THE EFFECT OF ZILPATEROL HYDROCHLORIDE ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS IN WEANER STEERS

BY

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DECLARATION OF ORIGINALITY

I declare that the work presented in this dissertation is original, to the best of my knowledge and belief, except as acknowledged in the text and that the material has not been submitted, either in whole or in part, for a degree at this or other universities. I also declare that I have complied with the rules, requirements, procedures and policy of the university.

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TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

ADG	Average daily gain
ARC-API	Agriculture Research Council- Animal Production Institute
BW	Live body weight
Ca	Calcium
CCW	Cold carcass weight
CF	Crude fiber
CP	Crude protein
DM	Dry matter
DMI	Daily dry matter intake
EE	Ether extract
FE	Feed efficiency
G:F	Gain to feed ration
F:G	Feed efficiency expressed as feed to gain ratio
GM	Gluteus medius
HCW	Hot carcass weight
IBR	Infectious bovine rhinotraccheitis
KPH	Kidney, pelvic and heart fat
LL	Longissmus lumborum
LM	Longissimus muscle
NDF	Neutral detergent fiber
NE	Net energy
OCM	Oil cake meal
P	Phosphorus
QG	Quality grade
TB	Triceps Brachii

TMR	Totally mixed ration
UNISA	University of South Africa
WBSF	Warner-Bratzler shear force
Wt	Weight
YG	Yield grade
ZH	Zilpaterol hydrochloride
B_1AA	Type 1 Beta- adrenergic agonist
β_2AA	Type 2 Beta- adrenergic agonist
βAA	Beta- adrenergic agonist

ABSTRACT

An experiment was conducted using forty-one Bonsmara steers (age ± 7 months) to determine the effect of zilpaterol hydrochloride (ZH) on the growth performance and carcass characteristics. The trial was structured using a completely randomized design with two treatments, control and ZH group. The steers were fed ZH for 28 consecutive days at the end of the finishing period and ZH was withdrawn from the diet 2 days prior to slaughter of the animals. The steers were placed in individual pens and weighed fortnightly throughout the 4 months trial. Zilpaterol hydrochloride (ZH) was included in the diet at a rate of 8.3 mg/kg of DM. Feeding of ZH increased ($P< 0.05$) body weight (BW) gain and ADG (1.102 vs. 1.444) and tended to increase ($P = 0.067$) feed efficiency (F:G) during the last month of the finishing period. There were no significant differences ($P> 0.05$) in daily dry matter intakes (DMI). For the control group, high treatment weight gains were significantly associated with high initial weight ($r = 0.424$, $P = 0.049$) and also high pre-treatment body weight ($r = 0.678$, $P= 0.001$). Treatment weight gain increased as the initial and pre-treatment weight gain increased in the control group. For the steers that were fed ZH, there was no significant correlation between the treatment body weight gain with initial weight ($r = 0.097$, $P = 0.694$) and also pre- treatment live weight ($r = 0.393$, $P = 0.096$). Supplementation of ZH significantly increased ($P < 0.0001$) the dressing percentage (56.4% vs. 58.4%) and had no significant ($P>0.05$) effect on the carcass weight. The outcome of the study suggest that supplementation of ZH in the diet during the last month of the finishing period enhances growth performance and shows the repartitioning capacity of the feed additive as a beta- agonist.

Keywords: Beta- adrenergic agonist, zilmax, growth performance, beef cattle, carcass characteristics

CHAPTER 1

1. INTRODUCTION

1.1 Background of study

Market cattle become inefficient during the last month of the finishing period, because they start depositing less muscle and more fat (Radunz, 2011). The use of growth promoting agents such as beta adrenergic agents (βAA) has been studied since the 1980s to improve growth performance, feed efficiency and final body weight (BW) during that period (Ricks et al., 1984b and c; Plascencia et al., 1999; Montgomery et al., 2009a and b). In addition to the improved cattle performance these βAA also increase the carcass weight, lean muscle and decrease fat deposition (Moloney et al., 1990; Chikhou et al., 1993a; Hilton et al., 2009).

Zilpaterol hydrochloride (ZH) is a βAA that has been made commercially available in Mexico, South Africa and the United States of America (USA) as Zilmax (MSD) for use in feedlot cattle during the last 20 to 40 days. Dietary inclusion of ZH in cattle results in an increase in average daily gain (ADG), improved feed efficiency (G: F) (Montgomery et al., 2009a; Avendano-Reyes et al., 2006) increased hot carcass weight, dressing percentage (Montgomery et al., 2009a, Chikhou et al.; 1993a; Fiems et al., 1993) and Longissimus muscle area (LM) (Plascencia et al., 1999).

Meat tenderness is an important factor in eating experience by consumers when consuming beef (Miller et al., 2001). Supplementation of ZH to feedlot cattle has been shown to increase Warner-Bratzler shear force (WBSF). Feeding of ZH has been shown to decrease meat tenderness by sensory panel (Hilton et al., 2009) and to also negatively affect consumer sensory scores (Hilton et al., 2009; Leheska et al., 2009). Strydom et al. (1998) demonstrated a decrease of 19% in initial and 15% in sustained tenderness with a

45-d ZH treatment. Leheska et al. (2009) also demonstrated a difference of 11% in overall tenderness of control steaks over ZH.

Hilton et al. (2009) and Leheska et al. (2009) demonstrated that supplementation of zilpaterol also decreased marbling score. However, in other studies marbling was not affected by zilpaterol treatment (Strydom et al., 1998, Plascencia et al.; 1999; Avendano-Reyes et al., 2006).

1.2 Problem statement

Although previous research studies conducted have shown other βAA such as cimaterol, clenbuterol, $L_{644,969}$ and ractopamine to increase growth performance and several carcass characteristics (Ricks et al., 1984a; Moloney et al., 1990; Chikhou et al., 1993), there is still limited data on the effects of ZH and results are contradictory. Feeding of ZH has been recently linked to lameness and heat stress in feedlot cattle in the USA. These reports are contradictory to previous research studies where feeding of ZH has been shown not to affect morbidity in cattle fed in large commercial pens (Van Donkersgoed et al., 2011; Montgomery et al., 2009b). Therefore, more experiments need to be conducted on the effects of ZH feeding in order to determine potential reasons for the inconsistent response.

1.3 Aims and objectives of the study

The overall aim of the study is to evaluate the effects of feeding ZH to Bonsmara weaner steers. The specific objectives of the study will be to determine the effects of ZH on:

a. Growth performance
b. Carcass characteristics

CHAPTER 2

2. LITERATURE REVIEW

2.1 Growth promoters

Growth promoters such as implants and beta- adrenergic agonists (βAA) are available for use in cattle to optimize production efficiency. These growth promoters primarily change partitioning of energy from feed and shuttle more to muscle instead of fat deposition, thereby increasing weight gain, ribeye area, and total red meat yield when used. Implants are products containing natural and synthetic hormones that are implanted in the ear and affect the hormone status of the animal to optimize growth (Radunz et al., 2011) whereas βAA are organic molecules that bind to adrenergic receptors and repartition nutrients to increase the lean/ adipose tissue ratio (Moody et al., 2000 and Ricks et al., 1984b) and do not affect the hormone status of the animal, thus are not steroids.

