The effect of environmental enrichment on behaviour, production parameters and meat quality of finishing lambs in a feedlot.

by

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DECLARATION

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NOTES

This thesis is presented in the format prescribed by the Department of Animal Science at Stellenbosch University. The structure is in the form of two research chapters and one observational chapter. It is prefaced by an introductory chapter which is followed by a literature review chapter and concluded with a general discussion and conclusion chapter. The language and style used in this thesis are in accordance with the requirements of the *South African Journal of Animal Science*. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between chapters, especially within the materials and methods section, is therefore unavoidable.

ABBREVIATIONS

ANOVA	Analysis of variance
ADG	Average daily gain
DFD	Dark firm and dry
DM	Dry matter
DMI	Dry matter intake
FAO	Food and Agricultural Organization of the United Nations
FCR	Feed conversion ratio
GLM	Generalised linear model
LSD	Least square differences
MANOVA	Multivariate analysis of the variance
NRC	National Research Council
pH_i	Initial pH
pH_u	Ultimate pH
SE	Standard error
WWF	World Wildlife Fund

SUMMARY

The effect of environmental enrichment in the form of a wooden platform on the production parameters, social, maintenance and feeding behaviour, frequency of stereotypical behaviours and meat quality of Merino lambs in an indoor feedlot was assessed.

In the first study, the effect of the wooden platform on weight gain, maintenance behaviour, social interactions and stereotypical behaviours was assessed. Two lambs were infected with footrot (infectious pododermatitis) prior to arrival at the feedlot and the effect of this disease on production parameters and behaviour was also included in the analyses. Lambs infected with footrot had the same final weight as healthy lambs, although they gained weight at a slower rate (y=1.27x+34.33 of infected lambs (n=13) versus y=2.06x+34.24 of healthy lambs (n=34)). This study found no differences in maintenance or stereotypical behaviours between lambs in treatment pens and lambs in control pens. Lambs in treatment pens did, however display a higher frequency of affiliative interactions of which the frequency increased over the fattening period. When correlations within the treatment pens were assessed, there was a significant positive correlation between affiliative interactions and the use of the platform and a significant negative correlation between the use of the platform and aggressive interactions.

During the second study, the effect of the wooden platform on production parameters (ADG and FCR), social interactions, stereotypical and feeding behaviours as well as physical meat quality indicators was assessed. In this study the lambs were housed in an indoor feedlot of which one side had large open windows. It became clear that these windows also had an impact on the welfare of animals and was thus included in the analyses. Lambs in treatment that were in treatment groups on the open side of the shed showed the highest ADG and the most desirable FCR, while lambs in control pens on the open side performed intermediately and lambs on the closed side (both control and treatment pens) had the least desirable FCR and lowest ADG. The wooden platform had no effect on the meat quality, however, lambs on the open side of the pen side had heavier carcasses, lower initial pH, more back fat and a higher drip loss percentage. Lambs in control pens showed higher frequencies of stereotypical behaviours and less affiliative interactions. These lambs also had a lower frequency of feeding bouts than lambs in treatment groups, however, there were no differences in dry matter intake between the groups. All lambs fed more during the morning than in the afternoons and the feeding bouts as well as time spent feeding declined over the fattening period. However, once again there were no differences in feed intake over the fattening period and lambs most likely fed more during the night when temperatures were lower.

Differences in temperaments and individual personalities of lambs most likely have a very large effect on whether or not the wooden platform will serve to improve animal welfare. Although the indicators measured did not prove the wooden platform to be overwhelmingly successful as a method of improving animal welfare, it had no detrimental effects on the lambs and it could be optimised to serve as an economical form of environmental enrichment in lamb feedlots.

OPSOMMING

Die effek van omgewings verryking in die vorm van ‘n hout platform op die produksie parameters, sosiale, onderhouds en voedings gedrag, frekwensie van stereotipiese gedrag en vleis kwaliteit van Merino lammers in ‘n binnenshuise voerkraal was geanaliseer.

Gedurende die eerste studie is die effek van die hout platform op gewigs toename, onderhouds gedrag, sosiale interaksies en stereotipiese gedrag geanaliseer. Met die aankoms by die voerkraal was twee lammers reeds geïnfekteer met ‘n aansteeklike vorm van vrotpootjie (infectious pododermatitis) en die effek van hierdie siekte op produksie en gedrag is toe ingelsuit by die analise. Lammer wat geïnfekteer was met vrotpootjie het dieselfde finale gewig gehad as gesonde lammers, alhoewel die gesonde lammers gewig opgetel het teen ‘n hoër tempo as siek lammers (y=1.27x+34 versus y=2.06x+34.24 van gesonde lammers). Die studie het geen verskille gekry in die onderhouds of stereotipiese gedrag tussen lammer in kontrole kampe en behandelings kampe nie. Lammer in behandelings kampe het wel ‘n hoër frekwensie van “affiliative” interaksies getoon. Hierdie frekwensie het ook toegeneem oor die periode in die voerkraal. Daar was ‘n positiewe korrelasie tussen “affiliative” interaksies en die gebruik van die hout platform en ‘n negatiewe korrelasie tussen die gebruik van die platform en aggressiewe interaksies.

In die tweede studie is die effek van die hout platform op produksie parameters (gemiddelde daaglikse toename en voeromset verhouding), sosiale interaksies, stereotipiese en voedings gedrag asook fisiese vleis kwaliteit indikators geanaliseer. Tydens hierdie studie was die lammers gehuisves in ‘n skuur waarvan die een kant groot, oop vensters gehad het. Dit het duidelik geword dat hierdie vensters ook ‘n vorm van omgewings verryking bied en die effek hiervan is ingesluit in die analise. Lammers in die behandelings groepe aan die oop kant van die skuur het die hoogste gemiddelde daaglikse toename getoon sowel as die mees gewensde voeromset verhouding, terwyl lammers in kontrole groepe aan die oop kant intermediêre resultate gelewer het en die lammers aan die toe kant van die skuur (beide die in kontrole en behandelings kampe) die laagste gemiddelde daaglikse toename en die hoogste voeromset verhouding gehad het. Die houtplatform het geen effek gehad op vleis kwaliteit nie, maar lammers aan die oop kant van die skuur het wel swaarder karkasse, laar aanvanklike pH, meer vet op die kruis en ‘n hoër vog verlies persentasie gehad. Lammers in die kontrole groepe het ‘n hoër frekwensie van stereotipiese gedrag en minder “affiliative” interaksies getoon. Hierdie lammers het ook minder gegaan na die voerbakke en minder tyd spandeer aan voeding. Daar was egter geen verskille tussen die innames van die onderskeie groepe nie. Al die lammers het meer gevoed in die oggend teenoor die middag en die

voedings het afgeneem oor tyd. Daar was egter nie verskille in die daaglikse voerinname nie en lammers het waarskynlik meer in die nag gevoed wanneer temperature laer was.

Verskille in temperamente en individuele se persoonlikhede het waarskynlik ‘n baie groot effek op die effektiwiteit van die hout platform as ‘n vorm van omgewings verryking. Alhoewel die analises nie oorweldigende bewyse gelewer het dat die hout platform wel lammers se welsyn kan verbeter nie, het dit geen nadelige uittwerkings gehad op die lammers nie en kan dit tog geoptimiseer word om te dien as ‘n ekonomiese vorm van omgewings verryking in lammer voerkrale.

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CONTENTS

The effect of environmental enrichment on the production parameters, meat quality and social behaviour of lambs finished in a feedlot.

CHAPTER 1

Introduction

The agricultural world has to meet massive expectations of meat production by increasing efficiency as well as yield to keep up with the ever growing global population set to reach 9 billion people by 2050 (FAO, 2012). The global trend to remedy these expectations has been to intensify farming practices by shifting from finishing animals on large open pastures, to feedlot systems. This shift has enabled farmers to produce a more standardised product while increasing productivity by finishing large flocks of animals on small areas (Miranda-de la Lama *et al.,* 2012; Teixeira *et al.,* 2014). Currently the sheep industry lags behind that of the poultry, swine and beef industries in terms of value adding, consistency and production efficiency (Montossi *et al.,* 2013). However, this can be addressed by increasing the speed to which new technological improvements are adopted into the industry.

The consumer's concern for the welfare of animals has been on the rise in recent years, with consumers preferring products from animals that experienced good animal welfare during their lifetime (Troy & Kerry, 2010). However, according to Koknaroglu & Akunal (2013), animal welfare has not been the main focus of the agricultural industry, being primarily focused on yield which has in turn caused animals to experience a decline in animal welfare due to intensive farming practices (Napolitano *et al*., 2010). In feedlot lambs, this decline in animal welfare has been due to transportation, exposure to novel environments and social groupings, feeding regime, frequent handling and a higher susceptibility to contract various diseases (Aguayo-Ulloa *et al*., 2013; Aguayo-Ulloa *et al*., 2015; Miranda-de la Lama *et al*., 2010a). Additionally, the environments in which these lambs are kept are barren compared to the pasture on which they were reared prior to entering the feedlot. This may cause stress due to boredom and frustration (Fraser, 1980; Wood-Gush & Beilhartz, 1983).

According to Fraser (1980), the main objective of animal welfare is to prevent disease and suffering among livestock. When this is accomplished, it will inevitably have enormous effects on the economic value of the animal as well as the product made available to the consumer. Animal welfare may be improved by enabling the animal to perform a variety of its natural behavioural repertoire while in a confined space such as a feedlot (Špinka, 2006). It has been suggested by de Azevedo *et al.* (2007) that structural enrichment elements and feeding regime may provide the most successful enrichment.

Previous studies have assessed the effects of bedding types (Jaboerek *et al*., 2016; Teixiera *et al.*, 2012) and a variety of structural elements on the welfare of lambs during the fattening period such as feeder ramps and feeder hoppers (Aguayo-Ulloa *et al.*, 2010; Aguayo-Ulloa *et al.*, 2014a; Aguayo-Ulloa *et al.*, 2014b; Aguayo-Ulloa *et al.*, 2015). These studies have all found differing degrees of improvement of the welfare indicators of lambs fattened in feedlots such as an increase in positive behavioural indicators, a decrease in stereotypical behaviours, an increase in the meat quality and higher average daily gains and lower feed conversion ratios.

The effect that these structural enrichment elements will have on the welfare of all lambs housed in the feedlot may differ according to individual differences in the personalities of the lambs as it relates to their stress response (Erhard *et al.*, 2004). Some lambs will cope with the stressors posed by the feedlot environment by retreating while others will confront the stressor (Koolhaas *et al*., 1991). These different coping styles may affect the efficacy of the structural enrichment provided to the lambs.

However, very little research on the use of environmental enrichment on the welfare and production efficiency of feedlot-finished lambs under South African conditions have been conducted. The objective of this study was therefore to assess the use of an economical wooden platform in terms of the value it may add to the welfare of lambs housed and fattened in an indoor feedlot. This assessment was based on the welfare indicators such as maintenance behaviour, social interactions, frequency of stereotypes, production parameters and physical meat quality attributes. The effect of the wooden platform on the feeding behaviour of lambs was also assessed. Additionally, the effects of infectious footrot on the behaviour and weight gain trends of lambs were also assessed as well as possible enrichment provided by large open windows in an indoor feedlot.

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CHAPTER 2

Literature Review

2.1. Current Trends in Global Sheep Production

According to the FAO Global Statistical Yearbook of 2012, the world population will increase by 2 billion people in the following two decades and reach 9 billion people in 2050. This increase in the world population will demand an increase in global agricultural production of 60% from the year 2005 (FAO, 2012). Although sheep meat is a niche product, only contributing to about 3% of the global meat industry, the sheep meat industry has to keep up with and contribute to the worldwide increase in meat production (Jacob & Pethick, 2014).

During the 1980's, people from developing countries were consuming about a third of the total meat produced globally. In recent years this fraction has increased to about half with an expected increase to two-thirds by 2020. This increase is mainly occurring in middle- and high income households in developing countries. With the increase in wealth comes a movement from eating mainly starches (maize, beans and rice) to eating poultry, red meat and fresh fruits and vegetables (Gregory, 2007).

Despite this dramatic increase in world population, there has been a decline in global sheep production over the past 20 years with Australia, New Zealand and Argentina experiencing a 50% decline in their sheep stock with the United States noticing an even bigger decline (Woodford, 2010). According to Woodford (2010), this decline may be explained by a range of factors including changes in weather patterns, diminishing natural resources, fluctuating meat prices and overall natural degradation. In 2011, the first increase in global sheep numbers since 2007 was reported by the FAO (2011) with an increase of 18 million head. This increase was largely driven by China, India and Australia.

The FAO (2012) mentions that sheep production may be increased by making use of better genetics or finishing lambs on grain in feedlots. This increase in global meat consumption has presented an opportunity for the meat industry to grow enormously with the main increase being in the intensive livestock sector (Gregory, 2007).

2.2. The Feedlot System

2.2.1. Effects on Meat

In an extensive production system lambs are finished on a pasture or field and the producer of these animals is therefore not only reliant on the natural resources such as food, water and shelter, but is also vulnerable to changes occurring in the environment. Furthermore, due to environmental factors such as global warming and the expansion of cities due to the growing world population, both the availability and the sustainability of these resources have decreased. It is therefore important to explore alternative production systems such as the feedlot system.

Within the feedlot system, sheep are first bred and reared on pastures and then moved to a feedlot during the finishing period before slaughter. The shift from the pastoral system has allowed for a standardised product as well as an increase in productivity with larger flocks being finished on a smaller area (Miranda-de la Lama *et al.,* 2012; Teixeira *et al.,* 2014).

According to Montossi *et al.* (2013), the sheep industry has to devise methods to keep up with the poultry, swine and beef industries despite their huge capital investment and size. This has to be done by increasing production and efficiency while adding value and consistency. Furthermore, there has to be an increase in new technological achievements as well as an increase in the speed to which these improvements are adopted into the industry. The methods that are used to make these improvements, should not compromise the sensory quality of lamb meat.

There have been various studies (Borton *et al.,* 2005; Diaz *et al.,* 2002; Priolo *et al.,* 2001) quantifying the qualitative differences between the carcasses of lambs that were finished in an extensive production system on a pasture-based diet and lambs that were finished in a feedlot (intensive production system) on a concentrate diet. These diets differ in that pasture-based diets are comprised of mainly roughage which is low in energy and protein, whereas concentrate based diets are formulated to be high in energy and protein in order to ensure maximum growth in the minimum amount of time.

There have been three major differences found between carcasses of lambs finished in the different production systems: The fatness of the carcass, the flavour of the meat and the colour of both the meat and the subcutaneous fat (Borton *et al.,* 2005; Diaz *et al.,* 2002; Priolo *et al.,* 2001; Velasco *et al.,* 2004).

Carcasses from lambs that are fed a concentrate-based diet tend to be heavier and have a higher fat content than that of lambs finished on pastures (Borton *et al.,* 2005; Diaz *et al.,* 2002; Priolo *et al.,* 2001). The leaner carcasses produced in extensive production systems may be due to the amount of exercise the lambs do while foraging for food (Priolo *et al.,* 2001) or due to the fact that the diet has lower energy levels than that of a lamb finished in a feedlot. The method of finishing lambs also has an influence on the carcass yield.

Lambs that are finished on pastures consume more roughage-based feed than lambs in a feedlot which plays a major role in the development of the digestive tract of the animal and therefore the afore mentioned lambs' digestive tract will comprise a larger percentage of their total body weight. Borton *et al.* (2005), Diaz *et al.* (2002) and Priolo *et al.* (2001) all found that lambs reared in a feedlot have a higher carcass weight and dressing percentage which can be attributed to a smaller digestive tract and more subcutaneous and kidney and caul fat; all three fat depots are typically included in the measurement of the carcass weight.

According to Diaz *et al.* (2002), lambs that are finished in an extensive production system will produce carcasses with darker meat. This darker colour can be attributed to a variety of factors such as a difference in the myoglobin content of the muscles, different ultimate pH of the carcass after slaughter or a difference in the fat content of the carcass (Priolo *et al.,* 2001). Priolo *et al.* (2001) also found that the subcutaneous fat of the lambs reared on pasture was slightly more yellow than that of the lambs finished in the feedlot. This can be attributed to the higher level of carotenoids in the fodder or grass that is deposited in the fat of the lambs reared in the extensive production system.

2.2.2. Footrot in the feedlot

Footrot is a mixed bacterial infection caused by *Fusobacterium necrophorum* and *Dichelobacter nodosus* and is an infectious diseases, which causes lameness in sheep (Eagerton *et al.*, 1969). It affects the hooves of the lambs and can range from a benign infection to very severe footrot. It is directly transmitted through infected faecal and soil material (Eagerton *et al.*, 1969) and causes mild to severe inflammation of the hooves. The successful transmission of the disease is dependent on the ambient temperature as well as the hydration of the stratum corneum of the interdigital skin (Raadsma & Eagerton, 2013). The symbiotic working between the two bacterium (*F. necrophorum* and *D. nodosus*) then results in the further invasion of the epidermis, which ultimately results in the development of footrot.

Footrot may be controlled in various manners such as foot pairing, selective breeding, targeted vaccinations, foot baths and antibiotics (Abbott & Lewis, 2005). The disease may also be eradicated through whole flock disposal, infected animal disposal and identification and treatment infected animals. Eradication of the disease is more demanding in terms of labour and finances and in many cases control and an adequate surveillance program is more suitable (Raadsma & Eagerton, 2013).

Footrot is one of the most important diseases in terms of economic losses with Australia estimating a loss of $18.4M for the year 2005-2006 (Sacket *et al.,* 2006). These economic losses are most likely attributed to the loss of body weight in infected lambs (Marshall *et al.,* 1991; Stewart *et al.*, 1984) due to the lambs being unable to walk to the feeder and feed as a result of severe pain in their hooves. Marshall *et al.* (1991) observed an 11.6% decline in body weight of lambs infected with footrot compared to that of the control group.

2.2.3. Effects on Animal Welfare

Koknaroglu & Akunal (2013) defines animal welfare as "providing environmental conditions in which animals can display all their natural behaviours in nature." In the last 50 years animal breeding, management practices and an improvement of the animal's environment have been the main focus points to provide dramatic increases in the yield of each individual animal. However, because maximising yield has been the main focus, animal welfare has not enjoyed much attention (Koknaroglu & Akunal, 2013). The intensification of animal farming has made it possible to produce animal products at a relatively low cost. These intensive farming systems have caused a dramatic decline in animal welfare, for example: Weak bones in chickens and pigs with a high prevalence of abnormal behaviour (Napolitano *et al*., 2010).

A lamb's natural environment is on an extensive field with different forms of environmental stimuli such as rocks, bushes and trees. These stimuli promote a variety of activities such as exploration, a higher activity level and social interaction (Dwyer, 2009; Tarou & Bashaw, 2011) which form part of the sheep's natural behavioural profile.

The finishing of lambs in feedlots has simplified the role of the farmer (breeder) in the production chain and with lambs being finished externally, the production efficiency as well as the homogeneity of the final product is improved (Miranda-de la Lama *et al*., 2009; Teixiera *et al*., 2014). Furthermore, the carrying capacity of the producer's farm is increased as the surface area required to finish a lamb need not be taken into account.

However, during the process of intensification, the amount of factors that may have a detrimental influence on the final product has increased with multiple transports, introduction to novel environments and high stocking densities, social mixing and an introduction to barren environments all contributing to a decline in animal welfare (Miranda-de la Lama *et al.,* 2009; Miranda-de la Lama *et al.,* 2010; Miranda-de la Lama *et al.,* 2012; Aguayo-Ulloa *et al.,* 2013). An additional stress factor is the adaption period that is required for the lambs to adjust the microbe populations in their rumen to the new, more concentrated feed. It is common to find instances of diarrhoea in lambs during this adaption period as all lambs respond differently to a change in feed.

