Enhancing animal welfare and improving production performance of feedlot cattle by introducing forms of environmental enrichment

by

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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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 three research chapters and is prefaced by an introductory chapter which is followed by a literature review chapter and concluded with a general conclusion chapter. The language and style used in this thesis are in accordance with the requirements of the *South African Journal of Animal Science*, with changes to increase readability. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetitions between chapters, especially within the materials and methods section, were therefore unavoidable.

ABBREVIATIONS

ADG	Average Daily Gain
DMI	Dry matter intake
DVS	Directorate Veterinary Science
FCR	Feed Conversion Ratio
GLM	Generalised linear model
LSMeans	Least square means
SEM	Standard error of means
TMR	Total mixed ration

SUMMARY

The effect of environmental enrichment in the form of shading, formation of a manure heap and the stimulation of increasing visits to the feeding trough on the maintenance behaviour, social behaviour and production parameters in a Namibian beef cattle feedlot were assessed.

In the first study, the effect of providing shading to the cattle on the weight gain, maintenance and social behaviour was assessed. The animals in the control group had a 300 g higher daily weight gain compared to the shade group. The maintenance behaviour did not differ significantly between the shade and control group, except for the feeding and drinking behaviour which was higher in the control group and could be linked to the higher dry matter feed intake. The social behaviour showed significant differences with more affiliative behaviours in the shade group. The cattle spent most of their time in the shaded area by either standing, lying down or walking, while more socialising (affiliative, aggressive and stereotypic) behaviour was observed in the non-shaded area. Cattle were utilising the shaded area more frequently than the non-shaded area, except in winter when the cattle were more active in the non-shaded area due to cooler temperatures. The results show that the animals in the shade group experienced a better welfare due to the availability of shading.

The second study assessed the effect of a manure heap in the middle of the pen on the weight gain, maintenance and social behaviour of the cattle. The manure group gained 200 g less weight per day compared the control group. No significant differences, between the manure and control group, were found for the social and maintenance behaviours, except for lying down and feeding. Lying down was the most frequent behaviour during the study and differed between the seasons. The off-heap area was generally more occupied by the cattle since only 5% of the pen was covered by the manure heap. The cattle of the manure group showed more positive behaviours, such as playing. For both groups, the lying down behaviour was more frequent in winter, while standing was more frequent in summer. On cooler and rainy days the manure heap was fully occupied, as it was a heat reservoir (of the previous day's sun shining on it) and a dryer area to stand and lay on after heavy rainfalls.

The third study investigated the effect of stimulating the animals' visits to the feeding trough by turning the feed in the feeding trough with a shovel. The aim was to get more cattle at the feeding trough to stimulate feed intake and thereby improve production. In this study, only the feeding behaviour was recorded by means of visits to the feeding trough. The feed stimulation group did not improve their weight gain per day (300 g/day less than the barren treatment) although they ate 300 g more feed per day than the barren treatment. The visits to the feeding trough were more stimulated by the feed mixer delivering feed or passing the trough than the manual turning of the feed with a

shovel. Lower feeding was recorded in spring and autumn due to the varying temperatures in Namibia during these seasons.

The temperament and individual personalities of the cattle, the human-animal interaction/bond and the adaptability of the cattle to the climate most likely had a more pronounced effect than the treatments evaluated on the animals' welfare. The treatments used in this study did not show a high success rate, but consumers' perception and the overall happiness of the animals observed makes it a worthy gesture to introduce these forms of environmental enrichment into a cattle feedlot in Namibia.

OPSOMMING

Die effek van omgewingsverryking in die vorm van skaduwee, bou van ‘n mishoop en die stimulasie van die beeste om meer gereeld by die voerbak te kom vreet op die onderhoudsgedrag, sosiale gedrag en die produksie parameters in 'n Namibiëse beesvoerkraal was ontleed.

Gedurende die eerste studie is die effek van skaduwee op die gewigstoename, onderhoudsgedrag en die sosiale gedrag van die beeste ontleed. Die diere van die kontrole groep het `n 300 g hoër daaglikse massatoename gehad teenoor dié van die skaduwee groep. Die onderhoudsgedrag het nie tussen die skaduwee en kontrole groepe verskil nie, behalwe vir vreet- en drinkgedrag wat hoër was vir die kontrole groep weens van die hoër daaglikse droë materiaal inname. Die sosiale gedrag het verskille getoon met meer affiliatiewe gedrag vir die skaduwee groep. Die beeste het meeste van hul tyd in die skaduwee gebied gestaan, gelê of beweeg, maar meer sosiale (affiliatiewe, aggressiewe en stereotipiese) gedrag is in die sonnige area waargeneem. Die beeste het meer tyd in die skaduwee area spandeer, behalwe in die winter wanneer die beeste eeder in die son wou wees weens die koeler omgewings-temperature. Die resultate toon dat die diere in die skaduwee groep beter diere-welsyn ondervind het.

Die tweede studie het die effek van die bou van `n mishoop in die middel van die kraal op die massatoename, sosiale- en onderhoudsgedrag van die beeste bestudeer. Die mishoop groep het 200 g minder massa per dag opgetel as die kontrole groep. Geen verskille is tussen die twee groepe se sosiale en onderhoudsgedrag gevind nie, behalwe vir lê en vreet. Die lê-gedrag was die mees algemene gedrag in hierdie studie en het seisoenale verskille getoon. Die mishoop het slegs 5% van die hele kraal beslaan, gevolglik het minder gedrag op die mishoop plaasgevind. Die beeste van die mishoop groep het meer positiewe gedrag, soos om te speel, getoon. In albei groepe het die beeste die meeste tydens die winter gelê en meer tydens die somer gestaan. Op koue en reënerige dae was die mishoop vol beset, waarskynlik omdat die hoop die hitte van die vorige dag behou het of die hoop droër sou wees na reënval.

Die derde studie het die effek van die voer in die voerbak met ‘n graaf te draai op die beeste se besoekfrekwensie aan die voerbak ondersoek. Die doel was om meer beeste meer gereeld by die voerbak te kry om sodoende voerinname te stimuleer en hierdeur die produksie te verbeter. In hierdie studie is slegs die voedingsgedrag gemeet deur middel van die aantal besoeke aan die voerbak. Die voer groep het minder massa opgetel (300 g minder as die kontrole groep), alhoewel hulle 300 g meer voer per dag as die kontrole groep ingeneem het. Die voermenger het die beeste meer gestimuleer as die draai van die voer. Die beeste het minder in die lente en herfs gevreet weens groot seisoenale temperatuurskomelinge van Namibië.

Die temperament en individuele persoonlikheid van die beeste, die mens-dier interaksie/verhouding en die aanpassing by die klimaat het waarskynlik ‘n groter effek op diere-welsyn teenoor die behandelings wat evalueer was. Die behandelings wat in hierdie studie gebruik is, het wel geen sukses getoon nie, maar die verbruikers se persepsie en die algehele geluk van die diere soos waargeneem, maak dit die moeite werd om hierdie vorm van omgewingsverryking in te bring by ‘n beesvoerkraal in Namibië.

CONTENTS

Chapter 1:

Introduction

The demand for more meat, especially in developing countries, is increasing by a factor of four and this growth is expected to continue until at least 2050, due to a rise in income and standards of living (FAO, 1997). The livestock sector in Namibia is one of the largest contributors to the agricultural sector and is of fundamental economic importance as it supports approximately 70% of the country's population. The contribution of the livestock sector to the direct income and employment has increased since independence and contributes 4% to the country's GDP due to the annual export of meat of approximately 80% of production (NAMMIC, 2015).

In the last decades of the 20th century, consumers are increasingly concerned about the welfare of farm animals which are slaughtered (Brandenberg, 2010; Aguayo-Ulloa *et al.*, 2014). The assessment on the positive emotions in animals is still not agreed to be the core component for good welfare (Boissy *et al.*, 2007). Confined livestock systems (feedlots in the case of cattle) are increasing in numbers with the systems being forced to yield maximal production outcomes with good and low cost feeding practices.

The Meat Corporation of Namibia (Meatco) is a meat processing and marketing company that serves markets locally and internationally on behalf of Namibian cattle producers. Meatco is also the largest exporter in Namibia of prime meat to Norway (7.16%), European Union (22.91%) including Germany, Denmark and Italy, United Kingdom (13.13%), and South Africa (24.02%) (Meatco, 2017). Meatco views animal welfare as a priority and its objective is to treat all animals with respect and as humanely as possible, resulting in a minimal amount of stress. No hormones or growth stimulants are allowed to be used on any cattle marketed to Meatco. Meatco is subject to the requirements and standards set by a number of premium customers that not only demand the highest standards in food quality and safety, but who also place strong emphasis on the animal welfare and other practices. The visitors to the feedlot assume that the cattle who are standing in the sun all year, with the extreme temperatures of the country, experience high levels of heat stress. Norway has high expectations of good welfare practices and visit Namibia for yearly audits on these practices (Meatco, 2017). Brandenberg (2010) reported that consumers are willing to pay higher prices for food where higher animal welfare standards are applied.

According to Koknaroglu & Akunal (2013), animal welfare is the provision of an environmental condition in which animals are allowed to display all their natural behaviours in nature. The animal should be free from thirst, hunger, fear, stress, discomfort, pain and diseases (Mellor, 2016) when kept in captivity. It has been suggested that structural and mental environmental enrichment may prevent captive animals from boredom, frustration and abnormal behaviour (Newberry, 1995; Oesterwind *et al.*, 2016).

Previous studies have assessed different forms of environmental enrichment such as the effect of scratching/rubbing arches and different scent-releasing devices (Wilson *et al.*, 2002) and the use of shading, sprinklers or misting systems (Mitlöhner *et al.*, 2001, 2002; Schütz *et al.*, 2011). The aim of these studies was to improve the animal welfare of cattle in a feedlot by increasing positive behaviour activities, increasing the average daily gain and feed intake with a lower feed conversion ratio. However, the effect on the welfare of the cattle with these structural forms of enrichment may differ according to the temperament of the individual animals.

Presently, no research on the use of environmental enrichment on the behaviour, production efficiency and welfare of feedlot cattle under Namibian conditions has been conducted. The objectives of this study were firstly to assess the effect of providing shading on the welfare and production parameters of feedlot cattle. Due to high summer ambient temperatures (17 – 35 °C or higher) experienced in Namibia it was expected that shade and season would have an influence on the production potential of the cattle. Secondly, the rising structure of a manure heap in the centre of the pen was hypothesised to increase the welfare of the animals by stimulating their playing behaviour and overall happiness. Thirdly, the stimulation of the cattle's visits to the feedlot by means of turning the feed manually with a shovel, two hours after the feed has been delivered was also hypothesised to improve the welfare of the cattle. The increasing visits were expected to increase the animals' production parameters such as the daily dry matter intake and average daily weight gain. The assessment of animal welfare was based on maintenance behaviours, social behaviour/interactions and production parameters. The stimulation experiment only assessed the feeding behaviour of the cattle and the effect of it on the production performance. The four types of seasons were taken into consideration and their effect on the behaviours and performances quantified.

The main objective of the study is to investigate the impact of environmental enrichment on the natural behaviour and production parameters of the feedlot cattle in Namibia. To achieve this objective the following hypotheses are proposed:

Hypothesis 1: That providing shade to cattle in a feedlot will improve their welfare status.

Hypothesis 2: That providing manure heaps to cattle in a feedlot will improve their welfare status.

Hypothesis 3: That providing human induced activities at the feeding trough to cattle in a feedlot will improve their production performance.

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Chapter 2:

Literature review

2.1. Evolution of cattle in Namibia and Namibian History

2.1.1. Climate

Namibia is situated south west in Africa, bordering south of Angola, north of South Africa and west of Botswana. Namibia has a surface area of 824 290 km^2 which can be divided into three topographic areas. The western part of Namibia is covered by the coastal plain of the Namib Desert, while the eastern part is covered by the semi-arid Kalahari. The largest and central part of Namibia is the Savannah plateau which covers half of the country (Sweet, 1998). Namibia became independent from South Africa in 1990 and has a population of 2.35 million inhabitants.

The agricultural sector is the largest and most important sector in Namibian economy. The most important factor that plays a role in the Namibian beef cattle sector is the environment. Namibia is one of the driest countries in the Sub-Saharan Africa with approximately 270 mm of rain per annum (Chiriboga *et al*., 2008). Therefore, Namibia is too dry for agricultural activities other than livestock farming which produces 75% of the total agricultural output in the country (Chiriboga *et al*., 2008). However, the environment has an effect on the animal productivity, growth potential and investments within this sector is however dependant on environmental conditions. Droughts, desertification and the effect of global warming are commonly experienced throughout Namibia and impacts negatively on animal mortality, a decrease in reproduction (due to cows not having an ideal body composition to conceive). Furthermore, it causes a reduction in herd size per farmer per ha and a reduction in carrying capacity. In an effort to alleviate this phenomenon producers are forced to use fodder supplementation or to move cattle to spared vegetation with more grassland available, thereby reducing profits.

2.1.2. Cattle evolution, domestication and the development of the Namibian beef industry including the economic value and meat prices

About 14 000 years ago, humans started the domestication of wild animals. Aurochs (*Bos primigenius*) was the single ancestor of modern domestic cattle. Through evolution, many of the strains mingled and formed cattle types in the southern African cattle population such as the Kuri and Watusi which have large horns, while the Tuli were short horned. Sanga and Zebu breeds were also present in Africa (Maree & Casey, 1993). Survival of indigenous cattle breeds in southern Africa was only possible due to adaptability to drought, tropical diseases, poor quality grazing, extreme ambient temperatures and internal and external parasites (Maree & Casey, 1993).

Survival is the primary drive in wild animals while production is the enforced objective in domesticated livestock. Selection for increased productivity, qualitative and quantitative, is of high importance with modern livestock production systems. These selection measures depend solely on the objective of the breeder, and include higher growth rates, increased milk yield, more wool per animal, earlier or later maturity and larger mature sizes. Today, cattle production has emerged from a rural occupation to a specialised industry. A transition from subsistence to commercial farming occurred. More and more farmers produce better and more standardised products by using new science and technologies (Maree & Casey, 1993).

The Namibian beef industry started growing significantly after 2000 and has a competitive advantage in the production of beef. This advantage is due to the fact that Namibia has approximately 70% Savannah grasslands which are suitable for grazing (Chiriboga *et al.*, 2008). The Namibian comparative advantage for beef production includes sparsely populated, has ample pasture which is the most important feed for communal and commercial extensive ranchers/farmers in the country. As feed costs are ever-rising the cost of feed is of critical importance. Although Namibia has plenty of grassland vegetation, the arid climate and soil conditions are not adequate for agricultural activities such as grain production which could be used as animal fodder. This forces farmers to import feed from neighbouring countries which raise the cost of beef production and cause the mentioned decline of beef produced by Namibian farmers (Chiriboga *et al*., 2008).

In Namibia, commercial farmland occupies most of the central and southern sections of the country and is more developed, export oriented and capital-intensive. In contrast, communal areas are situated in the north of the country and are subsistence-based and labour intensive (Sweet, 1998). The livestock census conducted by the Directorate of Veterinary Services (DVS) showed a decrease in cattle numbers from 2014 to 2015 (Directorate of Veterinary Services, 2015; Table 2.1). DVS has not conducted another census and no exact cattle numbers are available since 2015. The general figure of the cattle population in Namibia during 2016 was approximately 2.2 million (Khaiseb, 2017).

The Meat Corporation of Namibia (Meatco) is a meat processing and marketing company that serves markets locally and internationally on behalf of Namibian cattle producers. Meatco is also the largest exporter in Namibia of prime meat to Norway (7.16%), European Union (22.91%) including Germany, Denmark and Italy, United Kingdom (13.13%), and South Africa (24.02%) (Meatco, 2017). Namibia receives 31.70% of the total meat volume sold. Meatco operates two feedlots namely Okapuka near to Windhoek having a capacity of 9 500 cattle and the newly established feedlot;

Annasruh close to Gobabis who is aiming to facilitate 12 000 cattle, four abattoirs and a tannery. The aim of these feedlots is to continuously supply the abattoir with cattle to be slaughtered (27.3% by Meatco feedlots) for the quotas contracted with the international markets. The cattle slaughtered from commercial farmers are 62.8% of the total number and 6% from communal farmers (Meatco, 2017).

Table 2.1 The latest available cattle numbers reported in Namibia (Directorate of Veterinary Services, 2015; Khaiseb, 2017).

2013	**2014**	**2015**	**2016**
2 634 418	2 882 489	2 770 545	±2 200 000

The Meatco abattoir situated in Windhoek (30 km from the Okapuka feedlot and 200 km from Annasruh feedlot) is the biggest export abattoir in Namibia which slaughters cattle for meat to be exported to the EU. Figure 2.1 shows the trends of slaughtered cattle in Namibia from 2002 until 2015 (Directorate of Veterinary Services, 2015). During 2015, 125 991 cattle were slaughtered at export abattoirs under the DVS supervision while only 91 500 cattle were slaughtered by Meatco during 2016 (Directorate of Veterinary Services, 2015).

According to Olbrich *et al.* (2014), 49% of the Namibian marketed cattle each year are sold as live cattle (weaners or long weaners) to South African feedlots, and 51% are converted to beef. The Meat Board of Namibia (2010) announced that 150 000 eight months old weaners were exported to South African feedlots and 140 000 steers were slaughtered at Namibia's export abattoirs such as Meatco and Witvlei. The 2016 statistics from Meatco show that on average, 150 000 to 180 000 cattle, which are ~ 90% weaners, were exported to South Africa (Khaiseb, 2017). Namibia therefore is heavily integrated with the South African beef industry and prices. Namibian beef prices are therefore dependent on the South African carcass price as well as the availability of cattle in Namibia for slaughter purposes. The major consequence thereof is that farmers have been changing over from livestock farming to wildlife farming and/or other farming sectors.

During 2017, the number of exported carcasses, meat products and processed meat (kg) increased from 5 293 kg in January to 620 649 kg in March (Meat Board of Namibia, 2017). During 2016, the total volume of exported meat was 10 848 006 kg compared to 2017 6 968 602 kg (January-October). The meat price according to the Meat Board of Namibia (2017) was higher in March 2017 with N$ 33.47 per kg carcass compared to 2015 and 2016. During December 2017, the meat price for 'A' class animals at 260 kg was N$ 35.95/kg.

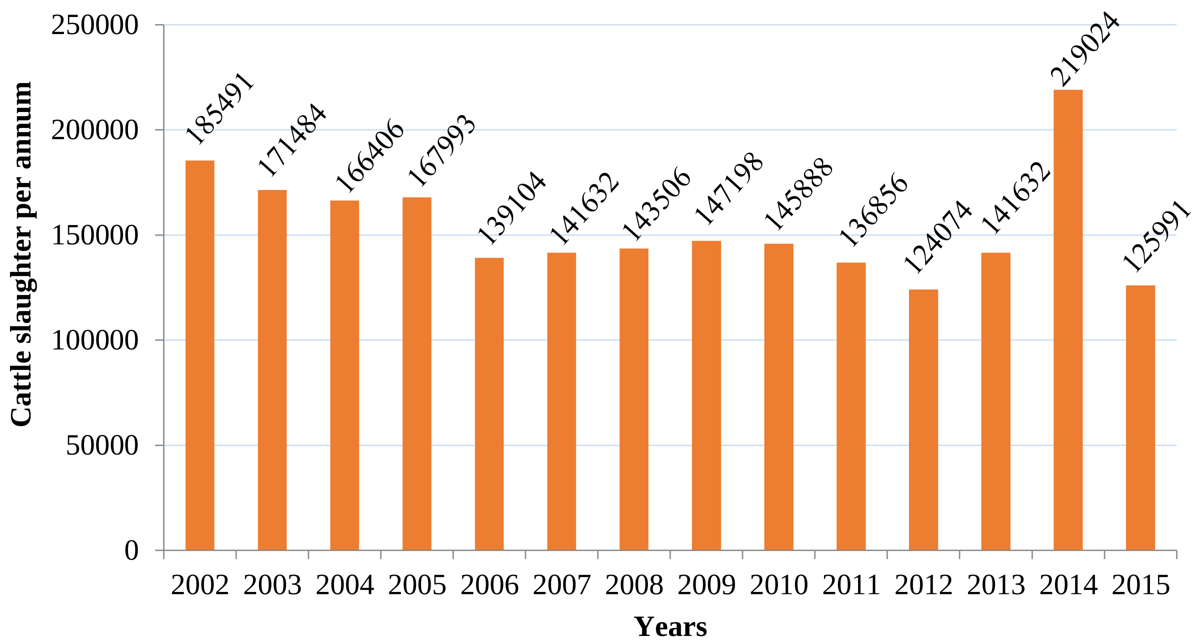

Figure 2.1 Trends in cattle slaughtered at export abattoirs in Namibia (Directorate of Veterinary Services, 2015).

2.2. Animal Welfare

2.2.1. What is animal welfare

Animal welfare is defined differently by many; but in general it mainly describes the environmental condition in which an animal lives. Koknaroglu & Akunal (2013) summarised a number of definitions and defined animal welfare as "provision of environmental conditions in which animals can display all their natural behaviours as in nature". Animal welfare is further explained by the "Five Freedoms" (Table 2.2) which should indicate their life as being 'as free as possible from' negative experiences such as thirst, hunger, discomfort, pain, fear, distress, malnutrition, disease and injury (Koknaroglu & Akunal, 2013; Mellor, 2016).

Mellor (2016) further defines animal welfare as a state that is subjectively experienced by an animal, and is a state within the animal. Silanikove (2000) defined welfare as a characteristic of an animal, and the welfare can vary from poor to good. Poor welfare means that the animal has difficulties in coping with his surrounding environment. Welfare and productivity are closely linked; for example: higher levels of diseases and mortality would decrease the growth, milk yield and reproduction of the animal. Unusual behaviours are mostly the signs of discomfort in the environment (Silanikove, 2000).

Table 2.2 The Five Freedoms and Provisions that promote animal welfare (Mellor, 2016).

Freedoms	Provisions
1. Freedom from thirst, hunger and malnutrition	By providing ready access to fresh water and a diet to maintain full health and vigour
2. Freedom from discomfort and exposure	By providing an appropriate environment including shelter and comfortable resting area
3. Freedom from pain, injury and disease	By prevention or rapid diagnosis and treatment
4. Freedom from fear and distress	By ensuring conditions and treatment which avoid mental suffering
5. Freedom to express normal behaviour	By providing sufficient space, proper facilities and company of the animal's own kind

John Webster was the compiler of these Five Freedoms and they have been published and quoted widely since 1994 (Mellor, 2016). It is unavoidable that animals will have short periods during their life where they experience some of these negative states. These Five Freedoms are mainly to understand, identify and minimise the negative welfare states of the life of an animal. When keeping social animals in a close confinement or barren environment (e.g. high stocking rate), negative experiences may occur and lead to amongst others, fear, anxiety, panic, frustration, anger, boredom and depression (Mellor, 2016).

In contrast, keeping animals in a spacious and safe environment provides them with rewarding experiences such as animal-to-animal interactive activities of bonding and affirmation, and play behaviour: these all reflect comfort, pleasure, interest, confidence and control. More specifically, these include feelings of being affectionately sociable, joyful, protected and secured, energised and engaged (Mellor, 2016). The theory behind this is to improve the outcome of welfare by understanding the fact that animals should be provided with positive environments, although some level of negativity cannot be eliminated completely (Mellor, 2016).

Boissy *et al.* (2007) also points out that the well-being of an animal is not only the absence of negative emotions, but also the presence of positive emotions. It is difficult to know what animals experience in terms of emotions, but the behaviour and brain chemistry of specific animal species is similar to humans. Therefore, it is likely that animals feel as we do. The behavioural aspects of positive emotions include the direct physiological consequences for the underlying motivational system. These are, for example, hunger – which requires the animal to eat food. This influences the blood glucose and leptin levels, and other parameters that are linked to the metabolic status of the animal (Boissy *et al.*, 2007).