2.1.1 Beta- adrenergic agonists

Beta-adrenergic agonists (βAA) are naturally occurring or synthetic organic molecules which act upon the beta receptors. Synthetic βAA have the same chemical structure and pharmacological effect as the natural catecholamines dopamine, norepinephrine, and epinephrine (NRC, 1994; Bell et al., 1998) and can be subdivided into type 1 (β_1AA) and type 2 (β_2AA). Adrenergic receptors are cell membrane receptors (Blair, 1983) and can be categorized into α and β receptors. β- receptors are categorized into two types known as β-1 and β-2 receptors which are characterized by differing infinity for adrenalin and nor- adrenalin. β_1 receptors have an affinity for two catecholamines and contract the heart muscle, whereas β_2 receptors have an affinity for adrenalin and causes smooth muscle relaxation (Lands et al., 1967). The effects of βAA are pronounced in ruminants,

with stimulation of β-adrenergic receptors on cell surfaces causing substantially increased skeletal muscle mass, cross-sectional area of individual muscles, or both (Chung and Johnson, 2008).

Strong type 2 beta adrenergic agonists (β_2AA) such as clenbuterol (Schiavetta et al., 1990), $L_{644,\ 969}$ (Moloney et al., 1990; Wheeler and Koohmaraie, 1992), and cimaterol (Quirke et al., 1988) have been shown to improve ADG and G:F and to also increase lean muscle and decrease fat deposition (Ricks et al., 1984b; Moloney et al., 1990; Chikhou et al., 1993b) as well as negatively affecting the beef shear force (Miller et al., 1988; Boucque et al., 1994; Moloney et al., 1994) when fed to cattle. The undesirable effect of these βAA on meat tenderness and shear force has been associated with an increase in preiger muscle calpastatin activity (Bardsley et al., 1992; Wheeler and Koohmaraie 1992; Luno et al., 1999). However, when the βAA zilpaterol hydrochloride (ZH) is supplemented, the μ- calpain and calpastating activities are not affected (Hilton et al., 2009).

Clenbuterol also decreases meat sensory panel scores for tenderness and juiciness (Luño et al., 1990). Geesink et al. (1993) demonstrated postmortem aging and muscle proteolysis to be significantly reduced in veal calves when clenbuterol is supplemented. Luño et al. (1999) and Wheeler and Koohmaraie (1992) also found similar results, where clenbuterol greatly reduced postmortem aging of muscles in heifers and steers as determined by sensory tenderness, WBSF and myofibril fragmentation index.

Schroeder et al. (2003) demonstrated that the supplementation of 300 mg/ animal/ day of βAA ractopamine increased the beef shear force, decreased trained sensory panel initial and sustained tenderness scores whereas juiciness, beef flavor and off- flavor were not

affected by the treatment. However, he also demonstrated that decreased doses of 100 and 200 mg/ animal/ day of ractopamine did not affect WBSF or sensory scores.

In an experiment conducted by Van Donkersgoed et al. (2011) with heifers comparing effects of ZH and ractopamine treatments, cattle fed ZH had a reduced feed intake (0.3 kg/ day) and had a heavier HCW (9.7 kg more). Other previous research studies have also demonstrated more carcass weight in steers fed ZH compared to ractopamine (Avendano- Reyes et al., 2006; Scramlin et al., 2010). It was also found that there were fewer Prime and AAA carcasses and more AA and A carcasses from heifers supplemented with ZH than from those fed ractopamine (Van Donkersgoed et al., 2011). The greater effectiveness of β_2AA in comparison to ractopamine hydrochloride may have been due to the predominant distribution of β- adrenergic receptor subtypes in bovine muscle and adipose tissue (Winterholler et al., 2007)

2.1.2 Factors affecting effectiveness of beta- adrenergic agonists

a. Age of animal

When βAA are fed to younger cattle, they demonstrate little or no response in muscle deposition or efficiency thus resulting in not being cost effective to feed (Radunz, 2011). In most animals, the performance in response to βAA treatment is optimized with animal maturity. In a study when clenbuterol was supplemented, lambs with an initial weight of about 40kg gained more than the control but the βAA had no effect on the weight gain of the lambs with an initial weight of 37.5kg (Baker et al., 1984). Williams et al. (1986) also found that clenbuterol had no effect on the growth performance of veal calves.

b. Period of feeding Beta- adrenergic agonist

Previous research trials have reported the use of ZH to be effective 20 to 40 days before slaughter. After this period the performance returns to the level prior to using the β-agonist. The body adapts to the active ingredient during this time and thus loses its efficiency (Radunz, 2011).

c. Dosage

Research trials have reported that feeding β- agonists at higher levels show little to no improvement on animal performance or muscle deposition and are not cost effective (Radunz, 2011). ZH has been approved for feeding to feedlot cattle at the rate of 7.5 to 8.3 mg/kg of DM (FDA, 2006).

d. Withdrawal period

Approximately 4 to 8 days after βAA are withdrawn from the diet, performance will return to the same level prior to the use of the feed additive. Hence, the animal will start to shift more energy to fat synthesis rather than muscle deposition. However, due to the rapid elimination (>95% in 72h), mainly via the urine (Shelver and Smith 2006), a withdrawal period of greater than 72h may result in the reversal of growth performance and carcass yield gains. Robles-Estrada et al., (2009) found that prolonging the period of ZH withdrawal pre-slaughter tended to decrease carcass adjusted ADG, G: F, apparent dietary net energy (NE), carcass dressing percentage and percentage lean yield. Beta-adrenergic agonists having hydroxilated aromatic rings (like ZH) are metabolized by conjugation and have relatively short plasma half-lives (Sumano et al., 2002).

e. Pen size

Greater responses have been observed in cattle fed in small research pens versus in large commercial feedlot pens. Montgomey et al. (2009a) reported a lower increase in ADG (14.2%) and feed efficiency (15.5%) when feedlot steers were fed zilpaterol in commercial large pens, whereas other researchers conducting experiments in smaller pens observed a higher increase. For example, Plascencia et al (1999) reported a 37% increase in ADG and a 39% increase in feed efficiency, respectively.

f. Days on feedlot diet

In a large pen in a commercial study with feedlot steers, ractopamine was shown to increase ADG (4.5%) and G: F (4.0%) over the entire 150 to 192-day feeding period, when it was fed during the final 28 days of feed but increasing days on feed from 150 to 192 decreased ADG, G: F and DMI (Winterholler et al., 2007).

g. Rate of absorption

The effectiveness of ZH for promoting growth performance depends, in part, on the rate of absorption from the digestive tract and its half-life in tissues and body fluids (Murdoch et al., 2005). Other factors affecting efficiency include the degree of endogenous transformation and excretion rate (Smith, 1998).

h. Sex of the animal

In a study with poultry, Clenbuterol has been found to reduce abdominal fat and increase carcass protein in females only (Dalrymple et al., 1984a). In pigs clenbuterol reduced the rate of gain in barrows, but not in gilts (Ricks et al., 1984c).

i. Breed

Research data on the effect of breed on the efficacy of βAA is still limited. The efficacy of clenbuterol has been demonstrated to be influenced by the strain in rats (Berne et al., 1985).