Some of the main stressors for lambs in a feedlot are the restriction of movement and the absence of retreat space (Morgan & Tromborgh, 2007). In many cases, the animal will perceive their proximity to their human caretaker as greater than what they are comfortable with and with the feedlot pens being barren and quite small, opportunities for concealment do not exist. The complexity of the environment will also have an influence on the behaviour of the sheep. It has been found that Merino sheep that are kept on a terrain without environmental stimulation spend more time being vigilant than animals that are kept on pasture (Dwyer, 2009).

Stereotypic behaviour refers to behavioural activities that are repetitive and seemingly functionless. These behavioural activities are unnatural and do not occur when the lamb is in its natural environment. In housed sheep (as in other ungulates) these stereotypic behavioural patterns presents as oral and oro-nasal activities which includes wool biting and partition chewing (Bergeron *et al.,* 2006). Wool biting refers to when one lamb chews and picks on another one's fleece while partition chewing refers to the incessant chewing of the portioning in the enclosure (Miranda-de la Lama *et al.,* 2012).

Stereotypical behaviour is often more prevalent and time consuming in animals that are either kept in aversive conditions or conditions with minimal stimulation (Mason *et al.,* 2007). It has been found that these stereotypic behavioural activities disappear as soon as the sheep are turned out to pasture while adding roughage to the feed shows no change, indicating that the inability of sheep to express their natural behaviour is the cause of their stereotypic behavioural activities (Gregory, 2007). These findings also support the hypotheses that the oral stereotypical bahaviour is caused by the inability of the herbivorous sheep to express its natural tendency to forage for food (Bergeron *et al.,* 2006).

Pigs provide a good example of what happens to an animal when it is unable to perform its natural behavioural activities in an intensive production system. Pigs are inclined to walk around during the day rooting and chewing, however they are not able to perform these behavioural activities in the barren pens where they are reared and therefore the pig will turn to tail biting and ear chewing as a way to cope with this. Even though genetic selection has been used to increase the growth and reproduction of these pigs, it has not been able to produce pigs that do not bite or chew one another. Pigs are therefore an example of the inability or even impossibility to outbreed an animal's natural behaviour (Bonney, 2006).

According to Špinka (2006), the ability of an animal to perform its natural behaviour, will have long term positive effects on the welfare of the animal as well as its proficiency to cope in social and stressful situations. Furthermore, Špinka *et al.* (2001) hypothesised that when animals have the freedom to play, their ability to deal with unexpected stressful situations is enhanced. These unexpected stressful situations may include human-animal interactions and *ante-mortem* handling at the abattoir.

The current feedlot system makes use of barren pens to hold animals, making no provision for environmental stimulation; these pens may compromise the ability of the sheep to perform a wide range of its natural behavioural activities. Natural behavioural patterns may be affected in terms of frequency, sequence and duration (Wechsler, 2007). This lack of environmental stimulus in the current feedlot system may cause the lambs to become bored and frustrated which has been described as "an aversive state of the animal when it is unable to perform natural behaviours that it feels strongly inclined to" (Fraser *et al.,* 2013) which may cause chronic stress in the animal, compromising the production performance of the animals as well as the sensory quality of the meat (Aguayo-Ulloa *et al.,* 2013; Teixeira *et al.,* 2012).

Even though the ability of the lamb to perform a range of natural behavioural activities will be beneficial in many aspects, it is unnecessary for the animal to be able to perform its entire repertoire of natural behavioural activities as some of these can have a detrimental effect on the welfare of the animal itself (Špinka, 2006). These detrimental behavioural activities may include stress after a flight reaction as well as aggression that may arise between animals that could be either rank-related or illness-related.

Currently there is very little known about the behaviour of lambs in a feedlot and this could prove detrimental because problems arising during the finishing period may compromise the final product that is made available to the consumer. These problems may include a product that is unnecessarily expensive or of low quality.

2.2.3.1 Types of animal welfare issues

Animal welfare issues may be divided into two groups. These are firstly the abuse or neglect of animals, which humans are responsible for and secondly, welfare issues where current management practices need to be adapted towards in order to improve the welfare of the animal (Grandin, 2014).

Furthermore animal welfare may be assessed according to two standards. The first is management-based and is used most commonly, because it is easy to assess as it is used to describe the environment of the animal. The second is animal-based and it is used to describe the animal itself. With the latter method the animal's behaviour is taken into consideration and an assessment can be made of its current physical and psychological wellbeing (Rushen, 2011). Even though with this method the assessments made are much more accurate, it is hard to implement due to various time and financial constraints that may arise. It is therefore important to conduct studies in which behavioural profiles form an important part of the study.

2.2.3.2. The use of environmental enrichment

Newberry (1995) defined environmental enrichment as a modification of the animal's environment which will lead to a significant improvement in the animal's life. These modifications range from adding structures to the environment such as toys and straw to changing the environment from captive to a semi-natural outdoor environment where animals are allowed to roam. The effect of environmental enrichment may be assessed according to many factors including, but not limited to, the animal's physiological response, more favourable production parameters, a higher quality product and behavioural changes (a higher prevalence of natural behavioural activities).

In lambs finished in a feedlot with various types of environmental enrichment, such as the addition of straw, feeder ramps, double bunkers and feed hoppers to the environment have been assessed (Aguayo-Ulloa *et al*., 2010; Aguayo-Ulloa *et al*., 2014a; Aguayo-Ulloa *et al*., 2014b; Aguayo-Ulloa *et al*., 2015). Aguayo-Ulloa *et al*. (2010) and Aguayo-Ulloa *et al*. (2014a) found significant improvements in the production performance of lambs kept in an enriched environment with both average daily gain and feed conversion ratios being higher. Furthermore, Aguayo-Ulloa *et al*. (2014a) and Aguayo-Ulloa *et al*. (2014b) found that environmental enrichment had a positive effect on dressing percentage and showed an improvement in both the intrinsic and sensory quality of meat. These types of environmental enrichment were also found to improve the immunity of lambs (Aguayo-Ulloa *et al*., 2015). When the behavioural profiles of the lambs were assessed, all studies found that lambs kept in enriched environments displayed less stereotypical behaviour than lambs kept in barren environments.

2.2.3.3. Public Concern

The welfare of animals in farming production systems has become a public concern. Consumers demand products that were reared, transported, handled and slaughtered in a humane manner (Troy & Kerry, 2010). Because of this, the meat industry has been forced to place greater importance on the welfare of animals. The consumer demands have also urged retailers to demand transparency and the in-depth auditing of meat production facilities to ensure that the product adheres to the basic expectations of the consumer in terms of animal welfare (Troy & Kerry, 2010).

There has been a transition from extensive to intensive production systems and with current trends in intensive sheep farming having a possible negative influence on the welfare of the lambs (Aguayo-Ulloa *et al.,* 2013), animal (sheep) welfare concerns have been raised by consumers. The public perception is that extensively farmed animals enjoy a better quality of life when compared to animals that are reared in an intensive system and are therefore preferred (Hughes, 1995). It is important that the producer remain informed of the consumer's perceptions and aim to adapt his farming practices accordingly.

2.3. Consumer preferences and perceptions

The current trends in meat consumption suggests that factors such as pricing and income may have a lower influence on the consumer's choice over time and that the quality of the meat will become a more important factor affecting the consumer's decision (Grunert, 2006; Henchion *et al.*, 2014). The consumer's perception of meat and meat products is the most important factor that needs to be addressed by the meat industry as it will have a direct influence on profitability (Troy & Kerry, 2010).

Meat consumers prefer meat that is of both high nutritional value and good quality, but even more so, they have to consider the product as being good value for money (Jacob & Pethick, 2014). Currently consumers also prefer lamb meat that had been reared extensively (grass-fed) rather than animals that were reared in a feedlot (concentrate-fed) as their perception is that grass fed lambs will produce a carcass that is more natural, has a higher nutritional value, is tastier and that these animals were reared in a more environmentally friendly manner (Font i Furnols, 2011).

The consumer will judge the product based on two aspects, both forming part of the overall assessment of the meat quality (Troy & Kerry, 2010) and even though the consumer's perception of quality is both subjective and variable, it is important to explore this complex perspective (Henchion *et al.*, 2014). The first assessment that is made is referred to as the "expected quality" measurement and this is judged at point of purchase, while the second assessment, "experienced quality", will be made during consumption (Acebrón Bello & Dopico Calvo, 2000).

Various intrinsic factors (colour, visible fat and exudate, tenderness, etc.) as well as extrinsic factors (price, packaging, brand, etc.) will influence the consumer's decision in purchasing the meat (Grunert, 2006; Henchion *et al.*, 2014). Furthermore, the consumer will also take credence attributes such as animal welfare, sustainability and food safety into consideration at the point of purchase with these characteristics becoming more and more important to the consumer (Grunert, 2006; Henchion *et al.*, 2014; Neopolitan *et al*., 2010). It is therefore important for the meat industry to take all these factors into mind during the production of meat and meat products.

2.3.1 Intrinsic Qualities

2.3.1.1. At Point of Purchase

According to the consumer the most important attribute that can serve as an indication of the quality of meat at point of purchase, is the colour, as it is the first attribute that may be assessed. It is therefore important that both colour and colour stability of meat must meet the expectation of the consumer as these attributes are used to evaluate the freshness and the wholesomeness of the meat (Font-i-Furnols & Guerrero, 2014; Troy & Kerry, 2010). Meat with higher colour stability will also have a longer shelf life, as these products will be considered acceptable by the consumer for a longer period of time (Font-i-Furnols & Guerrero, 2014). According to Troy & Kerry (2010), lamb meat is expected to have a brick red colour and as soon as the consumer feels that their expectations are not being met, they will discriminate negatively against the meat.

Another attribute that is important to the consumer, is the drip loss that is visible through the packaging with consumers preferring minimal visible exudate (Font-i-Furnols & Guerrero, 2014). Even though drip loss is unavoidable, it is of high importance to limit the moisture that is visible around the fresh meat as is may influence the consumer's perception of the quality of the meat due to its relation to the perceived juiciness of the meat (Font-i-Furnols & Guerrero, 2014, Troy & Kerry, 2010). The moisture that is visible in the packaging may be attributed to either the type of packaging used or the meat itself (exudate loss) with the latter being influenced by a variety of intrinsic and extrinsic factors, which may include rigor temperature, membrane integrity (Honikel, 1998) and stress prior to slaughter.

The third most important attribute that will influence the customer's choice at the point of purchase, is the visible fat which includes both subcutaneous fat and intramuscular fat (marbling). The fat will be evaluated by the customer based on the colour as well as the amount that is visible. The presence of intramuscular fat has been shown to increase both the juiciness and the tenderness of meat and should be no less than 3%, however with consumers becoming more health conscious, the fat percentage of the meat should ideally not be more than 7.3 % (Miller, 2002). Furthermore, Ngapo & Dransfield (2006) found that consumer's preference changed over the last 50 years with an increase of 54% (from 1955 to 2002) of British participants preferring the two leanest beef ribs options presented. Intramuscular fat can be influenced by a range of factors including age and weight at slaughter, animal breed, feeding strategy and growth rate (Warriss, 2010). The colour of the subcutaneous fat should ideally be either white or off white as consumers perceive yellow fat to be an indication of a malnourished and/or older animal (Troy & Kelly, 2010).

2.3.1.2. During Consumption

One of the biggest challenges in the meat industry is to provide the consumer with meat that is consistently of high sensory quality. It is therefore important to assess the attributes that are considered to be the most important by the consumer. According to Miller (2002), the most important attribute during the consumption of meat, is tenderness, with consumers being willing to pay more if tenderness can be guaranteed. In Europe it was found that consumers preferred the tenderness from light, concentrate-fed lambs to lambs that were heavier and finished on pastures (Font i Furnols *et al*., 2009).

Juiciness, flavour and succulence have the most influence on the overall palatability of meat and are therefore considered to be the most important factors - after tenderness - influencing the intrinsic quality of meat (Acebrón Bello & Dopico Calvo, 2000; Troy & Kelly, 2010). These attributes, however, are largely influenced by the pre-slaughter handling of the animal as well as the cooking of the meat. It is therefore important to place the pre-slaughter handling of the animal under high scrutiny as this may have detrimental effects on the quality experienced by the consumer.

2.3.2. Credence Qualities

In recent years there has been a trend where consumers are very interested in the "story" behind the product they are purchasing (Grunert, 2006). This phenomenon is not exclusive to the meat industry and the preference of free range eggs as opposed to non-free range by the consumer is a good example of this. Consumers may be deterred from buying animal products when information about the rearing conditions of the animal is available and found to be unacceptable with consumers being willing to pay higher prices for animals that were reared humanely (Kehlbacher *et al*., 2012; Neopolitan *et al*., 2007; Troy and Kerry, 2010).

According to Grunert (2006), due to various developments in the red meat industry in recent years such as the ongoing debate about the pros and cons of red meat consumption, the general food health debate and the various meat scandals globally, consumers tend to place more value on the issues related to food safety. This, however, is not an assessment that can be made on intrinsic cues and therefore, the consumer has to rely on the extrinsic cues.

2.4. Physical Meat Quality and Stress

Stress in animals is a complex physiological process which can be divided into two subcategories: physical stress and psychological stress. Physical stress may be easier to estimate as indicators such as sickness, broken legs, damaged skin, etc. are quite easy to see whereas physiological stress indicators may be harder to quantify and evaluate. These indicators in sheep may be animals that are behaving in a manner that is abnormal and could become difficult to define. It is, however, very important for the producer to identify and minimise both the chronic and acute stressors during the rearing and slaughtering period as these may have detrimental effects on the meat. Animals will also differ in their individual susceptibilities to different stressors which may produce a product that is inconsistent (Sañudo *et al*., 1998).

2.4.1. Dressing Percentage

Dressing percentage can also be referred to as meat yield and can be calculated as the weight of the carcass expressed as a percentage of the animal's weight before slaughter (Warriss, 2010). The parts of the animal which contribute to the marketable carcass differ for each species of animal. In the case of lambs, the carcass is the animal with its fleece, viscera, trotters and head removed; the average dressing percentage of lambs is 50% (Lawrie, 2006; Warriss, 2010).

There are many factors that may have an influence on the dressing percentage of an animal of which the most important are fatness, skin weight, sex, breed, nutrition and the length of the fasting period before slaughter (Warriss, 2010). As stated previously, lambs that are reared in an intensive production system will have a higher dressing percentage due to a higher amount of subcutaneous fat and kidney and caul fat and a smaller digestive tract than that of lambs reared on pasture.

2.4.2. Fat content

Sheep lay down fat in four major fat depots namely: Visceral fat (between organs), intermuscular fat (between muscles), subcutaneous fat (under the skin) and intramuscular fat (within muscles) (FAO, 2008). The fat is also deposited within these depots in this order as the animal ages with the subcutaneous layer being the most visible fat depot (Hossner, 2005; Lawrie, 2006; Warriss, 2010). Sheep that are reared in a feedlot tend to have a larger subcutaneous fat depot when compared to extensively reared sheep due their diet having a higher energy content and the sheep themselves having minimal physical activity (Diaz *et al.,* 2002). The subcutaneous fat layer also acts to insulate the carcass during the chilling period allowing for a higher level of activity by the proteolytic enzymes which improves the tenderness of the meat (Lawrie, 2006, Warriss, 2010).

In recent years there has been a trend with consumers preferring meat that has a lower fat content (Ngapo & Dransfield, 2006). Marbling refers to the amount of visible intramuscular fat and plays an important role in different aspects of the perceived quality with juiciness, tenderness and flavour being affected by this fat deposit (FAO, 2008; Miller, 2002). However, the percentage of marbling in a lamb carcass may vary from 0.5 to 8% (Troy & Kerry, 2010) and there have been many studies that concluded that marbling will have a minimal effect on the tenderness of meat with Thomson (2002) concluding that the correlation between marbling and meat palatability is very low.

According to Miller (2002), the ideal total fat content in a carcass should be between 3 and 7.3% with consumers finding fat content above 7.3% unacceptable. Consumers also perceive a high fat content to be one of the major risks associated with consuming meat as it has been linked to heart disease (Montossi *et al*., 2013). Fat content is, however, very market specific and the factors influencing it should be managed by the producer (Troy & Kerry, 2010).

Besides the amount of fat present in the carcass, the colour of the fat also plays a major role in the acceptability of the meat (Troy & Kerry, 2010). This colour may vary from off white to a yellowish or even an orange colour. These variations are mainly caused by the types of feed consumed by the animals as well as the conversion of fat-soluble compounds such as carotene to other forms such as vitamin A. Forage based diets contain high amount of carotene which is responsible for the yellowish fat. Maré et al. (2013) found that abattoirs discriminate against beef with a yellow fat colour due to the perception that South Africans dislike yellow fat and therefore a penalty is placed on these carcasses. Furthermore, 25% of beef that is made available to South African consumers are grass fed and have yellow fat. Consumers also preferred white fat with only 13.59% of consumers preferring yellow fat. This is contradictory as consumers prefer grass fed beef because of the perception that these animals are treated more humanely, but not the yellowish fat that accompanies it.

2.4.3. Tenderness

Meat tenderness has been found to be the most sought after factor by consumer and it is influenced by various factors of which four have a major influence: Enzyme (proteolytic) actions, muscle shortening (*post-mortem*), connective tissue type and content and marbling (Miller *et al.,* 1995; Miller *et al*., 2001). As previously stated, the amount of marbling will have a minimal effect on the palatability of the meat.

It has been found that exercise during the rearing period will produce a lamb with a leaner carcass and a hind quarter that has more tender meat, provided that the sheep only exercise in moderation (Gregory, 2007). Aalhus *et al.* (1991) also found that due to the lower fat percentage after moderate exercise the muscle volume will be greater leading to a higher myofibrillar protein to collagen ratio and therefore more tender meat.

However, lambs reared in a feedlot seldom gain any exercise, except if there is some form of environmental enrichment which allows “play”. Lambs that are finished in a feedlot containing environmental enrichment (straw, feed hoppers and feeder ramps) produce a carcass with more tender meat with Aguayo-Ulloa *et al*. (2013) finding a 27.9% increase in meat tenderness of lambs finished in environmentally enriched pens when compared to lambs finished in barren pens.

2.4.4. Post-mortem decline of pH and temperature

The *post-mortem* decline in pH in sheep carcasses will occur from 7, in a live animal, to between 5.6 and 5.4 over a 24-48 hours period when the carcass is stored in a chiller. This decline is due to the accumulation of lactic acid in the muscles produced during anaerobic glycolysis. When the iso-electric point of the muscle is reached at between 5.4 and 5.6, the enzymes that initiate glycolysis become inactive and further pH decline is not possible (Lawrie, 2006; Warriss, 2010). It is at this point where the ultimate pH is reached.

When animals experience *ante-mortem* stress and use most of their available muscle glycogen reserves, it may lead to a higher muscle ultimate pH (>6) which is known as DFD (dry, firm and dark) meat. Not only is this meat found to be undesirable by the consumer, but it also creates an environment for spoilage bacteria to flourish which will ultimately shorten the shelf life of the product (Newton & Gill, 1981).

The rate of pH decline is dependent on temperature during the development of rigor mortis (Lawrie, 2006; Tornberg, 1996) as both these factors will have an effect on muscle shortening as well as proteolytic enzyme activity (Dransfield, 1992). Geesink *et al.,* (2000) found that optimal muscle tenderisation (no negative affect of temperature on *post-mortem* proteolysis during storage) in lamb carcasses will be achieved at a temperature of 15°C at the onset of rigor. Carcasses with a thick subcutaneous fat layer will be better insulated and cool at a slower rate which will promote *post-mortem* glycolysis and ensure a desired ultimate pH (Lawrie, 2006; Priolo, 2001).

2.4.5. Water Holding Capacity (WHC)

The water holding capacity of meat can be defined as the ability of meat to retain water during the storage process, cutting and heating (Sales, 1996). Meat with a high WHC capacity is preferred as it has an influence on the juiciness of the meat during consumption with a higher WHC being associated with juicier meat (Font i Furnols & Guerrero, 2014). Approximately 72-75% of lean meat is comprised of water in a bound, immobilized or free form and is held together by the muscle filaments (Lawrie, 2006).

