycline also improves feed conversion, feed efficiency, live weight gain and dressing percentage (Wallace, 1970; Brown *et al.*, 1975).

Several studies (Muir & Barreto, 1979; Dutta & Devriese, 1981; Nagaraja & Taylor, 1987) have indicated that virginiamycin is also a potent inhibitor of ruminal lactic acid-producing bacteria. Therefore like ionophores, virginiamycin in the diet may help to stabilize ruminal fermentation and decrease variation in feed intake until sufficient numbers of lactate-utilizing bacteria are established within the ruminal ecosystem (Rogers *et al.*, 1995) by inhibiting the proliferation of lactate-producing bacteria (Rogers *et al.*, 1995) thus resulting in moderate lactic acid production (Coe *et al.*, 1999). Feeding virginiamycin also decreases the incidence and severity of liver abscesses and improves performance in growing and finishing feedlot cattle (Rogers *et al.,* 1995).

Table 1.2 Incidence of liver abscesses in steers and effects of antibiotic application (adapted from Preston & Willis (1974), with addition from other sources published post 1973).

Energy source	Total number of animals	Liver abscesses %		Authors
		Untreated	Antibiotics	
Maize	64	44	3[c]	*Harvey *et al.,* 1965
Barley	301	28	11.8[c]	*Wieser *et al.,* 1966
Sorghum	90	27	0[e], 3[c]	*Furr & Carpenter, 1967
Sorghum	150	61	16[e], 32[c]	*Furr & Carpenter, 1967
Maize	80	72	72[b]	*Haskins *et al.,* 1967
Barley	188	23	7[t]	*Macdearmid, 1967
Maize	80	18	0[c]	*Harvey *et al.,* 1968
Sorghum	222	28	10[c], 10[c]	*Furr *et al.,* 1968a
Sorghum	96	67	37[c]	*Furr *et al.,* 1968b
Post 1973 additions				
Milo, Barley	774	24.1	4.2[t]	Brown *et al.,* 1973
Corn	1829	56.2	18.6[t], 44.2[c]	Brown *et al.,* 1975
Corn	176	29	10[t]	Heinemann *et al.,* 1978
Corn	163	27	9[t]	Potter *et al.,* 1985
Corn	141	32	6[t]	Tan *et al.,* 1994
	6971	27.9	7.48[t]	Vogel & Laudert, 1994
Corn, Milo, Barley	3100	30.1	30.5,18.8,18.5[v]	Rogers *et al.,* 1995

[c]chlortetracycline; [t]tylosin; [b]bacitracin; [v]virginiamycin; [e]erythromycin.

* Cited by Preston & Willis (1974).

Generally the control of liver abscesses in feedlot cattle has depended on the use of tylosin antibiotics (Nagaraja & Chengappa, 1998). Several studies have suggested that tylosin feeding significantly reduces but does not completely prevent, the condition (Brown *et al.,* 1975; Heinemann *et al.,* 1978; Pendlum *et al.,* 1978; Brink *et al.,* 1990). According to Nagaraja & Chengappa (1998), the reduction in the incidence of liver abscesses due to tylosin feeding is 40 to 70%. In addition to this reduction, tylosin feeding also improves performance of cattle. A summary of 40 trials involving a total of 6971 cattle from all major cattle feeding areas of the United States showed that tylosin (11g/metric tonne of air dry feed or 90 mg/animal/day) feeding reduced the incidence of liver abscesses by 73% while, cattle fed tylosin gained 2.1% faster, converted feed to gain 2.6% more efficiently and yielded a slightly higher dressing percentage than the cattle fed no tylosin (Table 1.3).

Even though antibiotics were used to control the incidence of liver abscesses in feedlot cattle, their use in animal feeding has been banned in some parts of the world (such as the European Union and Scandinavia) and it is under pressure in the rest of the world. The antibiotics spiramycin, virginiamycin, tylosin phosphate and zinc bacitracin were banned in 1998 by European Union (Piron, 2002). Beside, the European Union is moving toward a total ban on the use of antibiotics in animal and food production.

Although ionophores have been shown to reduce the incidence of acidosis in feedlot cattle fed high grain diets, inclusion of ionophore antibiotics such as monensin, lasalocid, or laidlomycin propionate had no effect on the incidence of liver abscesses in several studies (Berger *et al.,* 1981; Potter *et al.,* 1985; Nagaraja & Chengappa, 1998).

The vaccines toxoid and antileukotoxin reduce liver abscesses in feedlot steers and heifers (Saginala *et al.,* 1997). However, knowledge on efficacy, dose and time of application is still scanty and can be ascribed to the lack of use of vaccines on a wider scale (commercial) in controlling liver abscesses (Nagaraja & Chengappa, 1998).

Table 1.3 Liver abscess control and feedlot performance of tylosin and non-tylosin fed cattle (Vogel & Laudert, 1994).

Item	Control	Tylosin-fed	% Improvement
No. of pens	266	279	-
No. cattle	3271	3700	-
Average days on feed	134	134	-
Liver abscesses, %	27.9	0.5[a]	73.1
DM intake, kg	8.72	8.72	-
Daily gain, kg	1.29	1.32[a]	2.3
Feed/gain	6.9	6.72[a]	2.6
Dressing percentage	61.65	61.8[a]	0.2

[a]differ significantly from control ($P< 0.01$).

In addition to the inclusion of antimicrobial compounds in the feed, adapting cattle to high concentrate diets gradually, avoiding either under or overfeeding, spreading intake by increasing feeding times, increasing roughage content of the feed, imposing quality control in mixing feeds, and providing adequate bunk space and fresh, clean water (Jensen *et al.,* 1954b; Elam, 1976; Bartle & Preston, 1991) are also useful in reducing the occurrence and severity of acidosis and consequently incidence of liver abscesses in cattle.

Research studies in which 100% concentrate diets were fed, results in a marked reduction in cattle growth performance (Preston & Willis, 1974), high incidence of digestive disorders (Jensen *et al.,* 1954a) and high percentage of condemned livers (Loerch & Fluharty, 1998). The study of Lister (1971) shows a reduction in the incidence of liver abscesses when roughage was made to replace a portion of the concentrate diets. In most feedlots, a low level (5 to 15%) of roughage is included to predominantly concentrate diets to reduce the incidence of liver abscesses and digestive problems (Brandt *et al.,* 1987 and Owens, 1987, both cited by Stock *et al.,* 1990). Generally the incidence of liver abscesses is higher when the roughage portion of the diet is low (Harvey *et al.,* 1968; Foster & Wood, 1970; Gill *et al.,* 1979; Figure 1.2).

Physical characteristics of the roughage offered also influences incidence of liver abscesses. Utley *et al.* (1973) reported a higher incidence of liver abscesses in steers fed ground or pelleted peanut hulls when compared with those on un-processed (whole) hulls. Mader *et al.* (1991b, 1993) demonstrated that cattle fed dry hay had a higher incidence of liver abscesses than their counterparts on silage.

Grain type has an influence on the incidence of liver abscesses (Hale, 1985, cited by Nagaraja & Chengappa, 1998; Rogers *et al.*, 1995). Grains that are categorized as "rapidly fermented," such as wheat, barley, high moisture corn and steam flaked corn promote acidosis, rumenitis and consequently liver abscesses (Fulton *et al.*, 1979; Stock *et al.*, 1987, 1990; Ladely *et al.*, 1995); and perhaps explain the higher incidence of acidosis in feedlot cattle fed wheat compared to those on other cereals (Elam, 1976).

Any grain processing technique that reduces particle size or causes gelatinization of starch granules has been shown (Stock & Britton, 1996) to increase acidosis and rumenitis, which are prerequisites for liver abscesses. As particle size becomes smaller, more starch is exposed to microbial digestion and results in an accelerated production of organic acids and mucopolysacharides, declining rumen pH and increased viscosity of ruminal fluid (Cheng & Hironaka, 1973; Hironaka *et al.*, 1973), which increases the possibility of acidosis.

Grain processing methods that increase the rate and extent of ruminal starch digestibility will enhance liver abscesses (Rogers *et al.*, 1995). Dry rolled wheat, dry rolled barley and early harvest corn have been reported to enhance rapid fermentation (Mader *et al.*, 1991a) compared to dry rolled corn or grain sorghum (Figure 1.3) and thus favour acidosis and its concomitant effects (rumenitis and liver abscesses). However, a study by Stock & Britton (1996) showed that feeding rapidly fermented grains (wheat, barley and high moisture corn) alongside slowly fermented grains (dry rolled corn, dry whole corn or dry rolled grain sorghum) could reduce acidosis and also improve feed efficiency and animal performance.

Furthermore, extensive processing methods, such as steam flaking, popping and micronizing, which entail heat application (Evers & Steves, 1985, cited by Cheng *et al.,* 1998) provide microorganisms easy access to nutrient-rich components of the endosperm (Cheng *et al.,* 1998) and can also favour acidosis, rumenitis and liver abscesses.

Fast ↑

Dry rolled wheat

Dry rolled barley

High moisture corn (bunker silo)

Steam flaked corn

* High moisture corn (stored whole)

Steam flaked milo

Dry rolled corn, reconstituted milo

Whole corn

Dry rolled milo

↓ Slow

Figure 1.3 Grains categorized by rate of breakdown in the rumen (Stock & Britton, 1996).

There is a wide variation in the incidence of liver abscesses in feedlot cattle, which can range from as low as 1 or 2% to as high as 90 or 95% in specific groups of grain-fed cattle (Nagaraja *et al.,* 1996b). Generally it averages from 12 to 32 % (Brink *et al.,* 1990). In addition, even though the incidence of liver abscesses is reduced due to the use of antibiotics, the reduction is not consistent even with the use of the same antibiotics. To quantify the effect of known sources of variation data were collected from published literature on the incidence of liver abscesses (appendix Table 1). The information collected includes grain type, level and processing of the grain, roughage type, level, and processing, type and level of protein supplements, number of days on the feed, type and level of antibiotic used, and the incidence of liver abscesses in control and treated animals. The grains used in most studies were maize, sorghum, barley, wheat and milo, but milo was not included in the analysis due to low number of observations. The grain processing used were cracking, dry rolling, flaking, grounding, steam flaking, and steam rolling. The effect of molasses was also assessed. The antibiotics encountered were chlortetracycline, virginiamycin and tylosin.

All these factors were tested to ascertain their effect on the incidence of liver abscesses. The effect of grain type was analysed as a dummy variable (where 1 = presence and 0 = absence of a particular grain from diets). The effect of grain processing and inclusion of antibiotic was analysed whether the processing methods and antibiotic type had any effect on the incidence of liver abscesses. A regression technique was applied to derive quantitative estimates of the effect of these factors on the incidence of liver abscesses. The data were analysed using GLM procedures (SAS, 1987).

The effect of grain type, grain processing and antibiotic type on the incidence of liver abscesses is presented in Table 1.4. From all the parameters only grain processing and antibiotic type had a significant effect ($P<0.0001$) on the incidence of liver abscesses. From the grain types only the presence of barley increased ($P<0.01$) the incidence of liver abscesses. The incidence of liver abscesses is related to consumption of high concentrate diets and sudden change of cattle from high roughage diets to low roughage diets (Nagaraja & Chengappa, 1998). The absence of a significant effect of the grain level or roughage level in this analysis might be due to the use of similar grain level in most studies.

Table 1.4 Effects of grain type, grain processing and antibiotic type on the incidence of liver abscesses in feedlot cattle.

Parameters	Number	Mean	Estimate	SE	Probability
Intercept			3.37	6.84	0.624
Maize			3.22	4.82	0.506
Sorghum			12.04	12.56	0.341
Barley			19.36	6.51	0.004
Wheat			-1.46	7.55	0.847
Molasses			5.31	3.89	0.176
Grain processing					<.0001
Dry rolling	4	52.32^{a}	36.15	9.13	0.0002
Flaking	4	46.71^{a}	35.51	9.31	0.0003
Grounding	48	26.19^{b}	16.62	5.44	0.003
Cracking	12	23.24^{b}	7.06	6.84	0.305
Steam rolling	2	15.00^{b}	0.00		
Steam flaking	10	10.60^{b}	0.00		
Rolling	14	6.21^{b}	-10.10	7.07	0.157
Antibiotic type					<.0001
None	47	30.49^{a}	8.54	4.64	0.069
Virginiamycin	17	25.85^{ab}	0.00		
Chlortetracycline	7	16.93^{bc}	-9.38	7.75	0.229
Tylosin	23	7.15^{c}	-10.54	5.68	0.67

^{a,b,c}means in the same row with different superscripts differ.

Regression techniques were applied to estimate the relationship of the incidence of liver abscesses and grain processing, antibiotic types and the grain types. Among the grain types, the presence of barley increased the incidence of liver abscesses while other grains had no effect due to high standard errors. The presence of barley increased the incidence of liver abscesses by 19.36%, sorghum by 12.04%, maize by 3.22% and molasses by 5.31% (Table 1.4). Wheat and barley are rapidly fermented grains and their presence in the diet of cattle is more likely to lead to acidosis and subsequently liver abscesses. The absence of wheat effect on the incidence of liver abscesses might be due to the low number of observation in the data set.

Among the grain processing methods, cracking, dry rolling, flaking, and grinding positively influenced the incidence of liver abscesses (Table 1.4). The use of rolling as a grain processing method negatively affected the incidence, while steam flaking and steam rolling had no effect (Table 1.4). The presence of the antibiotics tylosin and chlortetracycline reduced the incidence of liver abscesses, while the presence of virginiamycin had no effect (Table 1.4). The incidence of liver abscesses was high when the animals were finished without antibiotics. The incidence was reduced by 10% if tylosin was included in the feed and by 9% in the presence of chlortetracycline (Table 1.4).