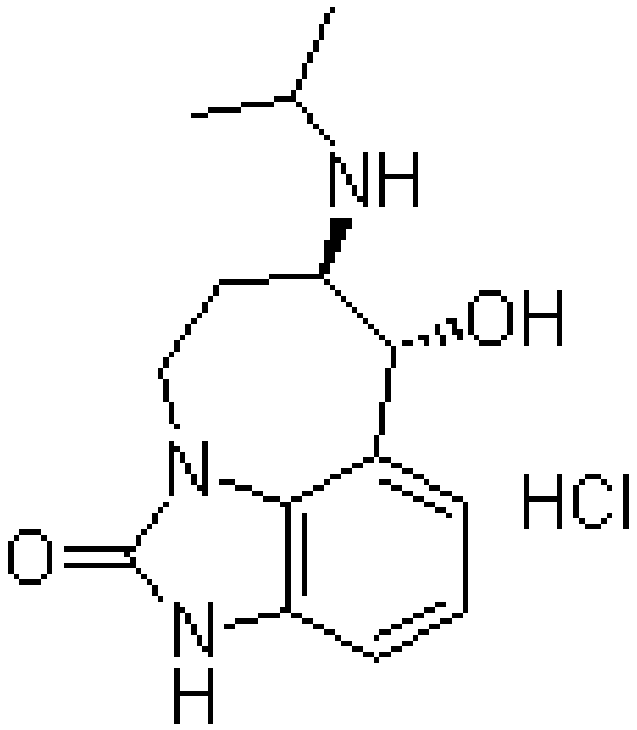
2.1.3. Negative consequences to feeding beta- adrenergic agonists

Research has not observed any negative effects on animal conformation. However, cattle with poor skeletal structure (post legged, straight fronted), the added muscle could cause these problems to become more evident (Radunz, 2011)

2.2 Zilpaterol hydrochloride

Zilpaterol hydrochloride (ZH) is a type 2 beta-adrenergic agonists (β_2AA) that is commercially available and functions as a repartitioning agent similar to other βAA (Hilton et al., 2009). The repartitioning capacity of βAA like ZH (Hilton et al., 2009; Ricks et al., 1984b), clenbuterol and ractopamine hydrochloride (Anderson et al., 1989) has been shown by a decrease in estimated carcass fat, increase in the estimated carcass protein and moisture. However, Ricks et al. (1984a) and Fiems et al. (1993) have observed that clenbuterol and cimaterol have much greater effect on decreasing estimated carcass fat than ZH (Hilton et al., 2009).

Figure 1. Molecular structure of zilpaterol hydrochloride



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2.2.1 Effects of zilpaterol hydrochloride on:

a. Performance of feedlot cattle

Previous research conducted on feedlot steers has shown that zilpaterol hydrochloride (ZH) increases BW gain and G: F (Plascencia et al. 1999, Montgomery et al., 2009a and b; Casey et al., 1997b). In a study done by Montgomery et al. (2009b) to determine the effect of the feeding duration of ZH, dry matter intake (DMI) was significantly reduced by ZH supplementation in heifers. In the same study heifers and steers fed ZH for the duration of 40 days had greater DMI than the ones fed for the duration of 20 days but ADG and G: F were not affected. In contrast to that in a study done by Vasconcelos et al. (2008), ZH was found to decrease DMI as the duration of feeding the additive increased from 20 to 40 days and to also increase the FE.

In previous research studies where cattle were fed in small pens, no effects of feeding ZH (Montgomery et al., 2009b) or ractopamine (Schroeder et al., 2003; Gruber et al., 2007) on mortality were found. However, Montgomery et al. (2009a) observed that feeding of ZH increased mortality in steers fed in commercial large pens. Feeding of ZH has been shown not to affect morbidity in cattle fed in large commercial pens (Van Donkersgoed et al., 2011; Montgomery et al., 2009b).

b. Carcass characteristics

Feeding of βAA has been reported to result in increased hot carcass weight (HCW) and dressing percentage (Chikhou et al., 1993a; Fiems et a., 1993; Avendano-Reyes., 2006; Montgomery 2009a). Previous research studies have demonstrated that feeding of ZH has been shown to increase dressing percentage, HCW and longissimus muscle (LM) area, whereas kidney, pelvic and heart fat (KPH) and marbling score were generally not affected (Casey et al., 1997a, b.; Plascencia et al., 1999; Robles-Estrada et al., 2009). ZH has also been shown to reduce yield grade (YG) and quality grade (QG) in feedlot heifers (Montgomery et al., 2009b; Robles- Estrada et al., 2009).

Although previous trials have demonstrated no effects of ZH on the 12^{th}- rib fat thickness (Casey et al., 1997a; Plascencia et al., 1999), Montgomery et al., (2009a) found a 9.5% decrease in the 12^{th}- rib fat thickness when ZH was fed. He also demonstrated that the empty body fat was 3.3% less for steers fed ZH, resulting from decreased 12^{th}-rib fat thickness and quality grade, and increased HCW and LM area. The author was of the opinion that ZH increases mature body size of steers fed βAA compared with the control at a common body composition (Owens et al., 1995; Guiroy et al., 2002) and is consistent with increased synthesis or decreased degradation of muscle protein (Beermann, 2002) and increased lipolysis, decreased fatty acid synthesis and esterification, or both (Mersmann, 2002).

Montgomery et al., (2009a) and Avendano-Reyes et al., (2006) also noted an increase in HCW that was greater than the increase in final BW when ZH was fed. This suggests a shift in mass from non-carcass to carcass tissues when βAA is fed. Several factors could have caused that, including decreased gut fill due to reduced feed intake, a greater repartitioning of fat and muscle in carcass than non-carcass tissues, or both (Montgomery et al., 2009a).

c. Liver abscesses

Research data regarding βAA effects on liver abscess is still limited. Although Montgomery et al., (2009a) found that supplementation of steers with ZH resulted in a decrease in liver abscess in spite of whether tylosin was fed in combination, Montgomery et al., (2009b) found that liver abscess rate was not affected when zilpaterol was fed. Montgomery et al., (2009a) suggested that the decrease in liver abscess when ZH was fed may be due to the decreased feed intake that occurs when ZH and other βAA are supplemented (Reeds and Mersmann, 1991; Bareille et al., 1997).

d. Warner- Bratzler shear force (WBSF) values

Supplementation of ZH has been shown to increase WBSF (Hilton et al., 2009; Leheska et al., 2009). Supplementation of ZH for 30 to 50 days has also been shown to increase WBSF of steaks from South African beef steers by 20 to 28% (Strydom et al., 2002) and to decrease with postmortem aging (Strydom and Nel, 1996). Hilton et al., (2009) reported that WBSF significantly decreased from 7 to 21 days postmortem among steaks from animals supplemented with ZH for 30 days. In contrast to other research studies, O' Neill (2001) observed no differences in shear forces values for meat from control and treatment cattle and the author was of opinion that ZH did not reduce beef tenderness.

Strydom and Nel (1996) documented the effect of ZH supplementation on the shear force of several muscles, including triceps brachii. They found no difference between control and treated shear force values taken at 7 and 14 days postmortem. Brooks et al., (2009) reported a significant increase in WBSF of longissimus lumborum (LL), Triceps Brachii (TB) and Gluteus medius steaks (GM) steaks.

e. Meat palatability

Supplementation of ZH has also been shown to affect consumer sensory scores (Hilton et al., 2009; Leheska et al., 2009). Hilton et al. (2009) reported a decrease in trained sensory panel juiciness, tenderness, beef flavour intensity and beef flavour by steaks from steers fed ZH compared to control. He also found that ZH treatment did not affect LM sensory panel off-flavour scores. The effects on juiciness, flavour intensity and beef flavour may have been attributed to decreased marbling (Montgomery et al., 2009 a and b).

However in the same experiment, consumer overall acceptability, overall quality, beef flavour and juiciness were not affected by ZH treatment. Shackelford et al. (1991) demonstrated that LM WBSF limit was 4.6 kg for 88.6% consumer acceptance, whereas Miller et al. (2001) reported a LM WBSF threshold of 4.00 kg for 94% consumer satisfaction. The author concluded that ZH effects on shear force reduced with postmortem aging and tenderness of LM aged 14 days does not appear to adversely affect consumer acceptance of beef from ZH-treated cattle compared with cattle not fed ZH.