Drip loss is an attribute with both economical and quality implications and it refers to the leaking of water from the meat during cutting and the storage phase and is very undesirable to the consumer (Font i Furnols & Guerrero, 2014; Troy & Kerry, 2010; Warriss; 2010). When muscle is converted to meat, there is build-up of lactic acid in the tissue which leads to a reduction in pH. High drip loss is associated with a low ultimate pH (<5). This is due to the fact that at this low pH myofibrillar proteins lose their ability to bind water at this point as their iso-electric point is between 5.4 and 5.5. Additionally, as the charge of the protein within the myofibril approaches zero, the repulsion of other structures is reduced and the spaces between these structures become smaller. When the meat is then cut, the structure of the myofibrillar protein is disrupted and large amount of exudate appear on the cut surface of the meat which results in an undesirable product (Troy & Kerry, 2010). Higher drip loss will also result in meat that is paler in appearance due to a higher occurrence of light scattering from the surface of the meat (Warriss, 2010). Drip loss may be influenced by genotype with Merino's having a higher ultimate pH than other breeds (Warner, *et al*. 2011*)*, but also by the *ante* and *post-mortem* handling of animals with highly stressful handling resulting in a higher loss of exudate (Barbut *et al.,* 2008).

During the heating/cooking process, there are many structural changes within the meat that will result in moisture loss (Honikel, 2004). The high temperatures associated with cooking meat will result in the denaturation of myofibrillar proteins which will result in the coagulation of these proteins and ultimately shrinkage of the myofilament which will lead to a loss of moisture from these fibres (Honikel, 1998). A higher cooking loss can be associated with a steep fall in pH *post-mortem* as well as the leaking of myofibrillar proteins due to the early breakdown of these components during proteolysis (Gregory, 2007).

The results of the effect of environmental enrichment on the WHC of lamb meat has been inconsistent with Teixiera *et al.* (2012) finding no difference between treatment and control groups and Aguayo-Ulloa (2014) finding that lambs from environmentally enriched pens had a lower WHC than lambs from control groups.

2.4.6. Colour

Even though the normal colour of the meat bears little to no correlation with the eating quality of meat, consumers still regard this attribute as the most important when choosing a product to purchase (Troy & Kerry, 2010). The colour of meat is determined by many factors including the myoglobin and haemoglobin (concentration, type and state), pH of the meat as well as the light scattering on the surface of the meat that was cut (Kropf, 1993; Lawrie, 2006). The myoglobin concentration in meat will vary inter- and intra-species and will be influenced by a range of factors including the age and diets of the animals, genetic and environmental factors and exercise (Livingston & Brown, 1981).

Myoglobin can exist as deoxymyoglobin, oxymyoglobin or metmyoglobin (Troy & Kerry 2010). Deoxymyoglobin contains iron that is in the ferrous state and is responsible for the purple/red colour that is associated with meat immediately after cutting a deep muscle or meat that is stored in vacuum packaging (Warriss, 2010). When deoxymyoglobin is exposed to oxygen, oxymyoglobin is formed which will give the meat a bright red colour (Troy & Kerry, 2010; Warriss, 2010). This is also the most sought after colour by consumers. The interaction between oxymyoglobin and oxygen will result in the formation of metmyoglobin. In this form of myoglobin the haem iron has been further oxidised to its ferric state and this will cause the meat to appear as a brownish colour which is unappealing to the consumer (Lawrie, 2006; Warris, 2010).

Aguayo-Ulloa *et al.* (2013) reported that lambs that are raised in an environmentally enriched feedlot will have a meat colour that is more attractive to the consumer. Animals with a higher activity level will produce darker meat due to higher levels of myoglobin in the muscles (Diaz, 2002; Priolo, 2002).

2.5. Conclusion

Animal welfare has always been an important factor to consider when rearing animals for both the farmer and the animal itself. However, in recent years it has become a very important issue for the consumer with the environment in which the animal was reared playing a major role in the choices consumers make when it comes to animal products.

Not only does the animal need to be raised in a humane manner, but the impact of the rearing environment needs to be taken into consideration as well as what both the physical and psychological impact during the rearing phase will have on the animal's production performance and the final product made available to the consumer. With the recent trends to finish lambs in an intensive environment rather than an extensive environment, the ability to understand the impact of the intensive rearing conditions on the natural behaviour of the lambs, has become important. However, very limited information regarding these factors is available.

The main objectives of this study is therefore to evaluate the impact of environmental enrichment in a feedlot on the natural behaviour profile and welfare of the Merino lamb and to investigate methods to remedy any stereotypical or destructive behaviour the lamb may exhibit during the finishing phase. This remedy will likely also have an impact on the production parameters of the lamb as well as meat quality and therefore both these factors will also be evaluated.

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CHAPTER 3

The effect of environmental enrichment and footrot on the weight gain and behaviour of lambs finished in a feedlot.

Abstract

The aim of this study was to investigate the effect of structural environmental enrichment on the productive performance and behaviour (maintenance behaviour and social interactions) of lambs finished in an indoor feedlot for five weeks. Additionally, the effect of infectious pododermatitis (footrot) on these attributes was also assessed. The lambs were housed in control pens similar to current feedlot conditions or treatment pens which contained wooden platforms (four pens per treatment, six sheep per pen) whereupon the sheep could climb and play. There were no interactions found between the main effects. There were no differences ($p \leq 0.05$) found between treatment and control with regards to the total weight gained over the fattening period. There were also no significant differences found between healthy lambs and lambs infected with footrot with regards to total weight gain over the fattening period, however, lambs infected with footrot gained weight slower than healthy lambs ($y=1.27x+34.33$ of infected lambs versus $y=2.06x+34.24$ of healthy lambs). Maintenance behaviour did not differ between treatments. However, lambs in the control group exhibited more aggressive behaviours whilst lambs in treatment groups exhibited more affiliative behaviours (an indication of good animal welfare). The frequency of stereotypical behaviours was similar between treatment and control groups. Within the treatment group, a positive correlation was found between affiliative behaviours and the use of the wooden platform, while there was a negative correlation between the use of the platform and aggressive interactions. Therefore, the wooden platform did have a positive effect on the welfare of lambs.

3.1. Introduction

Consumer perception is the driving force behind the meat industry and with consumers demanding a product that has been humanely reared, transported and handled, farmers have to consider animal welfare when designing an environment where lambs will be reared. Consumer demands have prompted retailers and farmers to place a higher value on animals that were reared in an environment that adheres to the consumers' perception of animal welfare (Troy & Kerry, 2010). There has been a shift in South Africa from the extensive system of rearing lambs to an intensive system (WWF, undated). This increases productivity as large flocks can be finished on a smaller area and also allows for a standardised product (Miranda-de la Lama *et al.,* 2012; Teixeira *et al.,* 2014). Globally, the shift from the extensive system to the intensive system has primarily focused on yield while animal welfare has not enjoyed much attention (Koknaroglu & Akunal, 2013). Furthermore, intensive farming practices have caused a decline in farmed animal welfare, for example: chickens have weaker bones and pigs display more abnormal behaviours (Napolitano *et al*., 2010).

Previous studies have highlighted the effect that transporting, feeding regime, exposure to novel environments and introduction to new social groupings has on the stress response (Miranda-de la Lama *et al*., 2010a) as well as the susceptibility to contract diseases and behaviour of lambs (Aguayo-Ulloa *et al*., 2015). However, there have been very few studies that investigated the effect of environmental enrichment on the behaviour, stress, productive performance and meat quality of finishing lambs in a feedlot. It is, therefore, necessary to develop environmental enrichment protocols to tackle problems associated with the animal welfare of lambs finished in a feedlot (Aguayo-Ulloa *et al.,* 2015).

The objective of this trial was to assess the effect of structural environmental enrichment and disease (footrot) on the behaviour profile (maintenance and social behaviours) and weight gain of lambs finished in an indoor feedlot.

3.2. Materials and Methods

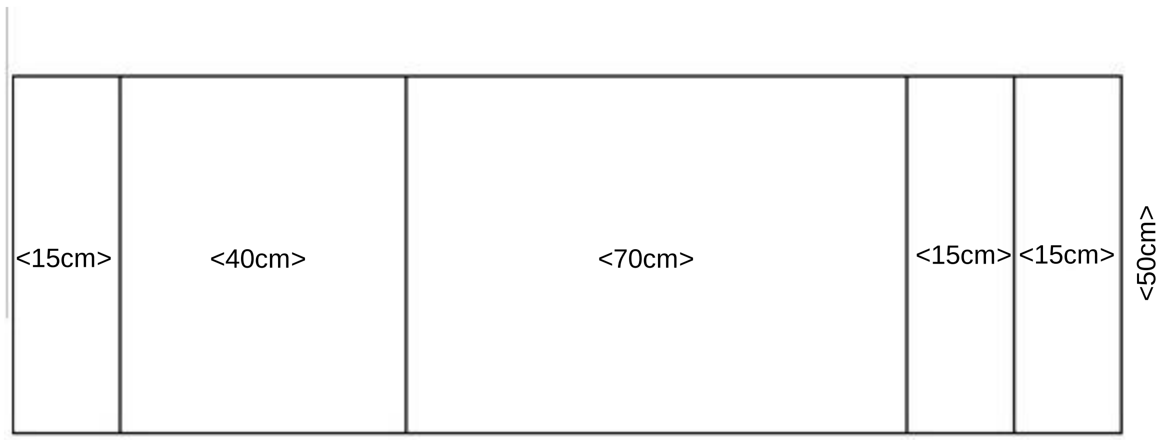
3.2.1. Management and Handling of Sheep

The experiment was carried out at Welgevallen Experimental Farm, Stellenbosch, Western Cape, South Africa (33°56'33"S; 18°51'56"E). This farm is located in the winter rainfall region and has average daily temperatures of 16°C and average nightly temperatures of 6°C during the winter season at which time this trial was conducted. The lambs were housed indoors on slatted floors in accordance with South African Feedlot Association (SAFA, 2008), the National Environmental Guidelines for Feedlots (SAFA, 2005). All protocols were approved by the University of Stellenbosch’s Animal Ethics Committee (SU-ACUM14-00012).

A total of 48 sheared Merino lambs (castrates (n=21) and ewes (n=27)) with average live weights of 33.9 ± 0.23 kg were used. The lambs were between the ages of eight to ten months when they entered the feedlot. The shed had eight pens (dimensions of 1.8 x 6.88 m) with six sheep in each (stocking density of 2.06 m^2/sheep). Four of the pens were used as treatment groups and contained a wooden platform made from recycled pallets (see Figure 3.1 for dimensions and Addendum A for pictures) while the other four pens were left barren and similar to current feedlot conditions. Lambs (n=6/pen) were randomly allocated to either a treatment pen (n=4 pens) or a control pen (n=4 pens). The lambs were fed a commercial concentrate feed Afgri Sheep Grower (15.3% crude protein and 10.95 MJ metabolisable energy/kg DM) and water on an *ad libitum* basis. Lambs were sourced from Tomi’s abattoir/feedlot who in turn sourced the lambs from various locations in the Western Cape. They were brought to Welgevallen experimental farm where they were adapted to the Afgri Sheep Grower feed over a period of two weeks. During this period lambs were fed hay and concentrate and the amount of concentrate was increased every three days while the amount of hay was decreased until the lambs were ultimately only fed concentrate. When this adaptation period was completed, the trial began. The feed was provided from individual hanging feeders, which were all placed next to one another on the one side of the pen while the individual drinkers were placed on the other side. The shed had multiple windows and air vents, which provided ventilation as well as natural light, however, additional artificial light was also provided from 08:00-17:00 as this trial took place during winter and most days were overcast. The lambs were fattened in the feedlot during the finishing phase for five weeks.

Prior to entry into the feedlot two lambs had already contracted infectious pododermatitis (footrot). During the trial the lambs were treated with a course of Lentrax as well as a 10% Formaldehyde footbath. This treatment was unable to eradicate the disease, which subsequently spread amongst the flocks and the focus of the trial changed to include the effects of infectious pododermatitis on the production parameters as well as the behavioural profile of the lambs in a feedlot. Of the 48 lambs in the total group, 13 lambs were infected with footrot and unable to recover. Of these 13 infected lambs, eight were in control pens and five were in treatment pens.

Side view of wooden platform



Top view of wooden platform

Figure 3.1 Dimensions of wooden platforms used.

3.2.2. Production Measurements

Lambs were weighed individually upon entry into the feedlot and again once a week thereafter, with the final weigh recording on the day of slaughter. The average daily gain (ADG) of each animal was then calculated on a weekly basis by calculating the difference between the weight of the current week and the previous week divided by seven days (one week). The concentrate in the feeders were weighed on a daily basis and refusals were weighed back once a week. The feed conversion ratio (FCR) was then calculated per group by calculating the difference in the concentrate added to the feeder and the refusals at the end of the week divided by the total weight gain of the group for that week.

3.2.3. Behavioural Measurements

Lambs were individually marked upon entry into the feedlot with coloured numbers using an animal friendly spray paint. A video recording device (model SEB-1020RN) was setup in the shed with four cameras placed 1.8 m above each pen. The behaviour profile of four pens in the middle of the shed was measured (two control and two treatment groups).

A recording was made every day from 08:00 to 17:00 (from sunrise to sunset). These recordings were then used to do instantaneous sampling (Martin & Bateson, 2007) every 15 minutes where the following behaviours were recorded by the same observer: standing (lamb standing on all four legs in a stationary position), lying (lamb resting on abdomen, front legs and the lower hind leg), walking (lamb on all four legs and in motion), feeding (lamb eating from the feeder) and drinking (lamb drinking from the drinker).

These same recordings were then used for continuous sampling where stereotypical behaviour (Mason 1991), use of wooden platforms and all social interactions were recorded and assessed to be either aggressive or affiliative and whether or not it involved physical contact (Miranda-de la Lama *et al*., 2011). The continuous sampling was done on day 2, day 9, day 16 and day 23. Furthermore, it was assessed which animal was the aggressor and which animal was the victim of the aggressive interaction (Ruiz-de-la-Torre & Manteca, 1999). Refer to Table 3.1 for a detailed description of recorded affiliative and aggressive interactions. With regard to stereotypical behaviours, different types were assessed: oral (licking or gnawing on fences, feeders, drinkers or wooden platforms), wool biting (lamb bites or pulls another lamb's wool) and body-rubbing (lamb rubs up and down against the fence). Finally, the use of the wooden platforms (lying or standing on the platform and time allotted) in the treatment pens was recorded.

Table 3.1 Description of continuous behaviour assessment

Affiliative				**Aggressive**							
With Contact		**Without Contact**		**With Contact**				**Without Contact**			
				Aggressor		**Victim**		**Aggressor**		**Victim**	
Action	**Description**	**Action**	**Description**	**Action**	**Description**	**Action**	**Description**	**Action**	**Description**	**Action**	**Description**
Licking	Lamb licks another lamb's body	Sniffing	Lamb sniffs another lamb's body	Head butt	Lamb uses his forehead to hit another lamb on any part of the body	Head butt	Lamb is hit on any part of the body by another lamb's forehead	Threatening	Lamb approaches another lamb with head down and lunges without making contact	Threatening	Lamb is approached by another lamb with head down and lunged at without contact
Nibbling	Lamb grooms another lamb's body using teeth			Mounting	Lamb mounts another lamb from behind without apparent sexual function	Mounting	Lamb is mounted from behind by another lamb without any apparent sexual function	Persecution	Lamb approaches another lamb causing the latter to move or run away	Persecution	Lamb is approached by another lamb causing it to move or run away
				Kicking	Lamb uses his foreleg to hit another lamb on any part of the body	Kicking	Lambs is hit on any part of the body by another lamb's foreleg	Avoidance	n.a.	Avoidance	Lamb runs or moves away from another lamb

3.2.4. Statistical Analysis

Data analysis was performed using SAS software for Windows Version 9.3. For production parameters a nested linear model was fitted with treatment nested within pens. These production parameters included weight gain per week and weight of lambs per week. The data was analysed based on both individual data and totals per pen. A linear regression was performed on the weight gain of all individuals and these regression lines were compared using ANOVA in terms of treatments as well as healthy lambs versus lambs with footrot. A two x two factorial model was used to compare the slopes of the weight gain of individual lambs. The studentised residuals were calculated and a Shapiro-Wilk test was performed to assess any deviations from normality.

For the instantaneous behavioural data a nested linear model was used with pen nested within subject. The data was presented as the percentage of time the lamb performed all of the behaviours per day.

For continuous behavioural data, individual lamb data were added per pen and per treatment per week. The data were analysed using the GLM procedure of SAS. The data were presented as average per animal per day with day as the repeated factor, treatment as the fixed effect and lamb as the random effect (Teixiera *et al.*, 2012). This model was used to assess the differences between treatment and control groups as well as the differences between weeks based on the average per pen. Furthermore, correlations between all behaviours where average per pen was used were assessed. This data were also used to assess the differences between individual lambs with a cluster analysis being performed using Ward's method of Agglomerative Hierarchical Clustering (AHC). Correlations based on individual lamb behaviour were assessed.

A significant difference was considered when $P \leq 0.05$ and least squares means (±standard error) are reported.

3.4. Results

3.4.1. Production Measurements

There were no significant differences found for weight gain between the treatment group and the control group. The weight gain trend for all pens is depicted in Figure 3.2. There were also no significant differences in the total weight gain between healthy lambs and lambs with footrot, except for week five. A difference ($P = 0.0013$) was found between the rate of weight gain of healthy lambs and lambs with footrot. Infected lambs gained weight slower than healthy lambs at a tempo of $y=1.27x+34.33$ while healthy lambs gained weight at a rate of y=2.06x+34.24. There were no significant differences found between the rates of weight gain of control groups and treatment groups.

In pen 6, three of the six lambs were infected with foot rot during the first week of the trial. This pen showed significant weight loss during the first week of the trial. After the first week, the lambs started gaining weight and showed compensatory growth during week two and week four.

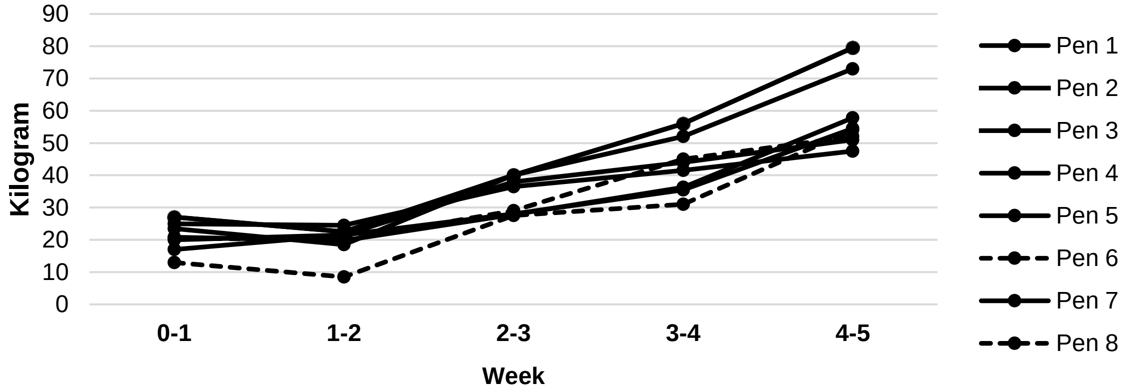


Figure 3.2 Cumulative weight gain per pen over fattening period. Treatment groups are indicated with a solid line and control groups with a dashed line.