From the above analysis, the use of barley and the use of either dry rolling or flaking as grain processing methods resulted in higher incidence of liver abscesses. Tylosin was the most effective in controlling liver abscesses followed by chlortetracycline.

1.2.5 CONCLUSIONS

High concentrate diets predispose cattle to nutritional disorders such as bloat, acidosis and liver abscesses. Bloat is associated with the ingestion of large amounts of rapidly fermented cereal grain and destabilization of microbial populations of the rumen. It occurs when rumen gas production exceeds the rate of elimination. Gas then accumulates causing distention of the rumen. Acidosis results from a series of biochemical and physiological stresses caused by rapid production and absorption of ruminal organic acid when an animal over-consumes a meal of readily fermentable carbohydrates. It is categorized as acute and sub-acute acidosis. In acute acidosis the animal is sick to the point of death or may have impaired physiological function and absorption. In sub-acute acidosis the animal has reduced feed intake. A liver abscess is a disease within the acidosis-rumenitis-liver abscess complex. Causative agents of liver abscesses include *Fusobacterium necrophrum;* a gram-negative obligate anaerobe, which is the most commonly isolated bacterium and *Actinomyces pyogenes*, a gram-positive facultative anaerobe that is the second most commonly isolated pathogen.

These disorders represent a major economic liability to producers, packers and consumers through reduced daily gain, feed efficiency, liver condemnation and death of the animals. Factors that affect the incidence of the nutritional disorders include diet composition such as concentrate level, grain type and processing, management practices like adaptation of cattle to high concentrate diets, breed differences and the use of feed additives.

The control of nutritional disorders generally depends on the use of feed additives such as ionophores and antibiotics. However, the use of antibiotics in animal feeding has been banned in some parts of the world (such as the European Union, Scandinavia). These antibiotics include spiramycin, virginiamycin, tylosin phosphate, and zinc bacitracin. The ban, based on concerns that the widespread use of antibiotics in animal feed can lead to an increase in antibiotic resistant strains of pathogenic bacteria, which may have an impact on human health. Although these antibiotics are not banned in some parts of the world, like in the United States of America (U.S.A.), South Africa, etc., the European move will inevitably have repercussions for those countries and export markets will be lost, unless alternative strategies are found to the use of antibiotics in feedlot cattle. Generally, the incidence and severity of liver abscesses increases as roughage level in the diet decreases (Harvey *et al.,* 1968; Foster & Wood, 1970; Brent, 1976; Gill *et al.,* 1979; Zinn & Plascencia, 1996). Therefore, increasing the roughage level in the diet without severely affecting the performance of the animals in an attempt to reduce acidosis and other related diseases could be one method of reducing these problems.

CHAPTER TWO

SURVEY ON THE INCIDENCE AND SEVERITY OF LIVER ABSCESSES ON FEEDLOT CATTLE SLAUGHTERED AT CATO RIDGE ABATTOIR

ABSTRACT

A survey on the incidence and severity of liver abscesses was done on 2318 cattle, which were slaughtered over a four-day period at Cato Ridge abattoir. The cattle studied were finished in three feedlots, namely Wondervale, Riversdale, and Triple C, which are located in KwaZulu-Natal province, South Africa. The condition of livers was scored as unaffected by abscessing, slightly abscessed, mildly abscessed and severely abscessed, according to an existing classification guideline. From the total number of animals slaughtered, 25.4% had liver abscesses. The total incidence of liver abscesses was significantly different ($P<0.01$) among the three feedlots. There was no significant difference ($P>0.05$) in the severity of liver abscesses either on the total incidence or among the feedlots. The total incidence was slightly higher in males (25.8%) than in females (24.4%). The survey shows that the incidence of liver abscesses was high at the abattoir and the difference among the feedlots was significant.

Keywords: Liver abscess, abattoir, survey, feedlot, beef cattle

2.1 INTRODUCTION

The incidence of liver abscesses is high in most feedlots and it is of economic value to producers, packers and consumers through wasted feed, decreased performance and carcass income and loss of edible liver. Liver abscessing is a common problem in feedlot cattle that use high grain diets because grain ferment rapidly, often resulting in ruminal acidosis and rumenitis, which are predisposing factors for liver abscesses (Smith, 1944; Jensen *et al.*, 1954a). Its incidence is high worldwide in intensively fed beef cattle including countries like the United States of America (U.S.A.), Europe, Japan and South Africa (Nagaraja *et al.*, 1996a). However, most of the information in the literature on the incidence, severity and effect of liver abscesses on performance of feedlot cattle emanates from the United States of America and Europe. Information dealing with the incidence and economic impact in South African feedlots is scarce. It is for this reason that a four-day survey on the incidence and severity of liver abscesses was done at Cato Ridge abattoir, on beef cattle arising from three different feedlots located in KwaZulu-Natal province, South Africa.

The objective of the survey was to investigate the total incidence and severity of liver abscesses in feedlot cattle slaughtered at Cato Ridge abattoir and to compare differences in incidence and severity of liver abscesses among three feedlots, from which the cattle originated.

2.2 MATERIALS AND METHODS

The survey was done at Cato Ride abattoir in feedlot cattle, arising from three feedlots. Cato Ridge abattoir was built in 1979 and is capable of handling 1200 cattle, 5500 sheep and 800 pigs a day. It is located half-way between Durban and Pietermaritzburg. Cattle slaughtered in Cato Ride abattoir mainly come from KwaZulu Natal, the Eastern Cape and the eastern part of the Orange Free State. Most of those cattle are finished in feedlots situated with in Natal and the eastern Orange Free State (Wallace *et al.,* 1983).

The Cato Ridge abattoir has a mechanically operated system. Primarily inspection and minor trimming is under taken online by meat inspectors. This acts as screen, those carcasses passing the inspection fit for human consumption. While Carcasses do not pass the Primarily inspection, are transferred for secondary evaluation by veterinarians.

Data on the incidence and severity of liver abscesses were collected from 2318 beef cattle slaughtered at Cato Ridge abattoir. The survey was done over a four-day period, from 01/04/ 2002 to 04/04/2002 by a team of two, one person inspecting the liver and a second recording the data. Livers were inspected on the slaughter line immediately after removal from the abdominal cavity. Carcasses were identified individually from the code number stamped on the carcass. This code number consisted of the batch number and the serial number of the carcass within the batch. Batch numbers could be reconciled with the origin (one of three feedlots namely: Wondervale (WVFL), Riversdale (RDFL), Triple C (TCFL) and gender (male or female) of the cattle.

The incidence and severity of liver abscesses were scored according to (Brink *et al.,* 1990) as follows:

Abscess score	Description
0	un-abscessed liver
A^-	1or 2 very small abscesses (less than 2.5cm in diameter) or abscesses scar present
A	2 to 4 active abscesses, generally under 2.5cm in diameter
A^+	one or more large (greater than 2.5 cm in diameter) active abscesses, portions of the diaphragm adhered to the surface of liver.

Statistical analysis

Livers were placed into two categories designated as sound (score O) or abscessed, regardless the size or number of abscesses (score A-, A, A+), to determine the total number and percentage of incidence of the total animals slaughtered and to test the difference among the three feedlots. Comparison between the severity of liver abscesses was done for the total incidence and among the feedlots. The comparison was between the contrasts A vs A-, A vs A+ and A- vs A+. Comparison between males and females on the incidence and severity of liver abscesses was done on the total number of animals slaughtered and among the three feedlots. All the statistical analysis was done by Chi-Square test, using the Minitab statistical package (Minitab, 1998).

2.3 RESULTS

From the total number of animals slaughtered, 1705 were steers, and 598 heifers. The sex of 15 animals was not recorded during the survey and their data were excluded when presenting the effect of gender on the incidence of liver abscesses. The distribution of incidence between gender class and among degree of severity is presented in Table 2.1. The total incidence was 25.4%. The incidence of liver abscess was higher in males (25.8 %) than in females (24.4%). However, this difference was not statically significant ($P > 0.05$). Gender of the animals did not affect (P>0.05) the severity of liver abscesses of the total number of animals slaughtered (Table 2.1).

Table 2.1 The over-all incidence and severity of liver abscesses between gender classes slaughtered at Cato Ridge abattoir.

Gender	Incidence of liver abscesses				Severity of liver abscesses					
	Sound		Abscessed		A-		A		A+	
	No.	%	No.	%	No.	%	No.	%	No.	%
Male	1266	74.2	439	25.8	226	51.5	29	6.6	184	41.9
Female	452	75.6	146	24.4	81	55.5	8	5.5	57	39.0
Total	1718	74.6	585	25.4	307	52.5	37	6.3	241	41.2

The distribution of incidence and severity of liver abscesses among the three feedlots is presented in Table 2.2. The incidence was 30.6% in WVFL, 28.1% in RDFL and 21.4% in TCFL. The incidence of liver abscesses differed (P<0.01) among the three feedlots, WVFL recording the highest proportion of affected livers and TCFL the lowest (Table 2.2). The severity of liver abscesses did not differ (P>0.05) among the three feedlots (Table 2.2).

Table 2.2 Incidence and severity of liver abscesses in cattle originating from three feedlots.

Incidence	WVFL		RDFL		TCFL	
	Number	%	Number	%	Number	%
Sound liver	295	69.4	603	71.9	828	78.6
Total abscess	130^a	30.6	236^a	28.1	226^b	21.4
A-	74	56.9	114	48.3	123	54.4
A	5	3.9	14	5.9	18	8.0
A+	51	39.2	108	45.8	85	37.6

[a,b] means in the same row with different superscripts differ significantly (P<0.01).

The effect of gender on the incidence and severity of liver abscess among the three feedlots is presented in Table 2.3. Gender of the animals had no effect (P>0.05) on the incidence of liver abscesses when the total number of animals slaughtered at the abattoir is considered. However, the effect of gender on the incidence of liver abscesses among the three feedlots was evident (P<0.01). The incidence in males was significantly different among the feedlots, but the incidence in females was not different. Males originating from WVFL had a higher incidence of liver abscess (P<0.01) than males from both the other feedlots (RDFL and TCFL), where the incidence did not differ significantly from one another amongst males (Table 2.3).

Table 2.3 Incidence and severity of liver abscesses in cattle from three feedlots differentiated by gender.

Origin	Gender	Incidence of liver abscesses				Liver abscesses severity score					
		Sound		Abscessed		A-		A		A+	
		No.	%	No.	%	No.	%	No.	%	No.	%
WVFL	Male	225	68.0	106[a]	32.0	60	56.6	4	3.8	42	39.6
	Female	70	74.5	24	25.5	14	58.3	1	4.2	9	37.5
RDFL	Male	338	68.7	154[a]	31.3	73	47.4	10	6.5	71	46.1
	Female	265	76.4	82	23.6	41	50.0	4	4.9	37	45.1
TCFL	Male	703	79.7	179[b]	20.3	93	52.0	15	8.4	71	39.7
	Female	117	74.5	40	25.5	26	65.0	3	7.5	11	27.5

[a,b] means in the same column with different superscripts differ significantly (P<0.01).

2.4 DISCUSSION

The survey was done in order to determine the incidence of liver abscesses in South African feedlots. The survey of liver abscesses at Cato Ridge abattoir indicated a high incidence (25.4%) of liver abscess in the three feedlots studied. These data show that the incidence of liver abscesses in feedlot beef cattle is severe enough to warrant research attention. Foster & Wood (1970) summarized data on the condition of liver abscesses from 2522 animals on feeding experiments at the University of Nebraska, U.S.A. and reported that at slaughter 24.8% of the livers were condemned because of liver abscesses. Similarly Brink *et al.* (1990)

studied the condition of liver abscess in 566 feedlot cattle from 12 experiments conducted at the University of Nebraska and found liver abscesses in 28% of the cattle. Hence, there is remarkable correspondence in the incidence of liver abscesses recorded in the present study, and those reported from U.S.A.

The effect of liver abscesses is of economic importance to producers and packers. Although the effect of severity of liver abscesses on performance and carcass characteristics of this survey was not evaluated, it could have similar effects as that reported by Foster & Wood (1970) and Brink *et al.* (1990), as the incidence was similar to those reports. Foster & Wood (1970) compared the performance and carcass yield of the cattle with sound livers and abscessed livers and found that cattle having abscessed livers had lower performance parameters than those with normal livers. Grade was depressed 0.1 of a grade and dressing percent was lowered by 0.48% units for the cattle with abscessed livers as compared to those with healthy livers. Daily gains were depressed from 1.17 to 1.10kg/day or 5.85% less for cattle with abscessed livers as compared to those with sound livers when final live weight was adjusted for equal dressing percentage.

Brink *et al.* (1990) also evaluated the association of severity of liver abscesses with feed intake, feed efficiency and daily gain of slaughtered cattle. They reported that severe liver abscess at slaughter was related to reduced carcass gain and dressing percentage. Cattle with A+ liver scores were the only group that differed significantly from non-abscessed cattle in daily feed intake, daily gain, and feed conversion ratio. Daily gain in severely abscessed (A+ score) cattle was reduced by 11% and feed efficiency decreased by 9.7%. Cattle with severe A+ liver abscesses also require more carcass trimming because of adhesion of abscesses to the diaphragm and surrounding organs, which are costly to the packer.