During the past 10 years, national and international regulations of welfare have increased tremendously to include elements that are beyond the basic survival of animals, especially farm animals. Practical, effective and economic initiatives should be implemented in the farming sector to achieve more than only survival of an animal but also well-being. These new elements are frequently compiled into the Five Domain Model. The Five Domain Model summarises the Five Freedoms into physical/functional domains namely 'nutrition', 'environment', 'health', 'behaviour' and 'mental' domains. Table 2.3 shows a summary of negative and positive affects assigned to each domain of the Five Domain Model (Mellor, 2016).

Table 2.3 A summary of the Five Domains Model including survival-related, situation- related factors as well as the mental domain of animals (adapted from Mellor, 2016)

<table>
<tr><th colspan="8">Physical/Functional Domains</th></tr>
<tr><th colspan="6">Survival-Related Factors</th><th colspan="2">Situation-Related Factors</th></tr>
<tr><th colspan="2">1. Nutrition</th><th colspan="2">2. Environment</th><th colspan="2">3. Health</th><th colspan="2">4. Behaviour</th></tr>
<tr><td>Positive</td><td>Negative</td><td>Positive</td><td>Negative</td><td>Positive</td><td>Negative</td><td>Positive</td><td>Negative</td></tr>
<tr><td>Enough water & food; balanced and varied diet</td><td>Restricted water & food; poor food quality</td><td>Physical environment comfortable or pleasant</td><td>Uncomfortable or unpleasant physical features of environment</td><td>Healthy, fit and/or uninjured</td><td>Disease, injury and/or functional impairment</td><td>Able to express rewarding behaviours</td><td>Behavioural expression restricted</td></tr>
<tr><th colspan="8">Affective Experience Domains</th></tr>
<tr><th colspan="8">5. Mental State</th></tr>
<tr><th colspan="4">Positive Experience</th><th colspan="4">Negative Experience</th></tr>
<tr><td>Drinking pleasures
Taste pleasures
Chewing pleasures
Satiety
Physical comforts</td><td>Vigour of good health & fitness
Reward
Goal-directed engagement</td><td colspan="2">Calmness, in control
Affectionate sociability
Maternally rewarded
Excited playfulness
Sexually gratified</td><td>Thirst
Hunger
Malnutrition malaise
Chilling/overheating
Hearing discomfort</td><td>Breathlessness
Pain
Debility, weakness
Nausea, sickness
Dizziness</td><td colspan="2">Anger, frustration
Boredom, helplessness
Loneliness, depression
Anxiety, fearfulness
Panic, exhaustion</td></tr>
<tr><th colspan="8">Welfare Status</th></tr>
</table>

2.2.2. Measuring animal welfare

Animal welfare is normally assessed by behavioural, anatomical, physiological, pathological and clinical diagnostic parameters (Mellor, 2016). These parameters are part of the survival-related factors and provide information about the negative-to-neutral states. This shows whether there is a presence or absence of physical/functional disruptions, which include the circulating stress hormone levels. These hormone levels reflect the insight of the external circumstances of the animal. Therefore, these parameters may be used to measure the potential benefits of improving the environment of the animal. However, the parameters are frequently inadequate to indicate the level of "happiness" and other positive attributes that the animal may experience (Mellor, 2016).

Therefore, measuring stress and distress in animals was and still is a challenge, because methods that are used to measure stress rely on the endocrine, behavioural, autonomic nervous system and immunological end-points. Using these methods is problematic when not taken under carefully controlled environmental conditions such as in a laboratory. For example, blood samples need to be taken to assess the cortisol levels but may itself cause stress (Koknaroglu & Akunal, 2013). Behavioural observation methods can be used to see if the animal lives under stress or not. For example, pigs in an intensive production system bite tails and chew ears when they are unable to perform their natural behavioural activities (Liebenberg, 2017).

Another method that Silanikove (2000) suggested is to measure rectal temperature to assess animal welfare. A rise in body temperature in domestic animals shows the transition from "coping with the environment" stage to "unsuccessful maintenance of body temperature" stage. However, the physical act of taking the temperature requires the animal to be either very tame or to be constrained in some manner and this act in itself again could be a stressful experience (Silanikove, 2000).

2.2.3. Enhancing Animal Welfare

Before the domestication of ruminants, animals lived freely and produced enough milk for their offspring. However, today dairy cattle are bred to produce high volumes of milk every day and feedlot cattle are fattened to produce large amounts of red meat in a very short period. Therefore, humans influence animal welfare to a large extent as they control the food and water availability, quality and variety, as well as space, environmental complexity and social groupings of both domestic and captive animals. Humans also determine the number and nature of interactions while animals rather react to than initiate the humans' actions (Waiblinger *et al.*, 2006). According to Koknaroglu and Akunal (2013) management practices such as dehorning, castration and branding at weaning are often painful to the animal and increase stress in animals, as well as cold and heat stress. Animal welfare is also important in the transportation process, pre-slaughter and slaughter practices (Koknaroglu & Akunal, 2013).

One of the most important factors to enhance welfare is to have a close human-animal interaction/bond (Hemsworth, 2003; Waiblinger *et al.*, 2006; Boissy *et al.*, 2007). This bonding can also enhance the fitness and biological performance of the animal which means that the animals can and do have the opportunity for experiencing positive states. The perspective of the animal towards the animal-human relationship depends on the existing relationship with the human, based on previous interactions. These can be negative/unpleasant, neutral or positive/pleasant as illustrated in Figure 2.2.

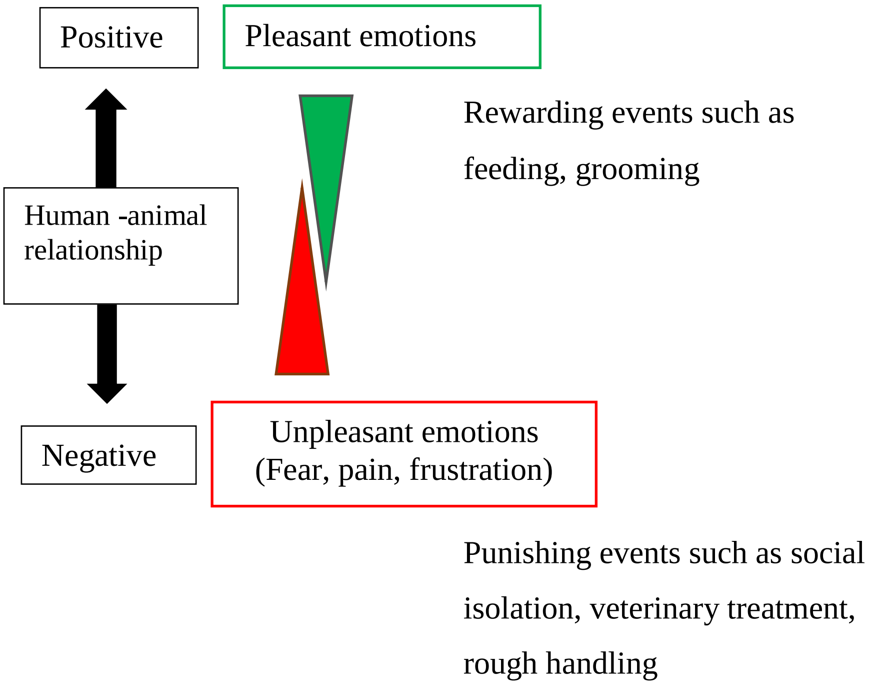

Figure 2.2 Two dimensions that an animal may perceive during the interaction with humans. Increasing levels of pleasant emotions improve the relationship while unpleasant emotions cause the animal to avoid humans (adapted from Waiblinger *et al.*, 2006).

By enhancing the long-term positive emotional state of the animal, it is important to take temperament and the genetic background of an animal into consideration. The temperament of the animal has an important influence on welfare and on various adaptive behaviours of that animal. The definition of temperament is described as the characteristics of the animal and accounts for consistent patterns of feelings and behaviour (Boissy *et al.*, 2007). In addition, temperament also affects aspects of production including growth rate, immune function, milk yield and meat quality, which are important productivity parameters. This again gives the industry an ethically sound product. The genotypic and environmental interaction is also an important determinant of animal welfare, which improves production. For example, the reactivity of a lactating dairy cow in the milking parlour was significantly influenced by their sires (Boissy *et al.*, 2007).

The new defining point of enhancing animal welfare is to focus on "positive affective engagement" (Mellor, 2016). This can be achieved by exercising 'agency' with animals. Agency is when an animal engages in voluntary, self-generated and goal-directed behaviour activities which the animal finds rewarding (Mellor, 2016). Animals produce best when they are in their environmental comfort zones and every species has different comfort zones. These zones depend on where and for what reason the animal is bred (Maree & Casey, 1993).

Environmental enrichment probably only counteracts some of the negative emotions experienced by an animal, but does not really provide positive emotions. The same argument applies to the health of the animal and these two parameters are closely correlated. The more positive emotions are promoted, the healthier an animal is and the better its welfare becomes. For example, play behaviour includes functional behaviours which are fleeing, fighting, sexual, or predatory behaviours and specific playing behaviours (Boissy *et al.*, 2007). The function of playing is to train the skeletal muscles, allowing the animal to assess its own physical and social abilities and to train its flexible kinematics and emotional responses. The two types of playing identified in calves are social and locomotor playing. Locomotor play can already be seen a few hours after birth while social behaviour occurs when calves are grouped together (Boissy *et al.*, 2007).

Affiliative behaviour also promotes positive emotions as it improves group cohesion, building or strengthening of bonds between group mates and reduces aggression. When mixing unfamiliar animals such as in feedlot systems, the agonistic interaction between individuals increase as they fight for hierarchy. With time, as the animals become familiar to each other, stress responsiveness of the herd will become less in the same pen.

Another behaviour that strengthens bonds and reduces tension in groups is allogrooming, which also serves as a hygienic (body care) function in animals. Allogrooming includes social licking that is mainly carried out on areas such as the head, neck or shoulder of the animal. It also displays a sense of feeling safe within its environment. Self-grooming is the maintenance of the animal's own body surface and this is achieved through licking, scratching and rubbing of the fur/pelt. Boissy *et al.* (2007) describes self-grooming as a relaxation effect which mainly occurs when animals live in barren environments. When animals are grouped, allogrooming is engaged rather than self-grooming, but an increase in self-grooming in these groups might indicate a lack of allogrooming and bonding effect.

2.2.4. Indirect factors affecting animal welfare and beef production with an emphasis on Namibia

2.2.4.1. The effect of season and ambient temperatures on animal welfare

Agriculture is primarily dependent on the weather and climate. Climatic change due to global warming is known and experienced as increased temperatures and reduced annual rainfall, which has an extreme impact on the heat stress of farm animals which influences the Namibian beef industry. This is due to the fact that, within the Sub-Saharan Africa, where Namibia is the driest country, droughts and global warming have an even higher impact on grasslands (Chiriboga *et al*., 2008). Grasslands are the primary source of fodder for Namibian beef producers.

Heat stress is a term that is usually used by thermal physiologists to describe the demand made by the environment to dissipate heat. Heat stress causes the animal to set physical, biochemical and physiological processes into play to try to counteract the negative effects and maintain thermal equilibrium (Silanikove, 2000). For example, cattle change their posture towards the sun to a vertical position in order to reduce the effective area for heat exchange. Cattle change their behaviour by standing more during hot weather conditions to maximise the surface area exposed to the environment, which is reduced when lying down, so that any airflow can help dissipate the heat around their body. Another adjustment the body of an animal undergoes to alleviate heat stress is to reduce the production of metabolic heat (Silanikove, 2000).

Domesticated animals are mainly active during the day and resting during the night, thus being diurnal in their habits, but they change their feeding pattern during hot weather conditions. They then rather feed before sunrise, at dawn and/or during the night and reduce their locomotion during the day. This applies to feedlot cattle as well, although they receive their feed sessions during the day; they spent more time on feeding during the cooler hours of the day (Mader, 2003).

Beef cattle are traditionally managed outdoors where they are exposed to natural and variable environmental conditions. The rule of thermodynamics as explained by Koknaroglu & Akunal (2013) is where the performance of farm animals is dependent on the amount of energy consumed and amount of energy used for maintenance. Energy requirements and feed intake depends on the environmental surroundings and ultimately influences animal production performance and welfare.

In colder climates, shelter, bedding and wind breakers should be used while in warmer climates sprinklers and shading should be implemented for the animals to cope with the variable weather conditions (Mader, 2003). However, the use of sprinklers in a feedlot is not an option with Namibia being a water scarce country.

2.2.4.2. The effect of housing and productive environment on animal welfare

The performance of feedlot animals is dependent on the environment they live in during their growing and fattening phase. The environment should be free from stressors for example shelter (shading) should be available to cool down (Koknaroglu & Akunal, 2013), good stocking density should be maintained, aggressive social behaviour such as bullying should be avoided, and most important, a good human-animal interaction should be maintained.

Housing *per se* is not really applicable to the Namibian beef industry as most of the cattle are free range and there is usually sufficient natural shade. Housing is however a potential issue in cattle feedlots, be they large commercial or small on-farm feedlots. Housing is an important factor that affects animal welfare; the house/pen of the animals should have sufficient space, good air circulation and pose a low risk of exposure to diseases. Cattle tend to lie under shelter most of the time during daytime to dissipate heat (Koknaroglu & Akunal, 2013).

The space per animal in a feedlot is crucially important both during the growing period and transportation (Koknaroglu & Akunal, 2013) as it has an effect on the production performance and health status of the animal. Feedlots recommend a space between 10 and 15 m^2 per animal for the animal to live without stress (Von Seydlitz, 2015). An increased lying down behaviour indicates good welfare, because a higher lying down frequency shows a good pen structure and stocking density (Ito *et al.*, 2009).

Frequently, in feedlots there is minimum opportunity for the cattle to exhibit normal behaviour due to space limitations and a barren environment. When an animal has the ability to perform its natural behaviour, this will have long term positive effects on the welfare and the animal will cope better in social and stressful situations. The "natural" behaviour could be a stressor itself, such as when intact bulls are confined with cows/heifers and riding becomes common. However, due to the nature of the weaner production system of beef in Namibia, most of the animals entering the feedlot are older steers and genders are not mixed (Von Seydlitz, 2015).

Stereotypic behaviour refers to behavioural activities that are unnatural and do not commonly occur when the animal is in its natural environment (Liebenberg, 2017). For example, sheep start chewing and picking on each other's fleece due to frustration or boredom and food seeking for partition chewing (Liebenberg, 2017). Cattle show a large rebound of playing when released from the confined environment, which builds up during the period of confinement (Boissy *et al*., 2007). Playing enhances the ability to deal with unexpected stressful situations which may include human-animal interactions and *ante-mortem* handling at the abattoir.

2.2.4.3. Adaptability characteristics

Cattle breeds have adapted over the years to their environmental conditions. A number of European breeds have been bred successfully in Namibia for over a hundred years and have adapted to the warmer and harsher climate. In Namibia, the major beef cattle breeds in the commercial sector are Brahman, Afrikaner, Bonsmara and Simmentaler (Sweet, 1998). Some farmers in Namibia farm with the Simbra, crossbreed of a Brahman and Simmentaler, to obtain the best characteristics of both breeds such as increased beef production and adaptability to the harsh environment. The Simmental has evenly distributed patches of light coat colours on a white background. The breed adapts easily to varying weather conditions and has a good feed conversion and efficiency (Manzanares-Miranda *et al*., 2014). The Brahman, however, varies in colour from light grey to almost black, with short, thick, glossy hair to reflect the sun rays and being able to feed even during the midday sun. The breed has an abundance of loose skin which increases the surface area for heat dissipation. A number of "new" breeds have also been developed by combining the characteristics of two or more breeds to develop a more robust breed for example the Bonsmara. Namibian cattle for example the Brahman, Simbra, Bonsmara etc., have been bred in Namibia over the past decades and are readily adapted to the climatic conditions.

Body surface traits of cattle play a significant role in regulating the internal body temperatures of animals when exposed to warm or cold environmental conditions. Namibian cattle were bred to adapt to the Namibian climate and the morphological characteristics such as hair length and diameter, number of hairs per unit area and thickness of the hair coat as well as the coat colour and reflectance allow heat to be exchanged with the environment (Bertipaglia *et al*., 2007).

Turner & Schleger (1960) reported that season, age, sex, breed types, nutrition, pregnancy and lactation and the heritability all influence the coat score. Heat exchange can occur through radiation, convection and conduction. In warm climates, an animal with a short, sleek, thin, light and a shiny coat colour will have an improved heat loss ability through the coat layer to the atmosphere (Bertipaglia *et al*., 2007). In colder climates, the exact opposite applies. The rule of Wilson described in 1854 that the hair coverage of the animal is closely related to the climatic environment; while the rule of Gloger described in 1833 that the coat colour is related to the climatic environment (Findlay, 1959; Kamilar & Bradley, 2011.).

The body conformation also plays a role in the adaptation of cattle in Namibia; adaptation to the environment is linked to the welfare of the animal. Climatic adaptation in cattle can be described by the four rules that are correlated to the anatomical characteristics. The rule of Bergman described in 1847 defines that smaller animals have a greater surface area to body weight ratio and therefore dissipate heat easier than larger animals with a smaller surface area to body weight ratio (Blackburn *et al.*, 1999). The rule of Allen which was defined in 1877 predicts that animals in warmer climates have a more oval shaped body conformation with longer ears, tails, limbs and snouts etc. while animals in cooler climates have a more compact or spherical shaped body conformation with shorter body parts (Findlay, 1959).

2.2.4.4. The effect of the nutritional status of the animal on its welfare

In intensive beef cattle production systems, high levels of concentrate feeds are fed to improve performance, profitability and sustainability. Studies mentioned by Koknaroglu & Akunal (2013) showed that high-concentrated diets increased the average daily gain of the animals but decreased ruminal pH. An imbalance of ruminal pH can cause nutritional diseases such as bloat and acidosis that has an effect on the normal behaviour, performance and welfare of the animal (Koknaroglu & Akunal, 2013). In feedlots, the formulated diet is of utmost importance as the animals cannot feed selectively as can pasture-raised animals. Therefore, feed and water are required to be fed *ad libitum* in feedlot systems.

High ambient temperatures increase the water intake of the animal and depress the appetite of the animal which results in less metabolisable energy being consumed and lower performance obtained. The total mixed ration of feedlot cattle is adjusted to the weather conditions, as in cooler conditions a higher energy diet tends to enhance cattle performance, while in warmer climates a lower energy diet tends to reduce heat stress and enhance performance (Mader, 2003). Management strategies to decrease heat stress-related production losses include more frequent feeding times and the amount of feed delivered that influences the metabolic heat production of the animal. Feeding the cattle later during the day and limiting their energy intake alleviates the rise in metabolic heat load and therefore the occurrence of heat stress without affecting the performance (Mader, 2003). Lower roughage dry matter intake reduces the heat being generated during ruminal fermentation and helps to maintain the heat balance (Beede & Collier, 1986).

2.2.4.5. Human-animal interaction

The human-animal interaction plays an important role on the welfare of the animal in a feedlot. The attitude and behaviour of humans towards animals determines the fear or confidence of the animal in human beings. This also serves to establish a bond between the human and the animal. The perception of the animal of humans can be divided into frightening, neutral or pleasant emotions (Waiblinger *et al.*, 2006). The temperament of the animal also has an effect on the bonding effect as more aggressive animals will be handled with more fear and/or aggressiveness from the human. These types of animals increase their stress levels to an extent where it negatively affects the production performance and welfare (Hemsworth, 2003).

Human knowledge of animal behaviour can only be improved by spending time together, observing the daily behaviour of the animal and respecting flight zones. Less handling during the growing phase usually causes wider distance between the human and animal bond and is not recommended, because a frightened animal does not trust a human after an unpleasant incidence (Waiblinger *et al.*, 2006).

2.2.5. Consumer perception of animal welfare

People have different viewpoints and criteria in judging what a good life for an animal is and how they should be treated. For example, some people prefer animals to roam freely rather than be kept in captivity, to have access to natural feedstuffs rather than refined and processed feeds such as grain.

Consumers are increasingly concerned about the welfare of farm animals which are slaughtered for beef products (Brandenberg, 2010; Aguayo-Ulloa *et al.*, 2014). The demand for high standards of animal welfare in food supply not only benefits the animals involved, but also enhances production efficiency and profitability, meets the expectations of the consumer and satisfies the domestic and international markets (IFC, undated).

Observers usually want to see positive emotions among the animals for example relaxed, playful, affectionate and social behaviour. Also, the manner how humans work with the animals plays an important role for observers when determining if the animals are taken good care of (Boissy *et al.*, 2007). The housing and management practices of farm animals under intensive systems reflect the increase in moral concern for animal welfare (Silanikove, 2000).

Brandenberg (2010) reported that Swiss people have a high level of concern about the welfare of farm animals due to the increase in demand for "animal-friendly" food products. These people are against animal experiments in laboratories and pet ownership. The consumers and tax-payers in Switzerland are willing to pay higher prices for "animal-friendly" food due to higher animal welfare standards.

According to Grunert (2006), at the point of purchase, the consumer's decision depends on intrinsic factors (colour, visible fat and exudate, etc.) and extrinsic factors (price, packaging, brand, country of origin, etc.) of the product. The first choice the consumer has is the "expected quality" which is judged at the point of sale while the "experienced quality" is judged during consumption (Grunert, 2006). The results of Hoffmann (2000) indicated that women tend to be more risk averse than men and therefore use the country of origin as a quality cue. In South Africa for example, increasing numbers of consumers shop at Woolworths due to its "Woolworths Free Ranch Brand" where the livestock were reared according to high animal welfare standards (Hoffmann, 2000).

Namibia exports prime beef cuts to Norway, Europe (United Kingdom, Germany, Denmark and Italy) and South Africa. These international markets request high standards of animal welfare and undertake annual audits in Namibia (Meatco, 2017). Consumers, today, are willing to pay higher prices for food where higher animal welfare standards are being applied (Brandenberg, 2010). Norway, especially, is willing to invest into infrastructure towards animal welfare e.g. to sponsor the shade netting to cover all the pens at the largest feedlot in Namibia situated near to Windhoek (Meatco Okapuka feedlot), as they believe shading in Namibia is important for the welfare of the cattle.

2.3. The origin and existence of cattle feedlots over the world

A feedlot is where cattle are kept in a confined area with *ad libitum* water and feed, and where the cattle are fed either by hand or mechanically for the purpose of increased production (Clark, 2006). Feedlot cattle do not have access to pastures and are therefore fed for production or weight gain with supplementary feeding. Feedlots produce their income by purchasing poor conditioned cattle from local farmers, increase the weight through means of intensive feeding practices, and then sell the fattened cattle to an abattoir where they are slaughtered for higher prices (Chiriboga *et al*. 2008).

Before feedlots became popular, dairy cows were kept on the farm to produce milk which could be processed into cheese, butter and cream for own use (Hubbs, 2010). Almost no cattle were butchered because milk was the primary protein and fat source. Today, feedlots have become an important sector in the domestic cattle industry and beef export industry, as beef is produced all year round with products of consistent quality and better traceability. It also adds an important economic value to a country and supports the grain industry (Hubbs, 2010).

2.3.1. Reasons for the use of a feedlot

There are numerous reasons why modern feedlots have become popular; Firstly, more cattle can be kept per unit area than on natural veld. Also, within confined areas cattle reduce their walking distances for feed and therefore need less feed to produce 1 kilogram of meat (Hubbs, 2010). Problems such as overgrazing, soil erosion and compaction are eliminated or minimised. Another reason is that cattle receive good quality and nutritious feed *ad libitum* all year round compared to pasture-fed cattle, where the nutritious level decreases during the winter season or during droughts because of minimal rainfall during these months/periods (Frylinck, 2013).