3.4.2. Behavioural Measurements

3.4.2.1. Instantaneous Sampling

There were no significant differences found between treatment and control groups for maintenance behaviours (walking, eating, sleeping, resting and drinking) based on the nested one-way ANOVA and the MANOVA. There were also no differences found between weeks for these behaviours. In Table 3.2 the means for maintenance behaviour are summarized; lambs spent most of their time (40%) standing and sleeping/resting (38%), while 17% of the day was spent eating and 4% was spent walking. Lambs devoted the least amount of time to drinking (1%) every day. There were no significant differences found for maintenance behaviour between healthy lambs and lambs with footrot.

Table 3.2 Least square means of behaviours (as % of time) recorded with instantaneous sampling of lambs in barren (control) or enriched environments (treatment) during the finishing phase of feedlot fattening.

Behaviour	Control	Treatment	P-value
Walking	4.26	3.58	0.302
Resting	38.06	37.70	0.877
Eating	17.61	16.13	0.191
Standing	40.31	40.20	0.953
Drinking	1.20	0.88	0.289

3.4.2.2. Continuous Sampling

Social behaviour was first assessed according to average per treatment with pens used as repeats over the total fattening period. There were significant differences found between treatments over the total fattening period with regards to the following behaviours: Affiliative with contact (p=0.003), aggressive with contact where the lamb was the aggressor (p=0.018) and aggressive with contact where the lamb was the victim (p=0.014). Treatment pens had a higher frequency of affiliative interactions with contact while control pens had a higher frequency of aggressive interactions both with and without contact. Differences between behaviours according to week were also assessed and significant differences were found between treatments with regards to the following behaviours: aggressive behaviours where the lamb was the victim in terms of with contact (p=0.011) and without contact (p=0.003) as well as stereotypical behaviours (p=0.028). Stereotypical behaviour had the highest frequency during week three and the lowest frequency during week four.

There were no significant differences between the amounts of time the lambs spent standing on the wooden platform between weeks, however the number of times lambs climbed on the box was significantly less in the first week of the fattening period.

Table 3.3 Least significant means (±SE) for the frequency of lambs climbing on platform and amount of time allotted (mins) to doing so per week.

Week	Amount of standing on platform	Time allotted to standing on platform
1	56^{b}±3	177.47^{a}±85.65
2	72^{a}±28	162.03^{a}±11.26
3	125^{a}±68	248.08^{a}±65.58
4	89^{a}±34	197.53^{a}±58.54

Significant differences between **weeks** are indicated by letters $^{a-b}$ within the same column. (P≤0.05).

The least square means (±standard error) per animal per week of all the sampled behaviours are presented in Figure 3.5. The behaviours were influenced by both time in the pen (days of finishing) and treatment. Affiliative interactions with contact showed significant differences in week three and week four while there were no significant differences between weeks or treatments for affiliative interactions without contact. Aggressive interactions with contact where the lamb was the aggressor or victim resulted in no significant differences between weeks or treatments. During week two there were significant differences (P=0.049) between treatment and control groups for aggressive interactions without contact where the lamb was the aggressor with the control group showing a higher frequency of this behaviour. While there were no significant differences found between weeks or treatments in week three and four for aggressive interactions without contact where the lamb was the victim, there were significant differences (P=0.004) between treatment and control groups during week two. The control group also showed a significantly higher frequency of this behaviour during week two when compared to the rest of the fattening period, while the treatment group had significantly higher frequency of the behaviour during week one when compared to week three and four. Stereotypical behaviour in the treatment group differed significantly between week one and week three with the control group as well as the treatment group; week one having a lower frequency of stereotypical behaviour in the treatment group when compared to the control and treatment group in week three.

Cluster analysis on the individual data of social interactions and stereotypical behaviour of each lamb over the finishing period highlighted three classes (refer to dendrogram, Figure 3.3). Class two contained only two animals which both had a serious case of footrot since the start of the trial. Class three only contained animals that were in the control group with the exception of animal 24 whereas class one contained all the animals from the treatment group, with the exception of animal 24. It also contained animals from the control group (animals 10, 15, 16 and 18), however all the other objects in the class (lambs from the treatment group) were grouped together before node 29 (with the exception of animal 1 and 22). The lambs from the control group within this class are therefore not as closely related as the lambs from treatment groups within the same class.

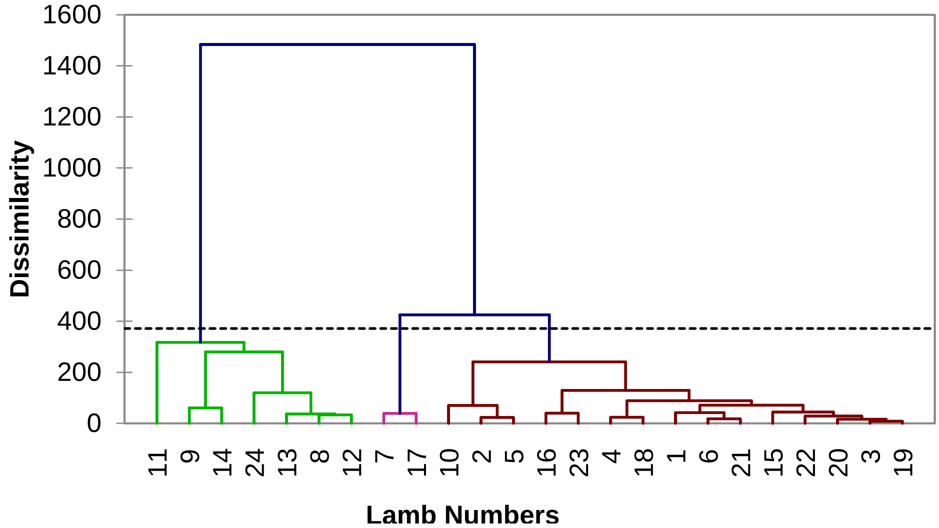


Figure 3.3 Dendrogram Clusters analysis of social interactions between individual lambs.

In Table 3.4 the class centroids for each class is given. With regards to affiliative behaviour (both with contact and without contact), class one and three had a higher average than class two. For aggressive interactions where the lamb was the victim (both with contact and without contact), class two had a much higher average than class one and three, while for aggressive interactions where the lamb was the aggressor (both with interaction and without interaction), class one had a much lower average than the other two classes. On the other hand, stereotypical behaviour was very similar between classes.

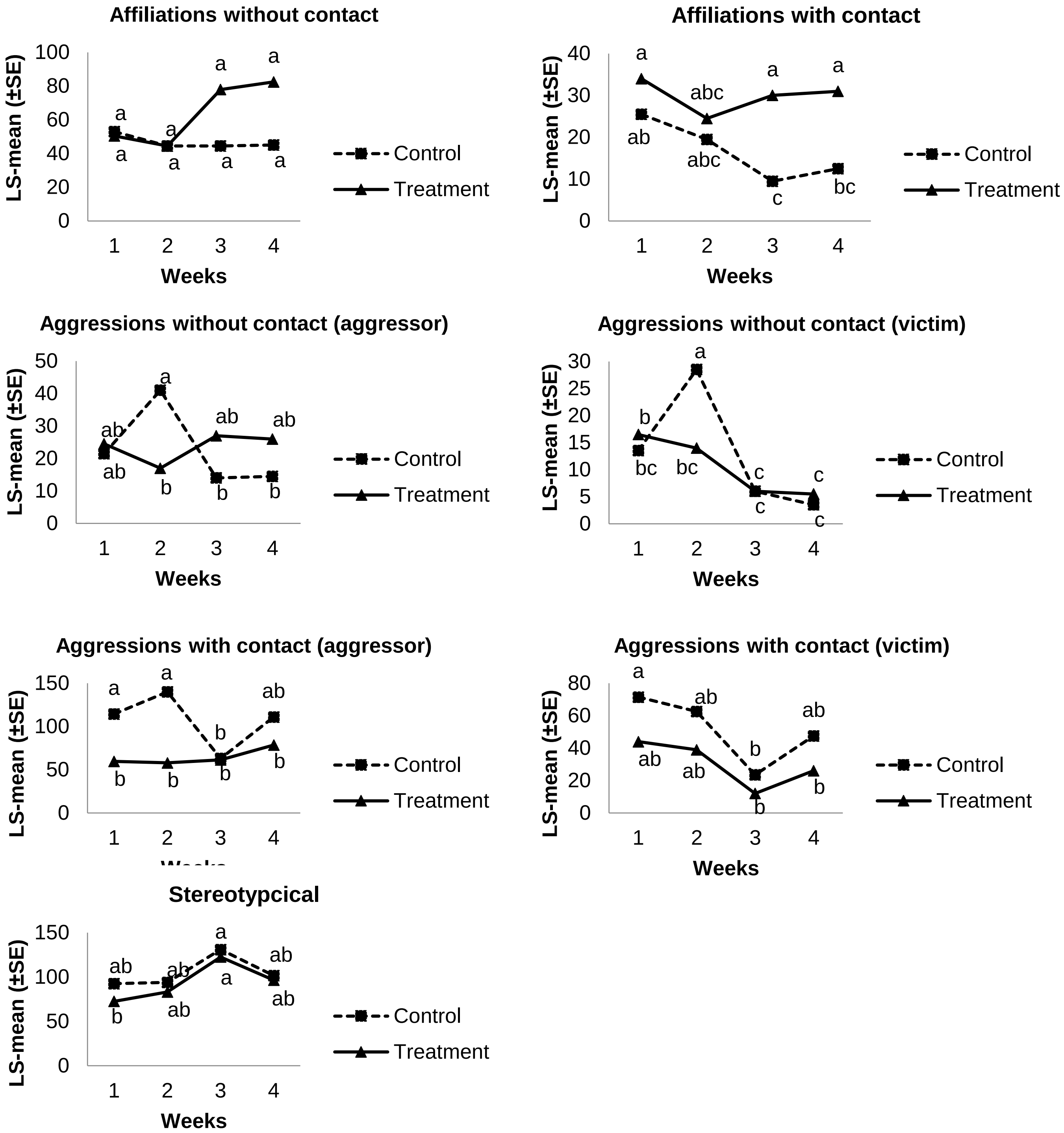


Figure 3.4.

Least square means (±SE) per animal per day for aggressive interactions with physical contact (total amount of butting, mounting and kicking) where the lamb was the aggressor and victim, aggressive interactions without physical contact (threats, persecution and avoidance) where the lamb was the aggressor and victim and affiliative interactions with contact (licking, nibbling) and without (sniffing), as well as stereotypic behaviour profile in terms of days after social mixing. Letters (a, b, c) indicate significant differences ($p \leq 0.05$) between weeks within the same treatment (horizontal) and significant differences between treatments within the same week (vertical).

Table 3.4 Class centroids for every class based on all recorded social behaviours.

Class	Affiliative interactio n with contact	Affiliative interaction without contact	Aggressive interaction with contact (aggressor)	Aggressive interaction with contact (victim)	Aggressive interaction without contact (aggressor)	Aggressive interaction without contact (victim)	Stereotypical behaviour
1	3.650	9.433	10.283	6.017	2.883	1.833	15.100
2	1.000	3.500	5.750	18.625	0.625	5.500	15.250
3	5.250	10.429	25.393	5.607	6.893	1.179	20.071

Correlations based on individual lamb data are depicted in Table 3.5. A high positive correlation was found between affiliative interactions with contact and affiliative interactions without contact. Affiliative interactions (with and without contact) had a negative correlation with aggressive interactions with contact where the lamb was the victim, while a negative correlation was found between the same type of aggressive interactions and affiliative interactions with contact. There was a positive correlation between aggressive interaction with contact and without contact where the lamb was the aggressor. A negative correlation was found between aggressive interactions with contact where the lamb was the aggressor and aggressive interactions without contact where the lamb was the victim. A negative correlation was also found between aggressive interactions with contact where the lamb was the victim and aggressive interactions without contact where the lamb was the aggressor. There was a positive correlation between aggressive interactions with contact and aggressive interactions without contact where the lamb was the victim. A negative correlation was found between aggressive interactions without contact between the victim and the aggressor. The frequency of eating in the morning was negatively correlated with aggressive interactions (both with contact and without contact) where the lamb was the victim.

Correlations were also assessed based on the average frequency of the behaviours on the entire experimental group irrespective of treatment/control (Table 3.6). A significant positive correlation was found between lambs that were victimized and lambs that victimized others (aggressive behaviour with and without contact). Lambs that were aggressive with contact (victim) and aggressive without contact (victim), also had a significant, positive correlation. The lambs' use of the platform showed a significant positive correlation with affiliative interactions with contact and a significant negative correlation with aggressive behaviours with contact (both victim and aggressor).

Table 3.5 Correlations between all social interactions and stereotypical behaviours recorded with continuous assessment in terms of individual lamb data over the fattening period.

	Affiliative with contact	Affiliative without contact	Aggressive with contact (A)	Aggressive with contact (V)	Aggressive without contact (A)	Aggressive without contact (V)	Stereotypical
Affiliative with contact	**1.000**	0.728	0.156	-0.421	0.433	-0.411	0.066
	0.000	0.000	0.465	0.040	0.034	0.046	0.759
Affiliative without contact	**0.728**	**1.000**	0.105	-0.417	0.199	-0.358	0.058
	< 0.0001	**0.000**	0.625	0.043	0.351	0.086	0.787
Aggressive with contact (A)	0.156	0.105	**1.000**	-0.285	0.712	-0.433	0.255
	0.465	0.625	**0.000**	0.177	< 0.0001	0.034	0.230
Aggressive with contact (V)	**-0.421**	**-0.417**	-0.285	**1.000**	-0.536	0.781	-0.051
	0.040	**0.043**	0.177	**0.000**	0.007	< 0.0001	0.813
Aggressive without contact (A)	**0.433**	0.199	**0.712**	**-0.536**	**1.000**	-0.575	0.074
	0.034	0.351	**< 0.0001**	**0.007**	**0.000**	0.003	0.732
Aggressive without contact (V)	**-0.411**	-0.358	**-0.433**	**0.781**	**-0.575**	**1.000**	-0.019
	0.046	0.086	**0.034**	**< 0.0001**	**0.003**	**0.000**	0.928
Stereotypical	0.066	0.058	0.255	-0.051	0.074	-0.019	**1.000**
	0.759	0.787	0.230	0.813	0.732	0.928	**0.000**

A (aggressor); V (victim). ($P \leq 0.05$).

Table 3.6 Correlations between all social interactions and stereotypical behaviours recorded with continuous assessment in terms totals irrespective of treatment over the fattening period.

	Affiliative with contact	Affiliative without contact	Aggressive with contact (A)	Aggressive with contact (V)	Aggressive without contact (A)	Aggressive without contact (V)	Stereotypical	Climbing on platform	Time allotted: Standing on platform
Affiliative with contact	1.000	0.419	-0.115	0.070	0.392	0.128	-0.334	0.585	0.706
		0.106	0.672	0.797	0.133	0.636	0.206	0.017	0.002
Affiliative without contact	0.419	1.000	-0.169	-0.304	-0.078	-0.229	0.169	0.306	0.460
	0.106		0.533	0.253	0.774	0.394	0.531	0.249	0.073
Aggressive with contact (A)	-0.115	-0.169	1.000	0.720	0.438	0.359	0.023	-0.488	-0.552
	0.672	0.533		0.002	0.090	0.172	0.934	0.055	0.027
Aggressive with contact (V)	0.070	-0.304	**0.720**	1.000	0.148	0.485	-0.298	-0.602	-0.580
	0.797	0.253	**0.002**		0.585	0.057	0.263	0.014	0.018
Aggressive without contact (A)	0.392	-0.078	0.438	0.148	1.000	0.578	0.025	0.267	0.227
	0.133	0.774	0.090	0.585		0.019	0.927	0.317	0.399
Aggressive without contact (V)	0.128	-0.229	0.359	**0.485**	**0.578**	1.000	-0.307	-0.274	-0.177
	0.636	0.394	0.172	**0.057**	**0.019**		0.247	0.304	0.512
Stereotypical	-0.334	0.169	0.023	-0.298	0.025	-0.307	1.000	0.075	-0.019
	0.206	0.531	0.934	0.263	0.927	0.247		0.781	0.945
Climbing on Platform	**0.585**	0.306	**-0.488**	**-0.602**	0.267	-0.274	0.075	1.000	0.940
	0.017	0.249	**0.055**	**0.014**	0.317	0.304	0.781		<.0001
Time allotted: Standing on platform	**0.706**	**0.460**	**-0.552**	**-0.580**	0.227	-0.177	-0.019	**0.940**	1.000
	0.002	**0.073**	**0.027**	**0.018**	0.399	0.512	0.945	**<.0001**	

A (aggressor); V (victim). ($P \leq 0.05$).

3.5. Discussion

3.5.1. Production Measurements

These results differed from results found by other researchers where significant differences were found in the slaughter weight (Aguayo-Ulloa *et al.*, 2010) and average daily gain (Aguayo-Ulloa *et al.*, 2014a) of lambs between environmental enriched and control groups, however in a later study, Aguayo-Ulloa *et al.* (2015) and Teixeira *et al.* (2012) also found no significant differences with regards to production parameters between treatment and control groups. This experiment only used a single wooden platform as an environmental enrichment source while other experiments used a combination of various environmental enrichment sources such as straw, feeder ramps and double bunkers. It is, therefore, a possibility that the environmental enrichment used in this experiment did not stimulate the lambs sufficiently (by being too small, not in the ideal location in the pen, etc.) to have an effect on the production performance. In addition, the lambs used for this trial were heavier when the trial started (±32 kg compared to ±19 kg in afore mentioned experiments) and were therefore also slaughtered at a later age and the effect of age and the use of platforms is unknown. Another factor that could have had an influence on the different finding, is that some of the previous studies used a fattening period of four weeks, while this study used five weeks and it is not known whether boredom with the environmental enrichment could develop over time with lambs. However, in this study there was no decline in the use of the platform over the fattening period.

It is, however, noteworthy that while the weight gain per pen over five weeks was between 47.5 and 57.5 kg, two of the four treatment pens gained 73.0 and 79.5 kg respectively (Figure 3.2). Therefore, two of the four pens showed significantly higher ADG and slaughter weights when compared to the other pens. It is possible that the lambs in these pens used the wooden platform more frequently than lambs in the other two pens (it is not possible to determine as only two of the four treatment pens were observed by the cameras, as more pens would have been impossible to assess due to time constraints). It was noticed by the observer that the lambs used the platform more when it was located near a window where the lambs could look outside or when standing on the platform enabled the lamb to chew on partitioning. It is therefore possible that certain lambs are more interested in the platform while others are less interested or not interested at all, which will have an effect on the efficacy of the wooden platform. Another possible explanation could be that other treatment pens had lambs that were very dominant and did not allow the other lambs to make use of the platform, unfortunately these pens did not have cameras mounted to them that would have allowed more critical analyses of the data. It could also be argued that should a larger experiment be conducted with more pens per treatment, a significant difference between control groups and treatment groups may be found. All the experiments done to date only had two to three pens per treatment (Aguayo-Ulloa *et al.*, 2010; Aguayo-Ulloa *et al.*, 2014a; Aguayo-Ulloa *et al.,* 2015; Teixeira, *et al.* 2012).

There was a difference (p = 0.0013) between the weight gain trends of healthy lambs and lambs with footrot. Lambs with footrot gained weight slower than lambs that were healthy (refer to 3.4.1) even though the final weights were similar. This is most likely due to compensatory growth as some lambs with footrot seemed to adjust to the pain the illness caused and exhibited behaviour profiles similar to healthy lambs with the exception of a very obvious limp.

Some lambs with footrot showed very poor weight gain, losing between 3 and 11 kg in the final two weeks of the finishing period, while some healthy lambs in the treatment pens gained between 10 and 15.5 kg over the entire fattening period. It is difficult, however, to draw a final conclusion on the magnitude of the effect of the presence of footrot on the production performance of the lambs as there were an insufficient number of lambs (only 13 of 48 lambs) that had footrot at the same period during the trail, nor were the level of infection similar between lambs. None the less, it is clear that those lambs with footrot performed poorer.