The results of this survey indicated that the incidence of liver abscesses varied markedly between the feedlots from 21.4% to 30.6%. This may be attributable to differences in management practices like adapting cattle to high concentrate diets, grain level, roughage level, type of processing or the use of antibiotics in the diet.

The result of this survey also indicated that the total incidence of liver abscesses was slightly higher in males than in females and is consistent to the report of Nagaraja & Chengappa (1998) who associated the higher incidence of liver abscesses in males to high feed intake. Males generally consume 1 to 3% more dry matter than females and females generally mature earlier and tend to finish earlier than males of a comparable weight (Dehaan *et al.*, 1995, cited by Nagaraja & Chengappa, 1998). High feed intake in steers might contribute to variation in their feed intake, which favours acidosis and consequently liver abscesses. In addition the longer number of days that males remain in the feedlot might also favour acidosis, a prerequisite of liver abscesses.

2.5 CONCLUSIONS

The result of this survey clearly showed that the incidence and severity of liver abscesses in the feedlot beef cattle was high and the difference in the occurrence of abscess among the feedlots studied was evident. The total incidence of liver abscesses was slightly higher in males than in females. Even though this survey is not inclusive enough to conclude about the incidence of liver abscesses in South African feedlots, it highlighted the potential extent of the problem and a survey which can represent the whole country is required to study the incidence and effect of liver abscesses in South African feedlots.

CHAPTER THREE

EFFECT OF ROUGHAGE LEVEL AND TYLOSIN PHOSPHATE ON PERFORMANCE AND INCIDENCE OF LIVER ABSCESSES IN FEEDLOT CATTLE

ABSTRACT

The study was conducted to assess the effect of roughage level and tylosin inclusion on animal performance and incidence of liver abscesses in feedlot cattle. Twenty steers, either purebred Brahmans, Simmentaler-Brahman cross, or Charolais-Brahman cross, with an average starting weight of 312.7kg (s.e. ± 7.18kg), were allotted to 20 pens, five animals (replications) per treatment. Urea-treated veld hay was used as a roughage source. Four rations were formulated using two levels of treated veld hay (20% and 40%) and two levels of the antibiotic tylosin (0 and 10ppm). Two abscessed livers (10%) were found in this experiment, in the animals receiving 20% roughage level and either of the tylosin treatments. The severity score of the abscessed livers was A- and A+, respectively. Inclusion of tylosin did not affect the performance or carcass characteristics of the steers. Roughage level did not affect average daily DM intake and carcass characteristics, but growth rate of the steers and feed conversion ratio was significantly different ($P<0.01$) between the hay levels. Roughage level and tylosin inclusion did not affect the cost of concentrates, carcass income and margin over feed cost, but hay cost differed ($P<0.05$) between hay level and tylosin treatments. It was concluded that tylosin did not affect the performance and carcass characteristics of the steers and the diet with 40% treated roughage level produced comparable results to the 20 % roughage level.

Keywords: Roughage, tylosin, liver abscess, gain, intake, carcass, steers

3.1 INTRODUCTION

The aim of any cattle feeder is to put as much weight as possible on an animal in the shortest time possible. To achieve this aim, emphasis has been given to maximizing energy intake, by feeding high concentrate diets. This system has been stimulated by several factors, including the greater energy density, ease of transport, and storage of grains relative to forages, and consumer preferences, like degree of marbling and white fat associated with grain-fed beef (Berry *et al.*, 1988).

Relatively cheap grains have provided an excellent and economical energy source. However, this has also resulted in an increasing problem with acidosis and other related diseases. The use of up to 80-90% grains in high-energy finishing diets has a major influence on acidosis and cattle performance (Stock *et al.*, 1987). Furthermore, ruminal acidosis leads to rumenitis, liver abscesses, and consequently decreased animal performance (Brent, 1976). High incidences of liver abscesses are of economic importance in feedlots. Generally the incidence of liver abscesses averages from 12 to 32% in most feedlots (Brink *et al.*, 1990). Foster & Wood (1970), Brown *et al.* (1975), Montgomery (1985), and Brink *et al.* (1990) reported the effect of liver abscesses on animal performance and carcass yield. These reports indicated that liver abscesses resulted in decreased daily gain, reduced feed intake and lower dressing percentages. Brink *et al.* (1990) reported 11% depression in daily gain and 9.7% decrease in feed efficiency in cattle with the most severe liver abscess (A+ liver abscess category).

The control of liver abscesses is generally dependent on the use of antimicrobial compounds, particularly tylosin (Nagaraja & Chengappa, 1998). However, feeding antibiotics for the control of liver abscesses is causing concern about possibly development of resistant bacterial strains. In December 1998, four antibiotics (spiramycin, virginiamycin, tylosin phosphate and zinc bacitracin) were banned by the European Union and Sweden from use in animal feed (Piron, 2002), in response to pressure from public health concern groups and European scientists. The ban took effect on 01 July 1999.

Therefore, alternatives to the use of antibiotics for the control of liver abscesses in feedlot cattle must be examined. Increasing the dietary roughage level, without severely reducing animal performance, can be one method of reducing liver abscesses. However, the low nutritive value and poor digestibility of roughage limit its use in finishing diets. Chemical or physical treatment of roughage could partly reduce this problem. Urea ammoniation is one method of improving the nutrient value of roughages (Hadjipanayiotou, 1982). Treatment with urea increases the availability of digestible cellulose and hemicellulose (Silva & Ørskov, 1988) and the nitrogen content of roughage as well (Kiangi & Kategile, 1981).

The purpose of the study was to investigate the effect of two levels of urea-ammoniated veld hay and tylosin phosphate inclusion on live weight gains, feed intake and feed conversion ratio, carcass characteristics, economic margins, and incidence of liver abscesses in feedlot cattle.

3.2 MATERIALS AND METHODS

3.2.1 Urea treatment procedure

Before the start of the experiment, a total of 792 bales of veld hay, approximately weighing 17.5 kg, each were stacked in a silage pit. The bales were stacked in four layers. The bales in each layer were separately weighed and feed grade urea was dissolved in water and spread evenly on to each layer of bales with a watering can, to provide a solution of 75kg urea and 400*l* of water per tonne (1000kg) of air-dry hay. Then the individual stacks were sealed airtight with plastic sheeting. Soil was used around the edges to hold the plastic down and thus exclude air. The process of ammoniation was allowed to proceed for eight weeks. After eight weeks the stacks were opened and the treated hay was exposed to the air to allow gases to escape before feeding to the animals. These procedures approximate optimum conditions for the on-farm ammoniation of roughages by an aqueous urea solution (Cloete *et al.*, 1983).

3.2.2 Test rations

Based on NRC (1984) standards, an assumption was made that medium frame beef steers, with a body weight of 300kg would consume approximately 7.2kg (on DM basis) of feed at the beginning of the trial and would gain an average of 1.1kg/day. The theoretical dietary concentrations required for medium growing steers are: metabolisable energy (11.2MJ/kg), protein (11.0%), Ca (0.43%), P (0.23%) (NRC, 1984). According to these requirements, four rations were formulated to investigate the over-all animal performance and incidence of liver abscesses of feedlot cattle, fed two levels of treated veld hay (20% and 40%) and two levels of the antibiotic tylosin (0 and 10ppm). Once the trial began, no adjustments were made to the ration.

The chemical composition of untreated and treated veld hay is presented in Table 3.1. The ingredient and chemical composition of the concentrate portion are given in Table 3.2. Cane molasses, cotton oilcake meal, calcium carbonate (limestone), phosphoric acid, urea, vitamin-mineral premix (for beef cattle), and salt were added to meet the energy, protein, mineral and vitamin requirements. Sulphur was added at a rate of 358 g/tonne of feed in diets 1 and 2 and 486g/tonne of feed in diets 3 and 4 to meet the 10:1 N-NPN to S ratio required. All diets contained 15ppm monensin sodium per tonne of feed during adaptation, and 20ppm during the finishing period. Tylan was added to the feed in diets 2 and 4 at a rate of 10ppm. All steers were implanted with Zeranol 72mg (Ralgro^{TM} Super, Intervet, South Africa) at the start of the experiment.

3.2.3 Animals and experimental design

The experiment was designed as 2x2 factorial, with two treated roughage levels (20 and 40%) and two tylosin levels (0 and 10ppm), with five replications per treatment, and one animal per replication. Twenty steers, either purebred Brahmans, Simmentaler-Brahman cross, or Charolais-Brahman cross, weighing between 268.7 and 354.7 kg with an average of 312.7 kg, were used in this experiment. They were of uniform conformation and medium frame type. On arrival, they were grazed together on a Kikuyu pasture. The animals were ear tagged for individual identification. The steers were eight pure Brahmans, eight Simmentaler cross and four Charolais cross. They were allotted to 20 pens (five animals per treatment). The pure

Brahmans and the Simmentaler crosses were stratified by weight within the genotype and randomly assigned to treatments, two animals per treatment from each genotype. The Charolais crosses were randomly assigned one to each treatment. After assigning cattle randomly to treatments, they were allotted to 20 pens on a random basis. The steers were kept in individual pens under a roofed shed with a pen size of 4.5x2.5m and feed trough space of 2.5m.

Table 3. 1 Chemical analysis (g/kg, DM basis) of the untreated and treated veld hay

Chemical analysis	Untreated veld hay	Treated veld hay
Dry matter	944.0	927.0
Crude protein	40.1	141.1
Calcium	2.4	3.2
Phosphorus	0.4	0.4
Ash	77.5	78.1
Crude fibre	422.6	444.2
Neutral detergent fibre	795.3	766.5
Acid detergent fibre	527.6	575.2
Acid detergent lignin	71.9	107.2
Acid detergent ash	53.2	57.1
Hemicellulose	267.7	191.3

Table 3.2 Ingredient composition (g/kg, as fed) and chemical analysis (g/kg, DM basis) of the concentrate portion of the test rations[a].

	Rations			
Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
Yellow maize meal	630.0	630.0	430.0	430.0
Cane molasses	50.0	50.0	50.0	50.0
Cotton seed oilcake meal	85.4	85.4	85.4	85.4
Limestone	18.3	18.3	17.5	17.5
Urea	5.0	5.0	5.0	5.0
Salt	2.5	2.5	2.5	2.5
Vitamin & min. premix	2.0	2.0	2.0	2.0
Phosphoric acid	6.3	6.3	6.9	6.9
Tylosin (mg/kg)	_	10.0	_	10.0
Monensin (adaptation[b])(mg/kg)	15.0	15.0	15.0	15.0
Monensin (finishing[c])(mg/kg)	20.0	20.0	20.0	20.0
Sulphur (mg/kg)	358.0	358.0	486.0	486.0
Chemical analysis:				
Dry matter	892.0	885.0	892.0	888.0
Crude protein	128.3	132.0	146.8	143.5
Crude fibre	55.0	51.3	55.5	55.4
Ash	45.2	58.2	72.3	74.4
Calcium	9.2	10.0	15.1	14.9
Phosphorus	5.2	5.2	6.2	7.1

[a]Diet 1: 20% ammoniated veld hay, 80% concentrate mixture without antibiotic tylosin.
Diet 2: 20% ammoniated veld hay, 80% concentrate mixture and the antibiotic tylosin.
Diet 3: 40% ammoniated veld hay, 60% concentrate mixture without antibiotic tylosin.
Diet 4: 40% ammoniated veld hay, 60% concentrate mixture and the antibiotic tylosin.
[b]adaptation: 0 –21 days.
[c]finishing: 22 days to slaughter.

3.2.4 Feeding procedure

3.2.4.1 Adaptation period

The animals were stepped up to their final diet over 21 days. On the first day of the adaptation period, they were offered 10% of the total concentrate (60 or 80% of the diet) with *ad libitum* hay feeding. Subsequently, the amount of concentrate was increased daily by 5% of the total concentrate in the diet, until the steers reached the full concentrate level of 60 or 80% of the diet. Hay was offered *ad libitum* and the concentrate was offered twice a day. The feeding times were from 08:00 to 09:00 in the morning and 15:00 to 16:00 in the afternoon, during the adaptation and finishing periods. Water was freely available at all times during the adaptation and finishing periods.

3.2.4.2 Finishing period

Animals were offered feed in amounts calculated to be 3% of body weight on dry matter basis. Feed was assumed to have a dry matter of 90%. Each animal had its own feedbag, which was weighed before being tipped into the animal's feed trough. Feed was given twice a day. Due to a feed mixer problem on the farm, hay was offered in a cafeteria feeding system and not in a total mixed ration (as originally planned). At 08:00 every Tuesday any feed not eaten was weighed back. In this way the intake of each animal was determined by difference once a week.

3.2.5 Body weight of animals

The initial and final body weights of the animals were calculated as the average of weights taken on three consecutive days at the beginning and end of the trial. Interim weights were taken at 14-day intervals between 07:00 and 08:00 in the morning, single day weighing, to determine the growth rate of the animals. The animals were also weighed after 21 days in the feedlot, at the end of the adaptation period. The data of the live body weight of the steers were plotted against time to determine the growth rate. From the regression, the intercept and slope of the linear regression equation of each animal was determined. The slope of the regression equation was used to indicate the growth rate of the steers instead of a calculated average daily gain. Feed conversion ratio (FCR) of the steers was determined as the average daily DM feed intake divided by the slope of the regression line of each animal.