2.3.2. Feedlots in Australia

In the mid 1960's the first commercial feedlot emerged in Queensland. The reason was to meet the demand of high quality products from overseas. Since then, feedlotting evolved into a major industry with approximately 400 across Australia due to tough climatic conditions (Australian and New Zealand Banking Group ('ANZ'), 2017). The number of cattle in feedlots being used for beef production in Australia, vary enormously and solely depend on the occurrences of droughts, the cattle cycle (low during herd rebuilding and high during insolvency phase) and grain costs (Australian and New Zealand Banking Group ('ANZ'), 2017).

2.3.3. Feedlots in North America

Beef was initially not part of the daily diet in North America, because milk was the protein and fat source and by-products such as butter and cheese could be produced from it. During the industrial revolution in the late nineteenth century, America went through technological and economical changes. Farm production improved hugely and new railroads were built to connect the "cattle cities" and transport maize supplies to different destinations (Hubbs, 2010). This revolution of the beef industry caused modern feedlot systems to be created. Gustavus Swift was the inventor of the modern feedlot system (Hubbs, 2010). He invented feedlotting for the purpose of adding profit to beef production by faster turnover, higher carcass weights and increased efficiency (Hubbs, 2010).

2.3.4. Feedlots in South Africa

The South African feedlot industry started during the 1960's, due to a shortage of quality grazing during the dry winter periods. The latter, forced farmers to feed their cattle grain and potato byproducts. In the beginning, feeding methods were unreliable and production performance was inefficient. Both nutritional skills and animal health knowledge were sourced from other countries. In addition, new milling, feeding and construction technologies were imported and adapted to meet South African requirements. During the 1990's, the South African meat industry grew as larger feedlots slaughtered their own cattle and managed the wholesaling and retailing on their own; they were now totally vertically integrated. During 2013, the South African feedlot industry produced about 75% of the total beef production in South Africa (Frylinck, 2013).

South African feedlot diets typically include growth stimulants to boost growth rate and the weight gain. This results in an increase of final weight before the cattle are slaughtered at an abattoir, which also increases the price.

2.3.5. Feedlots in Namibia

Most of the major abattoirs in Namibia are registered to export meat to the EU, which set high standards for the quality of meat that is imported. One of the standards is that meat being imported to the EU may not contain any hormones or growth stimulants such as ionophores which are frequently implanted into the animals themselves or incorporated into the fodder of the cattle. Namibian feedlots succeed in this standard as they do not allow any of the latter. This sets Namibian feedlots one step behind South African feedlots because they are unable to achieve high growth rates and high carcass weights over similar feeding periods or carcass fat levels as South African feedlots do and receive lower prices. The consequence of receiving a lower income per head at Namibian abattoirs is that Namibian farmers have created a niche market of producing weaners for export to South African feedlots (Chiriboga *et al*., 2008). The biggest feedlot in Namibia belongs to the Meat Corporation of Namibia (Meatco) and is situated near Windhoek where the Meatco export abattoir is situated. Figure 2.3 shows a photograph taken of a small part of the feedlot. The Meatco feedlot supplied 20 807 cattle to the Meatco abattoir during 2016 and since 1 January 2017 until 1 December 2017; 24 236 cattle from the feedlot have been sent to the abattoir.

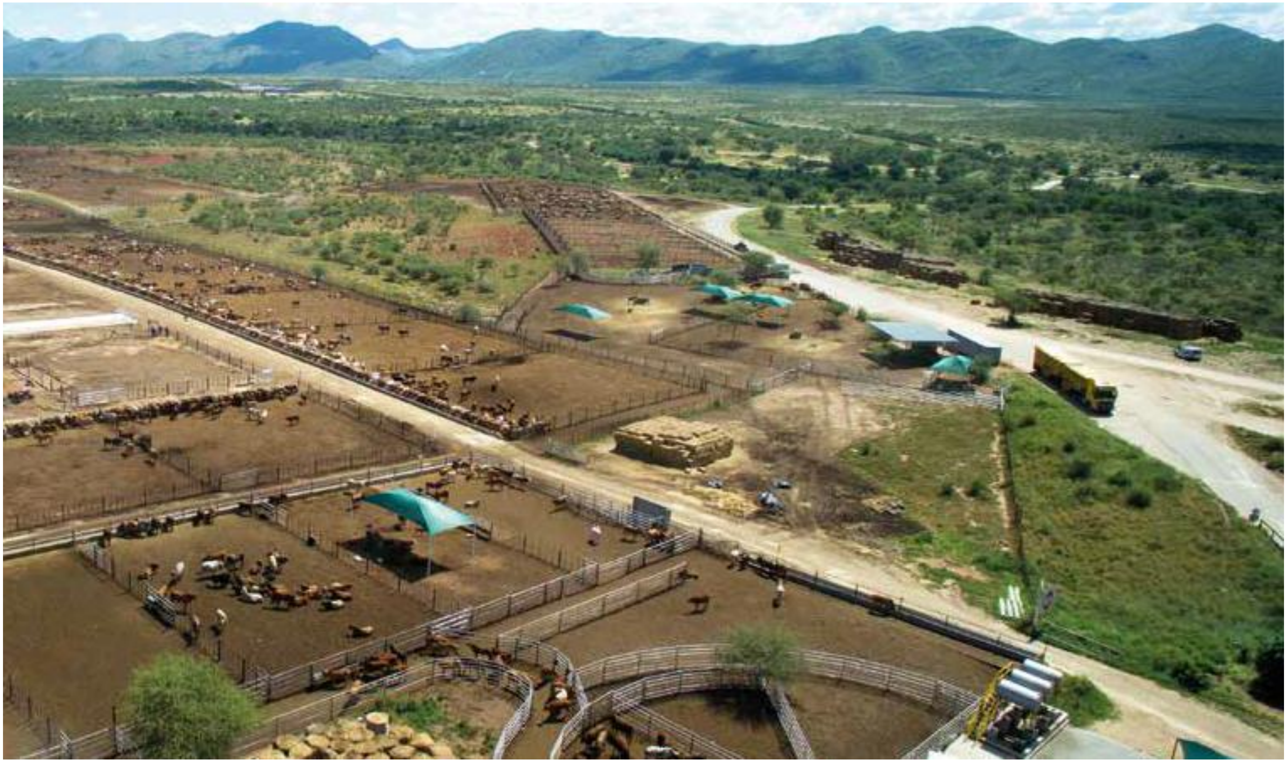

Figure 2.3 A photograph of a small part of the Namibian Meatco Okapuka feedlot near Windhoek.

2.4. Environmental enrichments

Environmental enrichment can be described as how the environment of captive animals can be changed to benefit the inhabitants. In the wild, animals have many different stimuli and challenges that lead to behaviour activities that are limited in captive animals. Animals in the wild exhibit adaptive capabilities such as spotting predators and finding food and mates (Oesterwind *et al.*, 2016). Captive animals live in an environment that is largely limited and structurally simple, namely artificial housing conditions, where the animals are limited in exhibiting species-appropriate behaviour. These limitations lead to frustration, promoting abnormal behaviour and boredom, which in the end relates to stress and reduced welfare (Oesterwind *et al.*, 2016).

Oesterwind *et al.* (2016) states that "the concept of environmental enrichment refers to the enhancement of housing conditions by the provision of a variety of new structures, items and challenges that elicit a higher degree of behavioural diversity." Environmental enrichment can be divided into different types, namely structural/physical, cognitive, sensory, food related and social enrichment.

Oesterwind *et al.* (2016) and Newberry (1995) describe enrichment as the introduction of objects or substrates into the environment of captive animals permanently or temporarily. Within a cattle feedlot, there are specific challenges in providing environmental enrichment due to the inherent nature of a large commercial cattle feedlot. The following are some interventions that may be of value into feedlots situated in Southern Africa: shade, "play" structures and enhancing human-animal interactions.

2.4.1. Shade

Exposure to high ambient temperatures affects both the behaviour and physiology of cattle. Cattle develop heat stress and their performance is negatively affected especially during the finishing phase in a feedlot. Heat stress in a feedlot occurs when the total body heat gain exceeds the animal's ability to dissipate body heat (Mitlöhner *et al.*, 2002). Individual animals respond differently to cope with the heat stress which is influenced by their genotype, hide characteristics, age, body condition, nutrition and health status (Sullivan *et al.*, 2011).

Environmental management such as providing shade, sprinkler or misting systems or both combined, can provide immediate relief from the effects of solar radiation (Mitlöhner *et al.*, 2001). Housing is one of the most important factors affecting the welfare of the animals. Feedlots do not generally supply shelter such as shading as it is seen as not being cost-effective. Nevertheless, Koknaroglu *et al.* (2008) found that cattle with access to overhead shelter performed better than those without overhead shelter. Mitlöhner *et al.* (2002), Schütz *et al.* (2009) and Gaughan *et al.* (2010) found that cattle spent more time in shade as ambient temperatures and solar radiation increased.

Behavioural responses of cattle when experiencing a heat load without shade are a decrease in feed intake, increase in water intake and more time spent lying down. When shading is available cattle will make use of the shade (Schütz *et al.*, 2009; 2014), increase their feed intake (Mitlöhner *et al.*, 2001; Brown-Brandl *et al.*, 2005), decrease their time at the water trough (Schütz *et al.*, 2010) and reduce their lying down time (Mitlöhner *et al.*, 2002; Schütz *et al.*, 2014).

Gaughan *et al.* (2010), Mitlöhner *et al.* (2002) and Sullivan *et al.* (2011) found that cattle in unshaded pens had a lower average daily gain (ADG), dry matter intake (DMI) and weighed less than those with access to shade. In contrast, Clarke and Kelly (1996) found that shade had no improvement on the ADG, DMI and meat characteristics of feedlot cattle.

The success of shading in dairy cattle production is better reported in scientific literature compared to beef cattle production. Various researchers have investigated the use of shade on dairy and beef cattle performance. All reported a positive effect on the performance and health of cattle (Muller *et al.*, 1994; Valtorta *et al.*, 1997, Brown-Brandl *et al.*, 2005; Kendall *et al.*, 2007; Schütz *et al.*, 2009). Dairy cattle's breeding performance is affected negatively by hot and humid weather as it reduces the fertility rate. The high and humid temperature does not only have an impact on reproduction, but also on the DMI as well as production. Studies have shown that shade and sprinklers should both be implemented at a milking parlour as the combined effects include reduced respiration rate, body temperature and provides a relief from insects (Kendall *et al.*, 2007).

Mitlöhner *et al.* (2001, 2002) and Gaughan *et al.* (2010b) reported a positive influence on the performance (ADG, DMI and FCR) of beef feedlot cattle with shading. However, no improvement of the ADG in feedlot cattle was reported by Clarke & Kelly, (1996) whilst inconsistent results have also been reported (Mader *et al.*, 1999; Brown-Brandl *et al.*, 2005).

2.4.2. Manure heaps

Adequate environmental enrichment could reduce negative emotional states which will in turn reduce the frustration that the animal may experience when they cannot express their behavioural needs. A lack of stimulation may lead to stereotypes which occur mostly in feedlot situations. Therefore, environmental modifications can improve the physical health of the animal by promoting ranges of movement to promote the skeletal muscle and cardiovascular fitness.

Some studies on lambs showed that a wooden platform or ramps of height ~ 0.35 m improved the growth rate and meat quality (Aguayo-Ulloa *et al.*, 2014). The lambs in the enriched pens have something to play with and had repeated daily exercise which was different to the lambs in the control pen. Here the lambs underwent a degree of boredom and frustration which led to stereotypic behaviour towards other pen mates (Aguayo-Ulloa *et al.*, 2014).

In pigs, the access to structures or objects stimulated the animals to spend more time on exploring these while animals without objects spent more time in exploring their pen and pen mates. Pigs in enriched environments, with available playing objects, had higher growth rates due to higher feed intakes. Their back fat was on average thicker than similar animals kept in barren environments. Beattie *et al.* (2000) agrees that environmental enrichment improves the welfare of pigs as their anti-social behaviour is reduced.

In cattle, different enrichment devices have been used such as a scratching/rubbing arch, a movable scratching/rubbing device, different scent releasing devices. Wilson *et al.* (2002) reported that the scratching/rubbing devices had more and longer durations of interactions than the scent devices. But overall the study showed that increased exploratory behaviour took place with the devices present.

According to literature, manure heaps have not been tested as an environmental enrichment. South African intensive dairy systems in the Western Cape use manure heaps as it is believed that the animals stand with their forefeet on the higher incline as this helps to release their stomach gases by burping. Without being able to release the gasses, bloating occurs due to gas production in their four-chambered stomach where microorganisms are used for digestion. This process is called “enteric fermentation”. Cattle who feed on high density/palatable diets as typically used in feedlots will have high gas production (Johnson & Johnson, 1995). Cattle release gas orally once every minute and the release of gas is silent and often goes unnoticed. South Africans believe that a manure heap reduces bloating because the animal can stand with its front legs on the heap to help gas to be released easier (Mapham, 2016).

The Meatco feedlot removes the manure more or less every three months, which equates to one feedlot cycle (Von Seydlitz, 2015). An alternative, could be to move the manure into a heap in the centre of the pen and after two feedlot cycles, the entire pen could be cleaned to prevent bacteria to develop in the ageing manure. This would be feasible as the dry climate experienced in Namibia will dry the manure and thus a wet manure heap would not be a problem as pertaining to bacteria borne diseases; bacteria require a minimum relative humidity to survive.

The hypothesis of this study was to investigate the behaviour of the cattle when being exposed to a manure heap in the middle of the pen. The aim was to improve positive social behaviour such as playing and the production parameters, to improve the animal welfare.

2.4.3. Stimulation of feed intake to improve the production performance

For beef production, castration of male cattle was an ancient practice and is still common in many countries. The reason was to have a rapid-fattening type of cattle and less indiscriminate mating. Nowadays, the main aim of a feedlot is to achieve high growth rates and feed efficiency. DeVries & von Keyserlingk (2005) reported that more frequent feeding would stimulate the feed intake, decrease competition among pen mates and would decrease the incidence of acidosis. An increase in dry matter feed intake would lead to improved feed conversion ratio and average daily gain of the animal (Gibson, 1981).

With lactating dairy cows, more frequent feedings proved to be positive for rumen fermentation; the diurnal fluctuations in pH and volatile fatty acid concentration in the rumen were reduced (Sutton *et al.,* 1986). The pH was maintained above 6.0 when the animals received more frequent feeding sessions (Sutton *et al.,* 1986). This indicates that animals eating more frequently will have healthier rumens and improved welfare status.

Animals in confined environments have challenges in the diversity of feeding behaviour. In feedlots, animals from different origins are grouped in the same pen. Social hierarchy caused by the interaction between newly combined animals, causes high levels of aggression in the first week. Dominant animals have priority access to feed bunk space, and will be followed by weaker animals after the more dominant feeders are satisfied (Sárová *et al.,* 2010). The less dominant feeders change their feeding behaviour by eating faster to maintain their DMI and spend less time at the feeding trough (Sárová *et al.,* 2010).

One of the hypotheses of this study was to investigate the feeding behaviour of cattle, in terms of visits to the feeding trough, when being stimulated by a human that turns the feed in the feeding trough. The aim was to increase the daily feed intake of the animals and therefore the production parameters such as average daily gain and feed conversion ratio.

2.5. Conclusion

Animal welfare has always been an important factor to consider when animals are reared for production purposes. Animals should be raised in the zone of optimal thermal well-being and in an environment of low stress levels. This could be achieved to provide shelter and structures for entertainment. However, in recent years it has become a very important issue for consumers on how the animals are reared from which they buy the products they wish to consume. The demand for meat products have increased and herewith also the demand for higher welfare standards during the production of the meat.

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Chapter 3:
The impact of shade on animal welfare, behaviour and production of feedlot cattle

Abstract

Animal welfare is of concern to many consumers and shading is a valuable resource for feedlot cattle especially in hot climates. The objective of this study was to investigate if feedlot beef cattle have a greater preference for shade and if production parameters and behaviour differs between cattle with (shade) or without (control) shading. Shade was provided by a green cloth of 80% solar radiation blockage covering a third (3.75 m^2 per animal per pen) of the entire pen (dimensions 45 x 30 m). Eight pens (n = 120 cattle per pen) where four pens were covered with shading and four without, were used in this experiment. Only ten animals of one pen per treatment were identified for the data collection of this study for a 90-day period. The 90-day period was replicated four times with different groups of cattle which were named spring, summer, autumn and winter. The ADG of each of the ten individuals per treatment was calculated using linear regressions of the weight gain throughout the study. Behaviour, including maintenance (standing, lying, walking, feeding and drinking) and social behaviour (aggressive = butting, mounting; affiliative = rubbing, sniffing, following other animals, licking; stereotypic = licking and rubbing) did not differ between the shade and control treatment groups. The cattle spent the total time either lying down, standing, feeding, drinking, and walking, in descending order. Due to the strong seasonal difference in the ambient weather of Namibia, different behaviour patterns were observed such as a higher feed and water intake during summer, higher standing rate in summer, higher lying rate in spring and a higher walking and social behaviour in winter. However, these differences were also found within the shade treatment. Social behaviour of the 10 selected animals per treatment was highest in the non-shaded area of the shade pen while standing and lying behaviours was higher in the shaded area. The ADG was higher in the control group which was not expected. Therefore, shade did not have an impact on the ADG, but on the behaviour of the animals. Certain aspects were observed that show an improved welfare of the animals with shading available.

3.1. Introduction

Heat stress in feedlot cattle occurs when the total body heat gain exceeds the loss of body heat (Mitlöhner *et al.*, 2002). Body heat is affected by environmental and metabolic heat and can be influenced by the genotype, body condition, nutrition, health status and age of the individual animal. The increase in body temperature changes the normal behaviour of an animal and impairs physiological functions. In addition, the performance of feedlot cattle is negatively affected as feed intake is reduced by heat stress during the finishing phase (Mitlöhner *et al.*, 2002).

Heat stress can be reduced by introducing environmental management such as supplying the animals with shading. Shade is not generally used in feedlots as it is not cost-effective, but the results it can have on the performance and welfare of the animal is significant. Different studies have shown that shade reduces heat stress in cattle and improves the ADG, DMI and final body weight (Mitlöhner *et al.*, 2001; Mitlöhner *et al.*, 2002; Brown-Brandl *et al.*, 2005; Gaughan *et al.*, 2010; Sullivan *et al.*, 2011). In contrast, Clarke & Kelly (1996) reported that shade did not show any improvement in the ADG, DMI and FCR of Hereford cattle kept in a feedlot.

Animal welfare has become an important issue in recent years, as the demand for meat increased globally and the interest of the public also increased in how and under which conditions the animal was raised, transported and slaughtered. Animal welfare is difficult to assess, but behavioural profiles may provide additional insight into the welfare of animals as the higher frequency of stereotypical behaviours indicate a decline in animal welfare, while more natural behaviours may indicate good welfare (Koknaroglu & Akunal, 2013).

Namibia is one of the sunniest countries in the world and its climate is generally arid due to higher evaporation than precipitation which leads to very low humidity. The country is divided naturally into different regions such as the evergreen Caprivi, central highlands around Windhoek, the Namib and Kalahari Desert and the Atlantic coast with almost no rainfall (Thuiller, 2006). During summer months the average temperatures lie at 35 °C during the day and 17 °C during the night. An overcast of clouds only occurs on days when it is raining during the rainy season which lasts from October to April. Rainfall is not always guarantied in Namibia and droughts occur more frequently (Sweet, 1998). Therefore, shading could be an important enrichment for feedlots in these climatic conditions as free ranging cattle on farms also tend to use shading of trees during hot days.

The aim of the trial was to assess the effect of shade on the social interactions, maintenance behaviour and production parameters of cattle in a feedlot system in Namibia compared to those kept in a traditional, barren feedlot. Due to the high summer ambient temperatures experienced in Namibia it was expected that shade and season would have had an influence on the production performance of the cattle. Cattle given shade to utilise were predicted to show fewer behavioural responses to increased heat load, spending more time under the shading and reduce their visits to the water trough compared to cattle with no shade. Also, less aggressive behaviours were predicted in the shade treatment and an improved ADG, compared to the cattle in the barren environment.

3.2. Materials and Methods

3.2.1. Study design

3.2.1.1. General

All the animal handling procedures were approved by the Stellenbosch University Animal Care and Use Committee (Ethical clearance certificate number: SU-ACUD15-00097). The experiment was conducted at the Meatco Okapuka Feedlot, Windhoek, Namibia (-22° 21' 3.8"S; 17° 2' 48.0"E) which is approximately 1 465 m above sea level. The mean annual rainfall at the feedlot is normally 370 mm which falls mainly during spring and summer months (October – April). The average temperatures on site are 30 °C for the hottest months (November – February) and 17 °C for the winter months (June – August). The maximum temperature was 38.8 °C, and the minimum temperature reached -3.9 °C during the time the experiment was conducted. The feedlot has a few gentle slopes but is mostly flat terrain.

A total of 7 680 cattle were processed through the feedlot over a period of 14 months during the entire study. The cattle breeds included were *Bos taurus*, *Bos indicus* and crosses of both. Only male cattle were used for the experiment namely oxen and bulls. The experiment was conducted over four feedlot cycles which were approximately three months per cycle. Each cycle had a pen (dimensions of 45 x 30 m) with 120 cattle (n = 120/pen) in each (stocking density of 11.25 m^2/cattle) which were allocated to each treatment: treatment shade vs. treatment control (n=4 pens/treatment). Only 10 animals out of the 120 cattle per treatment were used for behavioural observations per feedlot cycle (Figure 3.1). The cattle were sorted into weight classes when entering the feedlot to reduce bullying within the newly mixed group.

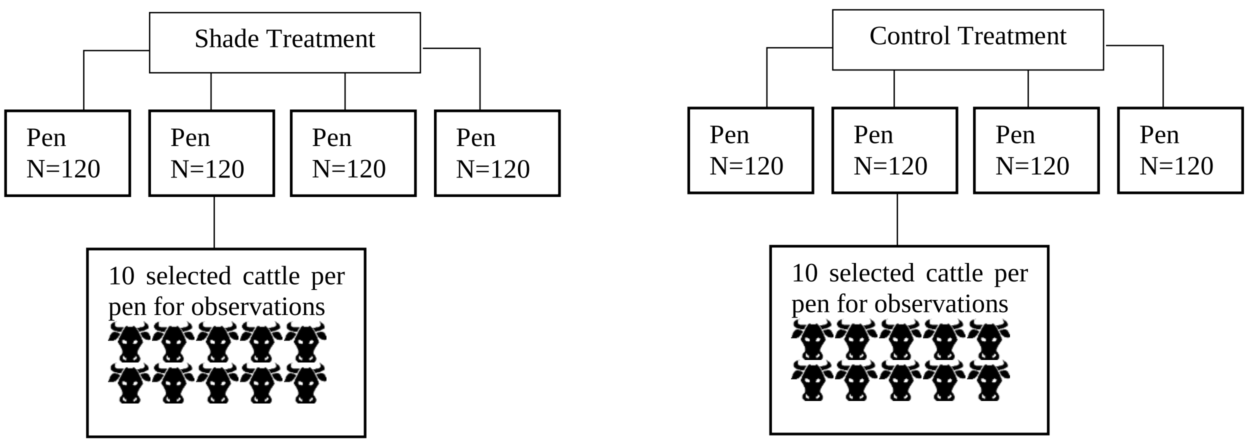

Figure 3.1 Flow diagram of the study design for every repetition of a feedlot cycle (spring, summer, autumn and winter).