3.5.2. Behavioural Measurements

3.5.2.1. Instantaneous Sampling

Aguayo-Ulloa *et al.* (2010), Aguayo-Ulloa *et al.* (2014b) and Aguayo-Ulloa *et al.* (2015) all found significant differences in maintenance behaviour between environmentally enriched pens and barren pens, while this study found no significant differences between treatments or weeks. As previously mentioned, the environmental enrichment used in this study was very simple when compared to the environmental enrichment used by these other researchers. It is therefore possible that the wooden platform was not sufficiently stimulating to elicit a significant difference in maintenance behaviour between treatment and control groups.

Previous studies also found that resting behaviour was significantly higher than any other behaviours recorded, while in this study lambs spent most of the time standing (40%) and only 38% of the day resting/sleeping with other studies finding that lambs rested more than two thirds of the day (Aguayo-Ulloa *et al.*, 2014b; Aguayo-Ulloa *et al.*, 2015). This could be due to external factors such as temperature. This trial was conducted during a very cold period and some days there was morning frost which is not common for this area. The lambs had been shorn prior to entry into the feedlot and would thus have lost the insulation effect of wool and were more prone to cold stress (NRC, 1981), which could have had an effect on the amount of time the lambs spent resting. These lambs were also older than the lambs used in previous studies which could have had an effect on the maintenance behaviour. The amount of time lambs spent eating and walking per day was very similar to afore mentioned previous studies.

3.5.2.2. Continuous Sampling

Social interactions in a group of lambs can be used as an indicator of the stability of the group as well as the welfare of the group (Broom, 1991; Weary *et al.* 2008). Miranda-de la Lama *et al.* (2012) and Ruiz-de-la-Torre and Manteca (1999) found that when lambs are exposed to novel environments and social mixing with unfamiliar lambs, both aggressive interactions and stereotypical behaviours will increase. However, according to Teixiera *et al.* (2012), a high level of aggressive behaviours could also be an indication of social instability in the group which is an indication of poor animal welfare, while Fraser *et al.* (1995) provided the theory that when animals are in a competitive environment (when resources are limited), aggressive interactions could increase.

Previous studies have found mixed results with regards to the effect of environmental enrichment on the social interactions (affiliative and aggressive) as well as the stereotypical behaviours of lambs with Miranda-de la Lama *et al.* (2012) and Teixiera *et al.* (2012) both finding higher frequencies of aggressive interactions at the beginning of the fattening period in groups fattened in pens without environmental enrichment, while Aguayo-Ulloa *et al.* (2014b) found no differences between treatments or weeks.

This study found a significant difference in the number of aggressive interactions with contact where the lamb was the aggressor and the victim, with both of these behavioural categories having the highest frequency in the control group. The frequency of aggressive interactions with contact where the lamb was the victim was also the highest in week one and second highest in week four. This could be an indication that lambs in the control pens found it more difficult than lambs in the treatment pens to adapt to the new environment due to their pens containing no stimuli. The increase in aggressive behaviours with contact where lambs were victimized towards the end of the trial could be because more animals where infected with footrot at the end of the fattening period as the disease spread through the group with these infected lambs being the victims (Figure 3.4).

Affiliative interactions differed significantly between treatment and control groups with lambs in treatment groups displaying a higher frequency of affiliative behaviours. The difference between treatment groups and control groups also increased over time although there was no statistical difference between weeks (Figure 3.4). Affiliative interactions have been described as behaviours that reduce aggressive interactions (Miranda-de la Lama *et al.,* 2010b) and therefore it should theoretically decline over time as the animals adapt to the novel environment and new social group (Miranda-de la Lama *et al.,* 2012). However, Boissy *et al.* (2007) found that many studies will determine the efficacy of animal welfare based on the reduction of stereotypes and aggressive interactions (indicators of poor welfare), while it should be based on an increase in affiliative interactions (indicators of good welfare). Therefore, it should be noted that the frequency of affiliative behaviour was similar over the fattening period for the lambs in treatment groups (Figure 3.4) while the lambs in the barren environments showed a decline in frequency over time; similar to what Miranda-de la Lama *et al.* (2012) found in their study. Teixiera *et al*. (2012) found that affiliative interactions increased over the fattening period, indicating that cohesion in the group was strong.

Previous studies found differences in the frequency of stereotypical behaviours in both treatments (Aguayo-Ulloa *et al.,* 2010; Aguayo-Ulloa *et al.,* 2014b; Teixiera *et al.* 2012) and weeks (Miranda-de la Lama *et al.* 2012). In this study there were no differences found in the number of stereotypical behaviours performed by lambs between treatments over the whole period, however, the lambs in the treatment group did display less stereotypical behaviours in week one when compared to the lambs in the control group, which could be an indication that these lambs adapted better to the novel environment due to the environmental enrichment provided (Figure 3.4).

There were, however, differences found in the number of stereotypical behaviours performed between weeks with week three having the highest frequency of stereotypes followed by week four (Figure 3.4). This is contradictory to Miranda-de la Lama *et al.* (2012) who found that the frequency of stereotypical behaviour declined over the fattening period. However, because stereotypical behaviours followed the same trends in both treatment and control groups, it is possible that this was either due to external factors or the spread of footrot.

Lambs climbed on the wooden platform more in the final week of the fattening period, however the amount of time they spent on the platform did not differ between weeks. It is possible that the number of times they climbed on the platform is related to the increase in frequency of other social interactions. In other words, because there was more overall movement of lambs in the pen, they moved over the box more.

The cluster analysis (Figure 3.4) grouped lamb 7 and 17 together. These lambs were infected with footrot upon arrival in the feedlot and they remained sick throughout the fattening period. All the other lambs were therefore infected after the trial had started. According to the cluster analysis, these two lambs were victimised more than the other lambs while they initiated aggressive interactions less than the other two cluster groups. These animals also showed much less affiliative behaviour (with and without contact) than the other two cluster groups, indicating that these animals experienced poor animal welfare due to footrot (and pain). These animals were easily victimised by other animals in the groups because they were unable to defend themselves. They, therefore, kept to themselves and had minimal interaction with other lambs in the group unless they were approached by another lamb. This would indicate that lamb feedlot management plans should have a standard operating procedure where lambs with footrot (and possibly other health issues) should be isolated and removed from the pen to minimise social victimisation of these lambs.

Correlations were assessed on both individual and group data. When correlations were assessed based on individual lamb data (Table 3.5), significant correlations emerged. Negative correlations between lambs that were victimised (both with contact and without) and affiliative interactions were noted. This, and the positive correlation between affiliative interactions with contact and aggressive interactions without contact supports the theory that animals that are experiencing bad emotions will be less likely to exhibit affiliative behaviours.

When correlation data was assessed based on individual data (Table 3.5), a negative correlation emerged between lambs that were victimised and lambs that were aggressors. In other words, the lambs that were aggressors were rarely victimised. This indicates that there is a very strong hierarchy between the lambs when their behaviour is assessed on an individual level. A lamb will either be a dominant, aggressive lamb or a victimised lamb. The hierarchy is established during initial social mixing and dominant lambs tend to stay dominant over the duration of the fattening period, even though the frequency of the aggressive interactions may differ between weeks. In weeks where there were less aggressive interactions, the lambs performing these interactions were still the same individuals. This is supported by the positive correlation between aggressive behaviours with and without interaction where the lamb was the aggressor as well as the positive correlation between aggressive behaviours with and without contact where the lamb was the victim.

The correlations based on group data (Table 3.6) indicated positive correlation between aggressive behaviours with and without contact where the lamb was the victim indicates that when a lamb was victimised, it was both with contact and without. A positive correlation between aggressive interactions with contact was noted where the lamb was the aggressor and the victim. The same correlation was found for interactions without contact. This is opposing to the individual data where there was a negative correlation between lambs being victimised and lambs acting as aggressors for aggressive interactions without contact. This discrepancy could be due to perspective. When viewing the correlation data based on individual lambs, victims remain victims and aggressors remain aggressors. However, based on the data for the total group, irrespective of treatment one gets a bird's eye view. Based on this data it would seem that when a lamb is victimised without interaction (persecuted or threatened), it will turn to the lamb nearest to it and persecute or threaten that lamb.

There was a positive correlation between lambs that stood on the platform (with respect to the number of times the lamb climbed on the platform and the amount of time spent on the platform) with affiliative interactions. The lambs experienced good animal welfare through the use of the platform and therefore exhibited more affiliative behaviours (Boissy *et al.,* 2007). There was also a negative correlation between aggressive interactions with contact (both where the animal was the aggressor and the victim) and the use of the platform (with respect to the number of times the lamb climbed on the platform and the amount of time spent on the platform); lambs that did not use the platform therefore experienced poor animal welfare and exhibited more aggressive behaviours.

There was, however no correlation between aggressive interactions where the lamb was the aggressor (the dominant lamb) and the use of the platform. It is therefore not only the dominant lambs that make use of the platform and it would seem as if there are other factors influencing whether or not lambs will climb on the platform as well as the amount of time spent on it. The lambs do use the platform differently, some lambs spent a lot of time on top throughout the trial while others hardly used it. Some lambs climbed on the platform many times during the first weeks and then this decreased towards the end of the fattening period while other lambs only started using the platform during the second half of the trial. Some lambs never climbed on the platform during the whole fattening period.

Lambs that were in treatment pens handled better during the weekly weighing (although not quantified), had a lower infection rate of footrot and also recovered quicker once they were infected with the disease supporting findings by Aguayo-Ulloa *et al.* (2015) that environmental enrichment improves the immunity of lambs. Future studies should include blood chemistry to quantify this potential benefit of environmental enrichment further.

The behavioural indicators of lambs with good welfare requires further research as the current descriptions of lamb behaviours do not include a section for “play” behaviours. In piglets hopping, pivoting, pawing, flopping, and head tossing are all behavioural indicators of playing (Donaldson *et al*., 2002; Newberry *et al.,* 1988). In this trial it was noted that lambs displayed similar behaviours which were, however, often categorized as aggressive interactions as these actions were often paired with head butting between lambs. These play indicators are possibly erroneously being categorised as aggressive behaviours as they present quite similar when captured/observed. Furthermore, Aguayo-Ulloa *et al*. (2014b) categorized mounting as both an affiliative (mounting with sexual intent or in play) and an aggressive interactions (mounting without sexual intent where the objective is to move the other lamb), indicating that in some instances the same type of behaviour can be either affiliative or aggressive under different circumstances.

3.6. Conclusion

The aim of this study was to investigate the effect of a wooden platform on the social behaviour of lambs as well as their feedlot performance. As some of the lambs were infected with footrot during the fattening period, the effect of this illness was also assessed with respect to behaviour and weight gain. This study did not show that the platform had any significant influence on the maintenance behaviour or the final weight of the lambs. Lambs with footrot did not perform differently in terms of maintenance behaviour. To fully assess the effect of structural enrichment on the production performance of lambs in a feedlot, a much larger study would have to be conducted.

Although there were no significant differences in maintenance behaviours, there were significant differences found between the social interactions. Lambs that were in treatment groups exhibited a higher frequency of affiliative interactions and a lower frequency of aggressive interactions. Stereotypical behaviours were the same between groups. When the social interactions of lambs with footrot were compared to that of healthy lambs, the lambs with the most extreme cases of footrot were victimised more and showed a lower frequency of affiliative interactions than healthy lambs.

When welfare is assessed based on the frequency of affiliative interactions rather than the absence of stereotypical interaction, this type of structural environmental enrichment did prove useful.

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CHAPTER 4

The effect of environmental enrichment on the production parameters, meat quality and social behaviour of lambs finished in a feedlot.

Abstract

This study investigated the effect of wooden platforms on the production traits, meat quality and behavioural profile (social interactions, stereotypes and feeding behaviour) of lambs finished in a feedlot. The lambs were housed in an indoor feedlot in control pens, similar to current feedlot conditions or treatment pens which included a wooden platform. The shed in which the lambs were housed had an open and a closed side and this was also taken into account when enrichment was assessed. Lambs in treatment groups on the open side of the shed had the highest ADG and lowest FCR, while lambs on the closed side (in both treatment and control groups) had the lowest ADG and highest FCR. Meat quality did not differ between treatment and control groups, however lambs on the open side had heavier carcasses, lower initial pH, more back fat and a higher drip loss percentage. Lambs in treatment groups showed a higher frequency of affiliative behaviours and a lower frequency of stereotypes than lambs in control groups. Lambs in treatment groups also had a higher frequency of feeding bouts and spent more time at the feeder than lambs in control groups. All lambs had a higher frequency of feeding bouts and spent more time feeding in the mornings than afternoons. Feeding bouts and feeding time declined over the fattening period for all lambs, although there were no differences in feed intake.

4.1. Introduction

In South Africa there has been a shift from extensive production systems where lambs are reared and finished on open plains to intensive systems where lambs are finished in a feedlot (WWF, undated). This shift has been prompted by the increasing world population, which is estimated to reach 9 billion people in 2050 (FAO, 2012) which has had the agricultural industry focused mainly on yield while animal welfare has taken a backseat (Koknaroglu & Akunal, 2013) despite the consumer demanding a product that has been humanely reared and handled. According to Troy and Kerry (2010), these demands have prompted some farmers to adhere to higher animal welfare standards. These standards may be achieved by the addition of different types of environmental enrichment to provide lambs with stimuli they would not experience in the current feedlot system.

One way of improving animal welfare is to provide lambs with environmental enrichment in order to provide lambs with external stimuli that may aid lambs in expressing their natural behavioural profile. These enrichments have included straw bedding, feeder ramps and feeding hoppers (Aguayo-Ulloa *et al.*, 2014a; Teixeira *et al*., 2012). The successfulness of the environmental enrichment provided may be hard to assess (Newberry, 1995), however, production performance and meat quality traits are often used as indirect indicators of animal welfare. Behavioural profiles of lambs may also provide additional insight into the welfare of lambs as the frequency of natural behaviours may indicate good welfare, while stereotypical behaviours will indicate a decline in animal welfare (Koknaroglu & Akunal, 2013).

The aim of this trial was to assess the effect a wooden platform would have on the social interactions, stereotypical behavior and feeding behaviour of lambs as well as the production and meat quality traits of these lambs compared to those kept in a traditional, barren pen.

4.2. Materials and Methods

4.2.1. Management and Handling of Sheep

This experiment was done at Welgevallen Experimental Farm located in Stellenbosch, Western Cape, South Africa (33°56'33"S; 18°51'56"E). This is a winter rainfall area with daily temperatures averaging 25ºC and nightly temperatures averaging 16 ºC during the time of the trial. This trial was conducted from middle February to end of March during the summer season. Lambs were housed indoors on slatted flooring in a well ventilated shed, complying with the regulations of the South African Feedlot Association (SAFA, 2008) and the National Environmental Guidelines for Feedlots (SAFA, 2005). The protocols used in this experiment were all approved by the University of Stellenbosch’s Animal Ethics Committee (SU-ACUM14-00012).

For this experiment 60 Merino castrated lambs with an average live weight of 33.9 (±0.23 kg) were used. These lambs were housed in ten pens which each had dimensions of 4.9 x 4.1 m. Each pen contained six sheep and therefore the stocking density was 3.48 m^2/lamb. Lambs were randomly assigned based on their weights to either a control pen (n=5) or a treatment pen (n=5). Treatment pens contained environmental enrichment in the form of a wooden platform (refer to Figure 3.1 for dimensions and Addendum A for pictures) while control pens were left barren, mimicking current feedlot conditions. One side of the shed had large open windows covered with chicken wire 0.87 m above floor level and 1.3 m in hight. The other side only had two small windows 1.22 m above floor level which were 1.4 m in length and 0.55 m in height. On the open side there were five pens of which three were control pens and two were treatment pens while the closed side had three treatment pens and two control pens.

These lambs were fed a commercial concentrate feed, Complete Sheep Finisher Feed from Meadow Feeds that contained 120 g/kg crude protein. Both feed and water were provided *ad libitum*. Feed was provided in a feeder (3 x 0.33 m) placed on the one side of the pen while individual drinkers were provided on another side. No artificial light was used as the natural light provided ±12 hours of illumination.

The lambs were sourced from Brakkekuil Farm located in Witsand, Western Cape, South Africa. Upon arrival into to feedlot, many lambs had contracted an eye infection which was cured before the start of the trial. Lambs were raised extensively and, therefore, they had to be adapted to the concentrate feed. This was done with an adaption regime whereby the lambs were fed roughage and small amounts of concentrate initially. Over a period of two weeks the roughage was decreased and the concentrated was increased every three days until the lambs were ultimately only being fed concentrate.

The trial was conducted over a period of five weeks.

While the trial was being conducted it became apparent the one open side of the shed also provided enrichment to the lambs, maybe even more so than the wooden platform provided and thus this factor was also included in the statistical analyses.

4.2.2. Production Measurements

Upon entry into the feedlot, every lamb was assigned a number and marked with an animal friendly spray paint on both sides as well as on the back. This aided in the identification of every lamb which was a necessity during this trial.

With the commencement of the trial, every lamb was weighed individually and once per week thereafter. The final weigh-in was the day before slaughter. The average daily gain (ADG) of every individual was determined by calculating the difference between the current week and the previous week's weight divided by seven (one week). The remaining concentrate in every pen's feeder was weighed back once a week (on the same day the lambs were weighed) and this was then used to calculate the feed conversion ratio (FCR) for the pen. Feed conversion ration was determined by calculating the difference between the concentrate added to the feeder during the week and the refusals of the same week divided by the total weight gain of the lambs in the pen.

4.2.3. Meat Quality Measurements

4.2.3.1. Slaughtering, pH and collection of samples

Lambs were transported together 35 km from Welgevallen Experimental Farm to Paarl Abattoir in Paarl, Western Cape. The lambs were all grouped together and kept in lairage overnight and provided with *ad libitum* water and no additional feed. Lambs were slaughtered in numerical order early the next morning. Lambs were first electrically stunned (200 Volts for 4 seconds) and then hung by the Achilles tendon. Thereafter the lambs were exsanguinated by severing the jugular vein (Cloete *et al.,* 2004). The lambs were skinned, eviscerated and dressed where after they were weighed to determine the hot carcass weight. A trained inspector assessed the carcasses of the lambs according the degree of fat, conformation and bruising as per the South African classification system (Agricultural Product Standards Act, 1990 (Act No.119 of 1990)).

Once the carcass was inspected, an incision was made in the left *Longissimus Dorsi* muscle at the 13th rib one centimetre from the spine and a temperature probe was inserted. The temperature of the carcass was recorded. Thereafter a portable pH meter was used to record the pH_i of the *Longissimus Dorsi.* The probe was inserted in the same incision and the pH was recorded.

Carcasses were cooled down in a refrigerator overnight at 4ºC. After 24 hours the carcasses were weighed to determine the cold carcass weight. The cold carcass weight was then used to determine dressing percentage of every lamb according to the following formula:

Dressing percentage (%) = (cold carcass weight / live slaughter weight) * 100

The left *Longissimus dorsi* (LD) muscle of every lamb was removed and the incision made to insert the pH probe was clearly marked. All the muscles were then transported in an industrial grade cooler to the meat laboratory at Stellenbosch University. Here the same incision was used to insert the pH probe in order to record pH_u.

4.2.3.2. Sample preparation

All the subsequent measurements were done on fresh muscles which were excised 24 hours *post mortem*.

4.2.3.3. Subcutaneous Fat

A handheld electronic calliper (mm) was used to measure the fat thickness at the 13th rib and between the 3rd and 4th lumbar vertebrae in order to determine the degree of fatness.