CHAPTER 3

3. METHODOLOGY

The study was conducted at the Agricultural Research Council - Animal Improvement Institute (ARC- API) Coordinates: 25º 53' 59.6" S 28º 12' 51.6" E, cattle feedlot and abattoir in Irene, Gauteng, South Africa. Animal ethical approval was obtained from the ARC – API and University of South Africa (UNISA) animal ethics committee.

3.1 Animal management

Forty one Bonsmara steers (age ±7 months, mean BW ±220 kg) were used for the experiment in 2012. For the first five days, the steers were maintained in holding pens with fresh water and fed hay *ad libitum*. The steers were subsequently processed on day five after arrival which included the following: weighing, vaccination against botulism and anthrax (Botuthrax, MSD), clostridial organisms (Covexin, Coopers), infectious bovine rhinotracheitis (IBR) and other respiratory diseases (Bovishield Gold 5, Pfizer), deworming (Lintex- 1, Bayer) and treated for external parasites, eartaged, implanted with Revalor S growth promoter (MSD). The steers were then placed in individual pens and weighed every two weeks throughout the four months trial. The steers were randomly allocated to the two treatments which consisted of ZH (22 steers) and control (without ZH) (19 steers).

3.2 Diets and treatments

During the first 18 days the steers were gradually adapted to a high concentrate diet (95%) using four transitional diets. Zilpaterol hydrochloride was included in one of the treatment diets for 28 consecutive days from day 89 and was withdrawn from the diet two days prior to slaughter of the animals. Feed bunks were evaluated visually in the morning

to determine the quantity of feed remaining from the previous day. Daily feed allotment to each pen was adjusted by < 5% to allow feed accumulation in the feed bunk. Contaminants in feed bunks were removed on a daily basis and orts were removed on a weekly basis. Feed refusal was measured and dry matter intake (DMI) was calculated. Feed ration samples were taken to the ARC- API commercial laboratory for nutrient analysis. The ingredient and nutrient composition of the final concentrate diet fed is shown in the following Table 1.

Table 1. Feed ingredients (%) and nutrient composition (g/kg DM, unless stated otherwise) of the finishing diet[1]

Item	***Control***[2]	***Zilpaterol***[3]
Ingredient,		
Hominy chop	62	62
Wheat bran	15	15
Molasses meal	10	10
Cotton OCM[4]	5	5
Grass hay	4.5	4.5
Feedlime	1.6	1.6
Urea	1.3	1.3
Salt	0.5	0.5
*Premix	0.1	0.1
Zilpaterol HCl[5] mg/kg	0	8.3
Nutrient composition (g/kg DM, unless states otherwise),		
Dry matter	873.3	873.3
Crude protein	149.2	149.2
Fat	63.4	63.4
NDF	444.8	444.8
Crude fibre	95.8	95.8
ME (MJ/kg DM)[6]	11.41	11.41
Starch	278.4	278.4
Calcium	7.3	7.3
Phosphorus	5.2	5.2

[1]Finishing diet for the last 30 on feed, from start of zilpaterol hydrochloride (ZH) supplementation until slaughter
[2]Treatment without ZH in diet
[3]Treatment with ZH in diet
[4]aottonseed oil cake meal
[5]Zilpaterol Hydrochloride
[6] Metabolizable energy, estimated from gross energy (NRC, 1996)
*Containing : 6×106 IU vit A; 3 g vit B1; 3.5 g; 30 g iron; 12 g Cu; 50 g, Monensin included at 33mg/kg feed.

3.3 Health observations

Animals were observed daily for signs of morbidity and other health conditions and recorded where applicable.

3.4 Slaughter and carcass evaluation

The cattle were slaughtered at the ARC abattoir. Hot carcass weights (HCW) were recorded on the day of slaughter. After the carcasses were chilled for 48 hours, the cold carcass weight (CCW) was measured. The dressing percentages were calculated as follows: (Hot Carcass Wt./Live Animal Wt.) X100. Fat scores were evaluated using the following scale: 0 = no fat, 6 = excessive fat. Dressing percentages were calculated.

3.5 Statistical Analysis

The data were analyzed using SPSS version 21. 2012. Pearson correlation coefficients between initial and pre-treatment weights with pre-treatment and treatment weight gains were computed. Independent samples t-tests were used to assess differences between means of the control steers and steers fed ZH on various growth performance indicators. Differences were regarded as significant at $P < 0.05$.

CHAPTER 4

4.1 RESULTS

No incidences of mortality or morbidity were observed and special attention was made to observe for lameness, but no symptoms were observed. Means and standard errors for feedlot performance of the steers are presented in Table 2.

Table 2. Means and SEM showing the effect of zilpaterol hydrochloride (ZH) on feedlot cattle performance

Item	Control	ZH[1]	SEM	P-value
Number of steers	22	19		
Initial wt, kg	208.8	205.2	7.49	0.633
Pre-treatment wt, kg	340.1	335.0	8.92	0.568
Final wt, kg	375.4	381.2	12.03	0.632
BW gain, pre-treatment, kg	131.3	129.8	6.90	0.826
BW gain, treatment, kg	35.3[b]	46.2[a]	4.73	0.026*
BW gain, day 1- end, kg	166.6	176.0	9.89	0.347
ADG, pre-treatment, kg/d	1.39	1.35	0.09	0.655
ADG, treatment, kg/d	1.10[b]	1.44[a]	0.15	0.026*
ADG, day 1- end, kg/d	1.32	1.38	0.09	0.580
DMI, pre-treatment, kg/d	6.568	6.471	0.30	0.747
DMI, treatment, kg/d	7.862	8.100	0.41	0.568
DMI, day 1- end, kg/d	6.876	6.853	0.31	0.942
F:G, pre-treatment, kg/kg	4.869	4.849	0.24	0.933
F:G, treatment, kg/kg	7.693	6.354	0.71	0.067
F:G day 1- end, kg/kg	5.356	5.090	0.27	0.327

*Means differ significantly at P < 0.05.
[1]ZH- Zilpaterol hydrochloride
BW- Body weight
ADG- Average daily gain;
DMI- Daily dry matter intake;
F:G– feed to gain ratio, kg dry matter intake/ kg gain
wt- weight

There were no significant differences (P > 0.05) on initial and pre-treatment body weights between the control and zilpaterol hydrochloride (ZH) group (Figure 2). Zilpaterol hydrochloride supplementation had no significant (P > 0.05) effect on the final body weights of the steers.