Feed was delivered twice daily between 07:00 and 17:00 and feed refusals were cleaned manually every morning. The cattle were fed a TMR (Meatco's own total mixed ration (TMR)) while fresh drinking water was available *ad libitum*. Cattle were sourced from various locations throughout Namibia and were brought to the Okapuka Feedlot. Due to the nature of the feedlot, no attempt was made to try to standardise the breed, body condition, starting weight, etc. This caused a large variation in breed and condition scores of the cattle used in the different repetition/seasons. Upon entry into the feedlot, the cattle were first adapted with a Starter ration for a period of one week. This ration included 40% roughage at a dry matter basis of 90%. Thereafter the cattle were fed a Grower 1 ration for three weeks which had a crude protein (CP) content of 140.10 g/kg, fibre content 123.13 g/kg and 11.50 MJ Metabolisable Energy (ME). For the following four weeks a Grower 2 ration was fed (CP = 140.40 g/kg, fibre = 110.84 g/kg and 11.77 MJ ME) and the last four weeks in the feedlot the cattle received a Finisher ration (CP = 140.51 g/kg, fibre = 105.43g/kg and 11.86 MJ ME). Cattle were therefore fattened in the feedlot for 11 weeks, with one week of adaptation. The experiment commenced on 22 July 2015 and was completed on 28 October 2016, to include all four seasons in Namibia. The four trials were named according to the time when they were half way through the feedlot cycle. Therefore, trial one was named spring; trial two, summer; trial three, autumn and trial four winter.

3.2.1.2. Shade structure

Green shade shelter with 80% blockage of solar radiation was used for the shade treatment, and the shade shelter was secured with a solid 3m high steel structure (15 m x 30 m) over each of the four pens. The shade was orientated in an east-west direction and only a third of each pen was covered with shade netting. The drinking and feeding area was not covered with shade netting and the shade did not overlap surrounding pens. The control group had no shade shelter in their pens. The water and feeding trough had the same layout as in the shade pens. The water trough was located between the feeding trough and the shade structure (see Figure 3.2 for dimensions).

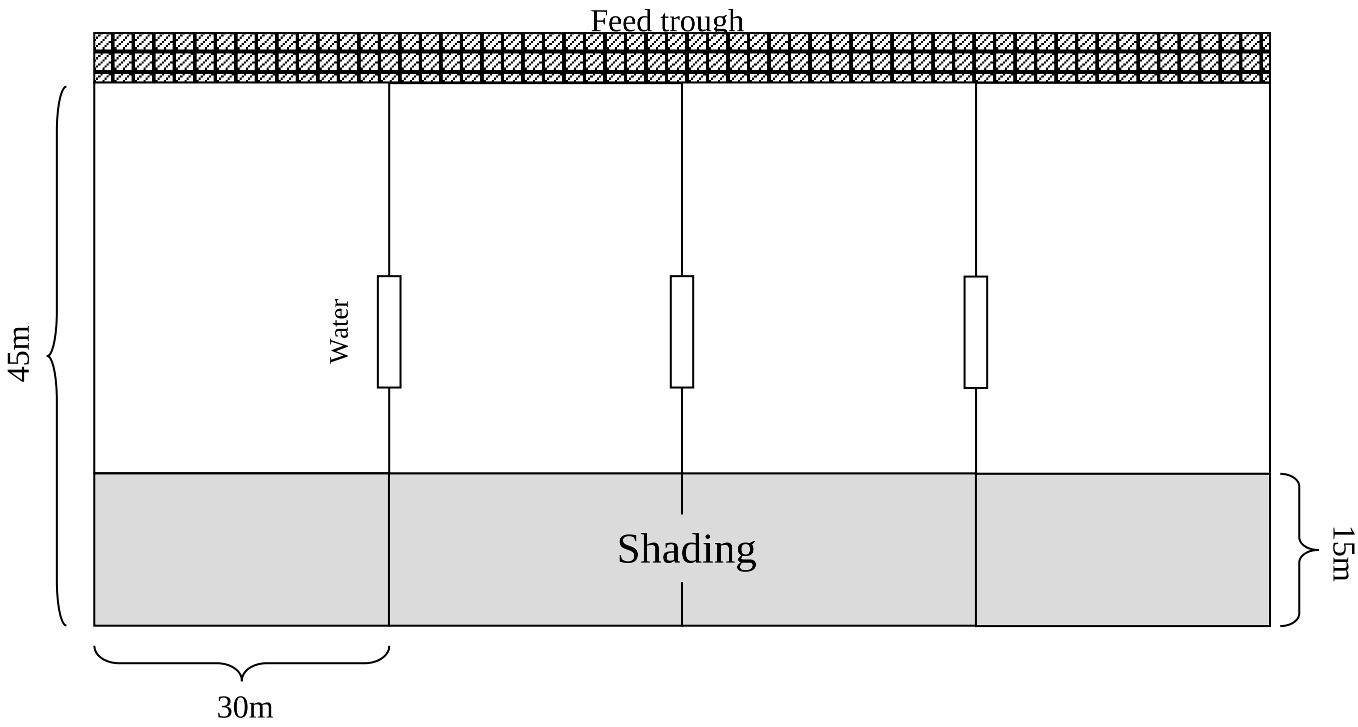

Figure 3.2 Dimensions of pens covered with a third shading (15 x 30 m shading per pen).

3.2.1.2.1. Cost analysis

The shading was set up by a Namibian company (Mega Shade, Windhoek). The construction of the structure for four pens located next to each other took three weeks and had a total cost of N$ 234 000.00. The cost for one pen was therefore N$ 58 500.00. Shading only one pen individually would increase the building material and increases the cost per pen; therefore it was considered to cover four pens which were placed next to each other.

3.2.2. Data collection

3.2.2.1. Growth performance and identification and treatment of sick cattle

Cattle were first weighed when registered (individually tagged) on day one at the feedlot and again the day when the cattle left the feedlot to be sent to the abattoir. Additional body weights were measured at a two to four-week intervals using a digital cattle scale (Rudweigh Scales). The cattle had access to water and feed before they were weighed, which could influence the weight to a small extent but this procedure was maintained for all animals at the feedlot.

The animals that enter the feedlot were divided into weight groups at the sorting station namely, small (250-280 kg), medium (281-320 kg) and large frame (321- >400 kg) before they were divided randomly into the different pens for this study. This procedure was maintained throughout the entire study.

All animals of the entire study that became sick and had to be temporarily removed from the pen to be treated, where recorded and sent back to the original pen as soon as the individuals were healthy again. The date when pulled from the pen, the ear tag number, pen number, reason of sickness, medicine used for treatment and the date when the animal was moved back to the original pen were captured. When one of the 10 selected animals were pulled to be treated they were sent to the original pen on the same day or within the next three days after treatment to prevent the animal from being removed from the study. However, in this study the number of cattle of the 10 selected animals that became sick were two for the control group and one that died in the control group; none for the shade group.

3.2.2.2. Determination of hair-coat colour

Coat colour groups of the cattle selected for observational purposes were scored according to absorption rates as described in Foster *et al.* (2009). The groups were scored from white (score 0), grey (2), yellow-fawn (4), light-red (6), red (8), dark-red (10), brown (12), dark-brown (14) to black (16). Coat scores were assessed when the 10 animals were randomly selected and marked. The aim of the study with regards to the coat colour of the 10 animals was to have five animals with dark coat colour, including scores from eight to 16 and five animals with light coat colours, from zero to six, from the same pen.

The hair coat scoring method according to Turner & Schleger (1960) was used as follows: extremely short (score 1), very short (2), fairly short (3), fairly long (4), long (5), woolly (6) and very woolly (7). Hair coat length was only measured for the winter trial of the 10 selected animals per treatment and the entire hair length, from root to tip was measured with a ruler. In this study the following measurements in centimetre were used for the scoring: score 1= 0-0.5cm hairs closely applied to the skin; score 2 = 0.6-1 cm hairs just able to be lifted by the fingers; score 3 = 1.1-2 cm hairs easily lifted; score 4 = 2.1-3 cm hairs curve outwards and ruffled easily; score 5 = >3.1 cm hairs distinctly long and loosely; score 6 = 0-3 cm fingers partly buried in soft undercoated hairs and score 7 = >3.1 cm greater length and thicker density than score 6.

3.2.2.3. Environmental variables

Two weather stations (Davis Vantage Pro 2, WeatherLink 6.0.3 Software) were located at the pens of the Meatco Okapuka Feedlot, one under the shade netting and the other in the direct sun. Both were placed approximately 2.0 m above ground level to be out of reach for cattle and other animals (mainly baboons) to prevent damage. The weather data was collected daily and included ambient temperature (minimum, maximum, mean daily temperature which was averaged over 24 hours and the average maximum and minimum temperatures), wind speed and direction and rainfall (Figure 3.3)

3.2.2.4. Production measurements

The average daily gain (ADG) of each of the 10 selected animals was calculated by means of linear regression. The difference between the weight at entry and the current weight was calculated and divided by the number of days on feed. This was repeated for every weighing session. The ADG for the full period was calculated by means of linear regression. The feed delivered and refusals that were weighed back the next day (sticks, rotten feed other) for each pen were recorded on a daily basis. The daily dry matter feed intake (DMI) per pen was recorded to calculate the amount of feed eaten per individual per day. The feed conversion ratio (FCR) was calculated per group by calculating the difference between feed presented and feed weighed back divided by the ADG of the group for the specific interval. Therefore individual feed intake could not be measured as this FCR represented the feed conversion ratio for the full group of 120 cattle in the pen. FCR was therefore not included in the data analysis.

3.2.2.5. Behavioural measurements

The cattle were observed from 4 August 2015 until 16 September 2016. The 10 animals per treatment were observed 21 times per day, twice a week from 7:00 to 17:00 for the first minute of every 30min interval using the *instantaneous sampling method* (Martin & Bateson, 2007). Only one observer was present and had one minute per treatment group to observe the 10 marked animals. Although each treatment had four pens, only one random pen was used for observation. The 10 animals were marked with the numbers one to 10 on their hind and fore quarters with an animal friendly cattle marking paint. Observations took place irrespective of weather conditions, (heavy rainy days, windy, cold winter days). The behaviours that were observed during the study, but not statistically analysed, were classified as ‘other’ behaviours.

Emphasis was placed on the maintenance behaviour of the cattle namely standing, lying, walking, feeding and drinking; these were recorded as described in Table 3.1 (Schütz *et al.*, 2011; Schütz *et al.*, 2014). In addition, the presence of the animal in the shaded or non-shaded area was measured with a *one-zero sampling method* (Martin & Bateson, 2007); one for when in the shaded area and zero when in the sun area. This was recorded in order to determine if the cattle utilised the shade which was available and if a specific activity was predominantly performed in the shade. The social behaviour was also recorded by the same observer and was divided into either aggressive or affiliation interaction. Butting, pushing and mounting fall under aggressive behaviour and rubbing, sniffing, licking and following another animal falls under affiliative behaviour. Stereotypic behaviour was divided into licking and rubbing and is defined when the animal makes contact with the infrastructure and not a pen mate. Table 3.2 explains each social behaviour in more detail (Liebenberg, 2017).

For data analysis, the sum of each behaviour was calculated, divided by 21, as this was the total observation recordings a day. Therefore, behaviour was presented as a percentage of time in the data of this study, and multiplied by 100 to represent it as a percentage of time spent.

Table 3.1 Definitions of maintenance behaviours that were used in the study.

Activity	Description
Standing	An inactive upright posture and no locomotion.
Lying	Body contact (flanks) of the animal with the ground.
Walking	Any change of body location within the pen.
Feeding	Feeding (when feed is ingested or could be seen in the mouth) and head in the feed trough
Drinking	Head over or in the water trough (includes body splashing).

Table 3.2 An overview of the social behaviours that were recorded in this study (Liebenberg, 2017).

Aggressive				Affiliation				Stereotypes	
With Contact		Without Contact		With Contact		Without Contact			
Action	Description	Action	Description	Action	Description	Action	Description	Action	Description
Butting	When the animal uses its forehead to hit another animal on any part of the body (Body knock and head knock).	Threatening	When an animal threatens another with its head down, but without actual contact.	Rubbing	When an animal is rubbing or scratching another animal with its body.	Sniffing	When an animal sniffs another animal's body (Nose-nose contact (greeting), nosing partner's body with nose).	Licking	Licking or gnawing repeatedly on feeders, walls, fences, wood or metal objects without feed consumption.
Pushing/ Bumping	When the animal uses its body to push another animal to access the feeding trough or water trough.			Licking	When an animal licks another animal's body	Following	When an animal follows another animal with the intention of keeping close to it.	Body-Rubbing	Against infrastructure.
Mounting	When an animal mounts another animal from behind with the intention of moving it. Without an apparent sexual function.								

3.2.2.6. Statistical analysis

The data analysis for this study was performed using XLSTAT 2017 and SAS for Windows version 5.4. XLSTAT was used for all ANOVA's which included the percentages of the behavioural data. The ADG for each individual was calculated by means of linear regression and PROC REG of SAS. The Bonferroni Post hoc test was used for all multiple comparisons and calculations for LSMeans. A probability of 95% was considered significant.

The behaviours were recorded and the sum of each behaviour was calculated per day, divided by 21 and multiplied by 100 to obtain the percentage of time spent on the specific behaviour. In order to compare all the values of the shade treatment with the control, the observed percentages for each day of the time the animals spent in the non-shaded and shaded area were summed and the mean was used for the analysis. No correlation between activity and time (days on feedlot) was indicated, therefore time was excluded in the final models.

3.3. Results

3.3.1. Deviations from the protocol

The number of animals that became sick during the entire study, including all animals of the entire study, was higher in the control group (236 cattle) than in the shade group (157 cattle). The most prevalent disease amongst the cattle at the feedlot was Pneumonia. The autumn trial was 30 days longer compared to the other three trials, as the feedlot had been placed under quarantine. Namibia has a policy via DVS of no tolerance for hormones or growth stimulants being used in feedlots and urine samples of the feedlot cattle showed traces of Zeranol. The DVS therefore placed the feedlot under quarantine until the final results were received. The outcome was that no growth stimulants were injected into the animals as Zeranol was found naturally in the cattle's body and the feed that was fed. This extended period had an influence on the number of cattle that became sick, the ADG and overall days in the feedlot.

3.3.2. General

In this study, the warmest months with a temperature above 35 °C were October till December 2015, January, February, and October 2016. The coolest months with a temperature below 5 °C were June till September 2016, with the coldest of -3.9 °C in July. The rainy months were December 2015 and January 2016 until March 2016 with the highest rainfall of 110 mm in December 2015 (Figure 3.3).

The shade weather station was slightly influenced from the shade netting at the height of two meters above the ground level. The daily maximum temperature was in general 1 or 2 °C lower in the shade, but exceptions occurred on some days where the temperature in the direct sun was cooler than under the shading due to radiation of the shade netting. However, closer to the ground level underneath the shading the temperature was cooler than in the sun.

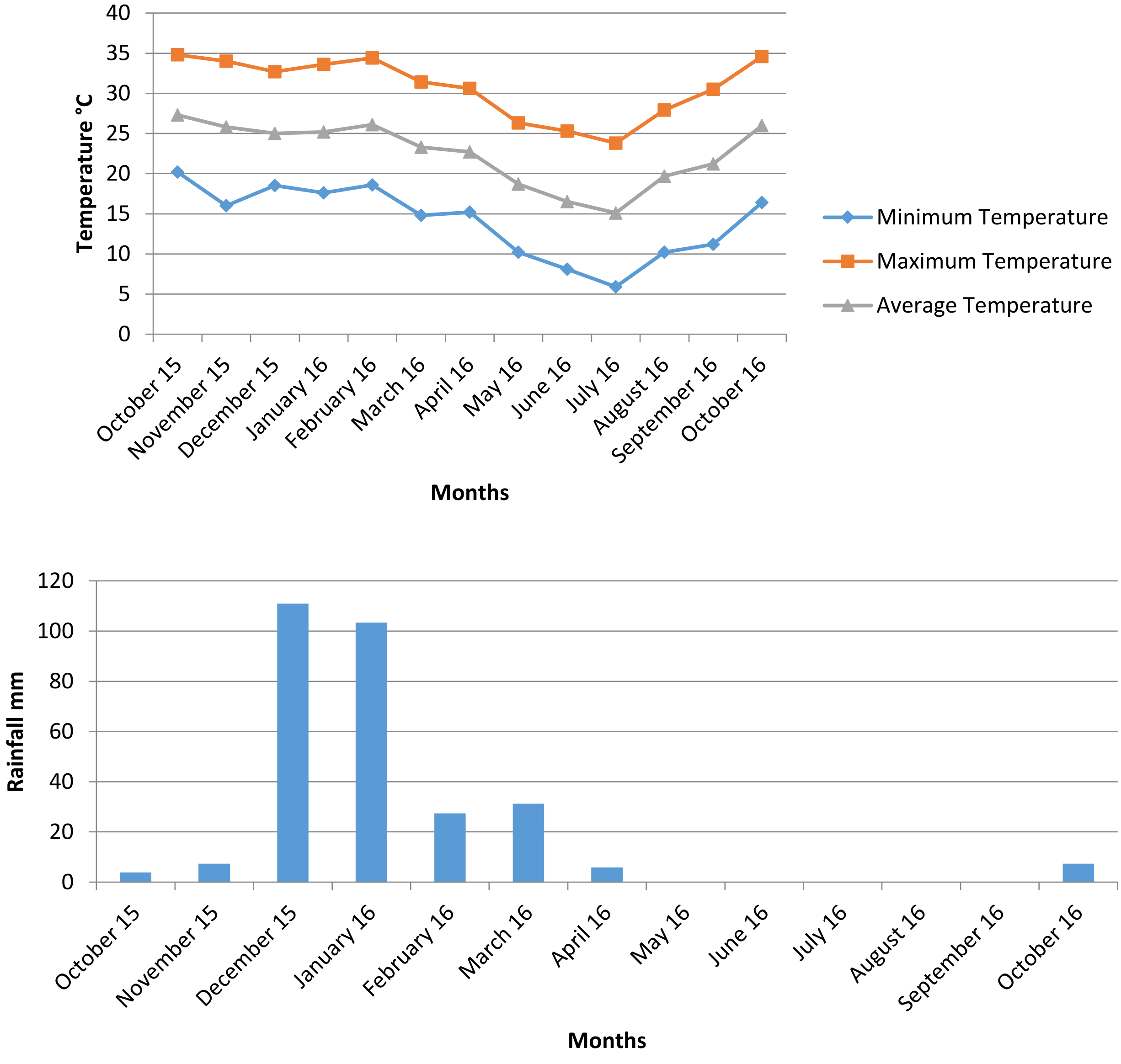

Figure 3.3 Average minimum and maximum temperatures measured over time in the non-shaded part of the pen and the average monthly rainfall which fell during the study at the feedlot.

3.3.3. Production measurements

In this study no differences (P = 0.16) were observed for ADG between shade and control groups. Shade had an LSMean (±standard error) of 1.7±0.08 and control 1.8±0.08. Table 3.3 represents the seasonal effect on the ADG between the two treatment groups. The seasonal effect on the ADG between the two treatments was only significant for the winter trial. . In absolute terms the average daily DMI of the control group (10.4 kg/head/day) was slightly higher than the shade group (10.2 kg/head/day) although it was not significantly different. According to the Bonferroni Post hoc test the interaction between the treatment and season was not significantly different and will not be discussed in further detail (P = 0.58).

Table 3.3 Least square means (±standard error) of the seasonal effect on the ADG between the two treatments groups.

Season	Shade	Control	*P*-value
SPRING	1.6±0.15	1.8±0.16	0.39
SUMMER	1.7±0.15	1.7±0.18	0.82
AUTUMN	1.7±0.18	1.9±0.15	0.53
WINTER	1.6±0.15	2.0±0.17	**0.05**

The growth rate of each individual that was used for recordings (n = 40 cattle per treatment for the entire study) was plotted on a graph and a regression line was fitted. The control group had only 39 cattle because one animal died during the study and was removed from the data set, while the shade group had 40 cattle in total (Figure 3.4). The two treatments are indicated with two different colours and each dot represents an individual weight recording.

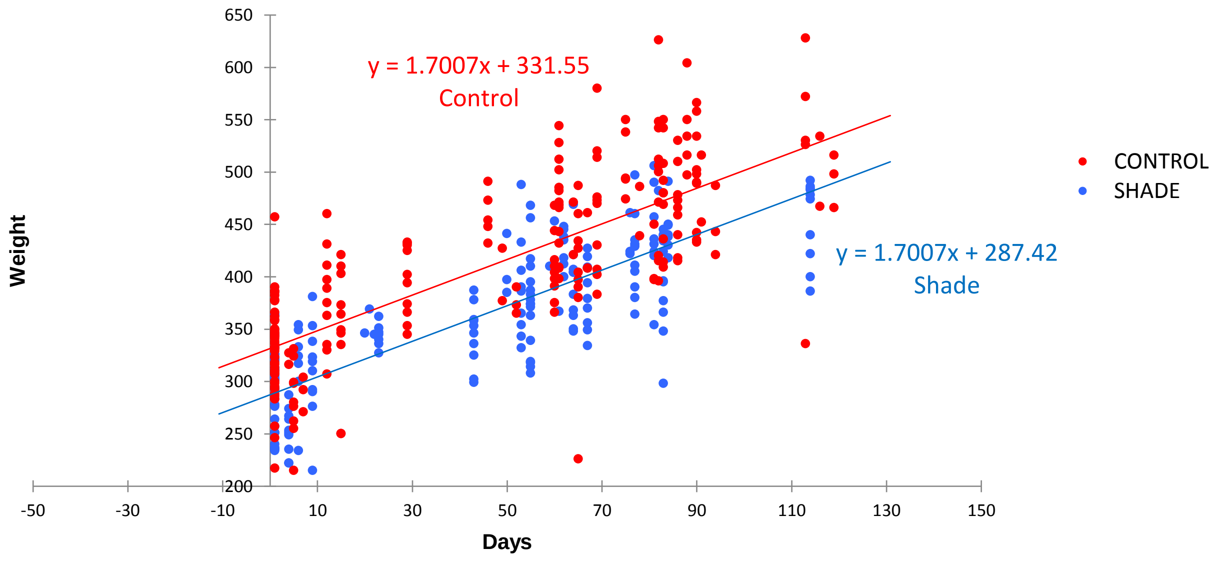

Figure 3.4 Regression lines of the treatments shade vs. control, indicating the growth rate of the 40 animals used for observations for all four trials.

Namibia has extreme summer and winter veld conditions which influences the body condition of the weaners when they enter the feedlot. The graph shows that the control group that entered the feedlot were 44.1 kg heavier than the shade group (due to coincidence).

3.3.4. Behavioural measurements

3.3.4.1. Shade vs. control

There were no significant differences between the shade and the control group for maintenance behaviours such as standing, lying and walking but significant difference was found for feeding and drinking. For feeding the difference between the two treatments LSMeans were 1.4% and for drinking 0.7% (Table 3.4). The social behaviours (butting, rubbing, mounting, sniffing, following, licking, stereo-rubbing and licking) were grouped as the animals spent little to no time on these activities (Table 3.5). Within the social group only rubbing was significant between the two treatments with a numerical difference of 0.5% higher for the shaded group. More numerical affiliative behaviours were seen in each treatment compared to aggressive and stereotypic behaviour. In Table 3.4 the means for maintenance behaviour show that cattle in the shade group spent most of their time lying (~43%) and standing (~31%), while 17% of the time was spent on feeding and 4% drinking. Walking (1.4%) was minimal and they socialized 4% of the day.

Table 3.4 Least square means (±SEM) for time spent (%) on behaviours for cattle in a feedlot, with either barren (control) or enriched environments (shade).

Behaviour	Shade	Control	*P*-value
Maintenance:			
Standing	30.5±0.49	30.0±0.45	0.440
Lying	43.4±0.52	42.4±0.49	0.190
Feeding	17.0±0.34	18.4±0.32	**0.002**
Drinking	3.5±0.16	4.2±0.15	**0.002**
Walking	1.4±0.10	1.3±0.10	0.440
Social	4.3±0.17	3.5±0.16	**0.001**

Table 3.5 Least square means (±SEM) for the time spent (%) for the social behaviour between the two treatment groups. Social behaviour was subdivided into aggression, affiliation and stereotypic behaviour.