4.2.3.4. Colour

Three steaks of 1.5 cm thickness were cut from every LD and trimmed of all fat and connective tissue. These steaks were then bloomed (exposed to atmosphere) at 8ºC for 45 mins. Meat surface colour was measured using a digital calibrated handheld colorimeter (Color-guide 45°/0° with aperture size 11 mm; illuminant/observer D65/10°) (BYK-Gardner GmbH, Gerestried, Germany) and three measurements were taken per sample of which the averages were used. The colorimeter was calibrated using the standards provided by BYK-Gardner black (L* = 0) and white (L* = 100) and used to record three colorimetric coordinates - L*, a* and b* - according to the CIELab colorimetric system as described by Honikel (1998). The chroma (colour intensity) and hue angle (dimensions) was determined with the a* and b* coordinates using the following calculations:

Chroma = $\sqrt{(A^{*2} + b^{*2})}$

Hue angle = $\tan^{-1} (b^*/a^*)$

4.2.3.5. Drip Loss

The drip loss percentage (%) of the LD was determined by the methodology described by Honikel (1998). One steak from each lamb was cut to be 1.5 cm thick, weighed (g) and sealed in an inflatable plastic bag. These bags were suspended in a refrigerator at 4ºC for 24h where after the steaks were removed and dabbed dry with a paper towel. The steaks were then weighed again and the drip loss was determined using the following calculation:

(Weight of sample after 24h (g) / initial weight of sample (g)) * 100 = drip loss percentage (%)

4.2.3.6. Cooking loss

The percentage (%) of cooking loss of the LD was determined by the methodology described by Honikel (1998). One steak with 1.5 cm thickness from each animal was cut and weighed (g). These steaks were then placed in individual plastic bags and sealed where after they were placed in a preheated (80ºC) water bath for 60 minutes. The bags were removed from the water bath and allowed to cool for 24h before the steaks were removed from the bags, blotted dry with a paper towel and weighed. The cooking loss of each steak was then determined using the following calculation:

(Weight of cooked sample after 24h (g) / initial weight of sample (g)) * 100 = cooking loss percentage (%)

4.2.3.7. Shear Force

Cooked samples were used to measure shear force according to the methodology described by Honikel (1998). Five core samples from the cooked LD of every lamb were cut parallel to the meat fibres measuring 1.27 cm in diameter and 1.5 cm in length. A Warner-

Bratzler attachment with a triangular blade, 1 mm thick, with a circular cutting edge was fitted to an Instron universal testing machine (Instron model 4444/H1028). This machine was operated at a speed of 200 mm and a load cell of 2.000 kN and samples were cut perpendicular to the meat fibres. The values of the shear force of every sample were expressed in Newton (N) and the mean of the five readings was used for further statistical analyses.

4.2.4. Behavioural Measurements

Four pens (two treatment and two control) on the closed side of the shed were monitored by a video recording device (model SEB-1020RN). Four cameras (one for each pen) were set up 1.9 m above floor level. The recordings were stored and collected for analysis upon completion of the trial.

Recordings were made every day from 08:00 to 17:00 (nine hours in daylight) and these recordings were then used for continuous sampling (Martin & Bateson, 2007). All of the analysis was done by the same observer. The recordings were used to analyse stereotypical behaviour (Mason, 1991), all social interactions (affiliative and aggressive both with and without contact) according to descriptors given by Miranda-de la Lama *et al*. (2011), feeding regime as well as the use of wooden platforms.

The recordings made for week one, week two, week four and week five were analysed on the same day every week (day 3, 10, 24 and 31). For every aggressive interaction, lambs were identified as either the aggressor or the victim (Ruiz-de-la-Torre & Manteca, 1999). A detailed description of all aggressive and affiliative interactions can be found in Table 3.1. Different types of stereotypical behaviours were identified and all group together. Stereotypical behaviours included chewing of partitioning, feeders, drinkers and wooden platforms as well as body rubbing (when the lamb rubs its body against walls or partitioning). The use of the wooden platforms were recorded by counting the number of times each lamb climbed on the platform with at least two feet and the time allotted to doing so. Finally, the feeding regime of lambs was assessed by recording the number of feeding bouts of each lamb as well as the amount of time the lamb spent feeding. These recordings were divided into morning (08:00-12:30) and afternoon (12:30-17:00) feeding times.

4.2.5. Statistical Analysis

Data analysis was performed using SAS software for Windows Version 9.3. Weight gain over the fattening period, feed intake, FCR and ADG were analysed based on the totals per pen and was assessed by a two x two factorial model with side and treatment as the two main effects. The same analysis was done for every week as well as over the total period.

Additionally, t-tests were performed for every parameter every week. A Shapiro-Wilk test was performed on the calculated studentised residuals to assess any deviations from normality.

Meat quality parameters were assessed by a nested two x two factorial model with treatment nested within pens and treatment and side as the two main effects. Additionally, a t-test was done for every parameter. This data had one outlier, however transformation of the data had no effect.

Continuous behavioural (social interactions and feeding behaviour) data were assessed based on individual lamb data, per pen per week data and per treatment per week data. The GLM procedure of SAS was used to analyse the data and it was presented as the average per lamb per day. In this analysis treatment was used as the fixed effect, while lamb was used as the random effect and day as the repeated factor (Teixiera *et al.*, 2012). This model analysed the differences between weeks (average per pen) and between treatment and control groups.

Correlations between all recorded behaviours were assessed based on individual lamb data as well as total group data.

A significant difference was considered when $p \leq 0.05$ and least square means (± standard error) are reported.

4.4. Results

4.4.1. Production Measurements

Over the total fattening period (35 days) there were interactions found between side and treatment for both FCR (p=0.044) and ADG (p=0.004). The least square means and standard error were calculated for each of these groups and can be found in Table 4.2. There was an interaction between side and treatment for FCR and ADG when the data were assessed over all five weeks. In terms of FCR there were no significant differences between treatment and control pens on the closed side of the shed while on the open side, treatment pens had a lower FCR. There were no significant differences between the open and closed side of the shed. Treatment pens on the open side of the shed had a significantly higher ADG and treatment pens on the open side also had a higher ADG than control pens on the same side. There were no significant differences between the control groups of the two sides. When these variables were assessed on a weekly basis, no significant interactions or differences were found.

Table 4.2 Least square means for the feed conversion ratio and average daily gain for treatment and control groups on both the open and the closed side over the whole experimental period. Values were calculated per pen (six lambs/pen).

	Closed		Open	
	Treatment	Control	Treatment	Control
Feed conversion ratio	8.194^{a}	8.255^{a}	7.243^{b}	9.108^{a}
Average daily gain (kg/d)	1.252^{by}	1.379^{b}	1.629^{ax}	1.286^{b}

$^{a-b}$ symbols in the same row indicate significant differences between treatment and control groups on the same side of the shed. $^{x-y}$ symbols in the same row indicate significant differences between sides within the same treatment. ($P \leq 0.05$).

4.4.2. Meat Quality Measurements

All carcasses were graded as A2 lambs, with a conformation score of three and no bruising. There was no interaction found between side and treatment for any of the meat quality attributes. Between treatment and control groups there were no significant differences found for any of the attributes, however there were significant differences between open and closed sides for some of the attributes listed in Table 4.3. Lambs on the open side had a higher final weight, higher hot and cold carcass weight, lower initial pH at slaughter, more back fat and a higher drip loss percentage.

Table 4.3 Least square means (±SE) and p-values for the physical meat quality attributes for lambs fattened in barren pens and in environmentally enriched pens.

Variable	Open	Closed
Final live weight (kg)	$51.15^{a}\pm0.75$	$48.53^{b}\pm0.79$
Hot carcass weight (kg)	$25.71^{a}\pm0.38$	$24.33^{b}\pm0.36$
Cold carcass weight (kg)	$25.07^{a}\pm0.38$	$23.72^{b}\pm0.35$
Dressing %	49.08±0.54	48.92±0.29
pH_i	$6.54^{a}\pm0.04$	$6.82^{b}\pm0.06$
pH_u	5.74±0.03	5.70±0.03
Fat at 13th rib (mm)	0.21±0.01	0.21±0.02
Fat Lumbar (mm)	$0.45^{a}\pm0.02$	$0.39^{b}\pm0.02$
Drip loss (%)	$1.75^{a}\pm0.06$	$1.49^{b}\pm0.06$
Cooking loss (%)	31.32±0.41	31.78±0.43
Tenderness (kg/cm^2)	38.02±0.38	39.30±0.58
Meat colour		
*L**	35.57±0.30	35.71±0.59
*a**	13.14±0.15	13.76±0.32
*b**	8.54±0.21	9.06±0.21
Chroma*	15.72±0.21	16.58±0.30
Hue angle*	32.90±0.45	33.67±0.80

$^{a-b}$ symbols in the same row indicate significant differences between treatment and control groups on the same side of the shed. ($P\leq0.05$).

4.4.3. Behavioural Measurements

4.4.3.1. Social interactions and stereotypical behaviour

For social interactions the only types of behaviour where there were significant differences found between control and treatment groups, was for affiliative interactions with contact, aggressive interactions without contact where the lamb was the aggressor and stereotypical behaviours. Lambs in treatment groups had more affiliative interactions with contact, less aggressive interactions without contact where the lamb was the aggressor and less stereotypical behaviours. There were no significant differences between treatment and control groups for any other social interactions. The least squares means (±SE) for all of the social interactions are depicted in Table 4.4. In Table 4.5 the differences in the frequency of social interactions between treatment and control groups within the same week can be found. No significant differences were found except in the treatment pens for aggressive interactions with contact where the lambs were the aggressor. During week three lambs were less aggressive, while in week five, lambs showed the highest frequency of these interactions. With the exception of stereotypical behaviour in week five, there were no differences between the frequency of social interactions between control groups and treatment groups within the same week.

Table 4.4 Least square means (±SE) for the number of all recorded social interactions between lambs in control pens and treatment pens over the fattening period.

	Affiliative with contact	Affiliative without contact	Aggressive with contact (A)	Aggressive with contact (V)	Aggressive without contact (A)	Aggressive without contact (V)	Stereotypical
C	$3.88^{a}\pm0.67$	17.75 ± 3.33	15.63 ± 1.92	28.13 ± 2.99	$16.14^{a}\pm3.87$	14.38 ± 3.73	$85.63^{a}\pm7.02$
T	$10.38^{b}\pm2.83$	27.75 ± 4.09	19.88 ± 3.49	31.75 ± 5.40	$10.38^{b}\pm2.93$	9.5 ± 2.77	$46.75^{b}\pm8.31$

Significant differences between treatment and control groups are indicated by letters ^{a} and ^{b} in the same column. Aggressive interactions where the lamb was victimized is indicated by a V and where the lamb was the aggressor is indicated by an A. Control groups are indicated by C and treatment groups are indicated by T. ($P\leq0.05$).

Table 4.5 Least square means for the number of all recorded social interactions between lambs in control pens and treatment pens shown per week.

	Affiliative with contact		Affiliative without contact		Aggressive with contact (A)		Aggressive with contact (V)		Aggressive without contact (A)		Aggressive without contact (V)		Stereotypical	
Week	C	T	C	T	C	T	C	T	C	T	C	T	C	T
1	5	6	22	25	20.5	20.5^{ab}	30	33.5	18	8.5	17.5	15	109	73.5
2	3.5	5.5	12.5	15.5	14	15^{ab}	25.5	31.5	18.5	14	15	9.5	79	42.5
4	3	13.5	14.5	32.5	13.5	13^{b}	24.5	21	12.5	4	10.5	5.5	77.5	39
5	4	16.5	22	38	14.5	31^{a}	32.5	41	15.5	15	14.5	8	77^{x}	32^{y}

Significant differences between treatment and control groups within the same week are indicated by the letters ^{x} and ^{y} in the same row, while significant differences between weeks within the same group are indicated by letters ^{a} and ^{b}. Control groups are indicated by C and treatment groups by T. ($P\leq0.05$).

4.4.3.2. Use of the wooden platform

The number of times lambs climbed on the wooden platform and the time the lambs stood on the platform is summarised in Table 4.6. Lambs stood on the platform significantly more towards the end of the fattening period than during the first week and consequently also spent more time standing on it.

Table 4.6 Least significant means (±SE) for the number of times lambs in treatment pens stood on platforms and the time allotted to doing so within every week.

Week	Number of times lambs climbed on platform	Time allotted to standing on platform (min)
1	9^{b}±3	17.23^{b}±0.52
2	15^{ab}±7	25.35^{b}±17.09
4	22^{a}±6	50^{a}±24.26
5	36^{a}±28	51^{a}±5.23

Significant differences between weeks are indicated by letters ^{a} and ^{b} in the same column. (P≤0.05).

4.4.3.3. Feeding behaviour

In Table 4.7 the differences in feeding behaviour between treatment and control pens (level of treatment) over the fattening period is indicated. Lambs in treatment pens had a higher frequency of feeding bouts and also spent more time feeding. The comparison between morning and afternoon feeding behaviour for the entire group, irrespective of treatment can be found in the same table. Lambs showed a higher frequency of feeding bouts in the morning than in the afternoon and also spent significantly more time feeding in the morning.

Table 4.7 Least significant means (LSM) for the total number of feeding bouts and total amount of time spent feeding over the fattening period.

	Level of treatment		*Time of day*	
	Control	Treatment	Morning	Afternoon
Number of feeding bouts	6^{a}	7^{b}	8^{a}	5^{b}
Time spent feeding (min)	30.45^{a}	38.49^{b}	39.06^{a}	30.36^{b}

Letters $^{a\text{-}b}$ in the same row within the same column (level of treatment or time of day) indicate significant difference. (P ≤ 0.05).

The differences in feeding behaviours between weeks within the same group (treatment and control) can be seen in Figure 4.1. Both feeding bouts and time spent feeding declined over the fattening period in both the morning and the afternoon. There were no significant differences between the feeding behaviours of lambs in treatment and control pens when the data was assessed on a weekly basis, however, from Figure 4.1 it seems that lambs in treatment pens had a higher frequency of feeding bouts and also spent more time feeding, with the exception of the final week.

With regards to differences between weeks, both lambs in control pens and treatment pens had the highest frequency of feeding bouts in the morning during week one (Figure 4.1.1). In control pens, there was no significant difference between the feeding bouts in week two, four and five, while lambs in treatment pens showed the lowest frequency in feeding bouts during week five while weeks two and four were similar. Lambs in both treatment and control pens followed the same trend in terms of time spent feeding in the morning. Lambs spent the most time feeding during week one and this declined over the fattening period (Figure 4.1.2). During week two lambs spent significantly less time feeding and they spent the least amount of time feeding in the morning during the final week (week five)

In the afternoons there were no significant differences in feeding bouts between weeks one, two and four while in week five lambs showed a significantly lower frequency of feeding bouts in both treatment and control pens (Figure 4.1.3). Lambs in control pens spent the same amount of time feeding in the afternoon throughout the fattening period, while lambs in treatment pens spent significantly less time feeding in the final week (Figure 4.1.4).

Correlations between social interactions, stereotypical behaviours and the use of the wooden platform based on individuals over the fattening period is summarised in Table 4.8. There was a positive correlation (0.549) between affiliative behaviours with contact and without contact. Affiliative interactions without contact also had a low correlation with aggressive behaviours with contact, both where the lamb acted as the victim and the aggressor. Aggressive interactions with contact and without contact where the lamb was the aggressor, showed a higher correlation than aggressive interactions with and without contact where the lamb was the victim. There was a positive correlation between stereotypical behaviours and aggressive interactions without contact where the lamb was the aggressor (0.307).

Stereotypical behaviours showed a negative correlation with the number of times the lamb climbed on the platform (-0.327), but not with the amount time the lamb spent standing on the platform. Affiliative interactions, both with contact and without, had a low positive correlation with the amount of time spent on the platform, while only affiliative interactions without contact had a positive correlation with the number of times the lamb climbed on it. Both the amount of time spent on the platform and the total climbs on the platform by individual lambs were correlated with aggressive interactions with contact where the lamb was the aggressor.

Both morning and afternoon feeding bouts showed positive correlations with stereotypical behaviours (0.364 and 0.355, respectively). Afternoon feeding bouts also had a positive correlation (0.264) with aggressive interactions where the lamb was the victim.

The entire group was also assessed for correlations based on the social interactions, stereotypical behaviours and use of the wooden platform and these findings are depicted in Table 4.9. Once again affiliative interactions with contact showed a high positive correlation with affiliative interactions without contact as well as the amount of time lambs spent standing on the platform. Affiliative interactions without contact also showed a high positive correlation with aggressive interactions with contact both where the lamb acted as victim and aggressor. There was a high positive correlation between the lamb as the aggressor and the victim for both aggressive interactions with contact and without contact.

Stereotypical behaviours showed a high negative correlation with both the number of times the lambs climbed on the platform and the time they spent standing on it. There were no correlations found between feeding behaviour and the other recorded behaviours.

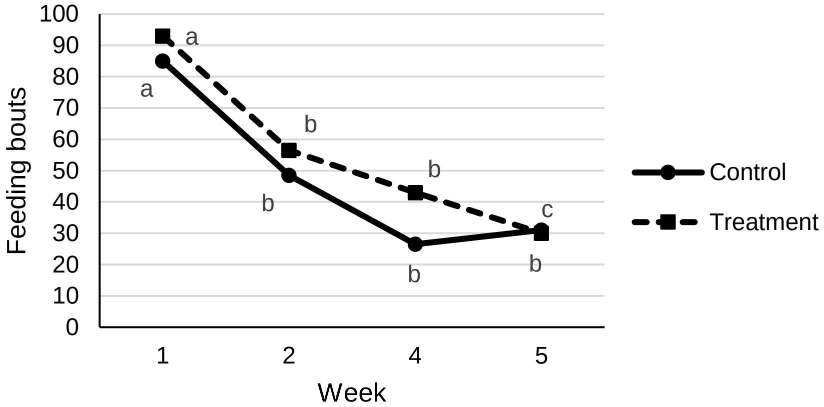

Figure 4.1.1 Frequence of feeding bouts in the morning for treatment and control pens per week over the fattening period.

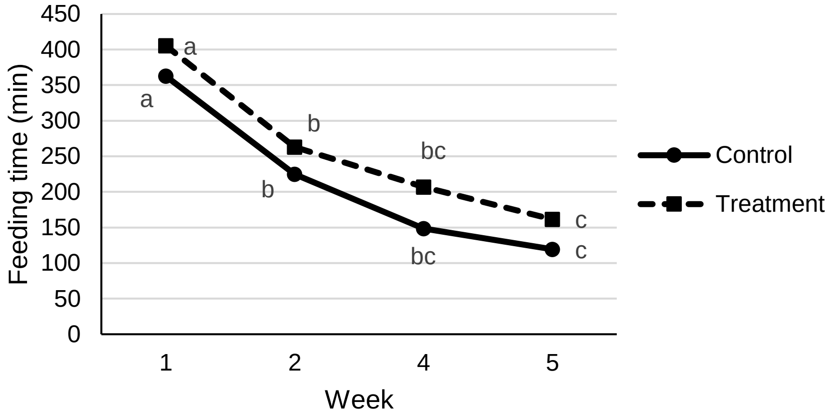

Figure 4.1.2 Time spent feeding in the morning by treatment and control pens per week over the fattening period.

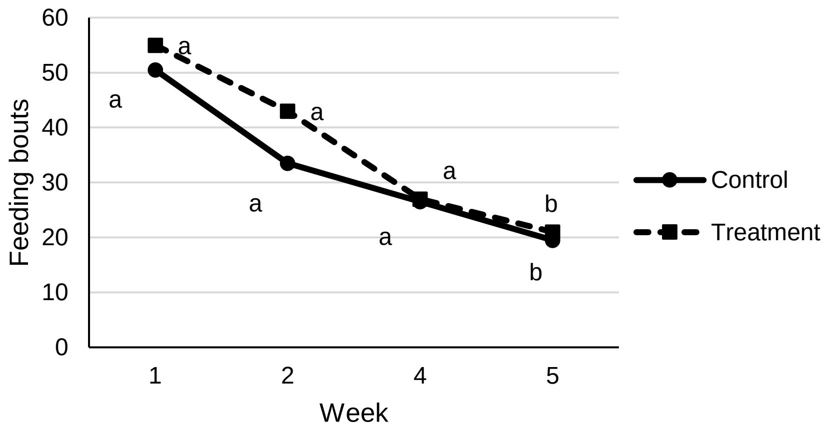

Figure 4.1.3 Frequence of feeding bouts in the afternoon for treatment and control pens per week over the fattening period.