At the end of the experiment the steers were sent to a commercial abattoir (Crafcor, Cato Ridge abattoir) according to the target weight. The crossbred steers were sent when they attained the weight of 420kg and the Brahman steers when they reached 400kg. Carcass data were collected for each steer. The incidence of liver abscesses, hot carcass weight, sub-cutaneous fat thickness, and carcass classification were recorded at the time of slaughter. One side of each carcass was quartered between the 3rd and 4th lumbar vertebrate and fat thickness was measured 50mm laterally from the midline of the spinal column. The dressing percentage was determined from the ratio of the hot carcass weight and average final weight, which was taken at three consecutive days at the end of the experiment. The carcasses were classified according to the South African meat classification system (Government Gazette, 1992) and the incidence of liver abscesses was recorded and qualified according to Brink *et al.* (1990) as follows:

Abscess score	Description
0	un-abscessed liver
A^-	1 or 2 very small abscesses (less than 2.5cm in diameter) or abscess scar present
A	2 to 4 active abscesses, generally under 2.5cm in diameter
A^+	one or more large (greater than 2.5 cm in diameter) active abscesses, portions of the diaphragm adhered to the surface of liver.

3.2.6 Economic analysis

Economic analysis of the treatments was also done using hay and tylosin levels as main effects. Feed costs were calculated separately for each ingredient. The calculations depended on the feed prices during the purchase of the feeds, in August 2001. In the hay cost, the cost of urea, plastic sheets for covering of the hay during treatment and labour costs for treating the hay were also included. For the labour cost the assumptions were as follows: during the treatment of the hay three people treated 2500kg of hay on average per day (6.5h). From this, one person could treat 840 kg of hay in 6.5h and 130kg in one hour. The cost of manpower was taken according to the payment of R12/h for the casual labour, at the university farm.

In order to represent the common price of beef prevailing in South Africa, the price statistics obtained from the Red Meat Abattoir Association (RMAA, 2002 – unpublished data) were used instead of the actual price obtained at Cato Ridge abattoir. Since the animals were slaughtered at different times, the carcass income was calculated from the average meat price over 33 weeks (starting from January 01, 2002 to September 01, 2002) given by the RMAA. However, the price for the carcass classes of A1 and A4 was not available from RMAA data and it was calculated from the prices obtained at the Cato Ridge abattoir, as follows. From the price obtained at the Cato Ridge abattoir, the price of A1 was 8.85% less than the price of A2. Similarly, the price of A4 was 3.70% less than the price of A3. These percentage differences were used to calculate the prices of A1 and A4 from the RMAA price of A2 and A3, respectively. The average meat prices (R.c/kg) for the carcass classes used were 11.87, 13.02, 13.18 and 12.69 for A1, A2, A3 and A4, respectively. After obtaining the cost of hay, concentrate and carcass income, margin over feed cost was calculated by subtracting the initial carcass value and total feed cost from carcass income. Initial carcass value was obtained assuming 50% dressing percentage and carcass class A1 for all the steers. The initial carcass value of the steers was calculated from the product of starting weight and the above assumption.

3.2.7 Chemical analysis

The dry matter (DM), ash, nitrogen (N), crude fibre (CF), acid detergent fibre (ADF), the minerals, calcium (Ca) and phosphorus (P) of the feeds were determined using the methods of the AOAC (1990). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using the method of Van Soest *et al.* (1991), while hemicellulose was estimated as the difference between the NDF and ADF values (Van Soest *et al.*, 1991). Acid detergent ash (ADA) and acid detergent lignin (ADL) were determined using the method of Goering & Van Soest (1970).

3.2.8 Statistical analysis

Data on the incidence of liver abscesses were insufficient to analyze the effect of hay level and tylosin inclusion on the incidence of liver abscesses statistically. Hence, only performance and carcass characteristics of the animals were compared for the effect of hay level and tylosin inclusion. The effect of hay and tylosin levels and their interaction effects on the variables were obtained by subjecting the data to two-way analysis of variance (ANOVA). Contrasts between treatments were done by applying the least significance difference (LSD) test. If any difference between sample means was greater than the LSD, they were significantly different at the given probability. Individual animals were used as replicates. Regression techniques were used to fit the linear model $y = a + bx$ using the body weight (y) of each animal against time (x) to determine the growth rate of the animals. The average number of days in the feedlot was calculated for each treatment and analyzed by using the Chi-square test (Minitab, 1998) to determine the difference among the treatments for the time taken to finish the animals. All the other statistical analyses were done using Genstat statistical package (GENSTAT 5, 1998).

3.3 RESULTS

During the adaptation period four steers (one from each of the four diets) lost weight. Interim weights were not recorded for one steer on diet two (20% roughage without tylosin) because it presented a problem when being led to the weighing scale. After the 56-day weighing it was weighed only on day 112. No bloat or other diseases were observed in the steers during the study, which lasted from 49 to 112 days.

3.3.1 Effect of urea treatment on the chemical composition of veld hay

The chemical composition of untreated and treated veld hay is presented in Table 3.1. It is evident that the CF, ADF, ADL and ADA increased due to urea ammoniation. DM and OM contents remained relatively stable. CP content of the veld hay was raised from 4.01% in the untreated to 14.11% in the urea-ammoniated hay. Hemicellulose decreased due to ammoniation.

3.3.2 Average daily gain and intake of animals

The average body weights, intercept and slope of the regression line, dry matter (DM) intake and feed conversion ratio (FCR) values are presented in Table 3.3. There was no significant difference ($P>0.05$) in initial live body weight, 21-day weight (end of adaptation) and breed of the steers in either hay level, tylosin level or their interaction effects. The interactions of roughage level and tylosin level did not affect (P>0.05) either growth rate, feed intake or feed conversion ratio (Table 3.3). The mean regression of body weight over time for the animals was linear. Roughage or tylosin levels did not affect (P>0.05) the intercept of regression of the lines. Slope of the regression line was used to determine the growth rate of the animals. Animals consuming 20% roughage level had a higher (P<0.01) growth rate than on the 40% hay diet. The effect of tylosin level on the growth rate of the steers was not significant (P>0.05).

Table 3.3 Growth, feed intake and feed conversion ratio of steers fed 20% and 40% treated veld hay and either with or without tylosin.

	Roughage level						
	20%		40%				
	Tylosin level		Tylosin level		SE	Probability	
Performance variable	0ppm	10ppm	0ppm	10ppm	(±)	Hay	Tylosin
Average initial weight (kg)	316.4	324.9	304.5	305.0	7.18	0.138	0.666
21 day wt (end of adaptation) (kg)	334.4	349.4	319.0	323.0	13.12	0.134	0.489
Average final weight (kg)	416.1	424.7	412.5	415.9	3.83	0.266	0.633
Intercept of the regression line	305.2	318.3	293.8	296.3	8.24	0.171	0.513
Slope of the regression line	1.506^{ab}	1.572^{a}	1.297^{b}	1.333^{b}	0.05	0.006	0.485
Average hay DMI (kg)	3.1^{a}	3.2^{a}	4.5^{b}	4.2^{b}	0.18	<.001	0.56
Average concentrate DMI (kg)	6.8^{a}	7.0^{a}	5.5^{b}	5.4^{b}	0.82	<.001	0.78
Average feed DMI (kg)	11.2	10.8	10.0	9.6	0.53	0.130	0.58
FCR	6.65	6.46^{a}	7.73^{b}	7.22	0.19	0.003	0.22

^{a,b} means in the same row with different superscripts differ significantly (P<0.01).

Feed conversion ratio (FCR) = average daily DM intake/ the slope of the regression line of each animal.

By analyzing the hay and concentrate DM intakes separately, there was a significant difference (P<0.01) in hay and concentrate intake between the two hay levels (Table 3.3). Average hay DM intake and average concentrate DM intakes of Diet 1 and Diet 2 were significantly different (P<0.01) from Diet 3 and Diet 4. The effect of the interaction between hay and concentrate level was not significantly different (P>0.05). There was no significant difference (P>0.05) in the total DM feed intake due to either hay levels or tylosin inclusion (Table 3.3). The feed conversion ratio of the animals consuming 20% hay was lower (P<0.01) than those on the 40% hay diet. The effect of tylosin on FCR was not significant (P>0.05).

3.3.3 Carcass characteristics

Two abscessed livers (total incidence of 10%) were found in this experiment, in the animals receiving 20% roughage level and either of the tylosin treatments (Table 3.4). The score of the abscessed livers was A- and A+ respectively. Carcass characteristics of steers fed two levels of treated veld hay and tylosin levels are presented in Table 3.4. Tylosin inclusion, roughage level or their interaction did not affect (P>0.05) hot carcass weight, dressing percentage or sub-cutaneous fat thickness. All steers in this experiment were in the A-age category. The carcass classification data of the steers were not analyzed due to free cells in the data; the numerical distribution of carcass classes is presented in Table 3.4. There was no significant difference (P>0.05) in the number of days in the feedlot due to hay or tylosin levels (Table 3.4).

3.3.4 Economic evaluation

The cost of hay, concentrates and total costs were calculated and analyzed separately. The statistical analysis is presented in Table 3.5 together with the carcass income and margin over feed costs. No interaction of roughage level and inclusion of tylosin were found to be significant (P>0.05) in either cost of hay, cost of concentrates or carcass income. Hay cost was higher for the 40% roughage than for the 20% roughage level. Inclusion of tylosin decreased (P<0.05) hay cost. The cost of concentrates consumed was not affected (P>0.05) by either hay level or tylosin inclusion. Even though the cost of hay was significantly different, roughage levels and tylosin level did not affect (P>0.05) the total feed costs. There was no significant difference (P>0.05) in carcass income or margin over feed cost between either of the roughage levels or tylosin level (P>0.05).

Table 3.4 Carcass data of steers fed 20% or 40% treated veld hay, and either with or without tylosin.

	Roughage level				SE	Probability	
	20%		40%				
	Tylosin level		Tylosin level				
Carcass characteristics	0ppm	10ppm	0ppm	10ppm	(±)	Hay	Tylosin
Average final live weight (kg)	416.1	424.7	412.5	415.9	3.83	0.27	0.63
Hot carcass weight (kg)	224.8	234.0	227.4	226.2	2.23	0.42	0.22
Dressing %	54.1	55.1	54.7	54.9	0.55	0.81	0.44
Sub-cutaneous fat thickness (mm)	3.2	2.8	3.1	3.8	0.17	0.08	0.54
Carcass classification							
A1	2	1	0	0			
A2	0	3	5	5			
A3	3	0	0	0			
A4	0	1	0	0			
Number of abscessed livers	1	1	0	0			
Percent of abscessed livers	5	5	0	0			
Number of days in the feedlot	74	67	88	91		0.77	0.77

Dressing % = hot carcass weight / average final weight x 100.

Carcass classification (according to south African classification system): A refers to the age class of the carcass where the steer has no permanent incisors. The number after the age class refers to the fatness of the carcass, where 0 = no fat, 1 = very lean, 2 = lean, 3 = medium, 4 = fat, 5 = slightly overfat, 6 = excessively overfat.

Table 3.5 Average feed costs and carcass income of steers (R.c/steer) fed 20 and 40% hay with or without tylosin.

	Roughage level					Probability	
	20%		40%				
	Tylosin level		Tylosin level				
Variable	0ppm	10ppm	0ppm	10ppm	SE (±)	Hay	Tylosin
Hay cost	181.6[a]	170.8[a]	333.9[b]	298.0[c]	7.04	<.001	0.03
Concentrate cost	624.0	553.0	557.0	537.0	28.80	0.33	0.28
Total feed cost	805.0	724.0	890.0	835.0	34.50	0.06	0.18
Carcass income	2845.0	2979.0	2961.0	2945.0	44.80	0.52	0.36
Margin over feed cost	206.0	356.0	263.0	342.0	47.3	0.75	0.11

[a,b,c]means in the same row with different superscripts differ significantly.

Margin over feed cost = carcass income - (initial carcass value + total feed cost).

Initial carcass value = starting weight x 50% (dressing percentage) x R11.87/kg.

3.4 DISCUSSION

The increment of CP from 4.1 in untreated to 14.1% in treated veld hay in this experiment was higher than the report of Cloete *et al.* (1983), which reported an increase of CP from 5.02 in untreated to 9% in treated wheat straw and Cloete & Kritzinger (1984), which reported 3.1 in untreated to 9.7% in treated wheat straw using 75g and 50g/kg urea and 400*l*/kg water, respectively. Seed (1983) and Seed *et al.* (1985) reported a comparable increase in CP to this study using 4% anhydrous ammonia for treating maize residue. The result of the chemical analysis of untreated and treated veld hay agrees with the report of Cloete *et al.* (1983), but disagrees with the finding of Cloete & Kritzinger (1984), which reports relatively small differences in CWC, and ADF content of untreated and treated wheat straw. The decrease in hemicellulose content due to ammoniation agrees with the work of Aitchison *et al.* (1986).

The intent of this research was to evaluate the effects of roughage levels and inclusion of tylosin on performance and incidence of liver abscesses, but the incidence of liver abscesses in this experiment was very low (10%) and only performance was compared for the effect of hay level and inclusion of tylosin. The generally low incidence of liver abscesses in this experiment could have been due to the feeding regime, which allowed gradual introduction of the steers to the high concentrate rations or the use of high roughage levels in the diet (20 and 40%). In addition, most of the steers were fed the finishing diet for a relatively short period of time (on average 80 days), whereas most of the work reported on feedlot cattle usually lasted for periods of three to four months (90 to 120 days) and this might also have contributed to the low incidence of liver abscesses recorded in this experiment.