Social	Shade	Control	*P*-value
Aggression			
Butting	1.2±0.10	1.2±0.09	0.72
Mounting	0.2±0.03	0.2±0.03	0.41
Affiliation			
Rubbing	1.6±0.10	1.1±0.09	**<0.0001**
Sniffing	0.2±0.03	0.1±0.03	0.30
Following	0.2±0.03	0.2±0.03	0.23
Licking	0.2±0.04	0.2±0.03	0.29
Stereotypic			
Rubbing	0.6±0.06	0.5±0.05	0.21
Licking	0.2±0.03	0.1±0.03	0.11

Due to the fact that small or no differences were observed in behaviour between the shade and control treatments, the study focussed further on the interaction between behaviour of the cattle and the different seasons they were exposed to during the experiments. Season had an effect on the behaviour of the cattle when no treatment effects were taken into consideration (Figure 3.5). The cattle were standing more during summer and least during spring, while lying showed the opposite trend. Feeding and drinking was generally higher during summer, closely followed by winter.

Walking hardly differed between summer and winter but was still higher than in autumn and spring. Socialising was highest during winter and lowest during summer.

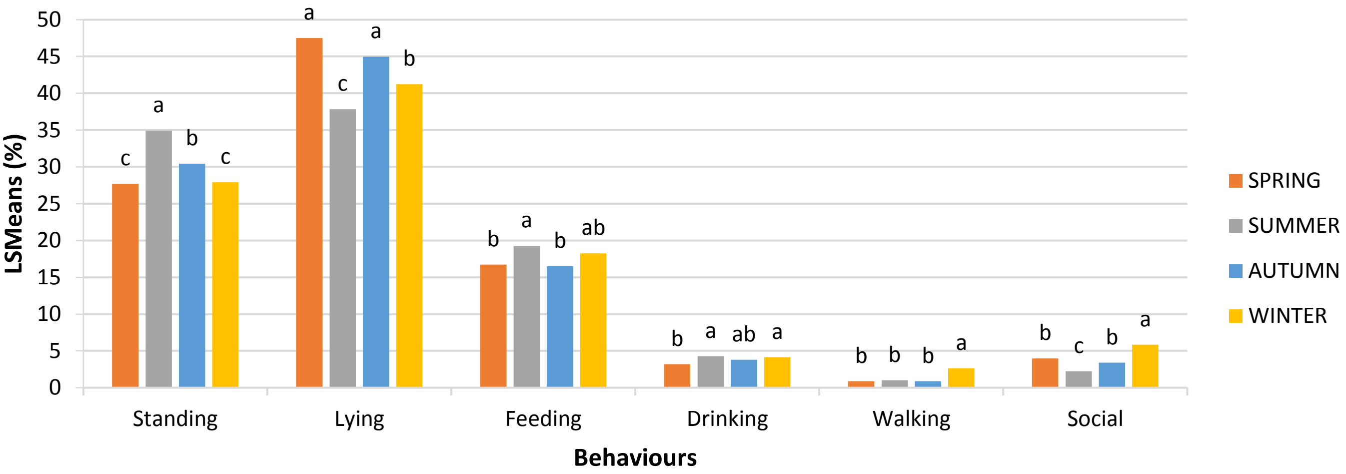

Figure 3.5 Least square means on time spent (%) for the season effect on the cattle behaviour in a feedlot with shade and control values being pooled. [a, b, c] Means with different superscripts differ significantly at $P \leq 0.05$ between the four seasons for each behaviour.

The interactions between the treatments and season were statistically significant ($P \leq 0.0001$) (Table 3.6). The behaviour that was recorded the most was the lying down behaviour and was highest during spring in the shade group. For feeding and drinking the shade and control group responded in a similar manner in each season with a higher feeding and drinking frequency in the control group during summer. The shade and control group showed more socializing behaviour in winter and least in summer. The shade and control group showed the highest standing behaviour during summer.

Table 3.6 Detailed summary of least square means for the behaviours between the barren (control) and enriched (shade) environment during the seasons. The bold values indicate the highest least square mean on time spent (%) while the grouping with the lowest value is underlined.

Season	Treatment	Standing	Lying	Feeding	Drinking	Walking	Social
Spring	SHADE	28.1^{cd} ±1.07	48.8^{a} ±1.15	15.7^{b} ±0.76	2.9^{b} ±0.35	1.0^{b} ±0.21	3.6^{bcd} ±0.38
	CONTROL	27.3^{cd} ±0.85	46.2^{a} ±0.91	17.8^{ab} ±0.60	3.6^{b} ±0.28	0.8^{b} ±0.17	4.4^{b} ±0.30
Summer	SHADE	35.7^{a} ±0.95	39.1^{cd} ±1.02	18.2^{ab} ±0.67	3.6^{b} ±0.31	1.0^{b} ±0.19	2.5^{de} ±0.34
	CONTROL	34.1^{ab} ±0.89	36.6^{d} ±0.95	20.4^{a} ±0.63	5.0^{a} ±0.29	1.0^{b} ±0.19	2.0^{e} ±0.32
Autumn	SHADE	27.7^{cd} ±0.85	47.8^{a} ±0.91	16.2^{b} ±0.60	3.5^{b} ±0.28	0.8^{b} ±0.17	4.0^{bc} ±0.30
	CONTROL	33.1^{ab} ±0.85	42.1^{bc} ±0.91	16.9^{b} ±0.60	4.1^{ab} ±0.28	1.0^{b} ±0.17	2.9^{cde} ±0.30

Winter	SHADE	30.5^{bc} ±1.01	37.7^{d} ±0.08	17.8^{ab} ±0.71	4.2^{ab} ±0.33	2.9^{a} ±0.20	7.0^{a} ±0.36
	CONTROL	25.3^{d} ±1.03	44.8^{ab} ±1.12	18.7^{ab} ±0.73	4.1^{ab} ±0.34	2.4^{a} ±0.21	4.6^{b} ±0.37

$^{a, b, c}$ Means with different superscripts differ significantly at P ≤ 0.05 between the behaviours (vertical).

3.3.4.2. Non-shaded vs. shaded area

As the shade treatment included both an area under shade netting as well as an area in direct sun the animals had a choice of utilization of covering/space. During observation of their behaviour the actual position was also recorded making it possible to analysis data within this area of choice. These results indicated significant differences between the behaviours of cattle when choices regarding sun exposure were made (Table 3.7). Cattle spent most of their time lying and standing under the shade than in the direct sun (P ≤ 0.001). The behaviours of feeding and drinking were not included in this analysis as the feed and water-trough were only present in direct sun. The difference between walking in the shaded or non-shaded area was so small that it was considered not to have a significant contribution as combined it only comprised 1.3% of the observations. The social behaviours were higher in the non-shaded area than in the shaded area but again a very small percentage of the time was spent on these activities.

Table 3.7 Least square means (as % of time) of the behaviours within the shade treatment only where the animals had the choice to utilise the shaded area.

Behaviours	**Shade**	**Non-shaded**	***P*-value**
Maintenance:			
Standing	18.3 ±0.41	12.2±0.41	**<0.0001**
Lying	24.3±0.60	19.1±0.60	**<0.0001**
Walking	0.5±0.07	0.9±0.07	**0.0005**
Social:	1.6±0.13	2.7±0.13	**<0.0001**
Aggression			
Butting	0.5±0.07	0.7±0.07	0.070
Mounting	0.1±0.03	0.1±0.03	**0.027**
Affiliation			
Rubbing	0.7±0.08	0.9±0.08	**0.019**
Sniffing	0.1±0.02	0.1±0.02	0.200
Following	0.1±0.03	0.2±0.03	**0.005**
Licking	0.1±0.03	0.1±0.03	0.145
Stereotypic			
Rubbing	0.2±0.04	0.4±0.04	**<0.0001**
Licking	0.1±0.02	0.2±0.02	**0.0004**

Season also influenced the choice of stay of the animals within the shade treatment ($P \leq 0.001$). The animals spent more time standing (26%) in the shade than in the sun during summer, lying (30%) in the shade during spring and walking (2%) and socialising (5%) during the winter in the shaded area. Their feeding was the highest (18%) during summer and lowest (16%) during spring while drinking was highest (4%) in the winter and lowest (3%) in spring as well. Figure 3.6 shows the effect of season on the behaviour of the cattle while having the opportunity to utilise the shaded area. Feeding and drinking were not included because the troughs of both, feed and water were only present in the non-shaded area. Overall, the animals were more active during spring, autumn and summer in the shaded area and during winter they were more active in the non-shaded area.

The coat colour was determined at the beginning of each trial when the ten animals were chosen for observational studies. Here, 50% light-coated (score 0 – 6) and 50% dark-coated (8 – 16) animals were randomly selected within all dark and light coated animals for each treatment. Some animals had a mixture of colours, for example, white and black colour coats and the major colour visually seen over the entire body was the final colour for record keeping. In addition, the hair length was measured, but only for the winter trial. In the shade treatment 40% of the cattle had a score of 6 (woolly; 0-3 cm), 30% a score of 3 (fairly short; 1-2 cm) and 10% each for score 2 (very short; 0.6-1 cm), 4 (fairly long; 2-3 cm) and score 5 (long; >3 cm). In the control treatment one animal died during the trial, therefore, 55% had a hair length score of 3 (fairly short; 1-2 cm) and 22% of score 4 (fairly long; 2-3 cm) and 6 (woolly; 0-3 cm). The coat length was not an influencing factor in the behaviour of the cattle and will therefore not be discussed further.

The coat colour of the selected animals did have an effect on the utilisation of the shaded area. For example in the spring trial both the darker (score 8-16) and lighter (score 0-6) coated animals were more concentrated in the shaded area when lying down or standing or socializing while in the autumn trial the darker coated animals were more concentrated in the shaded area and the lighter coated animals in the non-shaded area. In the winter trial, both light and dark coated animals spent most of their time in the non-shaded area but only on days when the temperature was lower than 10 °C. On warmer days, the darker coated animals were still utilising the shaded area most of the time compared to the lighter animals which were more in the non-shaded area. The hair length did not influence the behaviour as much as the coat colour of the animals.

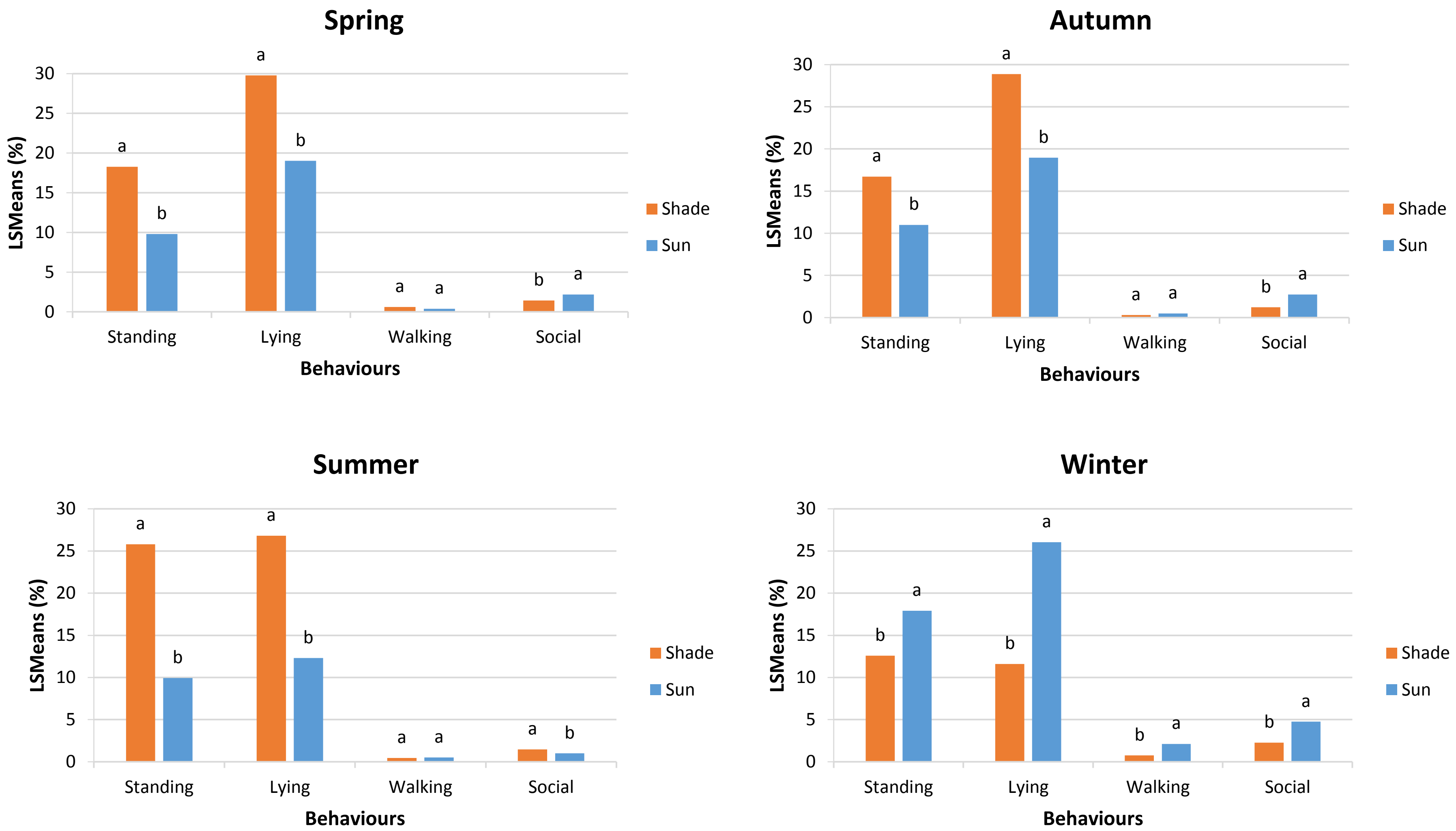

Figure 3.6 Least square means for time spent (%) on the behaviours during the four seasons for non-shaded and shaded area. [a, b] Means with different superscripts differ significantly at $P \leq 0.05$ between the behaviours in the two areas.

3.4. Discussion

Shading, which is a valuable resource for cattle, covered a third of the entire pen in this study, which is 3.75 m^2 shade/individual. Sullivan *et al.* (2011) reported that welfare improvements occurred when feedlot cattle have more than 3.30 m^2 per individual. Cattle utilised the shaded area more frequently than the non-shaded area especially when the ambient temperatures and solar radiation increased which was also reported by other researchers (Schütz *et al.,* 2009; Schütz *et al.,* 2010; Schütz *et al.,* 2014). The cattle started to use the shade from 8:00 am on warm days and 11:00 am on cooler days until 5:00 pm or even later (Figure 3.7). On very hot days, with a temperature above 35 °C, the cattle were either feeding or drinking, or were standing or lying in the shade but very few were in the non-shaded area of the pen. The weather stations set up in the two areas, showed a 2 °C lower temperature in the shade compared to the direct sun area.

This study showed a higher lying time than standing in the treatment groups, but previous findings reported a lower lying and higher standing time for similar treatment groups (Mitlöhner *et al.*, 2002; Schütz *et al.*, 2010; Schütz *et al.*, 2014). Cattle were lying down more in the shade treatment during spring, summer and autumn except for winter where the lying down time was higher in the control group. This could mean that the cattle in the shade group had less heat challenges during hot months than the control group. Although the ambient daytime temperatures in Namibia are similar during spring, summer and autumn but may drop below 10 °C during winter. In the current study the cattle lied down to preserve heat in winter and stand in summer to dissipate heat through evaporation. Koknaroglu *et al.* (2008) reported that animals with shaded shelter had the ability to dissipate heat during the day while animals without shade shelter could only dissipate the heat stored during the day at night. Therefore, shaded groups were able to relieve the effect of heat stress which again improves the animal welfare status of the animal. Even during the rainy season in Namibia the temperature does not drop with cloud cover on warm days.

The observations, under the category 'other' behaviours, showed that when it was raining the cattle were not very active, they stood in a clustered group with their hind quarters in the direction of the falling rain. As soon as it stopped raining, they started feeding, became active or lay down again. After heavy rains, the pens were muddy, often above ankle height (approximately 15 cm), especially underneath the shade netting, which caused the animals to stand or lie more in the non-shaded area than shaded area. As soon as the mud dried and became harder they used the shaded area again. This indicates that covering the entire pen with shade netting would not be beneficial to the cattle during the rainy season.

A number of 'other' behaviour were observed, and are linked to the social behaviour: when the team came into the pen to identify sick cattle, the cattle had to stand up and walk past the team, which regularly ended up in a running activity as some cattle were more afraid of the humans and if some cattle started stampeding; they stimulated the entire group to start stampeding. This activity would result in cattle having a higher internal body temperature and therefore a need to dissipate heat (Sullivan *et al.*, 2011) underneath the shading. Therefore, this activity could contribute to an increasing count of animals under the shaded area. Also, similar playing activity was also observed when the adjacent pen was removed for either weighing or marketing purposes.

Figure 3.7 Cattle lying under the shading already at 8 am, independent of coat colour or breed.

Hair length and coat colour cannot be examined in isolation because both are important for cattle in hot climates as it mediates the impact of solar radiation on the animals (Foster *et al.*, 2009). In this study, animals with longer hair length and lighter coat colour were expected to utilise the shade more than the short hair, light coated animals, however no differences were observed. In the warmer months both light and dark coated animals utilised the shaded area more frequent than the non-shaded area while in the winter the opposite occurred, especially when the temperature dropped below 10 °C. During the extreme cold days the cattle with lighter coat colours were more concentrated in the non-shaded area in the cool mornings and late afternoons, while in between they used the shaded area due to warmer temperatures. This phenomenon was also reported by Gaughan *et al.* (1998). The darker coated animals tend to respond quicker to the heat than the lighter coated animals and possibly explain the difference observed. Lighter coated animals reflect sun rays and need to stand in the sun, especially in the early mornings, to increase their core body temperature while darker coated animals absorb more heat through sun rays and therefore utilised the shade to cool down. In general, lighter coated animals were spending more time lying down than darker coated cattle due to the fact that cattle stand to maximise their surface area exposed to the environment and therefore increase the airflow around the body of the animal to lose heat through evaporation (Schütz *et al.,* 2009). Therefore lighter coated animals were less affected by warm weather while darker coated animals were more sensitive to heat stress. However, this study showed that no matter what coat colour the animal had, the animal changed its behaviour in response to increasing heat loads. Sullivan (2011) also reported that cattle alter their posture and seek for shade when heat stressed.

A behavioural pattern that occurred during cooler months was that the cattle slept underneath the shade netting at night time, which could be due to the isolation effect of the netting which is supported by the temperature reading. Under the shade net, the temperature during night time was about 1 °C warmer compared to uncovered areas (sun weather station). The cattle only moved into the non-shaded area when direct sunlight was evident on the uncovered areas. This means, during sunrise, the cattle were still underneath the shade netting and moved into the non-shaded area only when solar radiation increased.

Feed intake behaviour was significantly higher in the control group compared to the shaded group as measured in a higher average daily dry matter intake (DMI). Beattie *et al.* (2000) noted that animals in a barren environment have to increase their energy requirements to maintain their internal temperature, which could also be the reason for the increased feed intake in the control group of this study. Brown-Brandl *et al.* (2005) also found that the daily feed intake was higher and more constant in the control group because the animals ate more frequenly smaller meals to compensate for higher temperatures. Contradictory to the findings of this study, Mitlöhner *et al.* (2002) reported that the shaded group had a higher daily DMI especially in regions with a ambient temperature above 29.4 °C. The time spent on feeding was higher in summer and winter which may be due to more constant temperatures during these seasons; during spring and autumn the temperatures vary continuously.

Consistent improved performances were reported in the provision of shade for dairy cattle (Gaughan *et al.*, 1998; Kendall *et al.*, 2006), but in the beef cattle feedlot production system, results were not as consistent as expected. Although the feedlot lies in a region with ambient temperatures above this suggestion of 29.4 °C, the cattle in this study did not show any performance improvement with added shade. Due to the design of the feedlot and the existing infrastructure, the use of smaller groups of animals to define feeding patterns and measure accurate FCR and ADG recordings may be biased as the animals would then not be observed under normal production conditions. Mitlöhner *et al.* (2001), Mitlöhner *et al.* (2002) and Gaughan *et al.* (2010b) reported a positive influence on the performance of feedlot cattle with shading. In contrast, no improvement on the ADG of feedlot cattle was reported by Clarke & Kelly (1996) whilst inconsistent results have also been reported by several other researchers (Mader *et al.*, 1999; Brown-Brandl *et al.*, 2005). The environmental temperature determines which type of animal is suitable for a particular region. This means, when an animal does not adapt easily to the environment and heat causes the core temperature to rise above the preferred temperature, the animal will not perform in growth (Foster, 2009). Season had no influence on the production performance, except in winter when the growth rate was higher in the control group which may be because of the lower winter temperatures and thus less heat stress.

The time spent on drinking can be linked to feeding as cattle went to the water trough after they were feeding. Animals, however, increase their feed intake when they have water to drink. Season also has an effect on the time spent on drinking and was highest in the control group during summer. Beef cattle spend more time at the water trough and increase their water consumption during summer, especially if no shade is available (Schütz *et al.*, 2010). This is because water evaporation creates a cooler microclimate or they drink more due to the hot climate. Cattle in pens with shading are able to cool down under the netting and spent less time at the water trough. Another behaviour classified as 'other' that was observed during the study was when the water trough was cleaned, the cattle gathered around the water trough and found it interesting; due to the attendance of a human and due to the splashing of the water. During these periods the water trough was an attraction point and increased playing. Competition took place between the animals in the same pen and even the adjacent pen. Even when the cattle were waiting for their first delivery of fresh feed, the animals gathered at the feeding trough and started to play and chased-up the lying cattle. This activity and also the presence of a human at the trough, to remove feed refusals, stimulated the cattle to visit the feeding trough.

The walking behaviour was highest in the non-shaded area during winter which may be to stay in motion and generate internal heat to keep warm because during this period the average ambient temperature varied between 5.9 and 23.8 °C (Figure 3.3).

The social behaviour included more positive than negative behaviours and was significantly different between the shade and control group. Affiliative behaviours were more frequent in the shade group, whereas aggressive behaviours were higher in the control group. Rubbing which was classified as a positive affiliative behaviour, was higher in the shade group which is an indication that the animals were happier and calmer in the shaded treatment. Schütz *et al.* (2010) also reported a decreasing aggression in the shaded treatment. In general, more aggressive behaviour was found in the non-shaded area which may indicate that the cattle were more stressed in the non-shaded area during warmer weather conditions and experienced slightly better welfare when spending more time in the shaded area, similar finding were also reported by Boissy *et al.* (2007).

An interesting 'other' observation, was that the social behaviour was extremely high in the late afternoon which caused a big dust cloud above the feedlot. This could be due to decreasing temperatures which makes it more comfortable to move and play or because of an energy spike after the last delivery of feed. The playing of a pen stimulated the adjacent pen to join and finally caused the entire feedlot to show playing behaviours. This most likely is linked to a strong herding behaviour of cattle, which is again related to the historic fight or flight response strategy.

The lack of shading and the subsequent increasing heat loads of feedlot cattle could cause the number of morbid cattle to increase due to heat stress. In this study, the recorded morbidity was higher in the control group than in the shade group. The effect of shade on morbidity warrants further research. About three months after the shade netting was constructed for this study, the feedlot veterinarian insisted that shading should be set up in the recovery pen as well. She was convinced that shade structures reduced stress under higher temperature conditions and would assist in animal recovery which was supported by the study of Muller *et al.* (1994b).

The cost for setting up a structure such as that used in this study, is at N$ 234 000.00 which might seem very high, but when observing how the cattle prefer to spend most of their time during the day under the shading, makes it a worthwhile investment. Also, consumers believe that the animals have a better welfare when shading is made available to the feedlot cattle in Namibia (as seen by the Norwegian visitors who did a site inspection during the study).

3.5. Conclusion

The cattle in the feedlot utilised the shaded area more frequently than the non-shaded area which was expected before the study commenced. These cattle showed less aggressive and more positive affiliated behaviour patterns than the cattle of the control (barren) group. No improvement in the production performance of the shaded cattle could however be found. Season had a prominent influence on the behavioural patterns of the cattle such as both light and dark coated cattle having a higher shade utilisation during the warmer months and lower utilisation during the cooler months. Exceptions occurred where darker coated animals spent more time during warm days in the non-shaded area. This study shows that Namibian cattle are readily adapted to the high ambient temperatures.