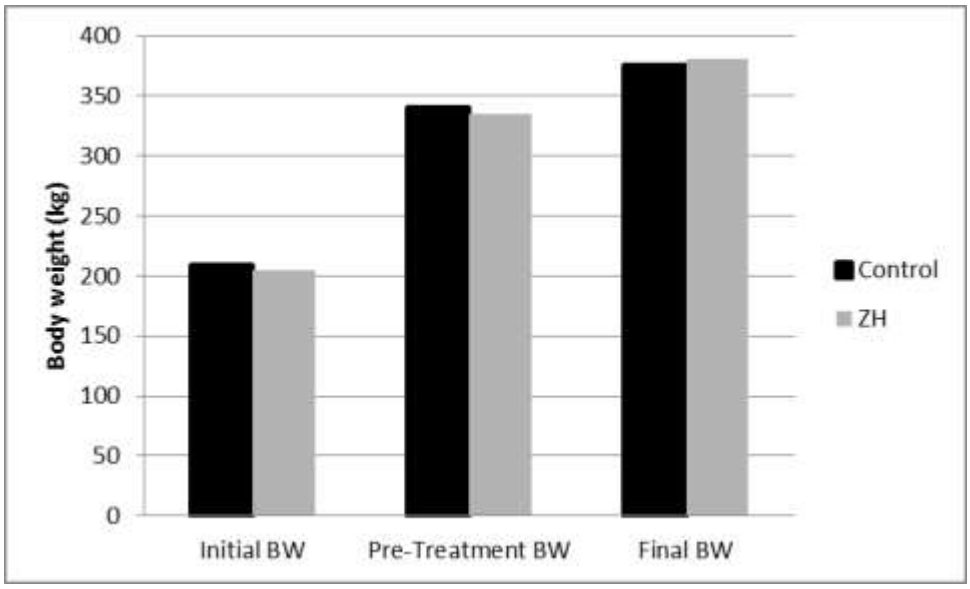

Figure 2. Mean live body weight (BW) of the steers

The mean total live BW gains are illustrated in Figure 3. No significant differences (P> 0.05) on pre-treatment and overall BW gain were observed between the two groups. However, steers fed ZH had a significantly higher BW gain during the last 30 days of finishing period compared to the control steers (P = 0.026). Supplementation of ZH to the steers increased the BW gain by 10.9 kg (23.59%) during the last 30 days.

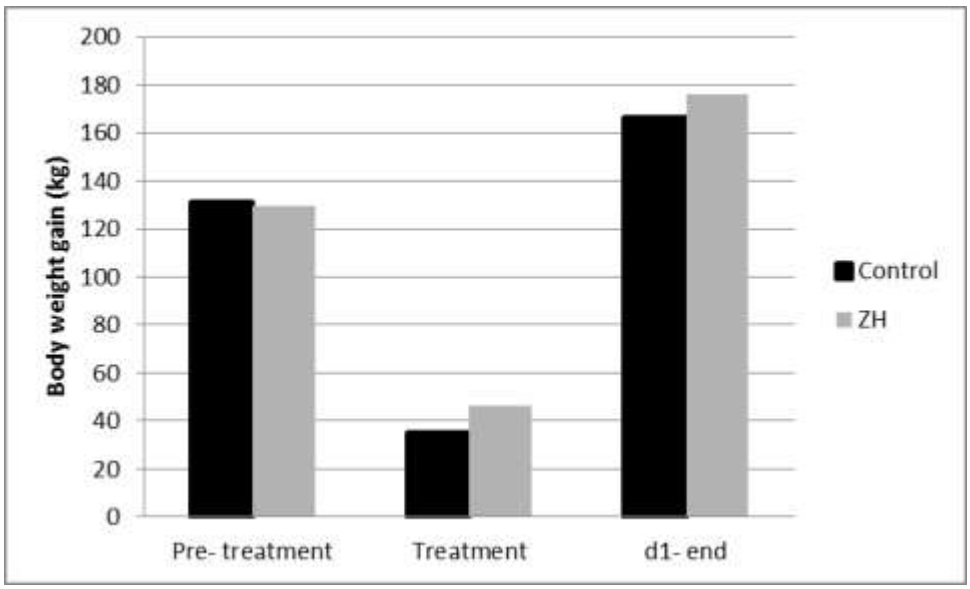

Figure 3. Mean live body weight (BW) gains of the steers

Effect of initial weight on the last 30 days weight gain is shown in Figure 4. Effect of pre-treatment weight on the last 30 days weight gain is shown in Figure 5. Steers fed ZH gained more weight than the control during the treatment period. Pearson correlation analysis showed that there was significant positive correlation ($r = 0.424$, $P = 0.049$) between the initial weight and treatment weight gain and between the pre-treatment weight and treatment weight gain ($r = 0.678$, $P = 0.001$) during the last 30 days of the finishing period for the control group. High treatment weight gains are significantly associated with high initial weight and with high pre-treatment weights. Treatment weight gain increased as the initial and pre-treatment weight gain increased in the control group. For the ZH group, treatment weight gains were not significantly associated with initial weight ($r = 0.097$, $P = 0.694$) and pre- treatment body weight ($r= 0.393$, $P = 0.096$).

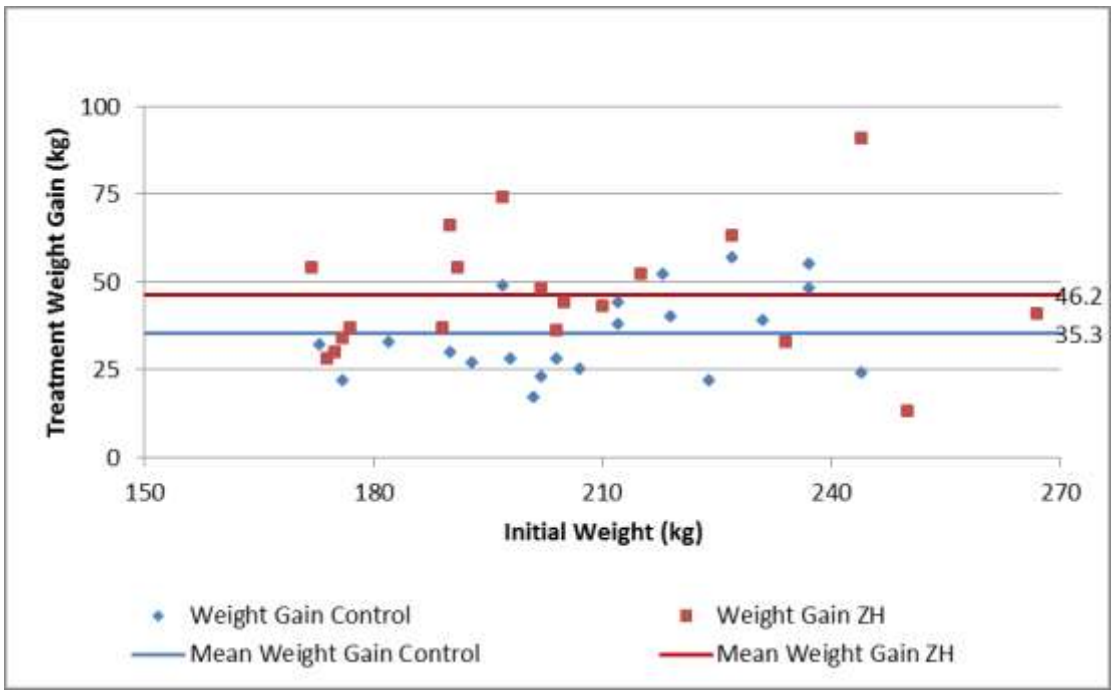

Figure 4. Effect of initial weight on treatment weight gain during the last 30 days.