The results of this experiment indicated that in terms of growth rate, feed intake, feed conversion, carcass weight and dressing percentage, steers responded similarly to diets with or without tylosin. This results supports the finding of Heinemann *et al.* (1978) and Pendlum *et al.* (1978), who reported that tylosin, had no effect on either feed intake or average daily gain. Though Potter *et al.* (1985) observed that tylosin increased ADG, they did not observe any effect of tylosin on feed intake and feed efficiency. Brown *et al.* (1973, 1975) reported significant effects of tylosin inclusion on average daily gain and feed efficiency, but no effect on feed intake. Summarizing the effect of tylosin on performance and incidence of liver abscesses of feedlot cattle, Vogel & Laudert (1994) indicated that tylosin improved daily gain, feed efficiency and dressing percentage, but had no effect on feed intake.

The effect of antibiotics on animal performance is at least partly due to the suppression of growth depressing microorganisms, rather than to a direct growth stimulatory effect. So the stimulatory effect of tylosin on ADG and feed conversion in cattle may be primarily due to a reduction of liver abscesses. The absence of any tylosin effect on performance in this experiment could be attributed to the low incidence of liver abscesses. Brown *et al.* (1975) also pointed out that improvement of animal performance due to tylosin inclusion was by reducing the incidence of liver abscesses.

Ruminant production based on low quality roughages is of particular interest because these materials are of little direct use as feedstuffs for non-ruminants. However, substitution of roughages for the normal energy sources (grains) in conventional production diets of ruminants at levels greater than 30% generally leads to substantial decrease in productivity (Pickard *et al.,* 1969). Using finishing beef cattle, Lamming *et al.* (1966) reported that as dietary milled barley straw increased from 10 to 50% in the diet, ADG decreased by 0.36± 0.15kg for every 10% increase in roughage level. Similarly, Swan & Lamming (1970) reported decreased live weight gain, carcass weight and dressing percentage when ground barley straw was increased from 30 to 70% in a beef cattle fattening diet.

Preston & Willis (1974) summarized the effect of added roughage to all concentrate diets and they found that there has been an increase in daily gain in about 60% of the cases where small amounts (up to 20%) of roughage have been added; improvement due to roughage appears to occur more frequently with maize grain than with ear maize or other cereals. Invariably feed intake is increased by the addition of roughage and in some cases this probably accounts for a proportion of the greater daily gain. When roughage exceeded 20% of the diet there was no further increase in feed intake or daily gain and beyond 40% both were reduced.

The effect of ammoniated roughages on performance of animals is dependent on the concentrate level of the diets fed to the animals (Garrett *et al.,* 1979; Horton, 1979). The work of Seed *et al.* (1985) showed that ammoniation of maize residues increased lamb performance at low concentrate levels (0 and 20%) as compared to untreated maize residues. However, no significant difference was found between treated and untreated maize resides at high concentrate levels (40 and 60%).

As expected, animals given higher levels of hay consumed more hay and had higher hay cost. Tylosin inclusion also resulted in lower hay cost as compared to those fed without tylosin. This difference was not expected, because tylosin did not affect hay DM intake (Table 3.3). Even though the roughage level had a significant effect on hay cost, it only tended to affect the total feed cost and had no effect on margin over feed cost. This may be due to the fact that all steers fed on a 40% hay diet were in the A2 carcass class, which fetched higher prices, thus compensating for the higher cost of hay.

High concentrate finishing diets usually result in reduced rumen pH and accumulation of lactic acid in the rumen, which causes lactic acidosis. These in turn results in reduced feed intake and poor performance of cattle and increased incidence of liver abscesses. Increasing roughage level and use of antibiotics are the two management practices commonly used to control these problems. However, roughage level usually remains low in finishing diets due to low digestibility and reduced feed intake. Its level can be increased after treatment (urea-ammoniation) to improve its nutritional quality.

4.5 CONCLUSIONS

In this experiment comparable results were found on performance of steers and economic aspects of production by using 20 and 40% level of urea ammoniated veld hay in finishing diets. Therefore, 40% treated veld hay and 60% concentrate mixtures can be used as a strategic alternatives to tylosin for controlling liver abscesses in finishing beef cattle without severely comprising animal performance and economic return.

CHAPTER FOUR

EFFECT OF FEEDING TWO ROUGHAGE LEVELS WITH OR WITHOUT TYLOSIN ON THE DEGRADABILITY OF DIETARY DRY MATTER AND CRUDE PROTEIN

ABSTRACT

The effect of roughage and tylosin levels as well as their interaction effect on the rumen degradability of untreated and treated veld hay and concentrate mixtures were examined in this experiment. The effect of treatment with urea on chemical composition and degradability of veld hay was also studied. The animals received a diet with two roughage levels, treated veld hay (20 and 40%) and two tylosin levels (0 and 10ppm). The experiment had four periods of 15 days each (10 days of adaptation and five days of incubation). Inclusion of tylosin to the diet did not affect the DM and CP degradation of the untreated and treated veld hay. Hay level did not affect the DM degradability of the untreated and treated hay but it had significant effect on the effective degradability (ED) of CP. In the concentrates incubated, tylosin affected the potential degradability (PD) of DM and the rate of degradation (C) and potential degradability (PD) of CP.

The CP content of the veld hay was increased from 4.01 to 13.10% due to urea ammoniation. The ADF and lignin contents were also increased due to urea treatment. Urea ammoniation resulted in a decrease in neutral detergent fibre (NDF) and hemicellulose contents of the hay. The dry matter and crude protein disappearance of the hay was higher in the treated than in the untreated hay. Wash loss or soluble fraction (A) and the effective degradable (ED) of the DM and CP of the veld hay were increased due to urea ammoniation. The slowly degradable fraction (B) and potential degradability (PD) of CP of the hay were also increased due to ammoniation. The other degradability parameters were not affected by urea treatment. The results show that inclusion of tylosin did not affect the degradability of the incubated feeds and comparable results were found using 20 and 40% roughage level in the DM and CP degradation parameters.

Keywords: Roughage, tylosin, dry matter, crude protein, chemical composition, degradability

4.1 INTRODUCTION

The rate of breakdown of carbohydrates is an important determinant of voluntary intake in ruminants (Balch & Campling, 1962). The degradation of protein in the rumen influences the protein supply for the host animals and the nitrogen available for the rumen microorganisms (Mehrez & Ørskov, 1977). Therefore, knowing the extent and rate of degradability of carbohydrates and proteins is important for ruminant feeding.

The nylon bag technique is a simple means of obtaining estimates of potential degradability of supplements and feedstuffs for ruminants (Kempton, 1980). This technique provides a powerful tool for the initial evaluation of feedstuffs and improving our understanding of the process of degradation, which occurs within the rumen (Ørskov *et al.,* 1980). It provides a means of ranking feeds according to the rate and extent of degradation of dry matter, organic mater, nitrogen or other nutritional parameters.

The technique involves incubating feed samples in the rumen of fistulated animals for periods of from 3-120 hours and subsequent determination of the disappearance of the different feed components. According to Kempton (1980), the major source of variation about measurements of degradability is associated with between diet and between animal variation. The between animal variation can be sufficiently reduced by replicating the measurements in not less than three animals. It was estimated that the use of one bag, three sheep and the measurement of substrate disappearance twice are necessary in order to obtain acceptable repeatability (Mehrez & Ørskov, 1977).

The objective of the study was to determine the effect of level of urea-treated veld hay and inclusion of tylosin in the feed on the disappearance of dry matter and crude protein in feedlot diets (chapter 3).

4.2 MATERIALS AND METHODS

4.2.1 Animals and diets

Four Jersey cows, weighing between 381-500kg and fitted with ruminal cannula were used to study the degradability of the experimental feeds. The internal diameter of the rumen cannula was about 120mm. The animals were kept in individual pens, under a roofed shed and were fed about 2% of their body weight. The cows were fed four diets of two hay levels (20% and 40%) with or without the antibiotic tylosin. The ingredients and percent composition of the diets were the same as the finishing diets of the feedlot trial (chapter 3). The ingredient composition and chemical analysis of the concentrate portion of the test ration is presented in Table 4.2. The feed offered was divided into two equal portions, and was given twice a day at 08:00 in the morning and 16:00 in the afternoon. Water was available all the time. The feeds incubated in the rumen of the cows includes untreated veld hay, treated veld hay, concentrate mixtures of Diet 1 (20% hay without tylosin), Diet 2 (20% hay plus tylosin), Diet 3 (40% without tylosin) Diet 4 (40% hay plus tylosin).

4.2.2 Experimental design

The experiment was designed as 4x4 Latin square with four animals, four periods and four diets. The four cows were randomly assigned to the four finishing diets containing two roughage levels (20 and 40%) and two tylosin levels (0 and 10ppm). Every animal ate each diet. The feeding system in each period is presented in Table 4.1.

Table 4. 1 The feeding system of the diets in each period during incubation time

Period	Cow 1	Cow 2	Cow 3	Cow 4
1	Diet 1	Diet 3	Diet 2	Diet 4
2	Diet 2	Diet 4	Diet 3	Diet 1
3	Diet 3	Diet 1	Diet 4	Diet 2
4	Diet 4	Diet 2	Diet 1	Diet 3

Table 4.2 Ingredient composition (g/kg, as fed basis) and chemical analysis (g/kg, DM basis) of the concentrate portion of the test ration[a].

	Rations			
Ingredients	Diet 1	Diet 2	Diet 3	Diet 4
Maize meal	630.0	630.0	430.0	430.0
Cane molasses	50.0	50.0	50.0	50.0
Cotton seed oilcake meal	85.4	85.4	85.4	85.4
Limestone	18.3	18.3	17.5	17.5
Urea	5.0	5.0	5.0	5.0
Salt	2.5	2.5	2.5	2.5
Vitamin & min. premix	2.0	2.0	2.0	2.0
Phosphoric acid	6.3	6.3	6.9	6.9
Tylosin (mg/kg)	_	10.0	_	10.0
Monensin (mg/kg)	20.0	20.0	20.0	20.0
Sulphur (mg/kg)	358.0	358.0	486.0	486.0
Chemical analysis				
Dry matter	877.0	877.0	876.0	880.0
Crude protein	142.0	141.6	166.0	160.2
Crude fibre	52.0	51.6	57.2	60.7
Ash	56.8	56.2	73.6	69.1
Calcium	10.9	10.0	16.5	15.0
Phosphorus	4.9	4.8	6.4	5.9

[a]Diet 1: 20% ammoniated veld hay, 80% concentrate mixture without antibiotic tylosin.
Diet 2: 20% ammoniated veld hay, 80% concentrate mixture and the antibiotic tylosin.
Diet 3: 40% ammoniated veld hay, 60% concentrate mixture without antibiotic tylosin.
Diet 4: 40% ammoniated veld hay, 60% concentrate mixture and the antibiotic tylosin.

4.2.3 Incubation procedure

Nylon bags of woven nylon material with a size of 14x8cm and pore size of 41μm were used. Untreated and treated veld hay samples were incubated in the cows consuming the four diets while the concentrate was incubated in the rumen of animals consuming only two corresponding diets (either 20- or 20+ or 40- or 40+ depending on the concentrate incubated). All the feeds were ground through a 2-mm screen before incubation. The bags were numbered, washed and oven dried to constant weight at 65°C for 24 hrs. After allowing the bags to cool down in a desiccator, empty weight was recorded. Feed samples of about 5g were weighed in duplicate nylon bags for each incubation period. The concentrates were prepared in triplicate for the 48 and 72 h incubation in order to get enough residues for nitrogen analysis. Samples for incubation were placed into the bags and each bag was tied separately with nylon fishing line, which is resistant to digestion by microorganisms. The other end of the fishing line was tied to a stainless steel weight and the bags were anchored to the cannula top.

The bags were incubated in the rumen of the cows in duplicate following the method described by Mehrez & Ørskov (1977). Bags were added sequentially and were incubated for 120, 96, 72, 48, 24, 12, 9, 6, and 3h for the hay and up to 72h for the concentrates. In the morning (08:00) of the first day of incubation the 120h samples were placed in the rumen of the fistulated cows. On the morning next day (08:00, day 2) the 96h sample were inserted at the same time as in day 1. The procedure was repeated until all samples were incubated.

At the end of the incubation, bags were removed from the rumen and washed thoroughly under running tap water to clear adhering ingesta, detached from the weights and washed for six consecutive cycles in a semi-automatic washing machine, each cycle lasting for four minutes. The washed bags were then dried in a force draught oven at 65°C for 48h, cooled in a desiccator, untied from the fishing line and weighed.

To determine the losses at zero hour, a set of bags, which were not incubated, but were washed, dried in the oven, cooled in a desiccator with the incubated ones and then weighed. The residue left in each bag was collected for nitrogen determination.

4.2.4 Chemical analysis

The dry matter (DM), ash, nitrogen (N), crude fibre (CF), acid detergent fibre (ADF), the minerals calcium (Ca) and phosphorous (P) of the feeds and N of the residue were determined using the methods of the AOAC (1990). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using the method of (Van Soest *et al.*, 1991) while hemicellulose was estimated as the difference between the NDF and ADF values (Van Soest *et al.*, 1991). Acid detergent ash (ADA) and acid detergent lignin (ADL) were determined using the method of (Goering & Van Soest, 1970).