Heat stress was not measured by means of rectal temperature or core temperature which would be recommended for further investigations. Also, water temperature and water usage of both treatments should be measured in future studies.

The introduction of shading into Namibian beef cattle feedlot systems is a rising importance to consumers as they have the perception of a "happier" animal when shading is available. Namibian beef is mainly destined for export into Europe and Norway and the potential of meeting a discerning modern consumer's concern about animal welfare cannot be under estimated. A consumer perception evaluation on the use of shade or not, will also shed more light on this phenomenon as it has been shown that modern consumers are willing to pay for higher welfare standards.

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Chapter 4:
The impact of a manure heap as a form of environmental enrichment on animal welfare, behaviour and production of cattle in a feedlot

Abstract

Environmental enrichment in an intensive animal system is a way to improve animal welfare, which is of high importance to the consumer, and the production performance of the animal. This study investigated the use of manure heaps as a form of environmental enrichment in a cattle feedlot in Namibia. Ten randomly chosen animals of 120 cattle in one pen per treatment were monitored for specific behaviours. The observations were repeated for four cycles (one cycle = three months): spring, summer, autumn and winter. Behaviour was recorded twice a week from 7:00 until 17:00 during the first minute of a 30 min interval. The manure heaps covered 5% of the surface area of the entire pen and were reshaped with a front loader every four days. The average daily gain (ADG) of each of the ten selected animals was calculated using linear regressions of the weight gain over time. The behaviour frequencies of maintenance (standing, lying, walking, drinking and feeding) and social behaviours (aggressive = butting, mounting; affiliative = rubbing, sniffing, following other animals, licking; stereotypic = licking and rubbing), did not differ between the two treatments. Cattle spent most of their time lying down and standing; the frequency varying between the four seasons where lying was longest in the spring and winter periods, whereas standing was longest in the summer and autumn periods. Affiliative behaviours were numerically more frequent in the manure group whilst aggressive behaviour was higher in the control group. ADG did not differ between the treatments. Therefore, although no significant difference occurred between the two treatments as pertaining to the production parameters, the observations made during the study showed a "happier" animal when a manure heap was present. It is in cattle's nature to lie on a higher object than the normal ground level.

4.1. Introduction

Environmental enrichment improves animal welfare by providing stimuli to perform species-appropriate behavioural and mental activities and thereby improving the biological functions such as health, reproduction success and fitness of animals (Ishiwata *et al.*, 2006). It is believed that the introduction of new structures and objects to the housing of animals will stimulate the behavioural diversity through learning abilities and decrease harmful, manipulative and social behaviours (Beattie *et al.*, 2000). When objects or structures are made available to animals they spend more time on exploring them but when no object or structure is available, they rather explore their pen and pen mates. Cattle also have different ways of approaching strange objects or structures depending on their personalities and temperaments.

Animal welfare is difficult to measure objectively when simple techniques are being used but the way animals are treated is of high importance to the consumer (Brandenberg, 2010). The effect of environmental enrichment on farm animals can be examined from the behaviour of the cattle. For example, cattle tend to lie down more often when enough space (m^2) is available per animal (good stocking density) which illustrates good welfare (Ito *et al.*, 2009). Studies have shown different forms of environmental enrichment that could be used in intensive pig, sheep and cattle systems. Very little research have however been done on the effect of enrichments with cattle feedlots. A scratching/rubbing arch and different scent-releasing devices were used as forms of enrichment by Wilson *et al.* (2002), but no research was attempted on structures such as manure heaps.

The aim of the study was to assess the effect of a manure heap as a form of environmental enrichment on the behaviour, welfare and production performance in a feedlot system in Namibia. The manure heap was chosen because a common behaviour was observed by farmers and also feedlots that cattle tend to play on any types of heaps such as sand heaps or termite hills on farms. The aim of this heap was to promote more physical exercise to increase feed intake and to promote the playing behaviour.

4.2. Materials and methods

4.2.1. Study design

4.2.1.1. General

All the animal handling procedures were approved by the Stellenbosch University Animal Care and Use Committee (Ethical clearance certificate number: SU-ACUD15-00097). The study was conducted over four feedlot cycles of three months per cycle. For each treatment, only 10 randomly chosen animals of one pen of 120 cattle were used for observations (Figure 4.1). The pen consisted of 120 cattle with a stocking density of 11.25 m^2/cattle. Only male cattle were used which varied across breeds from *Bos indicus, Bos Taurus* and crosses of both. Further details regarding the experimental design of the location and climate at the study site, the feeding regime and the duration of the study are discussed in Chapter 3 (section 3.2.1.1).

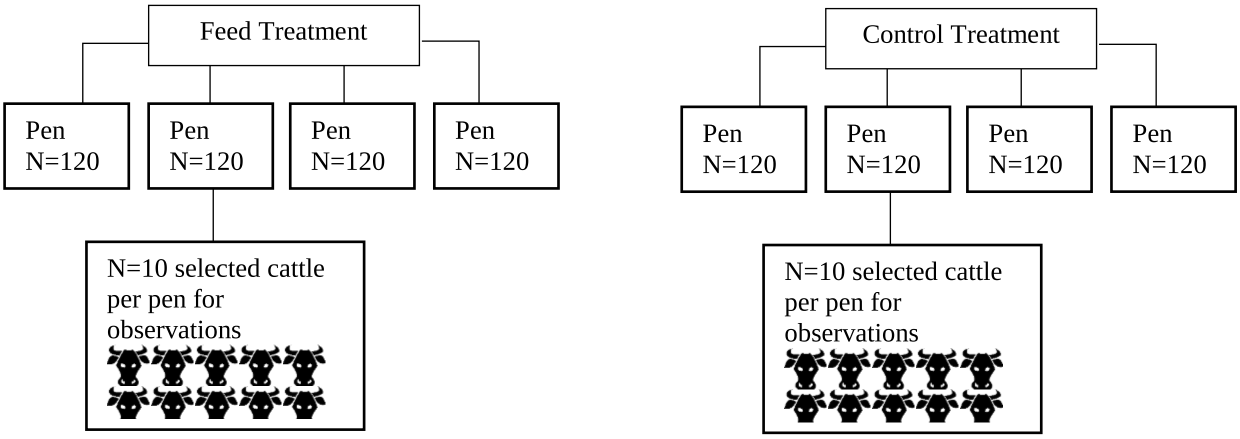

Figure 4.1 Flow diagram of the study design for every repetition of a feedlot cycle (spring, summer, autumn and winter).

4.2.1.2. Manure heap

The feedlot, which is situated 30 km north of Windhoek (-22° 21' 3.8"S; 17° 2' 48.0"E), has a routine to remove the top soil layer, mainly manure, every three months at completion of a cycle. The manure is usually removed from the pen however for this study the manure was moved into a heap in the centre of the pen with a dam-scrapper. A front-loader was used to shape the heap into a 3 m high and 10 m wide structure (Figure 4.2). The manure heap was only removed completely after the second feedlot cycle. The heap was re-shaped once or twice a week, depending on the cattle's frequency of activity on the heap. Some pens were so active that the heap had to be re-shaped every second day while others only required re-shaping once a week.

Figure 4.2 Illustration of a two day old manure heap which is already played down.

4.2.1.2.1. Cost Analysis

The cost analysis was calculated by recording the by adding direct costs of the activity of shaping and re-shaping the manure heap for the entire study of one year. The front-loader took 30 min to reshape a manure heap in one pen and used 1.825 litre of diesel for 30 min. The diesel price was N$ 11.25 per litre at that time. The cost per pen for one day therefore accumulated to N$ 20.53. If multiplied by the average number of days a month that was used for reshaping (N$ 20.53 x 10 days = N$ 205.30 per pen per month). This amount was then multiplied by 12 months (N$ 205.30 x 12 = N$ 2 463.60 per pen per year). The maintenance cost per annum of the front-loader (N$ 4 992.00) was added to the total cost per pen per year. The final cost for the front-loader to reshape one pen throughout the year was N$ 7 455.60.

In the manure group, fewer animals became bloated when compared to the control group. The treatment cost of one bloated animal was N$ 3.90 and it took approximately three to four hours for the animal to de-bloat. The problem with bloated animals is not the price per treatment, but the fact that the rumen has been affected which causes the animal to consume less feed for the next few days. This influences the growth rate of the animal.

4.2.2. Data collection

4.2.2.1. Growth performance and identification and treatment of sick cattle

The cattle were weighed on the first and last day of the feedlot cycle and additionally two to five times within the feedlot cycle. When an animal became sick and was treated for symptoms, the date when the animal was withdrawn from the pen, the ear tag number, pen number, reason of sickness, medicine used for treatment and the date when the animal was moved back to the original pen were recorded. More detailed information on the procedures is described in Chapter 3 (section 3.2.2.1).

4.2.2.2. Production measurements

The average daily gain (ADG) was calculated for the 10 animals per trial by means of linear regression. The feed conversion ratio (FCR) was calculated for the 120 cattle per pen together as a single value and was therefore not included in the statistical data analysis. Refer to Chapter 3 (section 3.2.2.4) for more details. The feed delivered and refusals that were weighed back for each pen was recorded on a daily basis. The daily dry matter feed intake (DMI) per pen was recorded to calculate the amount of feed consumed per individual per day.

4.2.2.3. Behavioural measurements

The 10 animals selected for observations in each treatment group were observed 21 times per day, from 7:00 until 17:00 in using the *instantaneous sampling method* (Mitlöhner *et al.*, 2001; Martin & Bateson, 2007) for the first minute of every 30 min interval, twice a week for three months. Maintenance behaviours such as standing, lying, walking, feeding and drinking were recorded as well as the social behaviour including aggressive (butting, pushing, mounting), affiliation (rubbing, licking, sniffing, following other animals) and stereotypical (licking and rubbing against an object and not a pen mate). The behaviour that was observed during the study which showed a behavioural pattern and were not statistically analysed were classified as 'other' behaviours. For more detailed information refer to Chapter 3 (section 3.2.2.5).

In addition, in the manure treatment the on-heap and off-heap behaviours were recorded separately. The off-heap had the same measurements as in the control group but the on-heap behaviours included standing on-heap, lying on-heap, walking over heap and playing on-heap. The playing behaviour was identified when the cattle ran or performed playful actions such as jumping with their tails lifted on the heap. For the manure vs. control data analysis, the on and off-heap percentages were added together to make up the manure group data.

4.2.2.4. Statistical Analysis

The data analysis for this study was performed using XLSTAT 2017 and SAS for Windows version 5.4. XLSTAT was used for all ANOVA analyses which included the percentages of the behavioural data. The ADG for each individual was calculated by means of linear regression and PROC REG of SAS. The Bonferroni Post hoc test was used for all multiple comparisons calculations for LSMeans. A probability of 95% was considered significant for all.

The behaviours were recorded and the sum of each behaviour was calculated per day, divided by 21 (total number of observations per day – every minute of each 30 minute interval from 7:00 until 17:00) and multiplied by 100 to obtain the percentage of time spent on the specific behaviour. In order to compare all the values of the manure treatment with the control, the observed percentages for each day of the time the animals spent on and off-heap were summed and the mean was used for the analysis. No correlation between activity and time (days on feedlot) was indicated, therefore time was excluded in the final models.

4.3. Results

4.3.1. Deviations from the protocol

The number of cattle per treatment that became sick during the entire study, including all cattle, was 215 cattle in the manure treatment and 236 cattle in the control. The most prevalent disease was Pneumonia. The autumn trial was 30 days longer than the other three trials, as the feedlot had been placed under quarantine. Namibia has a policy via DVS of no tolerance for hormones or growth stimulants being used in feedlots and urine samples of the feedlot cattle showed low signs of Zeranol. The DVS placed the feedlot under quarantine until the final results were received. The outcome was that no growth stimulants were injected into the animals as Zeranol was found naturally in the cattle's body and the feed that was fed. This extended period had an influence on the amount of cattle that became sick, the ADG and overall days in the feedlot.

4.3.2. General

Different farmers send their cattle in small groups to the feedlot which are mostly of the same breed and are generally sorted into the same pen at the feedlot. For example, if 50 cattle were sent from a farmer with similar live weights they were sorted together into a pen. Therefore, different breeds in the manure group behaved differently towards the manure heap. For example, in the spring trial the Nguni animals spent most of their time on the manure heap and were in general more active in social behaviours. Brahman animals in the autumn trial did not find the manure heap very interesting whereas in the winter trial the Brahman animals were more concentrated on the heap. On a cold day of 13 °C, it was noticed that some animals spent more time on the manure heap during the mornings. The reason for this was probably because the inside temperature of the manure heap, 20 cm from the surface, was 33 °C on the sun side and 31 °C on the shade side in the morning.

4.3.3. Production measurements

There was no significant difference in the ADG between the two treatments ($P = 0.19$). The manure group had a LSMean of 1.7±0.10 kg/day and the control group 1.9±0.10 kg/day. The effect of season on the treatment groups was also not significant (Table 4.1). The average daily dry matter feed intake (DMI) was similar for both manure and control groups at 10.4 kg/head/day. The pairwise comparisons test (Bonferroni Post hoc test) showed no significant difference between the interactions of season and treatment ($P = 0.83$) and will not be discussed in detail.

Table 4.1 Least square means (±standard error) of the seasonal effect on the ADG (kg/day) between the two treatment groups.

Season	Manure	Control	*P*-value
Spring	1.5±0.18	1.8±0.18	0.29
Summer	1.7±0.18	1.7±0.21	0.87
Autumn	1.8±0.17	1.9±0.17	0.59
Winter	1.7±0.17	2.0±0.18	0.17

The growth rate of each selected animal (n = 40) per treatment group across the study was plotted on a graph (Figure 4.3) and a regression line fitted. In the control group, one animal only had two weight points as the animal was removed from the pen for some time due to a sickness, and is therefore not part of the analysis. Therefore, the growth lines consist of 40 cattle for the manure treatment and 39 cattle for the control treatment. Each treatment is indicated with a different colour and each dot represents an individual weight recording. The control group had a 49.4 kg higher entry weight than the manure group which happened coincidently whilst the growth rate (kg/day) was similar.

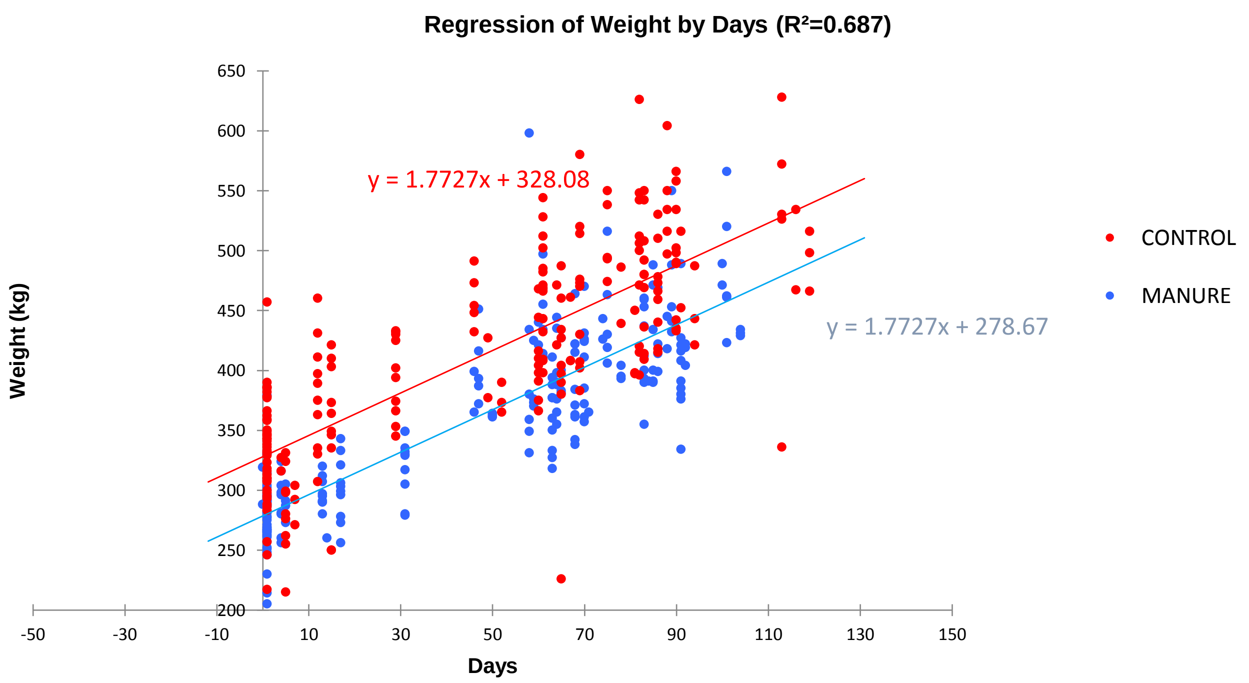

Figure 4.3 Regression lines of the treatments, Manure vs. Control, indicating the growth rate of the 40 selected animals used for observation during the entire study.

4.3.4. Behavioural measurements

4.3.4.1. Manure vs. Control

There were no significant differences between manure and control groups for the maintenance behaviours such as standing, walking and drinking. Significant differences were however found between the maintenance behaviours lying and feeding. Feeding had a LSMean of 1% higher in the control group whilst lying was 1.4% higher in the manure group. In both treatments, cattle spent most of their time lying down (~ 43%) and standing (~30%). Also, no significant differences were found for the social behaviours which were pooled (Table 4.1). There was a slight trend towards more affiliative behaviours than aggressive behaviours in the two treatments.

Table 4.1 Least square means (±SEM) of the time spent (%) on all the behaviours measured during the study (10 animals per treatment per trial) in either barren (control) or enriched environments (manure).

Behaviour	Manure	Control	P - value
Maintenance:			
Standing	30.0±0.46	29.9±0.47	0.89
Lying	43.7±0.50	42.3±0.51	**0.05**
Walking	1.3±0.09	1.3±0.08	0.84
Feeding	17.4±0.32	18.4±0.32	**0.02**
Drinking	4.0±0.15	4.2±0.16	0.43
Social:	3.6±0.16	3.5±0.16	0.55
Aggression			
Butting	1.1±0.09	1.2±0.09	0.41
Mounting	0.1±0.03	0.2±0.03	0.69
Affiliation			
Rubbing	0.9±0.08	1.1±0.08	0.16
Sniffing	0.2±0.03	0.1±0.03	0.11
Following	0.2±0.03	0.2±0.03	0.83
Licking	0.2±0.03	0.2±0.03	0.65
Stereotypic			
Rubbing	0.5±0.05	0.5±0.05	0.98
Licking	0.1±0.02	0.1±0.02	0.69

Season showed a significant effect on the behaviour when data of the two treatments were pooled (Figure 4.4). Standing was highest in summer together with autumn, while feeding was the highest in summer. Lying was highest in winter and spring and walking in winter. Socialising was highest in the spring season. Butting (aggression) was highest in spring whereas rubbing (affiliation) was highest in winter.

The cattle of the manure group spent more time playing on the heap during winter and less in summer (Figure 4.5). Season and treatment showed significant interactions for some behaviour types (Figure 4.5). For feeding the manure and control group responded the same in each season except in winter when the control group fed more frequently than the manure group. Likewise, the manure group showed more social behaviour in spring than the control group. For standing, the manure and control group were similar within each season but stood more in the summer and autumn season. Lying down was more frequent in the manure group during winter, and least in the control group during summer. Drinking did not differ significantly for the season*treatment interaction and will not be discussed in further detail.

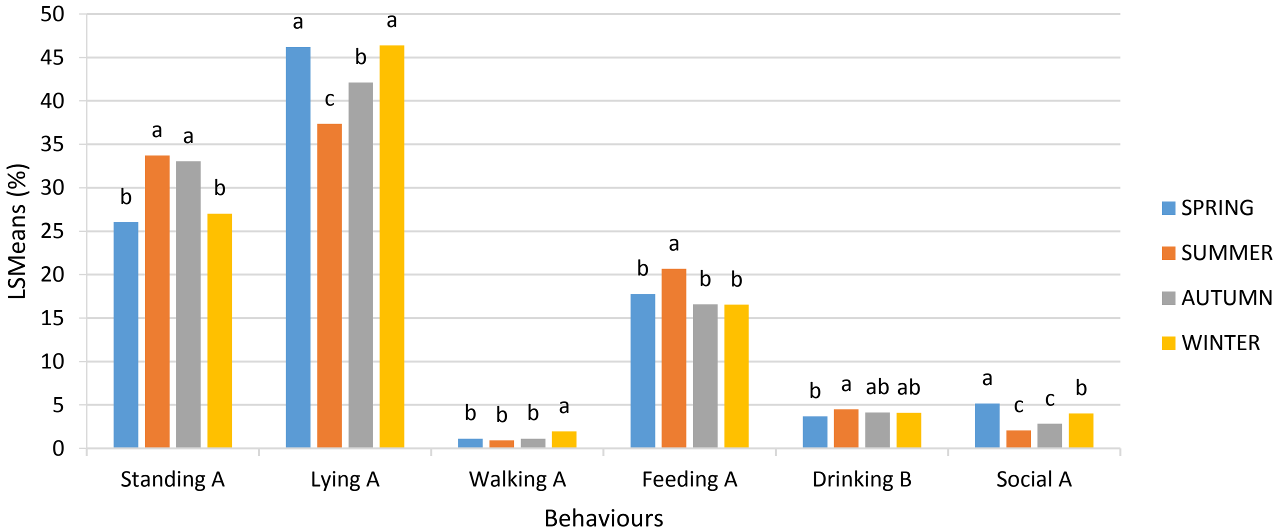

Figure 4.4 Least square means for time spent (%) for the season effect on the cattle behaviour between manure and control. The values of both treatments have been summed. Between the behaviours throughout the study the letter A next to the behaviour label = significant ($P \leq 0.05$) and B = not significant. $^{a, b, c}$ Means with different superscripts differ significantly at $P \leq 0.05$ between the four seasons for each behaviour.