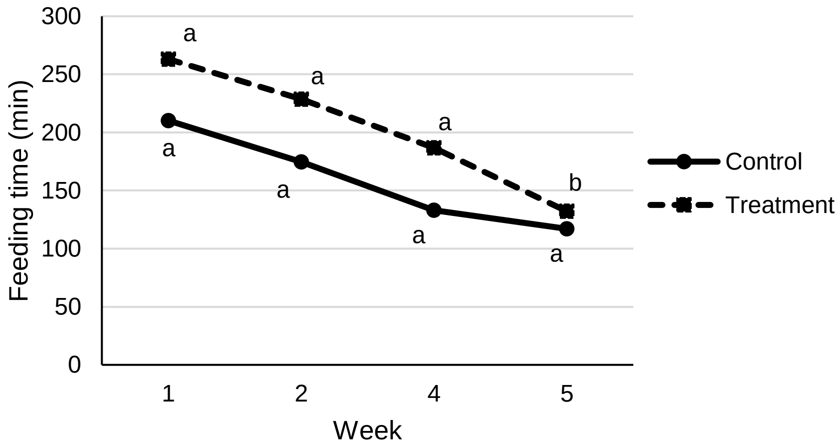

Figure 4.1.4 Time spent feeding in the afternoon by treatment and control pens per week over the fattening period.

Figure 4.1 Least square means (LSM) for feeding behaviour of lambs over the fattening period. Treatment groups are indicated by a dashed line while control groups are indicated by a solid line. Significant differences between weeks within the same treatment are indicated horizontally by the letters $^{a\text{–}c}$.

Table 4.8. Correlations between use of wooden platform, social interactions and stereotypes in terms of individual lamb data irrespective of treatment over the fattening period.

		Affiliative		*Aggressive with contact*		*Aggressive without contact*			*Platform use*	
		With contact	Without contact	Aggressor	Victim	Aggressor	Victim	Stereotypes	Amount	Time
Affiliative interaction	With contact	1.000	**0.549**	0.065	0.109	-0.135	-0.034	-0.017	0.165	**0.257**
	Without contact	0.549	1.000	**0.279**	**0.319**	0.024	0.105	0.173	**0.236**	**0.219**
Aggressive interaction with contact	Aggressor	0.065	0.279	1.000	-0.022	**0.534**	-0.162	0.141	**0.283**	**0.204**
	Victim	0.109	0.319	-0.022	1.000	-0.066	**0.352**	0.188	0.023	-0.028
Aggressive interaction without contact	Aggressor	-0.135	0.024	0.534	-0.066	1.000	-0.050	**0.307**	0.026	0.003
	Victim	-0.034	0.105	-0.162	0.352	-0.050	1.000	0.113	-0.181	-0.153
	Stereotypes	-0.017	0.173	0.141	0.188	0.307	0.113	1.000	**-0.327**	-0.189
Platform use	Amount	0.165	0.236	0.283	0.023	0.026	-0.181	-0.327	1.000	**0.723**
	Time allotted	0.257	0.219	0.204	-0.028	0.003	-0.153	-0.189	0.723	1.000

Significant interactions are indicated in bold numbers. (P≤0.05).

Table 4.9 Correlations between use of wooden platform, social interactions and stereotypes in terms of the total group irrespective of treatment over the fattening period.

		Affiliative		*Aggressive with contact*		*Aggressive without contact*			*Platform use*	
		With contact	Without contact	Aggressor	Victim	Aggressor	Victim	Stereotypes	Amount	Time
Affiliative interaction	With contact	1.000	**0.747**	**0.584**	0.114	0.027	-0.168	-0.258	0.320	**0.523**
	Without contact	0.747	1.000	**0.707**	**0.499**	-0.014	0.027	-0.126	0.449	0.429
Aggressive interaction with contact	Aggressor	0.584	0.707	1.000	**0.779**	0.322	0.250	0.119	0.232	0.148
	Victim	0.114	0.499	0.779	1.000	0.211	0.286	0.143	0.201	-0.043
Aggressive interaction without contact	Aggressor	0.027	-0.014	0.322	0.211	1.000	**0.841**	0.324	-0.349	-0.361
	Victim	-0.168	0.027	0.250	0.286	0.841	1.000	0.388	-0.357	-0.457
	Stereotypes	-0.258	-0.126	0.119	0.143	0.324	0.388	1.000	**-0.778**	**-0.830**
Platform use	Amount	0.320	0.449	0.232	0.201	-0.349	-0.357	-0.778	1.000	**0.861**
	Time allotted	0.523	0.429	0.148	-0.043	-0.361	-0.457	-0.830	0.861	1.000

Significant interactions are indicated in bold numbers. (P≤0.05).

4.5. Discussion

4.5.1. Production Measurements

In Table 4.2, on the closed side of the shed, there were no differences between control pens and treatment pens for either ADG of FCR, while on the open side of the shed the treatment pens gained more weight on a daily basis and had a lower feed conversion ratio. Furthermore, the treatment pens on the open side of the shed had a higher ADG than treatment pens on the closed side of the shed. This is an indication that the enrichment provided in the form of the wooden platform had no effect on the closed side of the pen. It is, therefore, likely that the open side of the shed provided more enrichment and played a larger role in the welfare of the lambs in the feedlot than the wooden platform did.

On the open side of the shed lambs probably experienced better welfare and could make use of the wooden platform more than lambs on the closed side of the shed. It could therefore have a larger effect on the production parameters of lambs. While the platform was ineffective on the closed side, it had no detrimental effects on the production parameters of the lambs.

4.5.2. Meat Quality Measurements

There were no significant differences found for any of the meat quality attributes between lambs in the treatment groups and lambs in the control groups. This could be due to the fact that the environmental enrichment was not substantial enough to elicit an effect on meat quality, however it could also be due to the breed of lambs used in the trial. The Merino breed is a dual purpose breed which is primarily a wool producer and therefore it is possible that the meat quality would not be affected by the environmental enrichment, but that wool growth and cortisol levels could have been affected. This breed was chosen as it is the most common sheep breed in South Africa.

Previous studies have found minimal differences in the meat quality of lambs finished in different feedlot environments. Aguayo- Ulloa *et al.* (2013) and Teixeira *et al.* (2012) found no differences in the meat quality between lambs finished in traditional, barren feedlots and enriched feedlots. In this study the open side of the shed also served as a type of environmental enrichment and some differences emerged.

Lambs on the open side had a higher final weight, higher hot and cold carcass weight which is similar to what Aguayo-Ulloa *et al.* (2014c) found. Enfält *et al.* (1993) found that drip loss may be associated with moderate exercise in pigs. The higher drip loss found in the meat from lambs on the open side of the shed may indicate that these lambs moved around in the pen more than those lambs on the closed side of the shed. A higher back fat percentage in lambs may act as a layer of insulation and prevent losses during cooling which in turn can increase the economic value of the carcass. Even though there were no differences found in the pH_u of the carcasses, the pH_i of carcasses from lambs located on the open side of the shed were slightly lower. This may also serve as an indicator that these lambs experienced lower stress levels and corresponds with findings by Crystall *et al.* (1982). The lower stress levels may be associated with human activity as these lambs would have seen more human activity around the experimental shed than the lambs exposed to the wall with minimal windows.

4.5.3. Behavioural Measurements

4.5.3.1. Social interactions and stereotypical behaviour

Unfortunately, at the beginning of the trial the effect of the open and closed side of the shed would have on the welfare of the lambs and that it would also serve as a source of enrichment was unknown. The cameras were only placed to view four pens on the closed side of the shed and as with the other parameters assessed, there were very little significant differences found between the social interactions of lambs in control pens and lambs in treatment pens.

The frequency of all social interactions stayed within the same range throughout the fattening period and significant differences between control pens and treatment pens were only found for affiliative interactions with contact and aggressive interactions without contact where the lamb was the aggressor (Table 4.4). The differences in affiliative interactions is significant and is an indication that the lambs in the treatment pens experienced slightly better welfare than those in control pens (Boissy *et al.,* 2007). This is consistent with findings by Aguayo-Ulloa *et al.* (2015). Overall, the total frequency of social interaction between lambs in all pens were much lower than that recorded in the previous trial (Chapter 3) and it is therefore possible that the higher frequency of aggressive interactions in the treatment pens was an anomaly rather than an indication of poor welfare or poor group cohesion.

There were very little significant differences in social interaction between weeks (Table 4.5). It is, however, noteworthy that both affiliative interactions with and without contact seems to increase over the fattening period in treatment pens, while it remained very similar in control pens. Aggressive interactions without contact where the lamb was the aggressor also seems to be slightly more in control pens which is similar to results in Chapter 3.

During the final week of the fattening period (week five) lambs in treatment pens exhibited significantly more stereotypical behaviours than lambs in control pens. Even though there were no significant differences during the prior weeks, it is clear in Table 4.5 that lambs in control pens exhibited a higher frequency of stereotypical behaviours. In treatment pens lambs followed the same trend and exhibited more than double the frequency of stereotypical behaviours in week one compared to week five. Aguayo-Ulloa *et al.* (2010) and Aguayo-Ulloa *et al.* (2014b) also found lambs in treatment pens to exhibit a lower frequency of stereotypical behaviours, however the stereotypical behaviour in these studies were only recorded over a period of seven days and thus do not report the differences over the whole fattening period. Miranda-de la Lama *et al.* (2012) also found that stereotypical behaviour decreases over the fattening period in a group of lambs, but did not include the differences between lambs in an enriched environment and lambs in a barren environment.

The frequency of stereotypes is thought to be an indication of the level of animal welfare in an intensive environment (Mason, 1991). Higher incidences of persistent behaviours (i.e. stereotypical behaviours) are associated with increased levels of frustration in lambs (Greiveldinger *et al.,* 2009) which is more prevalent during the initial period in the feedlot (Miranda-de la Lama *et al.,* 2012). Oro-nasal stereotypes have been associated with feeding regime (Yurtman *et al.*, 2002) and maternal separation (Latham & Mason, 2008). However, it is more likely that the decrease in frequency of stereotypical behaviours over the fattening period in the treatment pens is an indication that these lambs adapted better to their environment and therefore experienced a decreasing level of stress while lambs in the control pens experienced a consistent level of stress throughout the five week period.

Lambs also exhibited more stereotypical behaviours than aggressive behaviours (both with contact and without contact) where the lamb was the aggressor in both treatment and control pens. This difference was slightly less in treatment pens than in control pens with lambs in control pens exhibiting up to double the number of stereotypical behaviours compared to aggressive interactions with and without contact combined where the lamb was the aggressor. In treatment groups, this difference decreased towards the end of the fattening period. It is seems likely that lambs prefer persistent, nonsensical behaviours above aggressive interactions with other lambs as a method of coping with the stress and frustrations of an intensive environment. If this is true, lambs that were in treatment groups may have experienced better welfare and therefore preferred interacting with other lambs above stereotypical behaviours as a way of coping with stress and frustration especially since the difference between stereotypical behaviours and both affiliative interactions and aggressive interactions with contact decreased over time.

Correlations were assessed based on both the individual lambs as well as the entire group. When correlations based on both individual and group lamb behaviours were assessed (Table 4.8 and Table 4.9), there was a correlation between affiliative interactions without contact and aggressive interactions with contact, both where the lamb was the aggressor and the victim. Based on the group data, there was also a positive correlation between aggressive interactions with contact where the lamb was the aggressor and affiliative interactions with contact. This correlation is supported by the theory that lambs will exhibit affiliative interactions in order to reduce aggressive interactions (Miranda-de la Lama *et al.,* 2010b). Many times lambs first licked one another before head butting, or vice versa.

Affiliative interactions with contact were correlated with the use of the wooden platform based on both individual data (Table 4.8) and group data (Table 4.9). Additionally, based on individual data, affiliative interactions without contact were also associated with the use of the platform. A higher frequency of affiliative interactions are associated with good animal welfare (Boissy *et al.*, 2007) and this may be why these animals made use of the wooden platform more. Aggressive interactions with contact where the lamb acted as the aggressor were also correlated with the use of the wooden platform, which may indicate the use of the platform is associated with the lambs' place in the hierarchy of the group. A negative correlation was found between the frequency of stereotypical behaviour and the use of the wooden platform. This correlation was even higher when lamb data of the entire group were assessed (Table 4.9) and is an indication that when lambs are exhibiting stereotypical behaviours, they will most likely not climb on the wooden platform. In the previous trial (Table 3.6) the same correlation was not found. However, during that trial the wooden platform was located next to partitioning with chicken wire which the lambs chewed on while standing on the platform, while during this trial the wooden platform was placed next to a brick wall.

Stereotypical behaviours also showed a low correlation to aggressive interactions without contact where the lamb was the aggressor. This may be an indication that some of these lambs experienced poor animal welfare as both aggressive interactions and stereotypical behaviours are associated with poor animal welfare.

Based on individual data, there were correlations found between aggressive interactions with contact and without contact where the lamb acted as the victim as well as aggressive interactions with contact and without contact where the lamb acted as the aggressor. This indicated that when lambs are victimised, it is both with contact and without.

Both morning and afternoon feeding bouts showed positive correlations with stereotypical behaviours. This may be because lambs chewed on the sides of the feeder as well as the partitioning above the feeder (stereotypical behaviour) and would then start feeding. This type of behaviour could be used to manipulate lambs to feed more during the fattening period. If novel objects are placed around the feeder which the lambs are likely to be interested in, it could prompt these lambs into feeding more.

Afternoon feeding bouts showed a positive correlation with aggressive interactions where the lamb was the victim. This is most likely because lambs had a lower frequency of feeding bouts during the afternoon which meant that there were less lambs at the feeder during that time, allowing lambs that were being victimised in the group the opportunity to feed without being shooed away from the feeder by an aggressive lamb.

Similar to the previous study, when group data were assessed, a positive correlation emerged within aggressive interaction – both with contact and without – between lambs acting as aggressors and as victims. This supports the theory that when a lamb is victimised, it will then turn around and victimise another lamb in the group.

4.5.3.2 Use of the wooden platform

There was a significant increase in both the number of times the lambs climbed on the wooden platform and the amount of time lambs spent standing on the platform between weeks. Lambs climbed on the platform the least number of times during the first week of the trial while this frequency remained the same during weeks four and five. Some lambs never climbed on the platform throughout the entire finishing period.

Lambs in this study used the wooden platform much less frequently than lambs in the previous study (Table 3.3). In the previous trial lambs climbed on the platform double to eight times more during the same week. The lambs' preference to climbing on the platform is most likely related to the temperament of every individual lamb and their latency to approach novel objects (refer to Chapter 5.3.1).

4.5.3.3. Feeding behaviour

Lambs showed a higher frequency of feeding bouts during the morning (from 08:00 to 12:30) than during the afternoon (12:30 to 17:00). This is most likely related to the daily temperatures as the dry matter intake of the lamb declines when it is exposed to high ambient temperatures (NRC, 1981). In the mornings it was cooler and the temperature peaked during mid-day with a two to four degree Celsius differences between mornings and afternoons. Temperatures in the mornings (between 06:00 and 12:00) averaged 16ºC while temperatures in the afternoons (between 12:00 and 18:00) averaged 25ºC. Even though there was a significant decline in feeding bouts as well as time that the lambs spent feeding each week, there were no significant differences found in feed intake between weeks. This indicates that lambs progressively fed more during the night when the ambient temperature was lower and when they were not being recorded with each passing week.

Lambs in treatment pens also had a higher frequency of feeding bouts and spent more time feeding than lambs in control pens. Both heat and cold stress will have an effect on dry matter intake and it is therefore possible that the stress and frustration experienced by the lamb in the feedlot will also have an effect on the dry matter intake of the lamb. There were, however, no differences found for dry matter intake between the two groups. Other authors have found that environmental enrichment can have an effect on a wide array of physiological and immunological responses in lambs (Aguayo-Ulloa *et al*, 2010; Aguayo-Ulloa *et al,* 2015; Boissy *et al.*, 2007). It is possible that lambs in treatment pens were less susceptible to the differences in ambient temperatures than those in control pens and therefore spent more time at the feeder during the day.

4.6. Conclusion

The aim of this study was to assess the effect of environmental enrichment in the form of a wooden platform on the social, stereotypical and feeding behaviour of lambs as well as productive and meat quality traits. Ultimately, the open side of the shed proved to provide more in terms of environmental enrichment when production and meat quality traits were assessed.

The wooden platform in combination with the open side of the shed provided the lambs with an array of environmental stimulus aiding these lambs to experience less chronic stress which translated into higher average daily gains as well as higher final live weight. The wooden platform had no detrimental effects on the product delivered to the consumer and the open side of the shed even improved meat quality in some instances.

Overall, lambs with access to the wooden platform were able to express more of their natural behavioural repertoire with a higher frequency of affiliative behaviours and a lower frequency of stereotypical behaviours. These lambs also had a higher frequency of feeding bouts and spent more time feeding during the day, indicating that they experienced better welfare and had calmer temperaments.

The wooden platform was not as effective in this trial as other methods of enrichment have been in the past, however, this could be related to the temperament of the lambs used during this trial. The effect of the wooden platform was not detrimental to the lamb or the product delivered to the consumer and in some instances it aided the lambs to experience better welfare.

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CHAPTER 5

Lamb behaviour in an indoor feedlot

Abstract

Differences in the behavioural activities of lambs finished in the feedlot environment may be attributed to differences in personalities, coping styles, temperament and the extent to which emotions are experienced. These effects on lamb behaviour will in turn have an effect on the production of lambs and consequently the product that is delivered to the consumer. Many types of enrichment systems have been proposed to improve lamb welfare with positive outcomes, however, the reaction of lambs to the types of enrichment provided has varied and most of the enrichment systems suggested in previous studies are not economically viable in most South African feedlots. This chapter assesses the effect that a cheap wooden platform will have on the behaviour of lambs finished in a commercial feedlot as well as the differences in feeding behaviours between healthy and footrot infected lambs based on two different studies. As expected, some lambs used the platform while others remained uninterested throughout the trial period. This caused varied results, however, the wooden platform was not found to have any detrimental effects. Overall, lambs with access to the platform showed higher frequencies of affiliative behaviours and lower frequencies of aggressive interactions and stereotypes. It had no effect on meat quality, however, there was an improvement in ADG and FCR for lambs in treatment groups.

5.1. Introduction

Animal welfare is becoming increasingly important in applied animal ethology which refers to the behaviour of animals reared by humans. In this case, it is the responsibility of humans to ensure the wellbeing of the animal in terms of environment and quality of life. The welfare of animals may be assessed by the amount of positive emotions that the animal is able to experience (Boissy *et al*., 2007). The term “emotions” and “personality” and its use to describe differences in animal behaviour is still a controversial topic, however, according to Désiré *et al.* (2002) it is coming more relevant. The different personalities and coping styles of lambs will have an effect on how they react to stressful situations (Erhard *et al.,* 2004). These stressors may be caused by handling, transport, social isolation, novelty (objects or environments) and sudden events (Désiré *et al.,* 2002; Miranda-de la Lama *et al*., 2010a). Lambs will react in one of two ways, either confronting the thing they fear or avoiding it (Koolhaas *et al.*, 1991) and this will most likely have an effect on their behaviour and consequently their production and the product made available to the consumer. Especially when the fear that the lamb experiences is caused by the environment itself, as is the case in feedlots.