4.2.5 Calculations and statistical analysis

The proportion of DM and CP which had disappeared was calculated from the amount incubated and that left in the bag after incubation. The effects of hay level, tylosin level and type of incubated feed were considered in the model that was used in the analysis of variance to which the data were subjected. The disappearance of DM and CP was estimated by fitting the non-linear model proposed by McDonald (1981) and modified by Dhanoa (1988) to the degradation data for each component; variables were determined using the secant method (DUD), (SAS, 1987):

$$Y= W+B\ [1-e\ (-c\ (T-LT))]$$

Where Y is the disappearance of DM and CP at a time T; A = washing loss or solubility; B = degradable part of the insoluble fraction; C = rate of degradation of B; and LT, the lag time. The potential degradability (PD) was calculated as A + B. A passage rate (KP) of 0.04/h for hay and 0.07/h for the concentrates was assumed in order to calculate the effective degradability (ED) of DM and CP (Bonsi *et al.*, 1994, Nsahlai *et al.*, 1998). The data on the DM and CP degradation parameters of the hay and concentrate incubated is presented in appendix Table 2 and 3, respectively.

The data on DM and crude protein (CP) disappearance were subjected to the analysis of variance using the General Linear Model (GLM). The analysis was done separately for the hay and concentrates incubated. In the analysis of the hay degradation, the effects of roughage level, tylosin level and type of incubation feed as well as their interaction were considered in the model. With respect to the concentrates incubated, tylosin inclusion and the concentrate types were considered in the model. Contrasts between treatments were done by applying the probability of difference option of the least square means statement available in the GLM (SAS, 1987).

4.3 RESULTS

4.3.1 Chemical analysis of the untreated and treated veld hay

The chemical composition of untreated and treated veld hay is presented in Table 4.3. From Table 4.3 it is evident that the ADF, ADL, ADA and OM increased due to urea ammoniation. CF and DM contents remained relatively stable. CP content of the veld hay was raised from 4.01% in the untreated to 13.10% in the urea ammoniated hay. The contents of NDF and hemicellulose decreased, due to ammoniation.

Table 4.3 Chemical analysis (g/kg, DM basis) of the untreated and treated veld hay.

Chemical analysis	Untreated veld hay	Treated veld hay
Dry matter	944.0	913.3
Crude protein	40.1	131.0
Calcium	2.4	3.5
Phosphorus	0.4	0.5
Ash	77.5	83.9
Crude fibre	422.6	423.7
Neutral detergent fibre	795.3	706.9
Acid detergent fibre	527.6	583.3
Acid detergent lignin	71.9	90.7
Acid detergent ash	53.2	60.8
Hemicellulose	267.7	123.6

4.3.2 Dry matter degradability of the incubated feeds

The effect of feed type, hay level, and tylosin inclusion on DM degradation of veld hay is presented in Table 4.4. Roughage level, tylosin level or their interaction did not affect ($P>0.05$) any of the degradation parameters of the treated and untreated veld hay (Table 4.4). Treated veld hay had higher ($P<0.01$) wash loss (A) and effective degradability (ED) of DM

(Table 4.4). However, treatment of hay with urea did not affect (P>0.05) any other degradation parameters.

Table 4.4 Effects of feed type, hay level, and tylosin inclusion on DM degradation of veld hay incubated in the rumen of cows.

Degradation Parameters	Feed type		Level of hay				MSE
			20%		40%		
	UTVH	TVH	0ppm	10 ppm	0 ppm	10 ppm	
A (gkg^{-1})	94[a]	139[b]	118	120	110	117	74.1
B (gkg^{-1})	547	615	503	552	565	702	25170.9
C (h^{-1})	0.017	0.019	0.022	0.018	0.020	0.012	0.0001
LT (h)	3.04	3.03	3.13	3.00	3.00	3.00	0.014
PD (gkg^{-1})	640	754	621	672	676	819	25989.3
ED (gkg^{-1})	241[c]	321[d]	284	277	289	274	1970.6

[a,b]means in the same row with different superscripts differ significantly (P<0.01).

[c,d]means in the same row not sharing a superscript differ significantly (P<0.05).

UTVH = untreated veld hay, TVH = treated veld hay.

Number of observations of feed type = 8, hay = 16 and tylosin = 16.

Effect of feed type and tylosin inclusion on DM degradation of the concentrate mixtures is presented in Table 4.5. The type of concentrate mixture incubated did not affect (P>0.05) any of the degradability parameters of the dry matter loss (Table 4.5). Tylosin depressed (P<0.05) the potential degradability (PD) of DM but did not affect any other DM degradation parameters (Table 4.5).

Table 4.5 Effects of feed type and tylosin inclusion on DM degradation of concentrate mixtures incubated in the rumen of cows.

Degradation	Feed type				Level of tylosin		
Parameters	D1	D2	D3	D4	0ppm	10ppm	MSE
A (gkg^{-1})	616	628.7	631	595	606	630	5275.3
B (gkg^{-1})	310	296.6	283	327	325	283	5935.0
C (h^{-1})	0.070	0.071	0.075	0.062	0.064	0.076	0.0003
LT (h)	7.83	8.2	8.17	6.30	7.40	7.88	7.5
PD (gkg^{-})	926	925.3	913	922	931^a	913^b	555.8
ED (gkg^{-1})	766	780.2	768	742	756	772	2688.4

^{a,b}means in the same row with different superscripts differ significantly (P<0.05).

D1 = concentrate mixture of diet 1.

D2 = concentrate mixture of diet 2.

D3 = concentrate mixture of diet 3.

D4 = concentrate mixture of diet 4.

4.3.3 Crude protein (CP) degradability of the incubated feeds

The effect of feed type, roughage level, and tylosin inclusion on CP degradation for veld hay is presented in Table 4.6. The interactions of roughage level and tylosin level did not affect (P>0.05) any of the degradation parameters of CP of the treated and untreated veld hay. Tylosin inclusion did not affect (P>0.05) any CP degradation parameters for hay though the rate of degradation (C) tended to be slower (P=0.051) where tylosin was included. The diet with 40% roughage level increased (P<0.05) the effective degradability (ED) of CP of the incubated veld hay but did not affect (P>0.05) any other CP degradation parameters.

Urea treatment of veld hay increased (P<0.01) wash loss (A), slowly degradable fraction (B), potential degradability (PD) and effective degradability (ED) of the veld hay with no effect on rate of degradation (C) of B and lag time (LT) (Table 4.6).

Table 4.6 Effects of feed type, hay level, and tylosin inclusion on CP degradation of veld hay incubated in the rumen of cows.

Degradation Parameters	Feed type		Level of hay				MSE
			20%		40%		
	UTVH	TVH	0ppm	10 ppm	0 ppm	10 ppm	
A (gkg^{-1})	231[a]	638[b]	425	426	448	440	1915.3
B (gkg^{-1})	459[a]	256[b]	331	381	340	378	10014.8
C (h^{-1})	0.024	0.023	0.027	0.023	0.026	0.019	0.0001
LT (h)	3.04	3.05	3.10	3.10	3.01	3.00	0.019
PD (gkg^{-1})	690[a]	894[b]	755	807	788	818	6486.2
ED (gkg^{-1})	394[a]	730[b]	552[d]	556[d]	583[c]	558[d]	482.7

[a,b] means in the same row with different superscripts differ significantly ($P<0.01$).

[c,d] means in the same row with different superscripts differ significantly ($P<0.05$).

The effect of feed type and tylosin inclusion on CP degradation of the concentrate mixtures is presented in Table 4.7. Tylosin inclusion increased ($P>0.05$) the rate of degradation (C) and CP potential degradability (PD) of the concentrate mixtures but did not affect any other CP degradability. Wash loss (A) and slowly degradable fraction (B) were significantly different ($P<0.05$) among the concentrate mixtures, but other parameters were not affected ($P>0.05$) by the concentrate types.

Table 4.7 Effects of feed type and tylosin inclusion on CP degradation of concentrate mixtures incubated in the rumen of cows.

Degradation Parameters	Feed type				Level of tylosin		MSE
	D1	D2	D3	D4	0ppm	10ppm	
A (gkg^{-1})	735.2^{ab}	685.1^{a}	690.2^{a}	769.5^{b}	717.7	722.2	3612.91
B (gkg^{-1})	212.9	268.5	263.7	174.5	238.6	221.2	3622.05
C (h^{-1})	0.09	0.08	0.07	0.09	0.08^{c}	0.09^{d}	0.0004
LT (h)	9.07	6.57	6.63	9.70	7.73	8.25	8.054
PD (gkg^{-1})	948.0	953.6	953.9	944.0	956.4^{c}	943.4^{d}	230.17
ED (gkg^{-1})	855.4	820.6	820.8	863.1	838.2	841.8	1538.28

^{a,b,c,d}means in the same row with different superscripts differ significantly ($P<0.05$).

4.4 DISCUSSION

The antibiotic tylosin has an inhibitory effect on gram-positive bacteria and it may also have an effect on ruminal digestibility of feedstuffs and fermentation products such as volatile fatty acids (VFA). Baldwin *et al.* (1982) reported that inclusion of tylosin at a rate of 1g ml^{-1} inhibited cellulose digestion and VFA production by about 80% and 50%, respectively. However, Mitchell *et al.* (1969) did not find any tylosin effect on VFA concentrations. In this experiment, inclusion of tylosin in the diet did not affect DM and CP degradation of the untreated and treated veld hay. With respect to the incubated concentrates, tylosin depressed the DM and CP potential degradability (PD) and rate of CP degradation (C).

Roughage contains high concentrations of cell wall constituents, which represent an important energy source for ruminants. However, because of its low digestibility and intake associated with low nitrogen and other nutrients, it fails very often to meet the maintenance requirement of animals. Several attempts have been made to improve the nutritive value of roughage using different chemicals. These chemicals include NaOH, ammonia and urea. Among these urea is relatively safe and easy to handle.

In this experiment urea treatment of veld hay increased the crude protein value from 4.01 to 13.1%. Many authors reported similar results (Ben Salem *et al.,* 1994; Saenger *et al.,* 1983). Beside the crude protein increase, urea treatment decreased the fibre components of the hay. Hemicellulose was the fraction mostly affected by urea treatment. Several authors reported hemicellulose reduction by ammonia treatment. In the studies by Flachowsky *et al.* (1996) and Buettener *et al.* (1982) ammoniation decreased hemicellulose content of wheat straw and fescue hay, respectively. Horton (1981), and Saenger *et al.* (1983) suggested that parts of the hemicellulose are dissolved during ammoniation.

Several authors have reported the effect of chemical treatments on the degradability of roughages. Schneider & Flachowsky (1990) reported an increase in rumen dry matter degradability of wheat straw from 36.7% to 74.4% after ammonia treatment. The apparent digestibility of wheat straw was also increased from 43.9 to 52.7% due to ammonia treatment and from 46.5 to 53.0% due to urea treatment (Flachowsky *et al.,* 1996). The report of Dryden & Leng (1988) showed that the disappearance of total nitrogen and digestibility of dry matter from ammoniated barley straw was significantly greater than that of untreated or supplemented straw. Fahmy & Ørskov (1984) also reported an improved DM degradability of barley straw due to ammonia and sodium hydroxide (NaOH) treatments. The report of Horton (1981) showed an increase of NDF, ADF and cellulose digestibility of cereal (oat, barley and wheat) straw by approximately 5.8, 4.7 and 5.8% units, respectively due to ammoniation.

In this experiment the effective dry matter disappearance of veld hay was increased from 24.34 to 32.07% and crude protein disappearance from 39.4 to 73.04% due to urea treatment. Wash loss or soluble fraction (A) and the effective degradability (ED) of DM and CP were increased due to urea ammoniation. In addition the slowly degradable fraction (B) and potential degradability (PD) of CP degradability were increased due to ammoniation. Ben Salem *et al.* (1994) reported increased potentially degradable fraction from 61.4% in untreated sorghum stover to 68.4% due to urea treatment. The rate of degradation also increased from 2.88% h^{-1} for untreated sorghum stover to 3.67% h^{-1} for urea treatments. Magheni *et al.* (1993) also found that the degradability parameters of rice straw treated with urea were better than those of untreated rice straw. The high DM disappearance of the treated hay compared to the untreated hay could be attributed to the low NDF value of the former. Minson (1982) reported a high positive correlation of DM digestibility to CP content, and negative correlations to CF, NDF, and ADF contents.

Roughage level had a significant effect only on the effective degradability (ED) of CP of the incubated hay. The fact that diet of the animals had no effect on DM degradability of the incubated feeds might be an indication that the nutrient content of the diets was comparable and the diets with the higher level of treated hay (40%) had no limiting nutrient for the microbial activities, as compared to the 20% hay diets.

4.5 CONCLUSIONS

The results of this study have shown that tylosin had no effect on the degradability of the incubated feeds. Urea treatment of veld hay increased CP content, decreased NDF and hemicellulose contents. It also improved the disappearance of DM and CP of veld hay. Comparable results were found on the degradation parameters of DM and CP using 20% and 40% treated hay. Therefore, the diet with 20% treated hay can be substituted by the 40% treated hay and concentrate mixtures in feeding feedlot cattle.

CHAPTER FIVE

GENERAL DISCUSSION

In most feedlots the use of high grain diets is common in finishing beef cattle, and roughage is included in only small amounts. Several factors like ease of transport, storage, and energy density of concentrates relative to roughages contributed to this system. However, the use of high grain diets disturbs the normal functioning of microorganisms in the rumen, resulting in a range of digestive diseases (Allison *et al.,* 1964).

Digestive disorders are common problems in finishing feedlot cattle. The most prevalent digestive and nutritional disorders include acidosis, liver abscesses and bloat. Other disorders linked to nutrition include polioencephalomalacia, foot-rot, and urinary calculi (Galyean, 2001). A variety of nutritional, management, genetic, behavioural and environmental factors appear to be involved in the development of digestive disorders in feedlot cattle (Galyean, 2001). These disorders account for reduced performance, condemned livers at slaughter and death of animals. This increases the cost of production, which means that the consumer has to pay more for meat.