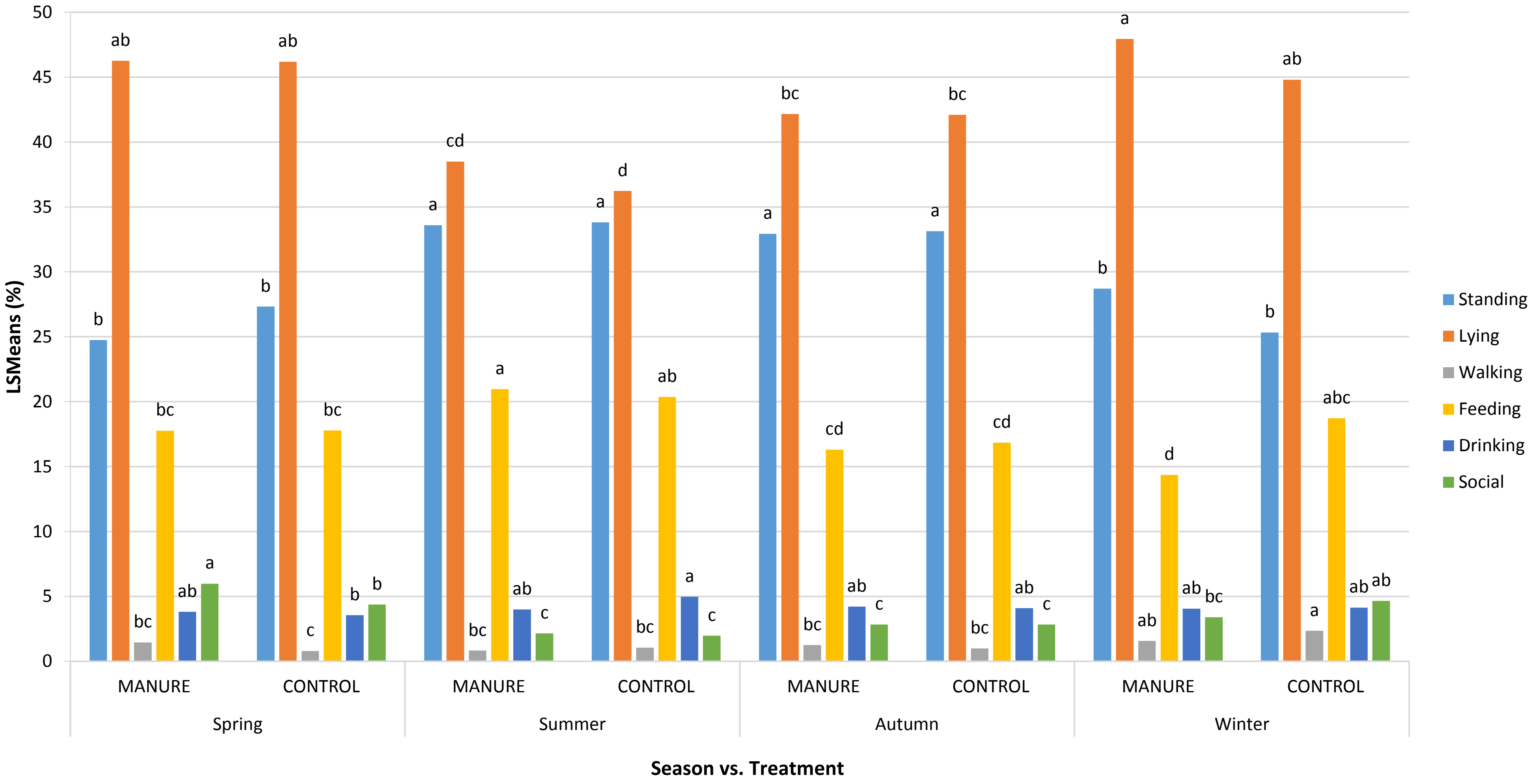

Figure 4.5 Least square means of time spent (%) for the behaviours of cattle for the barren (control) environment and enriched (manure) environment during the different seasons. [a, b, c, d] Means with different superscripts differ significantly at $P \leq 0.05$ between behaviours within each treatment*season combination (vertical). The following levels of significance between the behaviours in the different seasons were $P \leq 0.0001$ for standing, lying, walking, feeding and social while $P = 0.067$ for drinking.

4.3.4.2. Manure on vs. off

Within the manure treatment, behavioural data was recorded on and off-heap, where the cattle had the choice to spend time on the heap or not. Significant differences were found between the behaviours within the two areas of the same pen. The time spent on lying down was the highest in both pen areas when compared to standing, walking and social behaviour (Table 4.2). Overall the animals spent most of their time off the heap than on the heap. The cattle spent only 25% of the entire time on the heap by either lying down, standing, walking or acting socially with their pen mates (playing). Feeding and drinking activity were not included in the analysis as the troughs were only present in the off-heap area. The social behaviours could not be compared to each other as only playing was recorded as on-heap social behaviour while the other behaviours such as butting, rubbing, licking etc. were only recorded in the off-heap area. The R^2 values for the individual social behaviours were less than 10% when analysing the regression of the variables and are not analysed individually further. Therefore, the time spent on social behaviour was summed, with an R^2=24% and showed significant differences between the two areas and also between the seasons.

Table 4.2 Least square means (±SEM) for time spent (%) of the behaviours in the areas on or off-heap.

Behaviours	**On-heap**	**Off-heap**	**P- value**
Standing	7.6±0.36	22.4±0.36	**<0.0001**
Lying	10.3±0.51	33.4±0.51	**<0.0001**
Walking	0.1±0.06	1.1±0.06	**<0.0001**
Social	0.3±0.11	3.3±0.11	**<0.0001**

The season effect on the maintenance behaviours had *P*-values of <0.0001, where standing was highest off-heap in autumn (25%) while lying down was highest off-heap in winter (43%). Standing (10%) and lying down (19%) on-heap was highest during summer (Figure 4.6).

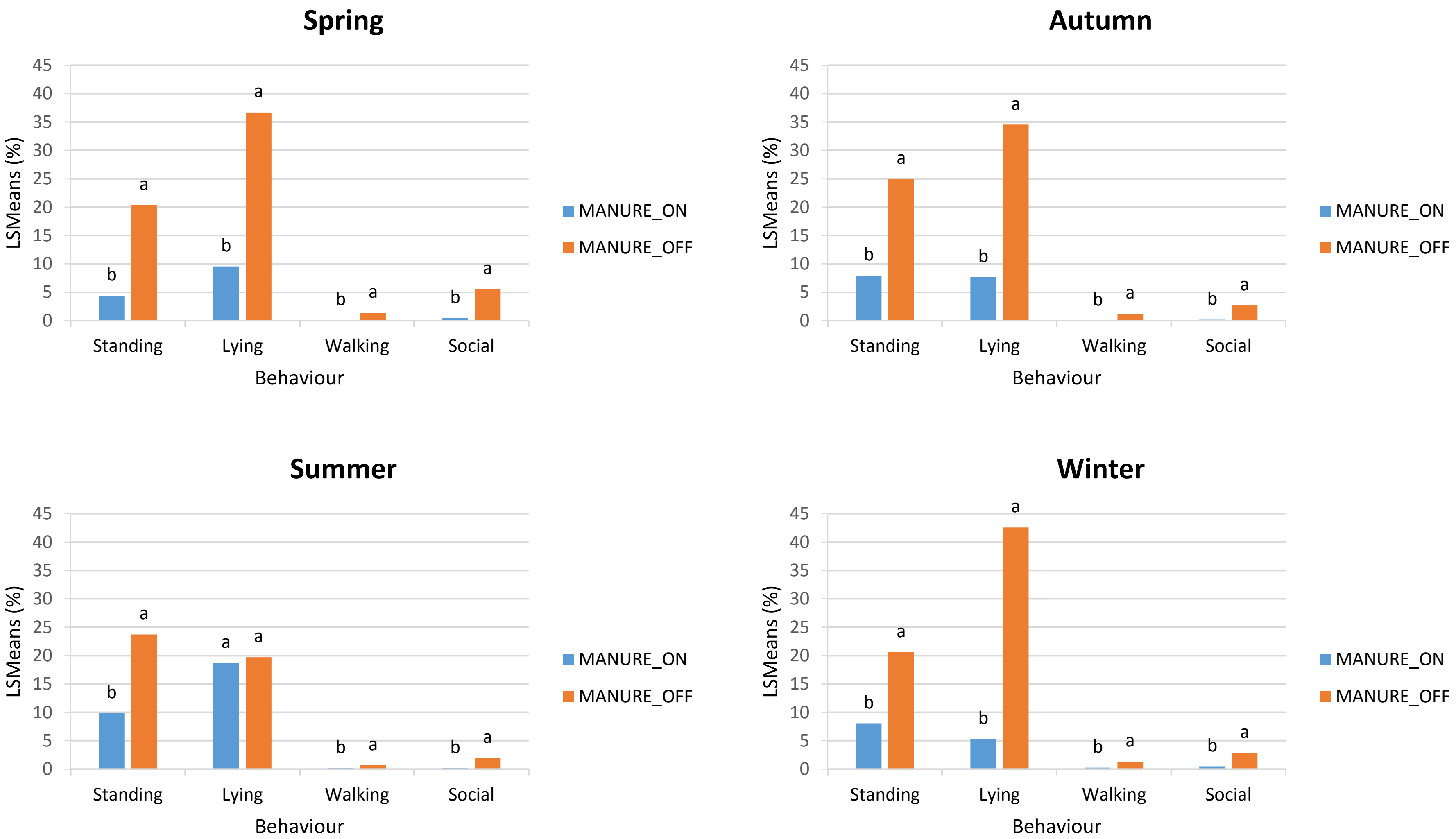

Figure 4.6 Least square means of time spent (%) on the behaviours in the two areas (on or off manure heap) during the four seasons. [a, b] Means with different superscripts differ significantly at $P \leq 0.05$ between the behaviours in the two areas.

4.4. Discussion

This is the first study on the utilisation of a manure heap as a form of environmental enrichment in a feedlot. No data has been published on this subject and therefore few references could be linked to the study. The behavioural differences were measured between (1) each treatment (manure vs. control), (2) manure on vs. off-heap as well as the (3) seasonal effect. The ADG of each treatment were analysed and also the seasonal effect on the ADG of the cattle.

The maintenance and social behaviour showed no significant difference between the enriched (manure) and barren (control) treatment, however significant differences were found between on and off-heap behaviour within the manure treatment. The cattle spent most of their time lying down which is a positive indication of welfare, because a higher lying down frequency is indicative of good pen structure and stocking density (Ito *et al.*, 2009). Standing time was also high and varied between the seasons. Feeding and drinking activities were almost similar for both treatments although higher feeding frequencies were expected in the manure group due to more physical activity such as playing on the manure heap. However, this shows that both groups, barren or enriched, have good health and welfare as differences in feeding patterns are an indicator of disease onset and morbidity (Miller-Cushon & DeVries, 2011).

The seasonal effect showed differences in all maintenance and social behaviours, except for drinking ($P = 0.067$), which could be explained by the fact that both groups were exposed to the same heat load. Overall, the lying down was the most frequent behaviour, especially in winter although there was more standing in summer. Higher standing time on warmer days allows an increase in the air flow around the body of the animal in order to allow heat dissipation (Schütz *et al.*, 2009). The increased lying activity on cooler days may be to prevent heat loss which results in a lower need to feed. This theory was further supported by the observations made where less feeding time was measured during cooler months.

The cattle spent more time off than on the manure heap. This result could be due to the fact that the manure heap only covered approximately 5% of the entire pen area. A manure heap in a feedlot pen increases the surface area, thereby effectively decreasing stocking density. Standing time off-heap was highest during autumn and lowest during spring while lying was highest during winter and lowest during summer. The highest standing activity on-heap was during summer and the lowest during spring and time spent lying was highest during summer and lowest during winter. On cooler mornings the cattle were lying on the manure heap as it may still have been warm due to the direct sun the day before. On warmer mornings, the cattle were rather standing on the heap and were seen lying down during midday.

The social behaviours which were grouped showed no significant difference between the two treatments, but were more frequent during spring and winter than in summer and autumn. The control group did not show more aggressive behaviour than the manure group despite the expectation that barren conditions limit the animals to exhibit species-appropriate behaviour which is expected to cause boredom and frustration (Beattie *et al.*, 2000; Oesterwind *et al.*, 2016). Aggressive behaviour cause dust in the feedlot which could lead to lung infections i.e. Pneumonia (Mitlöhner *et al.*, 2002). However, the overall occurrence of aggressive behaviour was low in this study (<14%) and similar to other collective social behaviours (stereotypic and affiliation). The fact that pneumonia was diagnosed more often in the control group than in the manure group, especially in the winter season was probably coincidental. In Namibia the driest and windiest season is during winter which explains the results of this study.

A behavioural pattern that was recorded as ‘other’ showed that the cattle started playing in the late afternoons which increased their social behaviour, not only on the heap, but also around it. Observations of the two groups showed more running activity and playing with pen mates in the manure group than in the control group, especially on the days when the manure heap was reshaped with a front loader machine. When the manure heap was reshaped with a high peak, the cattle climbed up the heap and butted against it with their head, as if it was a play mate.

The cattle in a feedlot don not need to walk far distances to find feed and therefore they only spend time on feeding, drinking, lying down and ruminating, which is repeated a few times a day. In the manure group the cattle followed the same pattern as in the control group however some animals stood with their front legs higher on the heap than the hind legs. It is postulated that this posture aided in the release of gases during rumination (Mapham, 2016). This could have reduced the cattle numbers suffering from bloating, which was supported by the number of bloat treated animals treated between the two experiments; less bloated animals were recorded in the manure group (34 animals) than in the control group (39 animals).

The cattle in the manure group did not show improvement in performance compared to the control group, although it was expected that the manure animals will show a higher feed intake due to more exercise and playing activity. Studies on pigs have shown that enrichment does improve growth rate especially when earth-like material is used as enrichment of flooring (Beattie *et al.*, 2000). A manure heap is similar to earth-like material used in pig facilities and has the advantage of keeping additional costs low. Unfortunately, the design of the feedlot and infrastructure does not allow for recording small behavioural effects or accurate individual feed conversion ratios and ADGs. However, confining animals to individual feeding or smaller groups may be biased because the animals are not observed under normal production conditions. The seasonal influence was not significant between the two treatments but it showed that the ADG of the cattle was numerically higher in the winter season and lowest in the spring season. This could be because of the high ambient temperatures in Namibia which could cause heat stress and more energy is used to maintain normal internal body temperature. Alternatively, animals entering the feedlot during winter are in a weak condition and may exhibit some form of compensatory growth with the higher plane of nutrition provided in the feedlot. However, this will be difficult to quantify due to the inherent variation typically found in animals that enter into any feedlot.

During the first days at the feedlot, the cattle were restless with a lot of mounting and butting as they fought to establish a hierarchy within the new group of cattle originating from different origins. Interesting observations which were classified as ‘other’ showed that cattle differed in adapting to a new environment including the manure heap. During the spring and winter trial periods the animals slowly familiarised themselves with the manure heap and it took them up to one week to spend more time on the heap. In contrast, the cattle in the summer and autumn trial were immediately curious about the heap and utilised it so often that the heap had to be reshaped every second day. These differences in making use of the manure heap could be related to the temperament of the cattle as well, although the seasonal effect was quite pertinent. Nguni cattle for example in the spring trial spent most of their time on the manure heap compared to the other breeds in the pen. This phenomenon was despite the presence of a variety of breeds. Brahman cattle were more concentrated on the manure heap during the autumn trial, but less concentrated on the heap in the winter trial when compared to the other breeds, even though the pen had a variety of breeds. This is not linked to the seasonal effect but rather to the temperament of the cattle. When cattle were less active or less sociable and had no interest in exploring, they were less present on the heap. This was also found in studies with lambs having access to a wooden platform where the lambs in the different trials reacted differently to the platform (Liebenberg, 2017). In one trial the lambs were consistently on the platform while in another trial less to almost none were on the platform. Cattle are similar to goats and sheep with regards to lying or standing higher than the normal surface level which was also proven by this study.

Another typical ‘other’ behaviour in the feedlot was during the rainy season when the cattle in the manure group had an advantage over the rest of the feedlot cattle as they had a dry heap to escape to, while the surrounding surface was muddy and wet. Less feeding was observed during rainy weather conditions because during heavy rainfall the cattle stood with their hind quarters facing the direction of the rain while forming a huddle to keep their heads out of the rain. However, when the first drops started to fall, all the cattle switch into play mode.

The cost for reshaping one manure heap, 10 times in a month for an entire year in the feedlot using a Caterpillar 908 front loader was N$ 7 455.60. The manure heap also showed fewer bloated animals which also reduces the cost per treatment (N$3.90 per animal) and the decline in feed intake of the affected animal. The most important aspect when decisions should be made is to consider the perceived happiness of the cattle in the manure group which is of high importance to the consumer perception.

4.5. Conclusion

Cattle tend to lie most of their time during the day, especially on higher areas than surface level. The manure heap provided to the cattle as a form of environmental enrichment showed no statistical differences in behaviour or production (ADG) when compared to the control. However, according to observations made during the study a difference could be seen by the random behaviour and impressions of welfare of the animals. Less aggressive behaviour and more playing activity was visible in the pen with the heap. Also, less bloating occurred in the group of the manure heap which is of great advantage for a commercial feedlot because fatalities due to bloat can be high. Even if no fatalities occur due to bloat, more labour time is required to remove and treat the bloated animals. During the rainy season the cattle were more prominent on the heap as it was drier on top of it than the surrounding flat areas and the cattle could therefore lie down more regularly. As mentioned, the manure heap only occupied a small area of the pen and it would be interesting to see how a larger manure heap may change/influence the behaviour and performance of the cattle. It is also recommended to investigate the effect of a manure heap in a feedlot under high rainfall areas as the muddy condition could decrease animal welfare and production parameters severely.

Finally, the animals utilising the manure heap were considered more adjusted to the feedlot conditions, especially during playing sessions, and were able to express more of their species-appropriate behaviour which is important for the consumer's perception when buying meat.

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Chapter 5:
The impact of feed stimulation and human/animal interaction on the behaviour and production of cattle in a feedlot

Abstract

Increasing feeding frequencies in a feedlot system are reported to be important to prevent acidosis in cattle which impairs the production performance and also the behaviour of the cattle. This study investigated the effect of stimulating feed intake by turning the feed manually two hours after feed delivery. This stimulation had the aim to improve the human-animal interaction and production performance of the cattle. Ten randomly chosen animals of 120 cattle in a pen were used during the control and stimulation treatments. The control group was stimulated, as normal, with a feed mixer delivering feed whilst the stimulation group had an additional stimulation two hours after delivery by turning the feed manually. The feeding behaviour of the 10 selected animals (number of visits to the feeding trough) for each treatment was observed for a minute every 30min using the *instantaneous sampling method.* The average daily gain (ADG) and daily dry matter intake (DMI) of the feed group was compared to the barren group which was observed under normal feedlot conditions. The cattle were observed two days a week, for three months from 7:00 until 17:00, depending on the feeding treatment. The observations were repeated for four feedlot cycles (1 cycle = 3 months) over four seasons; spring, summer, autumn and winter. The feeding space in the pens could occupy 37 cattle at any one time, but a high level of competition took place when the feed was delivered. The delivery of feed with a feed mixer (control = 25.8%) showed the highest percentage of visits to the trough compared to the manual turning of the feed (stimulation = 16.2%). The feeding behaviour was significantly (P = 0.004) higher in summer for the stimulation treatment and higher in winter for the control treatment. The ADG was higher for the barren group while the feed intake per head per day was higher in the stimulation group. Seasonal effects were significant between the treatment groups for both the ADG (barren vs. stimulation group). The ADG was the highest in winter for the barren group and in autumn for the stimulated group.

5.1. Introduction

The main objective of a feedlot is to increase the efficiency of converting feed into meat which can be described as the feed conversion ratio (FCR). The FCR depends on the quality and ingredients of the feed and on the condition, genetics and age of the animal. The aim is to have a lower feed input but a larger output in body weight gain. Therefore, an increase in the dry matter intake (DMI) of the animals with stimulation of increased number of visits to the feed trough would improve the FCR and the average daily gain (ADG) (Gibson, 1981). DeVries and Von Keyserlingk (2005) reported that the delivery of feed more than once a day would stimulate the feed intake, decrease competition among the pen mates and prevent acidosis in the rumen. The more even distribution of the daily intake of the cattle causes regular rumination periods which increase saliva production in order to buffer the ruminal pH (Moya *et al.*, 2015).

The attitude and behaviour of humans towards animals determines the fear or confidence of the animals to human and also the human-animal interaction. According to Waiblinger *et al.* (2006), the perception of the animals towards humans can be divided into frightening, neutral or a source of pleasant emotions. An increased contact with the animals improves the knowledge of the behaviour of animals and helps to introduce solutions to problems. With this study the human-animal interaction was intended to enhance the experience for the cattle as it was postulated that the animal should recognise that the human is the source of *ad libitum* feed and does no harm (Waiblinger *et al.*, 2006).

The aim of this study was to stimulate the cattle so as to increase their visits to the feed trough during the day by manually turning the feed, which was expected to improve the production performance in terms of higher feed intake and daily weight gain and the human-animal interaction of the feedlot cattle.

5.2. Materials and methods

5.2.1. Study design

5.2.1.1. General

The Stellenbosch University Animal Care and Use Committee (Ethical clearance certificate number: SU-ACUD15-00097) approved all the animal handling procedures used in the study. The study was conducted at the Meatco Okapuka Feedlot, Windhoek, Namibia and included four feedlot cycles of 3 months each which were named according to the season they were recorded in: spring, summer, autumn and winter trial. In this study, one group of ten selected animals in a pen of 120 (stocking density of 11.25 m^2/cattle), were compared by means of stimulation of either the feed mixer (control) or manual turning of feed with a shovel (stimulation) (Figure 5.1). This was repeated for each season, therefore the treatment had 40 cattle in total (n = 10 per treatment per season) for the entire study which were used for the data analysis of this study. More detailed information is explained in Chapter 3 (section 3.2.1.1).

5.2.1.2. Stimulation of feed intake

The cattle at the feedlot receive their feed in two portions during the day, and approximately two hours after the feed was delivered the feed was turned over with a shovel by the observer to record the feeding behaviour after the stimulation treatment. No additional action was used in this study as enrichment, only the stimulation of the cattle's curiosity at the feeding trough with the presence of a human and the sound of the shovel in the trough. The feeding trough of all the pens was 30 m in length which made it possible for approximately 37 animals to feed simultaneously. Each animal occupied on average 80 cm of feeding space. The cattle received the same total mixed ration (TMR) as the previous treatments (Chapter 3 and 4).

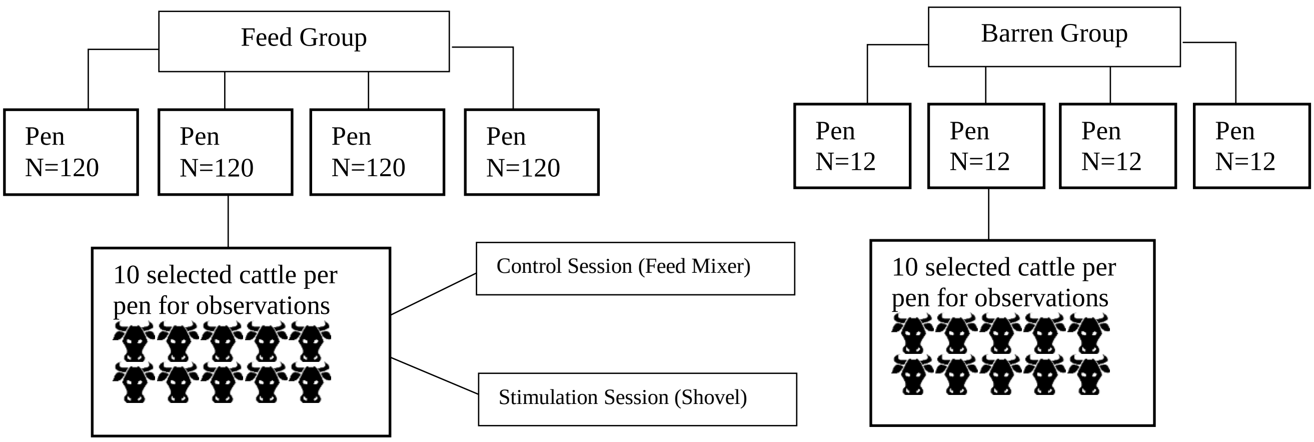

Figure 5.1 Flow diagram of the study design for every repetition of a feedlot cycle (spring, summer, autumn and winter). The barren group was only used to compare the production parameters between the feed and barren group (control group of shade and manure treatments).

5.2.2. Data collection

5.2.2.1. Growth performance and identification and treatment of sick cattle

The cattle were weighed on day one and day 90 which are the days when they entered and left the feedlot. Additional weights were measured in between and varied from two to five reweighings per cycle. All sick animals were removed from the pen and treated. As soon as the treated animals were healthy again they were returned back to their original pen. More details are explained in Chapter 3 (section 3.2.2.1).

5.2.2.2. Production measurements

For the analysis of the production measurements, the average daily gain (ADG) of the treatments was compared by regression analyses. The control data of the two previous experiments was used to compare the ADG and DMI to the feed stimulation group. The feed conversion ratio (FCR) could only be calculated for the entire pen of 120 cattle, as the facilities did not allow individual recording of feed intake, and could therefore not be analysed for the 10 selected individuals. The feed delivered and refusals that were weighed back for each pen was recorded on a daily basis. The daily dry matter feed intake (DMI) per pen was recorded to calculate the amount of feed eaten per individual per day.