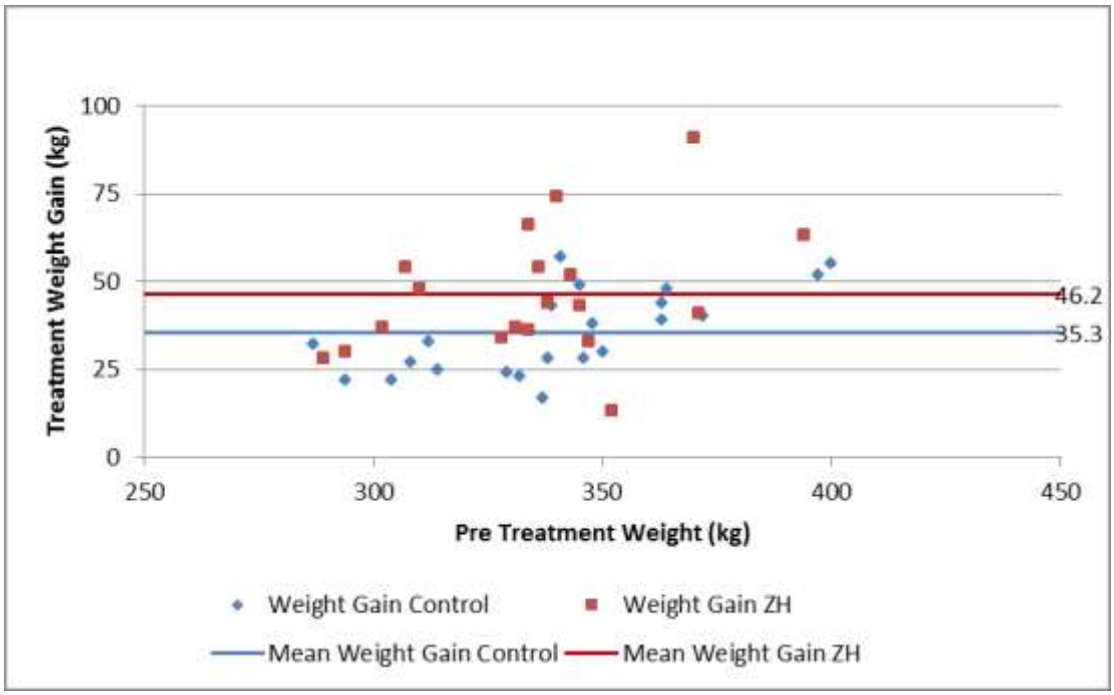

Figure 5. Effect of pre-treatment weight on treatment weight gain during the last 30 days.

The mean of average daily gains (ADG) of the steers during different periods of fattening are presented in Figure 6. Steers fed ZH had greater ADG during the last 30days of the trial compared to the control group ($P < 0.05$). As the treatment BW gain increased, the treatment ADG also improved. There were no significant differences ($P > 0.05$) observed on the daily dry matter intake (DMI) for the two treatments throughout the whole trial.

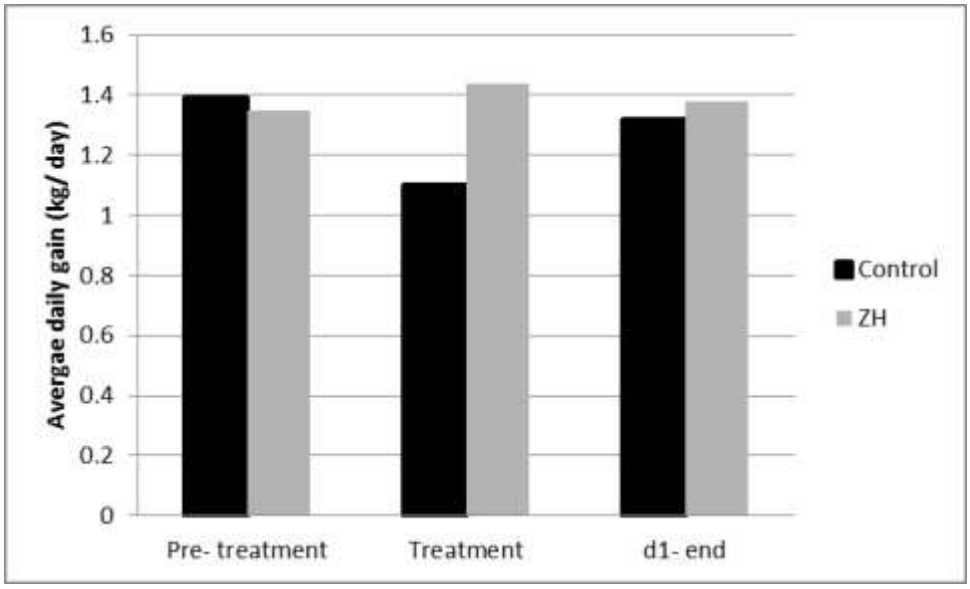

Figure 6. Mean average daily gains (ADG) of the steers

Feed efficiency (F: G) of the steers is presented in Figure 7. Pre- treatment feed conversion ratio was similar between the control and the steers fed ZH. ZH supplementation did not significantly influence the overall F:G but tended ($P = 0.067$) to increase the treatment F:G during the last month of the trial.

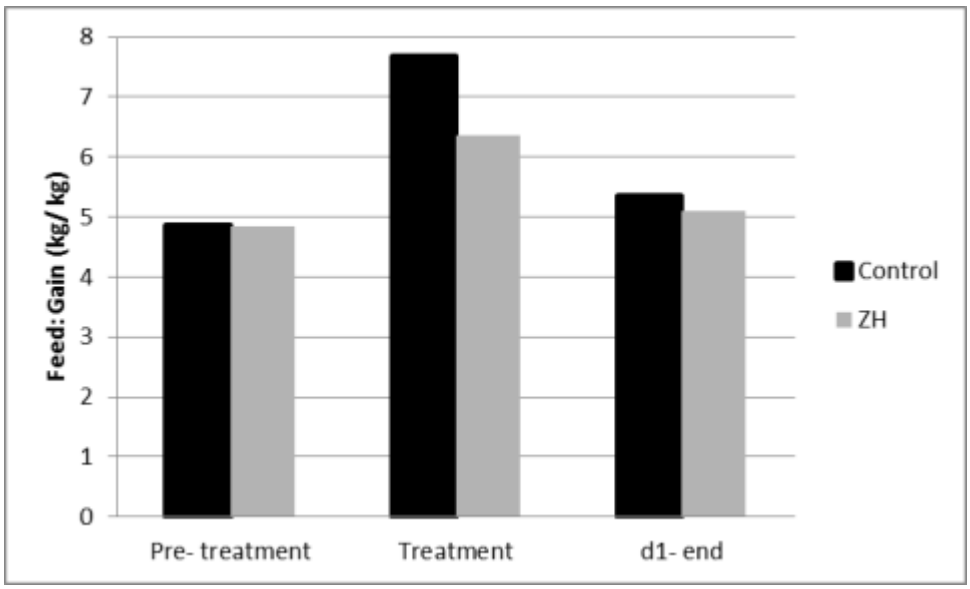

Figure 7. Mean feed efficiencies (F:G) of the steers

The effect of ZH on carcass characteristics of the steers is presented in Table 3.

Table 3. Effect of zilpaterol hydrochloride (ZH) on carcass characteristics of the steers

Item	Control	ZH	SEM	P- value
No. of carcasses	22	19		
Warm carcass wt.	211.8	222.7	7.01	0.129
Cold carcass wt.	208.7	219.6	6.97	0.126
Dressing percentage	56.4[b]	58.4 [a]	0.51	0.000*
Fat score (%):				
+1	0	5.3		
-2	4.5	5.3		
2	54.5	63.2		
+2	4.5	0		
-3	13.6	15.8		
3	18.2	10.5		
+3	4.5	0		

ZH- Zilpaterol hydrochloride
Fat score: 0-6 Scale; 0 = No fat, 6 = Excessive fat

Supplementation of ZH to the steers had no significant effect (P > 0.05) on the hot and cold carcass weights (Figure 8). However, steers fed ZH had heavier carcasses compared to the control group by 10.9 kg.