Cereal grains differ in their rates of ruminal fermentation. For instance the rate and extent of fermentation of wheat are greater than those of barley, sorghum, or corn (McAllister *et al.,* 1990). Varner & Woods (1975) observed the incidence of digestive disturbances among ruminants to differ with the wheat variety fed, and perhaps similar difference may exist among other cereal grains. Addition of roughage to a diet with a rapidly digesting grain source such as wheat may reduce acidosis and other related diseases by diluting the amount of grain fed to the animal. Roughage addition also may stimulate salivation during a meal, through increased rumination.

Besides the grain level in the feed, grain processing also affects the occurrence of the digestive disorders. Grain fed to cattle vary in amount and extent of starch digestion within the animal's digestive tract and any processing method that reduces particle size of the starch granule can increase the possibility of nutritional disorders (Stock & Britton, 1996). Feeding rapidly fermented grain (wheat, barley and high moisture corn) in combination with more slowly digesting grains (dry rolled corn, dry whole corn, or dry rolled grain sorghum) may reduce acidosis and other related diseases and improve feed efficiency (Stock & Britton, 1996).

The main interest of this trial was to compare the effect of two levels of ammoniated roughage with or without tylosin on performance, incidence of liver abscesses in feedlot cattle and degradation characteristics of the experimental feeds. The incidence of liver abscesses is very common in finishing feedlots, which use high grain diets. It is also related to rapidly changing cattle from high roughage diets to high grain diets (Jensen *et al.,* 1954a). Affected livers are condemned for human consumption. Since the liver represents approximately 2% of the carcass and liver abscesses cause reduced performance of the animals, the economic seriousness of this disease is considerable. In the present study, the incidence of liver abscesses from the feedlot trial was low (10%). This might be attributed to the high roughage level in the diet. However, the incidence of liver abscesses obtained from the survey at Cato Ridge abattoir was high (25.4%). This indicates that the incidence of liver abscesses in the three feedlots studied was serious, like in other countries. Increasing the proportion of grass forage or silage in the diet reduces the rate of fermentation in the rumen, stimulates saliva production and increases the pH of animal fluid (Cheng *et al.,* 1998). Therefore, addition of roughage to high grain diets can make a difference. However, roughage is poorly digested and low in nutritional content, and as a result the inclusion rate is very low in finishing diets.

The control of liver abscesses is generally dependent on the use of antibiotics. Five antibiotics (chlortetracycline, virginiamycin, oxytetracycline, tylosin phosphate and Zinc bacitracin) were developed for the control of liver abscesses. At first the antibiotic chlortetracycline was used and has given the most consistent response, but later tylosin gained much attention in the control of liver abscesses. Tylosin has proved to be more efficacious than other antibiotics, which is reflected in its widespread use in the feedlot industry.

Besides a reduction in the incidence of liver abscesses, an addition of antibiotics to a feed improves performance of cattle. Vogel & Laudert (1994) showed that the inclusion of tylosin in the diet of finishing cattle, reduces the incidence of liver abscesses, increases daily gain and feed efficiency, and leads to a higher dressing percentage when compared to cattle fed no tylosin. In this experiment tylosin had no effect on the performance of the animals. This could be attributed to the low incidence of liver abscesses in the experiment. Even though antibiotics are used to control liver abscesses in feedlot cattle, it is banned in some parts of the world, such as the European Union and Sweden. Export market can be also affected in those countries where the use of antibiotic in animal feed is not yet banned. Therefore, alternatives like increasing the roughage level of the diet could provide a solution for the withdrawal of the antibiotics.

Roughage is produced in large amounts in many countries. However, because of its relatively poor nutritive value and low digestibility only a small proportion is included in animal diets, and roughage remains an under-utilized source of nutrients for ruminant animals. When roughage is treated chemically or physically, live body weight gain of animals tends to increase with increasing digestibility, compared to untreated roughages.

Generally, the use of urea ammoniation increased animal production, in terms of growth and milk, owing to the higher nutritive value and intake of straw after treatment (Schiere & Nell, 1993). In this experiment the crude protein content of the veld hay was raised from 4.01% to 14.11% in the feedlot trial and to 13.10% in the degradability trail due to urea ammoniation. NDF and hemicellulose contents of the hay decreased due to ammoniation. The degradability of DM and CP of the veld hay was also improved due to urea treatment. As a result, the diets with 20% and 40% treated hay responded similarly with respect to the performance of steers. The cost of the feed, carcass income and margin over feed cost was also similar in both roughage levels. Besides, hay level did not affect the DM and CP degradability of the incubated feeds.

Therefore, the approach of using high levels of ammoniated roughage can be one method of reducing the nutritional disorders that result from feeding high concentrate diets without severely reducing animal performance as the use of antibiotics is banned in many countries and is under pressure in the rest of the world.

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Appendix Table1

Sources of variation in the incidence of liver abscesses collected from literature

Source	Grain Type	Grain level	Mo_ level	Grain prosess.	PS_ type	PS_ Level	R_ type	R_ process.	R_ level	Days IF	I_con trol	A_ type	A_ level	I_ treat
Wieser *et al.*, 1966	Maize	85	0	Ground	Undefined	15	None	None	0	196	28.2	CH	120	11.8
Fur & Carpenter, 1967	Sorghum	89	0	Steam_ro	CSC	10	None	None	0	111	61	CH	70	32
	Sorghum	89	0	Steam_ro	CSC	10	None	None	0	111	27	CH	70	3
Harvey *et al.*, 1968	Maize	90	0	Ground	SBM	6	None	None	0	160	25	CH	75	5
	Maize	85	0	Ground	SBM	6	R_hulls	Ground	5	160	20	CH	75	5
	Maize	85	0	Ground	SBM	6	R_hulls	Whole	5	160	15	CH	75	0
	Maize	90	0	Ground	SBM	6	Hay	None	5	160	10	CH	75	0
Brown *et al.*, 1973	Milo	91	0	Ground	CSC	6	None	None	0	149	25	TY	100	0
	Barley	86.5	5	Rolled	None	0	ALF	Pellets	5	151	2.5	TY	50	14.3
	Barley	86.5	5	Rolled	None	0	ALF	Pellets	5	151	2.5	TY	75	4.76
	Barley	86.5	5	Rolled	None	0	ALF	Pellets	5	151	2.5	TY	100	4.76
	Milo	93	0	Steam_fla	None	0	Hay	None	5	149	29.4	TY	50	5.55
	Milo	93	0	Steam_fla	None	0	Hay	None	5	149	29.4	TY	75	6.67
	Milo	93	0	Steam_fla	None	0	Hay	None	5	149	29.4	TY	100	0
	Wheat	90	0	Ground	None	0	ALF	Sun_cured	5	151	30.5	TY	50	7.69
	Wheat	90	0	Ground	None	0	ALF	Sun_cured	5	151	30.5	TY	75	0
	Wheat	90	0	Ground	None	0	ALF	Sun_cured	5	151	30.5	TY	100	6.06
Brown *et al.*, 1975	Maize	91	0	Ground	Undefined	9	None	None	0	153	37.5	TY	75	2.04
	Maize	91	0	Ground	Undefined	9	None	None	0	153	37.5	CH	70	14.29
	Maize	88	0	Ground	Undefined	10	Corn	None	2	157	48.04	TY	75	9.37
	Maize	88	0	Ground	Undefined	10	Corn	None	2	157	48.04	CH	70	56
	Maize	80	6	Ground	SBM	8	ALF	Ground	4	168	65.38	TY	75	7.69
	Maize	80	6	Ground	SBM	8	ALF	Ground	4	168	65.38	CH	70	52
	Sorghum	83.5	4	Flaked	Undefined	12.5	None	None	0	154	59.67	TY	75	23.24
	Sorghum	83.5	4	Flaked	Undefined	12.5	None	None	0	154	59.67	CH	70	44.24

Appendix Table1 (continued)
Sources of variation in the incidence of liver abscesses collected from literature

Source	Grain Type	Grain level	Mo_ level	Grain process.	PS_ type	PS_ level	R_ type	R_ process.	R_ level	Days _IF	I_con trol	A_ type	A_ level	I_ treat
Pendlum *et al.*, 1978	Wheat	91.7	0	Ground	SBM	8.3	Corn	Silage	*Ad-lib*	140	14.6	TY	75	6.3
Heineman *et al.*, 1978	Maize	66.4	15	Ground	None	0	ALF	None	18	127	29	TY	90	10
Potter *et al.*, 1985	Maize	75.4	8	Rolled	Urea	0.9	ALF_oat	None	12	133	22.73	TY	90	9.09
	Maize & Beet	86.7	0.1	Ground	U_CSC	2.86	ALF_CS	None	9.9	142	63.64	TY	90	0
	Barley & Beet	46.5	25	Ground	Urea	0.5	ALF_CS	None	27	140	25	TY	90	15
	Maize	86.9	0.4	Ground	Urea	0.28	ALF_BH	None	11.3	154	31.25	TY	90	21.74
	Maize	83.7	4.1	Ground	Urea	0.82	Mixed hay	None	10	141	64.58	TY	90	12.5
	Maize & Beet	81	0	Ground	None	0	ALF	None	18	127	15	TY	90	13.64
	Maize	70	5	Cracked	U_SBM	8.6	Corn cobs	None	10	119	60	TY	90	5
	Maize & Barley	75.4	8	Rolled	Urea	0.9	ALF_oat	None	12	119	5	TY	90	0
	Maize	72.7	0	Rolled	Urea	0.43	ALF	None	25.3	223	0	TY	90	12.5
	Maize	80.8	0	Rolled	Urea	0.8	ALF_CS	None	18.6	100	2.08	TY	90	4.17
	Maize	72.9	0	Ground	Urea	2.7	Corn	Silage	25	106	6.38	TY	90	4.35
	Milo	80	0	Ground	U_CSC	5	ALF	None	4.9	140	10	TY	90	0
Tan *et al.*, 1994	Maize	79.2	0	Rolled	None	0	Sorghum	Silage	12	109	32.4	TY	90	5.5

Appendix Table1 (continued)
Sources of variation in the incidence of liver abscesses collected from literature

Source	Grain Type	Grain level	Mo_ level	Grain prosess.	PS_ type	PS_ level	R_ type	R_ process.	R_ level	Days _IF	I_ control	A_ type	A_ level	I_ treat.
Rogers *et al.*, 1995	Maize	80.74	5	Cracked	SBM	4.5	Corn	Silage	8	231	13.1	VG	11	8.1
	Maize	80.74	5	Cracked	SBM	4.5	Corn	Silage	8	231	13.1	VG	19.3	6.1
	Maize	80.74	5	Cracked	SBM	4.5	Corn	Silage	8	231	13.1	VG	27.6	3
	Maize & wheat	79	6	Dry Rolled	None	0	CSH_ALF	Pellets	7.4	154	60	VG	11	45
	Maize & wheat	79	6	Dry Rolled	None	0	CSH_ALF	Pellets	7.4	154	60	VG	19.3	54.3
	Maize & wheat	79	6	Dry Rolled	None	0	CSH_ALF	Pellets	7.4	154	60	VG	27.6	44.3
	Maize	83.6	4	Cracked	None	0	Corn	Silage	10	137	38.1	VG	11	51.6
	Maize	83.6	4	Cracked	None	0	Corn	Silage	10	137	38.1	VG	19.3	28.4
	Maize	83.6	4	Cracked	None	0	Corn	Silage	10	137	38.1	VG	27.6	28.1
	Barley	85	0	Ground	None	0	Barley	Silage	10	122	58.5	VG	11	66
	Barley	85	0	Ground	None	0	Barley	Silage	10	122	58.5	VG	19.3	52.2
	Barley	85	0	Ground	None	0	Barley	Silage	10	122	58.5	VG	27.6	38.4
	Maize	81.94	3.75	Steam fla.	CSC_SBM	4.6	CSH_ALF	None	8	136	9.4	VG	11	4.6
	Maize	81.94	3.75	Steam fla.	CSC_SBM	4.6	CSH_ALF	None	8	136	9.4	VG	19.3	3.4
	Maize	81.94	3.75	Steam fla.	CSC_SBM	4.6	CSH_ALF	None	8	136	9.4	VG	27.6	4.9
	Milo	79.45	3.1	Ground	None	0	Corn_CSH	Silage	12.03	128	35.7	VG	11	28.7
	Milo	79.45	3.1	Ground	None	0	Corn_CSH	Silage	12.03	128	35.7	VG	19.3	11
	Milo	79.45	3.1	Ground	None	0	Corn_CSH	Silage	12.03	128	35.7	VG	27.6	15.7

MO= molasses
PS= protein supplement
R= roughage
IF= number of days in the feedlot
I= incidence
A= antibiotic
Treat= treatment
Ro= rolling
Fla= flacking
CSC= cotton seed cake
SBM= Soya been meal
R_hulls= rice hulls
ALF= alfalfa
CH= chlortetracycline
TY= tylosin
VG= virginiamycin
U_CSC= urea and cotton seed cake
U_SBM= urea and Soya been meal
BH= brome hay
CS= corn silage, CSH= cotton seed hulls