5.2.2.3. Behavioural measurements

In this study, measuring the feeding behaviour of the feed (stimulated) group consisted of observations after feeding with a feed mixer (control) and again on the same animals after shovelling the feed (stimulation). This means that the same 10 animals that were selected for the feed group were recorded in both treatments. The 10 selected animals were marked with an animal friendly cattle marking paint on their forequarters and forehead with the numbers one to ten for easy identification during sampling. The control treatment was classified when the feed mixer delivered feed to the pen while the stimulation treatment was classified when the feed was manually turned over. The *instantaneous sampling method* (Mitlöhner *et al.*, 2001; Martin & Bateson, 2007) was used to record the number of visits to the feeding trough every minute for 30 min after a control and stimulation treatment (n = 31 recordings per treatment) from 7:00 until 17:00, twice a week for three months (three months = one feedlot cycle). The duration of stay at the feed trough was not taken into account. The recording took place from the time the head of the animal was over the feed trough until the animal withdrew its head from the feed trough, even when not physically feeding.

The visits to the feed trough were summed for both the control and stimulation treatment, ranging between one and two sessions a day, divided by 31 or 62 and multiplied by 100 to render a percentage of time spent at the feeding trough per individual.

General behavioural observations that were noted during the study were classified as ‘other’ and will be discussed later in Section 5.4. These behaviours were not included in the statistical analysis but were used to support the statistics that were analysed.

5.2.2.4. Statistical analysis

The data analysis for this study was performed using XLSTAT 2017 and SAS for Windows version 5.4. XLSTAT was used for all ANOVA’s which included the percentages of the behavioural data. The ADG for each individual was calculated by means of linear regression and PROC REG of SAS. The Bonferroni Post hoc test was used for all multiple comparisons calculations for LSMeans. A probability of 95% was considered significant for all analyses.

The number of visits to the feed trough per treatment per day were summed, divided by either 31 (one session only per day in minutes) or 62 (two sessions per day) and multiplied by 100 to obtain the percentage of each behaviour per animal. No correlation between activity and time (days on feedlot) was indicated, therefore time was excluded in the final models.

5.3. Results

5.3.1. Deviations from the protocol

The animals that were diagnosed with a sickness throughout the study, including all cattle (4 x 120 = 480 cattle per treatment per season), were more in the barren group (236 cattle) than in the feed stimulation group (206 cattle). Pneumonia was the most prominent disease for both treatments during the study, except in the winter trial where the feed stimulation group had higher levels of bloody diarrhoea incidents. The autumn trial was 30 days longer as the feedlot had been placed under quarantine. As discussed, Namibia has a policy via DVS of no tolerance for hormones or growth stimulants being used in feedlots and urine samples of the feedlot cattle showed low signs of Zeranol. The DVS placed the feedlot under quarantine until the final results were received. The outcome was that no growth stimulants were injected into the animals as Zeranol was found naturally in the body of cattle and feed that was fed. This extended period had an influence on the amount of cattle that became sick, the ADG and overall days in the feedlot.

5.3.2. Production measurements

The ADG showed a significant difference between the two treatments groups (P = 0.007). The feed stimulated group had an LSMean of 1.5±0.08 kg/day and the barren, 1.8±0.08 kg/day. The season effect on the treatments was only significant (P = 0.02) for the winter season (Table 5.1). The average dry matter feed intake (DMI) was 10.7 kg/head/day for the feed group and 10.4 kg/head/day for the barren group. According to the Bonferroni Post hoc test the interaction between the season and treatment showed no significant difference and was therefore not included in the final models (P = 0.47).

Table 5.1 Least square means (±standard error) of the seasonal effect on the ADG (kg/day) between the two treatments groups.

Season	Feed	Barren	*P*-value
Spring	1.3±0.17	1.7±0.15	0.09
Summer	1.4±0.16	1.5±0.16	0.68
Autumn	1.7±0.16	1.8±0.15	0.45
Winter	1.6±0.16	2.1±0.18	**0.02**

Figure 5.2 shows the growth rate of each individual used for recordings (n=40 per treatment for the entire study) fitted on a regression line and showing a 16.7 kg higher entry weight for the barren group. As already mentioned in Chapter 3 and 4, one animal died in the barren group (control group for chapter 3 and 4) and was therefore removed from the data analysis. Therefore, only 39 animals for the barren group are illustrated on the figure. The two treatments are indicated with two different colours and each dot represents an individual weight recording.

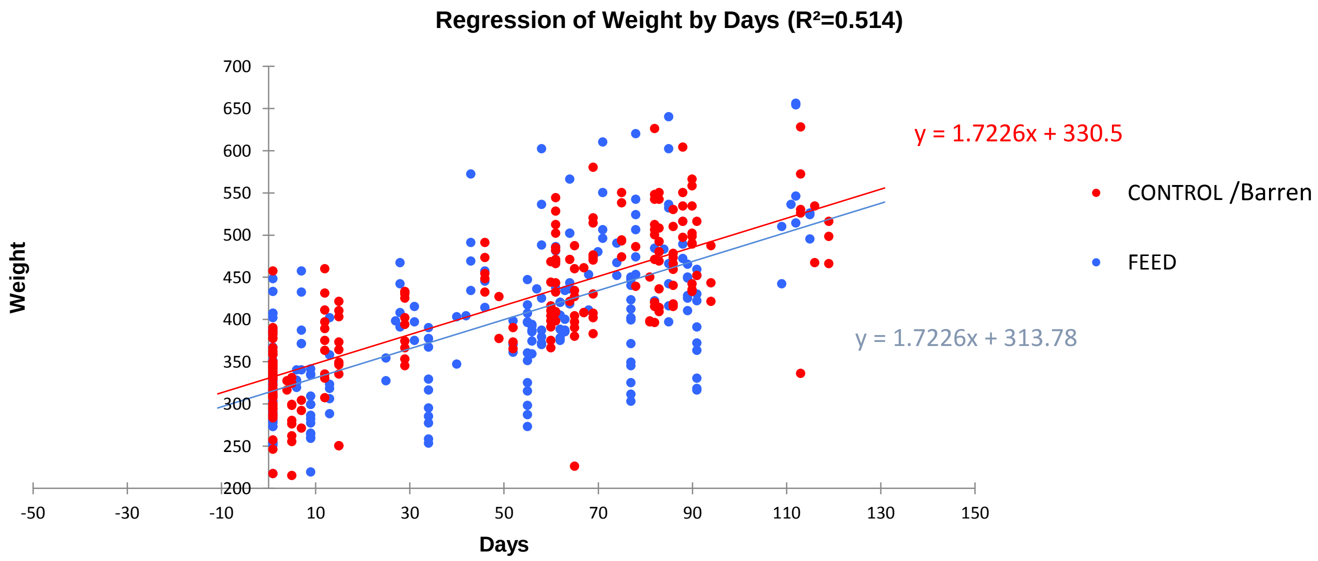

Figure 5.2 Similar growth rate over time for the treatments feed vs. barren (control group of shade and manure heap treatment), where 40 cattle's weight gains were recorded during the entire study for each treatment (n = 10 per season).

5.3.3. Behavioural measurements

5.3.3.1. Stimulation vs. control

There were significant differences when comparing the two treatments (P ≤ 0.0001). The LSMeans (±SEM) for the time spent on visiting the feeding trough was 25.8±0.76 for the control treatment and 16.2±0.76 for the stimulation treatment. The time spent on feeding in the stimulation treatment showed that the additional manual turning of the feed did not stimulate the cattle to visit the feeding trough as much as they do after the feed mixer has passed. The feed mixer appeared to be still the better stimulant for the animals to visit the feeding trough.

The season effect on the feed trough visits for the combined treatments was significantly different (P ≤ 0.0001). During spring the LSMean (±SEM) for visits at the feeding trough was 17.5±0.99, summer 24.3±1.13, autumn 21.3±0.99 and winter 20.9±1.17. The interaction between the season and the treatments also showed differences as illustrated in Figure 5.3 (P = 0.004). During summer the cattle were visiting the feeding trough more frequent with the stimulation treatment and more during winter in the control treatment, although the highest DMI was recorded in autumn.

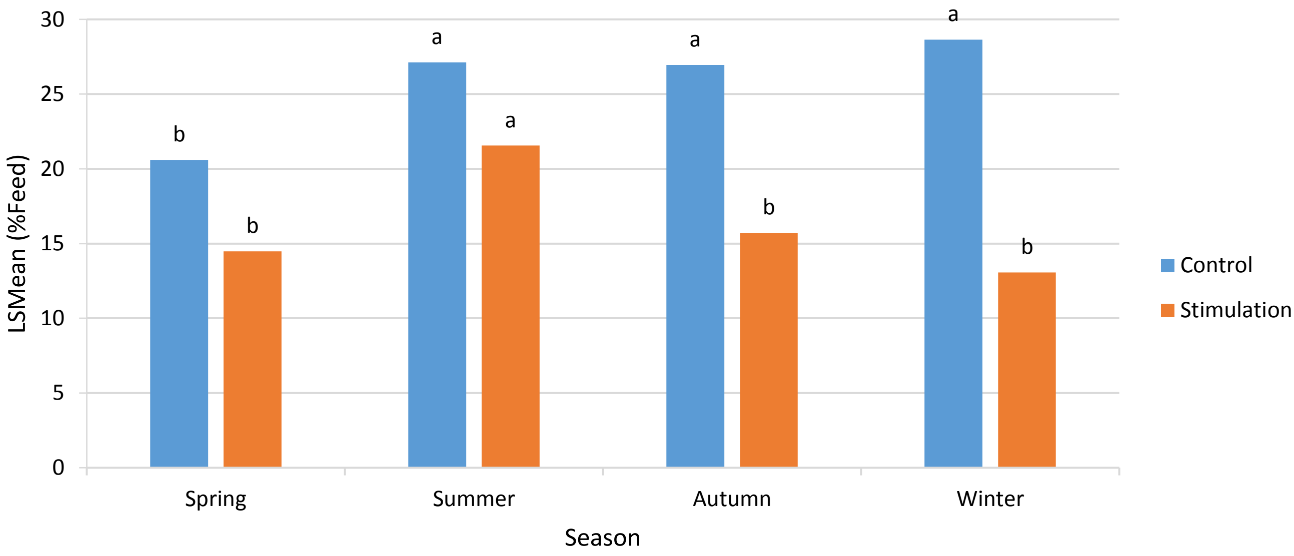

Figure 5.3 Least square means of visits (%Feed) at the feeding trough during the two treatments including control treatment (feed mixer passing feed trough) and stimulation treatment (manual turning of feed with a shovel). [a, b, c] Means with different superscripts differ significantly at P ≤ 0.05 between the four seasons for each treatment.

5.4. Discussion

The turning of feed in the feed trough was used as a form of environmental enrichment in this study and it showed significant differences in the visits to the feed trough behaviour (P ≤ 0.0001) and the ADG (P = 0.007) between the feed stimulation and barren group. The feeding behaviour of animals in a feedlot is very important as differences in the feeding patterns are indicators for the onset of diseases or simply the competition in the social environment (Miller-Cushon & DeVries, 2011). During the entire study, including all cattle and not only the 10 selected ones, fewer (12.7%) sick cattle were recorded in the feed stimulated group compared to the barren group, which could be related to the stimulation of visits to the feeding trough which reduces the incidence of acidosis.

According to DeVries and von Keyserlingk (2005), an increasing frequency of feed deliveries resulted in a more even distribution of feeding time over the day, which prevents the ruminal pH to drop too low to cause acidosis.

Animals in the barren group gained weight significantly (P = 0.007) faster than in the stimulated group (1.8 kg/day vs. 1.5 kg/day) despite the fact that the feed group consumed more feed per animal per day. This could be due to the increased human interaction at the feeding trough per day in the feed stimulation group, as some animals have a greater fear towards the presence of a human being than other animals. Results of this study suggest that the additional action of feed stimulation in the feed group had no effect on the ADG. Gibson (1981) reported an increased ADG and growth efficiency when the feeding frequencies were increased. DeVries and von Keyserlingk (2005) also reported that more distributed feed deliveries would reduce the competition and aggressive behaviour at the feed trough. This again would modify the feeding times of the lower ranked cattle and may increase feed intake, which results in an improved FCR and higher ADG. The daily DMI per head in this study was on average lower for the pens that were used for observations, which could be because of the human interaction at the pen twice a week for an entire day or just by coincidence. The importance of the feeding regime at a feedlot is that the animals need to receive feed *ad libitum* and not only two smaller amounts to prevent the pH of the rumen to fall sharply and reduce cellulolysis (Sutton *et al.*, 1985). Moya *et al.* (2015) explained it as regular ruminations which produce saliva to buffer the ruminal pH, when feed delivery was distributed more evenly throughout the day. Therefore, stimulating the animals with enrichment such as the turning of feed with the shovel would be of advantage for the rumen health of the animal even though this study did not support this statistically.

The number of the animals at the feeding trough during the first week was, as expected, high for the control and stimulation treatment, but decreased over time; a phenomenon also reported by Sowell *et al.* (1998). This could be due to the fact that the animals came from extensive conditions where they had to search for feed while in the feedlot the feed was supplied *ad libitum*. The cattle were more stimulated by the feed mixer, because they likely linked the sound of the delivery feed machinery and the smell of the freshly mixed feed to the happy feeling they experience when receiving feed. When the feed was delivered and the trough did not have much feed in it, a lot of pushing and butting occurred in front of the feeding trough. In contrast, on days when enough feed was still available in the trough and the feed mixer passed, less pushing occurred and in general, fewer cattle were stimulated to visit the feeding trough probably because the animals were satisfied. An 'other' behaviour was observed during the inspections on sick cattle when more cattle were noted to visit the feed trough. This could be attributed to the inspector encouraging the cattle in each pen to stand up for the correct identification of symptoms. A behaviour that was observed and also categorised as ‘other’, showed that the cattle had a pattern of drinking after they were feeding before lying down to ruminate.

The first three minutes during the first week of the stimulation treatment showed the highest levels of activity, because the sound of the shovel turning the feed stimulated the cattle as well as the natural inherent curiosity of the animal towards the human presence and his/her actions. This interest depends on the temperament and character of the animals, because a shyer animal might get closer to the trough but will not start feeding until the person is out of the flight zone. In contrast, an animal with a higher degree of curiosity and less anxiety towards humans will be at the trough to investigate the actions and/or start feeding. An ‘other’ observations showed that when the trough of a pen had places where there was a heap of feed and other places with no feed; the number of animals increased at the trough after turning the feed, most likely because the feed was distributed more evenly in the trough.

A human-animal interaction is the relationship between a human and an animal which has reciprocal effects on each other (Hemsworth, 2003). This relationship has an effect on the fear or confidence in humans, the productivity and the welfare of the animals (Hemsworth, 2003; Waiblinger *et al.*, 2006). This means the attitude of the human present at the feeding trough determines if the animal will visit the feeding trough to feed or not. The perspective of the animal towards the existing relationship with the human, is based on previous interactions (Waiblinger *et al.*, 2006). For example, if an animal originated from a farmer that never handled the animal by either injecting it or keeping it at the house pens for stock take purposes, the animal will be wild and anxious when in close proximity to humans. These animals will not be frequent feeders when stimulated by the turning over of feed.

The social hierarchy in a newly combined group of animals causes higher levels of competition and fighting during the first few days (Sárová *et al.*, 2010). This was also supported by the current study, but it caused displacements of the cattle with lower social ranking from the feed trough, while the high ranking cattle spent more time at the feeder especially during the feed stimulation treatment. Beattie *et al.* (2000) reported that higher levels of pen mate-directed behaviours in pigs caused lower feed intakes. These higher ranked cattle or dominant feeders usually perform better, as they have no competition for feeding space after the establishment of the hierarchy (Huxley, 2006). In this study, the dominant feeders showed higher attendance at the feeding trough, independent of the feed mixer or stimulation with the shovel. The less dominant feeders mostly visited the trough only when the more dominant feeders were satisfied.

The seasonal effect was also significant on the feeding behaviour of the cattle and visits to the feed trough were highest during the summer season for the stimulation treatment and winter for the control treatment. This could be related to the energy requirements of the cattle to maintain their internal temperatures (Beattie *et al.*, 2000). The ambient temperatures of this study showed higher variations during spring and autumn while during summer and winter the temperatures show less variation. This means that sudden cold fronts may occur during spring and autumn than during summer which influences the feed intake of the cattle. A behaviour categorised as 'other' was observed and supported by the temperature measured and the feed intake recorded. On hot days of ≥ 35 °C, the cattle spent most of their time at the feed trough but feed intake was reduced when a sudden cold front appeared. Cattle tend to preserve heat when lying down and reduce their standing time to prevent the loss of heat. Active feeding was also reduced on days with strong winds and rain, as it was noticed that the cattle change their behaviour as soon as the weather conditions become unpleasant. When the first rain drops fell, some cattle started running around with their tails up in the air while others either started feeding or stayed lying down. Only when the stronger rain started did the entire group form a bundle with their heads under each other's bellies.

Interesting 'other' observations were made regarding the reasons why the cattle stopped standing or feeding at the feed trough. These 'other' behaviours were: 'competition between pen mates' by being pushed, butted with horns, head or body or mounted out of the queue when the trough was completely occupied by other cattle; the animal was satisfied; being scared of the tractor or human passing the trough which caused the animal to walk away. Another reason was the hierarchy in the group of cattle and the dominance of some of them as discussed, and the weather conditions such as strong winds and rain.

5.5. Conclusion

Animals in the control group gained weight significantly faster than in the feed group although the feed group consumed more feed per animal per day. This suggests that the additional action of feed stimulation with a shovel in the feed group had no effect on the ADG. However, the stimulation with a shovel did increase the number of visits to the feeding trough, but not as much as the presence of the feed mixer. Therefore, the feed mixer was more successful in stimulating the feed intake of the animals. The cattle's numbers of visits to the feeding trough were higher in the summer season and winter due to energy requirements to maintain their internal body temperature.

In future studies, the recording of the individual animals' daily feed intake should be considered, to compare the feed conversion ratios between the treatment groups. An electronic data collection system such as the 'GrowSafe System' should be implemented to record the amount of feed intake of each individual, at what time of the day and also the pressure it put on the trough depending on how hungry the animal was. Also, observing smaller groups of animals or introducing video recordings would allow more recordings of the behavioural patterns during the day.

5.6. References

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Chapter 6:

General conclusions and recommendations

This study assessed the effect of three different forms of environmental enrichment on the maintenance behaviours (standing, lying, walking, feeding and drinking), social behaviours (aggressive = butting, mounting; affiliative = rubbing, sniffing, following other animals, licking; stereotypic = licking and rubbing), the production parameters and on the welfare of cattle in a commercial beef feedlot system in Namibia.

The first form of environmental enrichment assessed the effect of providing shade to the cattle on the maintenance and social behaviour, weight gain and overall impact on the animals' welfare. There were no significant differences found between the shade and control group for the maintenance behaviour such as standing, lying and walking, except for feeding and drinking. The social behaviour was significantly different for the affiliative behaviour, rubbing only and was expressed more in the shade group than the control group which indicates that the enriched animals experienced a better welfare. Season had a prominent effect on the behaviours of the two groups, showing that increased feeding and drinking behaviour was recorded in summer and lying was in general the most frequent behaviour in the cooler months. Higher lying frequencies are an indication of a well-adjusted animal. More important was the comparison between the non-shaded and shaded area within the shade group. These animals showed significant difference between the maintenance and social behaviours. The coat colour of the cattle was also a determining factor for the utilisation of the shaded area; darker coated animals used the shaded area more frequently, especially during summer, than the lighter coated animals. The cattle in the shade group did not show an improvement in the ADG which leads to the conclusion that the Namibian cattle are readily adapted to the extreme weather conditions. However, modern consumers are known to have increased their interest in the wellbeing of the cattle and shading is one of the findings which improves the welfare of the animals.

It is recommended that rectal temperatures or core temperatures of the cattle should be measured between the animals in the control group and shade group to investigate what effect solar radiation has on the heat stress of the Namibian cattle. The water temperature and water usage between the two groups should be measured in future studies, for more supportive results on the usage of shade in a feedlot. It should be considered placing the shade netting over the feeding trough, as this could increase feed intake as the cattle would not have to leave the shade to feed. In this study, it was considered but due to the design of the pens/troughs, the poles of the structure would reduce the feeding space at the feeding trough.

The second form of environmental enrichment assessed the effect of a manure heap in the middle of the pen on the weight gain, the maintenance behaviour and social behaviour of the cattle. The cattle in the manure group did not gain more weight than the control group, although a higher ADG was expected before the study commenced. There were no significant differences found between the control and manure groups on the social and maintenance behaviours, except for lying and feeding. However, more playing was observed in the manure groups especially when the manure heap was reshaped. Season also affected the behaviour of the cattle in both groups, showing more lying and standing in spring and winter. For feeding, both groups responded similar in each season except in winter when the control group fed more frequently than the manure group. The presence of the cattle on or off the manure heap was also recorded which showed that the cattle utilise the heap to release gases which prevents bloating and for socialising such as playing and butting. The manure group showed lower number of bloated animals compared to the control group, which improves the well-being and the feed consumption of the individual/group over time. During cooler mornings the cattle tend to spend more time on the heap as it had preserved some heat from the previous day. The heap also seemed to be a dry escape area, when the rest of the pen was muddy and wet after heavy rainfall. This shows that the advantages of a manure heap are that during higher rainfall periods the animals are able to keep dry and warm. Future studies could repeat this study in heavy rainfall areas such as during winter in the Western Cape of South Africa.

The third form of environmental enrichment investigated whether the stimulation of manually turning the feed in the feeding trough would have an effect on the number of visits of the cattle to the feeding trough and weight gain. Stimulation did not show an improvement in the ADG, despite the fact that the feed stimulation group did have on average a higher daily DMI per animal. The reason for less feed trough visits during the stimulation treatment could be because after the feed mixer delivered fresh feed, the majority of cattle would already have eaten and were satiated. Only the more dominant and/or curious feeders were noted visiting the feed trough during the stimulation treatment. The feeding frequency was highest in summer for the stimulation treatment and highest in winter for the control treatment, which could be due to a higher energy requirement to maintain the internal body temperature. The effect of increasing feeding frequencies by means of delivering more frequent feed by the mixer could be studied in future research.

This study has been conducted in a commercial feedlot with 120 cattle per pen. The disadvantage hereof is that no accurate feed intake, FCR and ADG could be calculated individually for the trial animals than when only those 10 selected cattle per treatment group would have been kept isolated. Human errors were also part of this result, because of the large amount of animals that need to be processed at the feedlot scale, errors at weighing were possible. However, results would be biased if smaller groups of animals were used as they would not be observed under normal production conditions. It is recommended to introduce a feed monitoring system such as the GrowSafe System, to record each individual's daily feed intake, time spent on feeding, feeding patterns and the pressure applied on the feed depending on the hunger level. This system works electronically and registers the ear tag when passing the transponder of the feed trough opening.

In future studies, meat characteristics should also be analysed on feedlot cattle being stimulated by these forms of environmental enrichments. Studies have reported that the effect of heat stress on the carcass quality is improved when feedlot cattle are protected with shading. For the manure treatment it would be interesting if the animals would have a lower final pH and more tender meat due to more positive socialising and physical activity. This study only recorded physical playing in the manure group. It should be considered in future studies to include this behaviour as it is a good indicator of the happiness of the animal and happiness is linked to better welfare. Also, the effect of a larger (area) manure heap on the behaviour of cattle should be evaluated.

This study did not take breed type and constant entry weights of all the animals into account, due to the vast breed crosses being used for farming in Namibia. The separation of breed types would also be of advantage to link the temperament/individual personality of the cattle to the behaviour they express.

In conclusion, although the treatments used in this study did not show an improvement in the production parameters, consumer perception on the animal welfare plays an important role and informal discussions with visitors to the feedlot all indicated a positive attitude towards these enrichment activities. The cost of introducing the forms of environmental enrichments is worth the fact that the overall behaviour was shown to be more positive when the cattle lived in an enriched environment and again the impact of the consumer perception needs to be quantified.