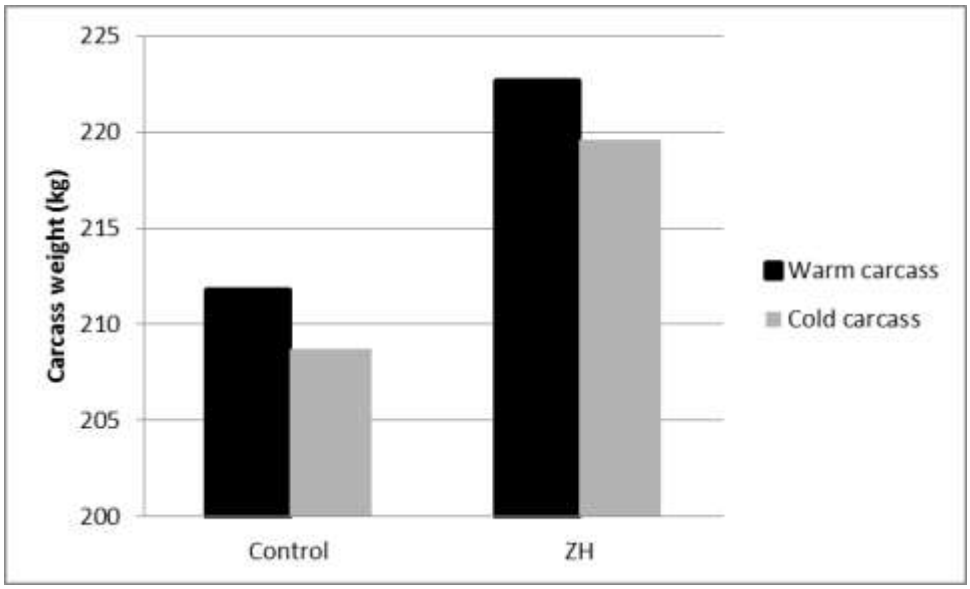

Figure 8. Effect of ZH on carcass weights of the steers

The dressing percentage was significantly higher (P = 0.0000) for the steers fed ZH by 2% (Figure 9).

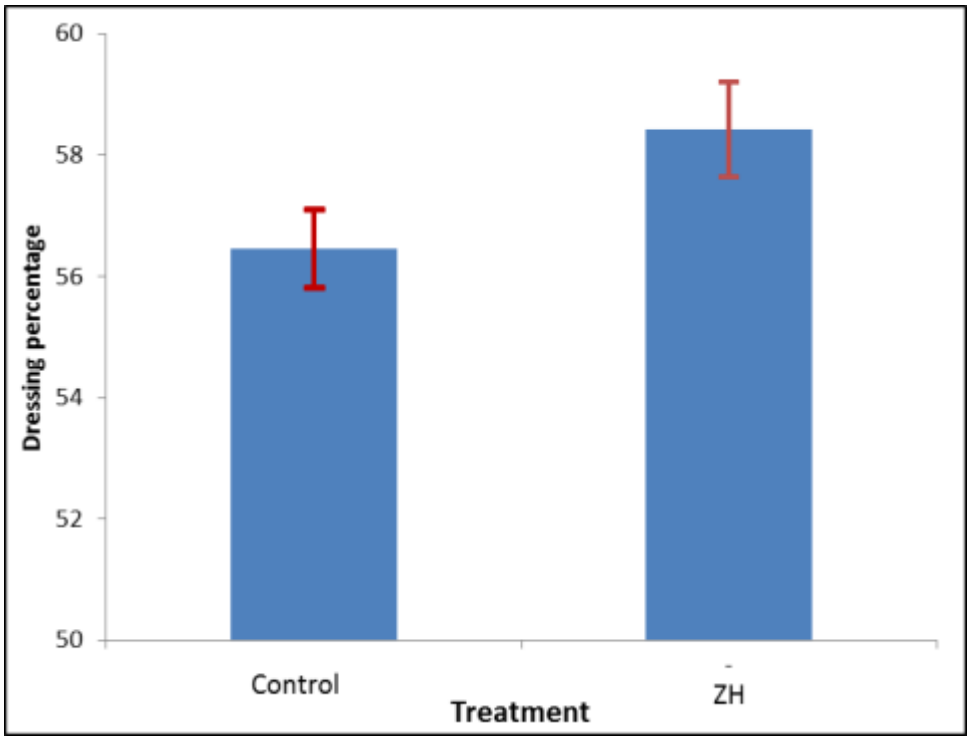

Figure 9. Mean of dressing percentages (Bars showing SE)

All the steers had a conformation of 3 and class of 1. Fat code classification of the carcasses is presented in Figure 10. Most steers had a carcass fat code of 2 (Lean).

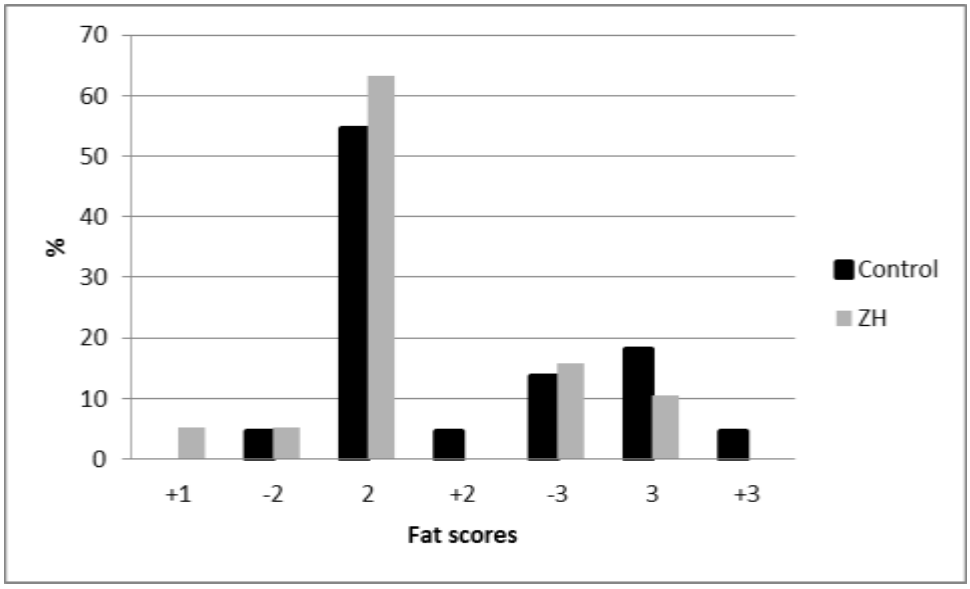

Figure 10. Fat code classification of the carcasses
Fat scores: 0 = No fat, 6 = Excessive fat

CHAPTER 5

5.1 DISCUSSION

The results of the present study are similar to those observed by Holland et al. (2010), who also found that ZH supplementation had no effect on the final BW. The results of the present study also revealed that higher live body weight gains during the last 30 days of fattening were positively associated with higher initial and pre-treatment body weights (BW) in the control group. However, for the steers fed ZH, they was no association between the treatment weight gain with the initial weight and pre-treatment weight. This suggests that ZH supplementation during the last 30 days of fattening enhanced live body weight gain during that phase.