Appendix Table 2
DM degradation parameters of veld hay and concentrate mixtures

Obs	ftype	diet	period	A	B	C	LT	KP	PD	ED	tylo	hay
1	1	1	2	138.309	792.625	0.00910	3.0000	0.04	930.93	285.180	1	20
2	1	1	3	135.256	556.080	0.02874	3.0000	0.04	691.34	367.767	1	20
3	1	1	4	155.091	416.051	0.02346	3.0000	0.04	571.14	308.909	1	20
4	1	2	1	152.212	580.938	0.00630	3.0000	0.04	733.15	231.219	0	20
5	1	2	2	149.781	629.367	0.02740	3.0000	0.04	779.15	405.611	0	20
6	1	2	3	133.298	364.873	0.03445	3.4942	0.04	498.17	302.138	0	20
7	1	2	4	146.120	566.582	0.02063	3.0000	0.04	712.70	338.889	0	20
8	1	3	1	130.782	682.775	0.02286	3.0000	0.04	813.56	379.068	1	40
9	1	3	2	134.660	964.365	0.00696	3.0000	0.04	1099.03	277.547	1	40
10	1	3	3	137.422	602.005	0.01334	3.0000	0.04	739.43	287.939	1	40
11	1	4	1	129.328	720.663	0.01365	3.0000	0.04	849.99	312.680	0	40
12	1	4	2	144.402	595.776	0.02062	3.0000	0.04	740.18	347.051	0	40
13	1	4	3	121.316	430.005	0.02178	3.0000	0.04	551.32	272.910	0	40
14	1	4	4	130.907	611.111	0.02847	3.0000	0.04	742.02	385.002	0	40
15	2	1	2	95.984	624.721	0.00904	3.0000	0.04	720.70	211.189	1	20
16	2	1	3	104.863	505.260	0.01802	3.0000	0.04	610.12	261.758	1	20
17	2	1	4	89.591	417.720	0.01972	3.0000	0.04	507.31	227.528	1	20
18	2	2	2	91.158	588.113	0.01956	3.0000	0.04	679.27	284.332	0	20
19	2	2	3	77.863	290.024	0.03331	3.4407	0.04	367.89	209.647	0	20
20	2	2	4	98.532	535.751	0.01704	3.0000	0.04	634.28	258.580	0	20
21	2	3	1	101.868	985.495	0.00766	3.0000	0.04	1087.36	260.172	1	40
22	2	3	2	91.604	522.407	0.01254	3.0000	0.04	614.01	216.318	1	40
23	2	3	3	103.064	455.797	0.01424	3.0000	0.04	558.86	222.745	1	40
24	2	4	1	97.417	769.549	0.00779	3.0000	0.04	866.97	222.887	0	40
25	2	4	2	84.445	504.073	0.02159	3.0000	0.04	588.52	261.147	0	40
26	2	4	3	85.254	367.134	0.02022	3.0000	0.04	452.39	208.529	0	40
27	2	4	4	90.415	522.583	0.02686	3.0000	0.04	613.00	300.354	0	40
28	3	1	1	513.590	381.773	0.08598	3.2226	0.07	895.36	724.034	1	20
29	3	1	2	636.117	256.923	0.07435	9.5107	0.07	893.04	768.451	1	20
30	3	1	3	732.011	219.113	0.07559	10.9988	0.07	951.12	845.776	1	20
31	3	1	4	630.219	301.740	0.07706	8.4388	0.07	931.96	788.330	1	20
32	3	2	1	664.144	239.661	0.07515	10.7937	0.07	903.81	788.223	0	20
33	3	2	2	600.483	360.382	0.06305	7.1931	0.07	960.87	771.263	0	20
34	3	2	3	562.907	368.527	0.05578	5.7937	0.07	931.43	726.340	0	20

Appendix Table 2 (continued)
DM degradation parameters of veld hay and concentrate mixtures

Obs	ftype	diet	period	A	B	C	LT	KP	PD	ED	tylo	hay
35	3	2	4	690.292	244.789	0.09204	9.9851	0.07	935.08	829.336	0	20
36	4	1	1	512.143	393.836	0.06290	2.9734	0.07	905.98	698.544	1	20
37	4	1	2	579.987	323.257	0.06696	8.1013	0.07	903.24	738.029	1	20
38	4	1	3	684.674	266.142	0.07090	9.1814	0.07	950.82	818.597	1	20
39	4	1	4	654.533	251.262	0.08122	9.8223	0.07	905.80	789.486	1	20
40	4	2	1	685.834	211.576	0.08460	11.2597	0.07	897.41	801.611	0	20
41	4	2	2	575.362	390.852	0.05476	5.8954	0.07	966.21	746.916	0	20
42	4	2	3	532.511	415.640	0.04688	4.7749	0.07	948.15	699.215	0	20
43	4	2	4	700.733	229.997	0.09303	10.6465	0.07	930.73	831.979	0	20
44	5	3	1	669.650	248.175	0.09218	7.5075	0.07	917.83	810.711	1	40
45	5	3	2	613.049	292.202	0.05678	7.5179	0.07	905.25	743.911	1	40
46	5	3	3	533.346	405.370	0.04182	3.0000	0.07	938.72	684.958	1	40
47	5	3	4	693.282	199.031	0.08548	10.9974	0.07	892.31	802.703	1	40
48	5	4	1	523.684	376.808	0.06506	3.1137	0.07	900.49	705.200	0	40
49	5	4	2	526.778	427.291	0.04336	4.7654	0.07	954.07	690.225	0	40
50	5	4	3	570.763	344.968	0.05220	5.9729	0.07	915.73	718.124	0	40
51	5	4	4	630.393	321.907	0.06108	7.5411	0.07	952.30	780.400	0	40
52	6	3	1	730.290	182.386	0.11856	9.2788	0.07	912.68	844.967	1	40
53	6	3	2	694.562	213.849	0.07894	11.3175	0.07	908.41	807.907	1	40
54	6	3	3	538.722	374.476	0.05062	5.2672	0.07	913.20	695.877	1	40
55	6	3	4	661.282	214.589	0.10510	8.9246	0.07	875.87	790.083	1	40
56	6	4	1	681.530	213.048	0.081700	10.659	0.07	894.578	796.270	0	40
57	6	4	2	524.835	418.750	0.050036	5.636	0.07	943.585	699.387	0	40
58	6	4	3	559.114	347.600	0.047729	5.511	0.07	906.714	700.036	0	40
59	6	4	4	659.015	295.032	0.069478	8.798	0.07	954.047	805.978	0	40

Obs = number of observations
ftype = type of feed incubated where:
1= treated veld hay,
2= untreated veld hay,
3= concentrate mixture of diet 1,
4 = concentrate mixture of diet 2,
5 = concentrate mixture of diet 3,
6 = concentrate mixture of diet 4

Appendix Table 3
CP degradation parameters of veld hay and concentrate mixtures

Obs	ftype	diet	period	A	B	C	LT	KP	PD	ED	tylo	hay
1	1	1	1	680.953	309.089	0.00911	3.0000	0.04	990.04	738.286	1	20
2	1	1	2	618.706	237.738	0.02023	3.0000	0.04	856.44	698.547	1	20
3	1	1	3	556.246	311.640	0.04171	3.5267	0.04	867.89	715.320	1	20
4	1	1	4	669.837	180.471	0.02671	3.0000	0.04	850.31	742.093	1	20
5	1	2	1	675.159	116.692	0.02850	3.0000	0.04	791.85	723.710	0	20
6	1	2	2	563.640	346.817	0.03782	3.2727	0.04	910.46	732.181	0	20
7	1	2	3	663.490	144.242	0.02837	3.0000	0.04	807.73	723.344	0	20
8	1	2	4	626.943	253.820	0.02390	3.0000	0.04	880.76	721.888	0	20
9	1	3	1	663.281	263.492	0.02623	3.0000	0.04	926.77	767.632	1	40
10	1	3	2	584.564	319.622	0.02622	3.0000	0.04	904.19	711.121	1	40
11	1	3	3	650.044	255.570	0.01509	3.0000	0.04	905.61	720.062	1	40
12	1	3	4	653.570	362.436	0.00819	3.0000	0.04	1016.01	715.144	1	40
13	1	4	1	692.087	246.905	0.01564	3.0000	0.04	938.99	761.490	0	40
14	1	4	2	589.538	328.868	0.02906	3.0000	0.04	918.41	727.921	0	40
15	1	4	3	656.368	174.839	0.02232	3.0000	0.04	831.21	718.986	0	40
16	1	4	4	669.372	236.873	0.02910	3.0000	0.04	906.25	769.132	0	40
17	2	1	1	243.720	650.727	0.01318	3.0000	0.04	894.45	404.977	1	20
18	2	1	2	160.803	530.344	0.02025	3.0000	0.04	691.15	339.031	1	20
19	2	1	3	193.050	455.890	0.03097	2.9915	0.04	648.94	392.001	1	20
20	2	1	4	285.735	368.330	0.02257	3.0000	0.04	654.06	418.597	1	20
21	2	2	1	254.292	371.977	0.01956	3.0000	0.04	626.27	376.464	0	20
22	2	2	2	169.518	625.892	0.01930	3.0000	0.04	795.41	373.221	0	20
23	2	2	3	264.865	249.398	0.03931	3.5297	0.04	514.26	388.486	0	20
24	2	2	4	178.267	537.818	0.02402	3.0000	0.04	716.08	380.062	0	20
25	2	3	1	183.866	641.698	0.01974	3.0000	0.04	825.56	395.929	1	40
26	2	3	2	281.670	468.552	0.01491	3.0000	0.04	750.22	408.907	1	40
27	2	3	3	220.943	353.300	0.02575	3.0000	0.04	574.24	359.312	1	40
28	2	3	4	283.997	360.446	0.01555	3.0000	0.04	644.44	384.914	1	40
29	2	4	1	252.389	436.929	0.02714	3.0000	0.04	689.32	429.007	0	40
30	2	4	2	230.872	481.915	0.02509	3.0000	0.04	712.79	416.641	0	40
31	2	4	3	259.865	335.994	0.02413	3.0000	0.04	595.86	386.276	0	40
32	2	4	4	236.227	475.026	0.03291	3.0897	0.04	711.25	450.646	0	40
33	3	1	1	763.797	160.236	0.11910	10.0170	0.07	924.03	864.717	1	20
34	3	1	2	737.033	191.684	0.07968	10.1299	0.07	928.72	839.072	1	20
35	3	1	3	749.524	215.479	0.09694	8.4201	0.07	965.00	874.651	1	20
36	3	1	4	707.720	242.130	0.10316	7.3416	0.07	949.85	851.971	1	20

Appendix Table 3 (continued)
CP degradation parameters of veld hay and concentrate mixtures

Obs	ftype	diet	period	A	B	C	LT	kp	PD	ED	tylo	hay
37	3	2	1	774.333	175.838	0.08158	11.3590	0.07	950.17	868.971	0	20
38	3	2	2	699.960	271.996	0.06986	8.1496	0.07	971.96	835.825	0	20
39	3	2	3	701.614	238.725	0.08081	8.1734	0.07	940.34	829.533	0	20
40	3	2	4	747.355	206.829	0.12132	8.9444	0.07	954.18	878.507	0	20
41	4	1	1	694.624	227.851	0.09793	7.7925	0.07	922.47	827.499	1	20
42	4	1	2	733.776	196.706	0.08479	10.5759	0.07	930.48	841.526	1	20
43	4	1	3	647.516	331.595	0.04550	3.0000	0.07	979.11	778.150	1	20
44	4	1	4	688.334	250.068	0.10042	7.8541	0.07	938.40	835.685	1	20
45	4	2	1	761.603	209.251	0.07900	9.5241	0.07	970.85	872.549	0	20
46	4	2	2	622.675	353.030	0.05860	3.0000	0.07	975.71	783.549	0	20
47	4	2	3	620.838	340.318	0.05607	3.0000	0.07	961.16	772.193	0	20
48	4	2	4	711.244	239.371	0.10323	7.7929	0.07	950.61	853.887	0	20
49	5	3	1	820.085	139.224	0.08644	10.9584	0.07	959.31	897.014	1	40
50	5	3	2	654.181	293.260	0.06499	3.0360	0.07	947.44	795.375	1	40
51	5	3	3	616.830	325.326	0.07478	3.0822	0.07	942.16	784.867	1	40
52	5	3	4	582.393	363.516	0.07032	7.4449	0.07	945.91	764.571	1	40
53	5	4	1	740.347	203.692	0.07741	9.4701	0.07	944.04	847.311	0	40
54	5	4	2	680.553	283.895	0.05985	7.0334	0.07	964.45	811.407	0	40
55	5	4	3	667.738	281.803	0.05765	3.0000	0.07	949.54	795.006	0	40
56	5	4	4	759.358	219.204	0.07260	9.0120	0.07	978.561	870.961	0	40
57	6	3	1	825.913	127.487	0.11955	9.7496	0.07	953.400	906.319	1	40
58	6	3	2	806.994	142.675	0.08694	11.8462	0.07	949.668	886.030	1	40
59	6	3	3	705.157	223.673	0.08507	8.9112	0.07	928.831	827.866	1	40
60	6	3	4	821.839	108.030	0.13687	11.9268	0.07	929.869	893.315	1	40
61	6	4	1	802.383	139.070	0.08694	11.3370	0.07	941.453	879.424	0	40
62	6	4	2	693.382	238.502	0.06919	8.3214	0.07	931.884	811.942	0	40
63	6	4	3	674.986	274.109	0.05301	3.0000	0.07	949.095	793.113	0	40
64	6	4	4	825.103	142.684	0.09299	12.5384	0.07	967.787	906.509	0	40