Environmental enrichment may present a way to improve the welfare of lambs, however, the efficacy of the enrichment will be influenced by the different personalities of the lambs. If lambs prefer the reactive coping style described by Erhard *et al*. (2004), it is likely that it will have minimal effect on the behaviour of lambs, with these lambs choosing retreat rather than embracing the enrichment provided. Differences in the personalities of lambs and how it relates to feeding behaviour and physiological responses has also been studied by Rice *et al.* (2016) who did find that these factors are significantly related, however the extent of these relationships are still unclear.

Within the two previous studies (Chapters 3 & 4) there were many observations made that could not be measured statistically within the scope of the specific trials. This chapter therefore serves as an observational chapter focussed on assessing general behavioural patterns that were not included in the original experimental design. This chapter will not include additional statistical analysis of the lambs' behaviour, however, some additional observations will be made on the basis of results found in Chapters 3 and 4. For the methods of statistical analysis in both of these experiments please refer to Sections 3.2.4 and 4.2.5, respectively and for results of these analysis, refer to Sections 3.4 and 4.4.

5.2. Materials and Methods

Two trials were conducted on the Welgevallen Experimental Farm located in Stellenbosch, Western Cape, South Africa (33°56'33"S; 18°51'56"E). In both trials lambs were housed indoors in a well ventilated, well-lighted shed on slatted floors for a five weeks finishing period where after the lambs were slaughtered at a nearby abattoir. These procedures comply with the regulations set by the South African Feedlot Association (SAFA, 2008) and the National Environmental Guidelines for Feedlots (SAFA, 2005). All protocols used in both experiments were approved by the University of Stellenbosch's Animal Ethics Committee (SU-ACUM14-00012). For a detailed description of the management and handling of lambs in the respective experiments, please refer to Sections 3.2.1 (experiment one) and 4.2.1 (experiment two).

Lambs were observed using a video recording device (model SEB-1020RN) and in both studies, the behaviour of the lambs in four pens were recorded. Two of these pens were left barren, similar to current feedlot conditions while the other two pens contained a wooden platform (Figure 3.1) which served as environmental enrichment. The lambs were recorded from 08:00 until 17:00 (from just after sunrise to just before sunset) as the first experiment was conducted during winter months and the facility was reliant upon sunlight for lighting. Lamb behavioural analysis included social interactions, stereotypical behaviours, maintenance behaviours, use of the wooden platform and feeding behaviours. In the first experiment, a few lambs were infected with footrot prior to arrival in the feedlot and the disease could not be eradicated. The effect of this illness on the behaviour of the lambs was therefore also included in the analysis. Refer to Sections 3.2.3 and 4.2.4 for a more detailed description of how behaviour was measured in each experiment.

5.3. Discussion

5.3.1. Lamb behaviour and the wooden platform

Between the first and the second study, there was a noticeable difference in the use of the wooden platforms by the lambs. In experiment one, there were two pens in which the lambs made use of the wooden platform frequently throughout the day. These lambs stood on the platform in groups of three, played around it and took refuge on or around it when a handler entered their flight zone. In the second experiment, however, lambs seldom made use of the platform (Table 4.6). While some lambs in the first study did not make use of the platform, the number of lambs that did not use the platform in the second study was significantly more. It seemed that these lambs were simply not interested. In the two treatment pens that were located on the open side of the shed (Chapter 4), lambs stood on the platforms to peer out the windows during the day.

These differences in the use of the wooden platforms (Table 3.3 and Table 4.6) could be related to the temperament or personality of the lambs. In the second study lambs seldom showed play behaviour while in the first study this was a daily occurrence, especially in the morning and before sunset. This could speak to the temperament of the lambs involved in each study as well as to the stability of the social groups.

The behaviour of lambs can be arranged along five key axes based on different responses. These include exploration or avoidance of novelty, activity, bold or shyness, aggression and sociability (Gosling, 2001). Some research has assessed the effects of temperament on the adaptation of lambs into a feedlot, however, most of this research has been focussed on the lamb-human interaction (Dodd, 2012; Waiblinger, 2009) and the reactivity of lambs (Erhard *et al.,* 2004; Koolhaas *et al.,* 1999). Very little research has been done to assess the effect of individual personality (temperament) on the behavioural and physiological responses of lambs, however, according to Koolhaas *et al*. (1999), it will be difficult to accurately predict the individual differences between lambs and its effect on welfare and production.

In both of these studies it was clear that some lambs were shy-feeders and that these lambs also showed minimal social interactions and minimal interest in the enrichment provided in the treatment pens. These lambs did not interact with other lambs, be it aggressive or affiliative. They rested or stood to the side of the pen when other lambs played or fed. In the second study the percentage of these lambs were significantly more than in the first study. Overall the lambs in the second study showed less activity, less sociability and avoided novelty (the wooden platform).

The efficacy of the platform will largely depend on the temperament and reactivity of the lambs in the pen. Erhard *et al*. (2004) found that lambs differ in their latency to approach novel objects in a pen, however, this study only assessed the effect prenatal nutrition will have on this reactivity, while it may also be influenced by an array of other factors. Furthermore, Koolhaas *et al.* (1999) categorised the coping styles of animals to be either reactive or proactive. Animals that react proactively will be active in coping with the stressors that an environment poses with aggressive and affiliative interactions while animals that follow a reactive coping style will retreat and avoid the stressor. Factors that may affect behavioural reactivity include age, sex, genotype and maternal environment (Dodd *et al.,* 2012). Lambs that are finished in a feedlot tend to be of a similar age and the same gender (mostly castrates) and therefore genotype and maternal environment will be the main factors influencing coping style (lamb reactivity). Erhard *et al.* (2004) also found that when the ewe is underfed while pregnant, it will have an effect on the behaviour of the lamb later in its life (increased emotional reactivity and impaired cognitive flexibility). It may have been the case that the ewes that carried the lambs of the second study were underfed when compared to ewes that carried lambs in the first study as the area from which the lambs for the second trial were sourced, experienced extreme drought. This may also account for the differences in temperaments between lambs in the two studies.

Originally it was theorised that lambs will become accustomed to the platform in the pen and use it less frequently as the fattening period continued. This proved incorrect in both studies. In the first study the use of the platform each week was unpredictable and no definite trend could be established, however, lambs did use the platform the least during the first week. In the second study, lambs used the platform more as the fattening period continued, however, as previously mentioned the lambs in this trial did not climb on the platform nearly as regularly as lambs in the previous trial and it is therefore also impossible to establish a definite trend.

If lambs do not explore, are less active or less sociable, they will be less prone to make use of the enrichment and it will most certainly have a minimal effect on their behaviour and physiological stress level and consequently their production performance (ADG and FCR) and meat quality.

Another factor that may influence the use of the wooden platform is its placement in the pen. When platforms are placed against partitioning or against a solid wall instead of in die middle of the pen, lambs tend to use it more. Possibly, because when they rest or sleep, they do so in these areas instead of in the middle of the pen. When the lambs were frightened, they tended to move towards the sides of the pen, especially to the area where the wooden platform was located. The size or shape of the platform may also influence how much time the lambs spent on the platform (although the same pens and platforms were used in both trials). If it is too large and complex, it may limit the floor space available to the lambs which will have a negative influence on their welfare, however, if it is too small in relation to the available floor space or the number of lambs in the group, it may not be as effective. This study did not acquire information as to the ideal platform based on group size and available floor space as it was outside the scope of the research, however, it would be recommended to investigate this further.

5.3.2. Feeding behaviour

According to various surveys catalogued by Jolly & Wallace (2007), 5-20% of the flock in a feedlot can be classified as shy-feeders while Stockman (2004) found that to be true of 14% in a Merino flock (cited by: Jolly & Wallace, 2007). The factors associated with the number of shy feeders range from the feed itself (formulation, toxins, etc.) to social hierarchy within the group (the shy feeder may be the subordinate) to the differences in the lambs' temperaments. An exploratory study by Rice *et al.* (2016) found a relationship between the temperament, feeding behaviour and blood cortisol levels of lambs during the first week lambs spent in the feedlot even though the extent of these relationships are still unclear.

In this study there were a few lambs that were clearly not interested in the feeder. In the first study this could have been linked to sheep being infected with footrot, however, in the second study when the feeding behaviour of lambs was assessed more comprehensively, there were lambs that visited the feeder less than five times during the entire day and spent less than 45 mins feeding. On one particular day, one lamb fed once during the entire day for less than three minutes.

Lambs seldom spent more than 10 minutes at the feeder at any one time, rather feeding in short bouts frequently throughout the day. Feeding bouts, represented in Table 4.7, were generally concentrated more in the morning (before the second feeding at 12:00) than in the afternoon. This is most likely related to the differences in temperature throughout the day. Lambs preferred lying down during the warmer afternoons and fed during the mornings when it was cooler. Feeding bouts were interrupted by other lambs joining at the feeder or if the lamb became distracted and walked away only to return a few minutes later. When lambs went to the feeder simultaneously due to stimulus (adding feed to the feeder or a handler passing the feeder) they moved alongside the feeder, changing their position often. This behaviour was also noted by Rice (2016) and the amount of activity is possibly related to cortisol levels and stress during feeding time.

Lambs were stimulated to feed not only when new feed was added to the feeder, but also when a handler would pass through the shed. It is therefore not necessary to add feed to stimulate feeding behaviour, simply passing the feeder would elicit the same reaction. The lambs become conditioned thinking that when a human passes the feeder, it is time to feed similar to Pavlov's dog. Because lambs are able to recognise human faces and associate these faces with good and bad experiences (Kendrick *et al.,* 2001), less lambs would go to feed when an unfamiliar handler passed than when a familiar handler passed the feeder. Later in the finishing period, some lambs had a much smaller flight zone with these lambs not interrupting their feeding bout when the handler passed less than one meter away.

5.3.3. Effect of footrot on lamb behaviour

During the first study, two lambs arrived at the feedlot infected with infectious pododermatitis (footrot). All available treatment options (refer to Section 3.2.1.) were exhausted, however the disease still spread through the entire group, infecting at least one lamb in every pen throughout the course of the fattening period.

In some cases, the lamb showed symptoms for a few days and then recovered after treatment. The lambs that were grouped as lambs with footrot are lambs that were unable to recover from this illness. Of the 48 lambs in the total group, 13 lambs were infected with footrot and unable to recover. Of these 13 infected lambs, eight were in control pens and five were in treatment pens. This is not a large difference, however, the lambs that were in treatment pens seemed to respond to treatment faster than those in the control pens. This is supported by Aguayo-Ulloa *et al.* (2015) who found that enrichment can improve a lamb's immunity.

Lambs that were infected by this disease responded in various ways in terms of behaviour. Some lambs lied down for the entire day, only standing once or twice to feed for a few minutes, while other lambs seemed unfazed by the obvious pain they were experiencing (identified by serious limping, red and swollen hooves, etc.). Some lambs lied down for a few days after being infected and then started moving around and exhibiting behaviours similar to that of healthy lambs such as social interactions and walking around in the pen. It is therefore possible that lamb's (infected with footrot) behavioural repertoire can remain unchanged and similar to that of a healthy lamb with the exception of a severe limp.

5.3.4. General behaviour

Lambs that were in treatment groups tended to lie down or sleep close to one another on or around the wooden platform while lambs that were in control groups tended to rest scattered all over the pen. The lambs in both groups tended to rest along the sides of the pens and in the second experiment they favoured the solid walls above the partitioning (metal bars) when resting. Lambs rested for long periods of time during the morning around 10:00 and during the afternoon around 14:00.

While the group was resting, one lamb would stand up and go around the group sniffing, kicking or head butting other lambs until most of the group was active. In some instances one of the lambs that had been woken up by the first lamb would join in his efforts to wake the rest of the lambs. This behaviour could be related to survival, where one or two lambs would indicate to the rest of the group that they had spent a certain period of time resting and were required to be vigilant again. It could also simply be related to the temperament or differences in personalities between lambs. Some lambs would lie down very rarely and when the rest of the group rested, they would be a hindrance to these other lambs.

Lambs are very curious animals. When novel objects were introduced in the pen (such as water hoses, brooms or buckets) they immediately approached the object and started chewing on it.

Most stereotypical behaviour can be categorised as oro-nasal and consisted of chewing the partitioning, the feeders and drinkers and the edges of the wooden platform. Objects such as drinkers which were not fixed to the floor were moved around the pen.

Two theories have been put forth surrounding affiliative interactions between lambs in a feedlot. The first by Boissy *et al.* (2007) who suggested that a high frequency of affiliative interactions are a sign of good animal welfare and group cohesion and should increase over time, while Miranda-de la Lama *et al.* (2012) suggested that these interactions should decline over time as it is typically used to reduce the frequency of aggressive interactions (Miranda-de la Lama *et al.,* 2010b). Although these theories are not directly opposed to one another, they do associate affiliative interactions with different levels of animal welfare. Boissy *et al.* (2007) associates it with good animal welfare, while Miranda-de la Lama *et al.* (2010b & 2012) associates it to some degree with poor animal welfare. It is possible that both are true in different situations. When lambs are introduced into a novel environment and an unstable group dynamic, affiliative interactions may increase in an attempt to reduce aggressive interactions, however, if good animal welfare is to be maintained during the fattening period these interactions should also increase while behavioural activities associated with poor animal welfare (such as aggressive interactions and stereotypical behaviour) should decrease.

5.4. Conclusion

Lambs that use a proactive coping style and that are more likely to approach novel objects will most likely benefit the most from environmental enrichments in feedlots, especially when the enrichment provided is of a structural nature instead of enrichment such as different types of bedding. These lambs will make more use of the wooden platform and will most likely interact more with other lambs which may improve the welfare of the flock as a whole. In these two studies, lambs that used the platform more frequently displayed better ADG, FCR and higher affiliative behaviours indicating a better state of welfare. Lambs that use a reactive coping style will not suffer any detrimental effects from this type of enrichment as these lambs (in treatment pens) performed similar to lambs in control pens.

Feeding behaviour is largely influenced by temperament as well as temperature and the occurrence of shy-feeders should be investigated further, especially with the likelihood that the production traits of these lambs can be influenced by environmental enrichment. It is possible that if the enrichment provided is not perceived as threatening to these lambs, they may be influenced to display lower stress levels and feed more. In this case it will not be necessary to remove these lambs from the feedlot as soon as they have been identified (the current practice in commercial feedlots).

This chapter assessed the behaviour of lambs in an indoor feedlot based on observer observations. The validity of these observations were then linked to previous literature on the subject. It was found that the behaviour of a lamb will be primarily influenced by its inherent temperament which according to the literature, is determined by the maternal environment as well as genotype. This will affect the behaviour of the lambs on many levels including social interactions, feeding behaviour and its latency to approach novel objects (such as the wooden platform placed in the pen).

5.5. References

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CHAPTER 6

General conclusions and recommendations

This study assessed the effect that structural environmental enrichment in the form of a wooden platform will have on the social, maintenance and feeding behaviour, frequency of stereotypes, production parameters and physical meat quality characteristics of finishing lambs in an indoor feedlot.

The first study assessed the social and maintenance behaviour, frequency of stereotypes and weight gain of lambs. In this study two lambs were infected with a contagious form of footrot (infectious pododermatitis) prior to arriving to the feedlot. The disease could not be eradicated and the effect of the disease on afore mentioned parameters were also assessed. Both the enrichment and illness had minimal effects on the maintenance behaviour and frequency of stereotypes performed by the lambs. There were significant differences found in social interactions between lambs in treatment groups and lambs in control groups as well as healthy lambs and footrot infected lambs which led to the conclusion that lambs that were healthy and in treatment pens, experienced the best welfare while in the feedlot. It is recommended that when lambs enter a feedlot with a footrot infection, these lambs be removed to ensure that other lambs remain healthy especially if the number of infected cases are low as in this case.

In the second study, the effect of the wooden platform on social interaction, feeding behaviour, production parameters and meat quality was assessed. It was found that not only did the wooden platform provided enrichment, but that the one open side of the shed had a larger effect on the welfare of animals than the wooden platform. For both production parameters (FCR and ADG) and meat quality attributes, the side of the shed where the lambs were located had a larger positive effect than the presence of the wooden platform in the pen. There were minimal differences between social interactions as lambs in this study displayed a reactive coping style contrary to lambs in the first study that seemed to prefer a proactive coping style. However, lambs in the control pens did display a higher frequency of stereotypes and less affiliative interactions compared to those lambs in treatment pens, indicating that these lambs experienced poorer welfare. Lambs fed more during the morning when temperatures were lower with averages of 16ºC (between 06:00 and 12:00) versus averages of 25ºC (between 06:00 and 12:00) in the afternoon and over the fattening period tended to feed more at night than during the day. This is an indication that temperature and human activity in the feedlot has a large effect on when lambs choose to feed. Lambs were also stimulated to go to the feeder by the (same) handler walking past without the handler having to add feed to the feeder. The lambs performed stereotypical behaviours around the feeders, chewing the partitioning and the feeder itself, typically with the lamb feeding for a few minutes after performing these stereotypical behaviours.

It is recommended that the feeding behaviour of lambs be assessed further to investigate different stimuli which may prompt the lamb into feeding more and increasing its DMI. Adding feed to the feeder may not be the only stimulus and there could be more economical strategies that may be employed for example adding a novel object close to the feeder or instructing a handler who the lambs are familiar with, to pass the feeder a few times during the day.

This study only investigated feeding and other behaviours during the day as the cameras were not able to record analysable data during the night and during the first study (which was conducted during winter) sunlight was very limited. Seeing as lambs seemed to prefer feeding at night as the fatting period went on, it is recommended that this be taken into account in follow-up studies.

Most previous studies have focussed on identifying negative factors in the lives if lambs (such as fear, stress and frustration). There has been minimal to no research done on what lambs finished in a feedlot environment would like. Due to this, the main focus of previous research has also been to eliminate poor welfare indicators such as high frequency of stereotypes and aggressive interactions with limited knowledge gained in terms of improving good welfare (indicated by affiliative interactions). It is recommended that research be done to identify what these lambs in feedlots would like to do and experience (most likely similar to lambs in extensive environments) and approach the subject of improving their welfare from this angle as well.

Both previous studies and this study have been conducted in an indoor feedlot with less than 10 lambs per pen. In South Africa, most commercial feedlots are outdoors and pens house large amounts of lambs. It is recommended that the effect of a wooden platform (or any type of structural enrichment) be assessed under these conditions.

Currently, there are no descriptors for play behaviour of lambs finished in a feedlot. In both these studies lambs exhibited behaviours that were similar to play behaviours described in other intensively raised and finished animals (such as pigs). These behaviours include hopping, pivoting, pawing, flopping, and head tossing. Play behaviours in lambs must be identified in order for these behaviours to be used as indicators of good animal welfare in lambs.

Environmental enrichment in a feedlot can take on many forms and placing a novel object such as a wooden platform into the pen may be the most economical and practical solution (compared to for example straw bedding). However, the ideal shape, size and placement of this platform will have to be investigated further as the platform dimensions and placement used in this study has not been proved to be the most efficient for improving animal welfare. The effect it will have on the welfare of the lambs is also debatable as it will be largely influenced by the temperament of the lambs. Lambs that prefer reactive coping styles will most likely shy away from any novel object placed in the pen. It is, however, worthy to note that the addition of the platform had no detrimental effects on behaviour, production or meat quality and that it either had no effect or a positive effect. The lambs that did make use of the platform displayed a higher frequency of positive behavioural indicators, gained more weight and had a more desirable feed conversion ratio while lambs that had access to the platform but did not make use of it, performed similar to lambs in control groups.

It would be interesting to investigate the effect of genotype on temperament/individual personalities and adaption to feedlot environments amongst South African sheep breeds (Dorper, South African Mutton Merino, Dohne Merino and Merino), particularly as these breeds vary greatly in their maturity types with the Dorper being an earlier maturing breed (and thus seldom being finished in a feedlot) whilst the Merino is a late maturing breed.

ADDENDUM A

Figure 1 Wooden platform built from discarded pallets used for enrichment.

Figure 2 Lambs standing on wooden platform.

Figure 3 Lambs feeding in shed with open side (on the left) and closed side (on the right).