In the present trial, ZH supplementation had a positive effect on the ADG of the steers during the last 30 days of fattening compared to the control group. Casey et al. (1997b) and Montgomery et al. (2009a) also reported an increase in ADG when ZH was supplemented to the diet. In previous trials conducted using other animals, an enhanced growth performance has been described as the effect of βAA when compared to controls. An increase in the rate of BW gain has been observed when cimaterol a βAA was fed to broilers (Dalrymple et al., 1984b), pigs (Walker et al., 1989) and also in lambs (Beermann et al., 1986).

The effect of feeding ZH on DMI is inconsistent and varies among the previous research trials. The outcome of this study is similar to a study by Avendano-Reyes et al. (2006) who reported no significant differences in daily DMI when ZH was supplemented to the diet. However, the results are in contrast to those reported by Holland et al. (2010), who showed that ZH supplementation for 20 days decreased (P=0.02) DMI at the end of the finishing period. The improved feed efficiency has been described as the effect of ZH in previous studies (Plascencia et al., 1999; Beckett et al., 2009; McEvers et al., 2013).

Steers used in this trial exhibited lower feed efficiency than those observed in other ZH studies.

The higher dressing percentages of steers fed ZH in the present study, is comparable to previous reports of the effects of ZH on dressing percentage (Avendano-Reyes et al., 2006; Montgomery et al., 2009a; Chikhou et al., 1993; Fiems et al., 1993). In this study ZH tended to increase carcass weight. Montgomery et al. (2009b) reported that the HCW of steers fed ZH were 16.4 kg heavier and the dressing percentage also increased by 1.5% compared to the control. The results of this study suggest the repartitioning capacity of ZH as a beta-adrenergic agonist. Feeding of βAA enhances muscling of the carcass and this was shown by an increase in the carcass weight. Most steers had a carcass fat score of 2 (lean) which is desirable for consumers in South Africa.

CHAPTER 6

6.1 CONCLUSION AND RECOMMENDATIONS

The outcome of the study demonstrated that ZH has the capacity to repartition tissue growth in steers to improve the carcass characteristics and yield. ZH significantly increased the rate of live BW gain during the last 30 days of fattening and also increased the muscle weight without causing any morbidity and mortality. ZH also did not cause any lameness in the cattle. The results of this study are similar to previous research trials, where ZH enhanced growth performance of the steers. More experiments with ZH need to be conducted in order to determine the factors affecting the efficacy of the βAA.

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APPENDIX

ANALYSIS OF ZILMAX DATA

Group Statistics

	Treatment 1 (N= 22)		Treatment 2 (N= 19)	
Treatment	Mean	Std. Deviation	Mean	Std. Deviation
Initial Weight	208.8	19.716	205.2	28.053
Pre-Treatment Weight	340.1	29.790	335.0	26.870
Final Weight	375.4	38.834	381.2	37.903
Pre-Treatment Weight gain	131.3	24.849	129.8	18.204
Treatment Weight Gain	35.3	11.869	46.2	18.177
Final Weight gain	166.6	32.246	176.0	30.781
Pre-Treatment Average Daily Gain	1.392	0.328	1.352	0.231
Treatment Average Daily Gain	1.102	0.371	1.444	0.568
Final Average Daily Gain	1.324	0.312	1.376	0.282
Pre-Treatment Dry Matter Intake	6.568	1.006	6.471	0.882
Treatment Dry Matter Intake	7.862	1.413	8.100	1.201
Final Dry Matter Intake	6.876	1.070	6.853	0.856
Pre Treatment Feed Conversion Ratio (F:G)	4.869	0.874	4.849	0.658
Treatment Feed Conversion Ratio (F:G)	7.693	2.050	6.354	2.507
Final Feed Conversion Ratio	5.356	0.941	5.090	0.744
Warm Carcass Weight	211.8	22.003	222.7	22.828
Cold Carcass Weight	208.7	21.781	219.6	22.778
Dressing Percentage	56.4	1.524	58.4	1.710

Table 1 Means and standard deviations for the various measurements

Carcass fat scores

Fat Code	Treatment 1 *N* (%)	Treatment 2 *N* (%)
+1	0 (0.0%)	1 (1 (5.3%)
-2	1 (4.5%)	1 (5.3%)
2	12 (54.5%)	12 (63.2%)
+2	1 (4.5%)	0 (0.0%)
-3	3 (13.6%)	3 (15.8%)
3	4 (18.2%)	2 (10.5%)
+3	1 (4.5%)	0 (0.0%)

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	T	df	***p-value*** (2-tailed)	Mean Difference	Std. Error Difference	Comments
Initial Weight	2.135	.152	.481	39	.633	3.61	7.49	No significant difference
Pre-Treatment Weight	.257	.615	.576	39	.568	5.14	8.92	No significant difference
Final Weight	.221	.641	-.482	39	.632	-5.80	12.03	No significant difference
Pre-Treatment Weight gain	.463	.500	.222	39	.826	1.53	6.90	No significant difference
Treatment Weight Gain	1.881	.178	-2.311	39	**.026**	-10.94	4.73	**Significant difference Treatment 2 has a significantly higher treatment weight gain (mean = 46.2kg, std dev = 18.18) than Treatment 1 (mean = 35.3kg, std dev = 11.87) Note that the coefficient of variation (cv) is 39.4% for Treatment 2 and 33.6% for Treatment 1. Thus the trt weight gains for treatment 2 are relatively more dispersed (or more variable) than the trt weight gains in Treatment 1.**
Final Weight gain	.031	.861	-.951	39	.347	-9.41	9.89	No significant difference
Pre-Treatment Average Daily Gain	.976	.329	.450	39	.655	.04	.09	No significant difference
Treatment Average Daily Gain	1.881	.178	-2.311	39	**.026**	-.34	.15	**Significant difference**

								Treatment 2 (mean = 1.44kg, std dev = 0.57) has a significantly ADG than Treatment 1 (mean = 1.10kg, std dev = 0.37) Note that this information is simply a repetition of the results for Trt Weight Gain, since ADG is simply the trt weight gain divided by the nuber of days on treatment (in this case 32 days).
Final Average Daily Gain	.074	.786	-.558	39	.580	-.05	.09	No significant difference
Pre-Treatment Dry Matter Intake	.022	.883	.326	39	.747	.10	.30	No significant difference
Treatment Dry Matter Intake	1.042	.314	-.576	39	.568	-.24	.41	No significant difference
Final Dry Matter Intake	.473	.495	.073	39	.942	.02	.31	No significant difference
Pre Treatment Feed Conversion Ratio (F:G)	.132	.718	.084	39	.933	.02	.24	No significant difference
Treatment Feed Conversion Ratio (F:G)	.000	.993	1.882	39	.067	1.34	.71	No significant difference
Final Feed Conversion Ratio	.378	.542	.993	39	.327	.27	.27	No significant difference
Warm Carcass Weight	.003	.954	-1.552	39	.129	-10.88	7.01	No significant difference
Cold Carcass Weight	.000	1.000	-1.565	39	.126	-10.91	6.97	No significant difference
Dressing Percentage	.091	.765	-3.898	39	**.000**	-1.97	.51	**Significant difference Treatment 2 has a significantly higher Dressing percentage (mean = 58.4%, std dev = 1.71) than Treatment 1 (mean = 56.5%, std**

								dev = 1.52) Note that the coefficient of variation (cv) is 2.9% for Treatment 2 and 2.7% for Treatment 1. Thus there is not much difference in the dispersion (or variability) in the dressing percentages observed in the two groups.

Table 2: Independent Samples Tests for differences between the means of Treatment 1 and Treatment 2