Phenotypic characterisation of Meatmaster sheep using quantitative and qualitative trait analysis

by

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Declaration

I, Stephan Becker, hereby declare the research done in this dissertation for a Master's degree in Agriculture and submitted by me, is my own independent work and has not previously been submitted by me or any other university.

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Stephan Becker   Date

Bloemfontein

Dedication

This dissertation is dedicated to my wife Estelle Becker, my daughter Jonelle and my mother Vini Becker. Thank you for believing in me and encouraging me to pursue this task.

A special thank you to my father Koos Becker who introduced me to Agriculture and for teaching me so much.

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List of abbreviations

LBM: Linear Body Measurements

SD: Standard Deviation

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Abstract

The aim of the study was to create a phenotypic analysis of the Meatmaster breed, utilizing linear body measurements, subjective assessments of body form, slaughter data and pedigree performance data (collected only from the ewes). The linear body measurements and pedigree performance data were collected from one hundred and eighty-seven rams (187) and two hundred and twenty-two ewes (222) of all age categories, measured both in incisor counts and number of days lived. Linear body measurements were used as the main instrument of measuring different body parts and the following means in both rams and ewes were measured: Body Weight (rams= 80.47±13.33 kg, ewes= 57.51±12.43 kg), Head Length (rams= 23.93±1.55 cm, ewes= 22.68±2.05 cm), Neck Length (rams= 28.35±5.16 cm, ewes= 29.61±3.82 cm), Chest Girth (rams= 102.45±8.42 cm, ewes= 92.95±8.08 cm) Tail Length (rams= 38.24±4.88 cm, ewes= 36.64±4.70 cm), Wither Height (rams= 63.91±4.04 cm, ewes= 58.99±4.86 cm), Chest Depth (rams= 37.51±2.97 cm, ewes= 34.47±2.97 cm), Chest Width (rams= 23.47±2.56 cm, ewes= 21.24±2.85 cm), Body Length (rams= 78.95±5.59 cm, ewes= 72.67±6.06 cm), Rump Length (rams= 21.82±3.29 cm, ewes= 20.77±1.93 cm) Rump Width (rams= 23.87±2.82 cm, ewes= 21.36±3.15 cm), Skin thickness (rams= 2.846±0.5 mm, ewes= 2.805±0.5 mm), Pelvis length (ewes= 7.66±.98 cm), Pelvis Width (ewes= 7.66±.90 cm), Pelvis Area (ewes= 46.69±10.62 cm²) and Scrotal Circumference (rams= 35.12±3.03 cm). All body measurements had a significant difference (P<0.001) between the genders, except for neck length (P>0.001) and tail length (P>0.001). The pedigree performance records of one hundred and seventy-seven (177) ewes showed the following means: Age at First Lambing (15.242±3.8 months), Number of Times Lambed (3.33±1.8), Number of Lambs Born (4.36±3.4), Number of Lambs Weaned (3.44±2.5) and Average Inter-lambing Period (258.64±151.3 days). Slaughtering data were compiled from two thousand two hundred and fifty one (2251) animals of different genders and ages the means are as follows: A0 (16.388±4.2 kg), A1 (16.098±3.1 kg), A2 (16.949±3.2 kg), A3 (18.138±3.5 kg), A4 (15.33±5.6 kg), A5 (14.80±0 kg), A6 (16.30±8.2 kg), Mean of A-grades (16.77±4.1 kg), AB1 (22.10±0 kg), AB2 (27.117±7.2 kg), AB3 (22.90±0 kg), Mean of AB-grades (24.039±13.8 kg), B1 (25.01±14.8 kg), B2 (26.656±5.2 kg), B3 (28.15±16.3

kg), B4 (27.80±0 kg), Mean of B-grades (26.904±13.3 kg), C2 (25.127±4.3 kg), C3 (24.633±7.1 kg) and Mean of C-grades (24.88±4.9 kg). A stepwise regression was carried out using SPSS (Version 26) to determine the individual influence of body measurements on performance. An F to enter level of 0.05 was used to determine the significance of the partial contribution of each effect. Pearson correlations were conducted on the body measurements in both rams and ewes, following the guidelines of Field (2009). In order to investigate the difference between various age and area categories the Hochberg's GT2 post hoc test was conducted. A Multiple Regression Analysis was conducted on five models using LBM as the variables. In the next step of the multiple regression analysis the tool of Model Summary boxes was used. The Durbin-Watson statistical test was used for the assumption to be made that the residuals are independent (or uncorrelated). A significant (P<0.01) correlation (89.5% for rams and 89.7% for ewes) were found between body weight and chest girth, this was the highest correlation found between all the body measurements and body weight. The only negative correlation to body weight was that of neck length (-8% for rams and -9% for ewes) and had no significant correlation (P>0.05). An interesting predictive value of R^2= 0.140 was observed between the body measurement wither height and the performance trait average inter-lambing period as well as a predictive value of R^2= 0.154 between the body measurement wither height and the performance trait number of lambs born. This seems to be a characteristic of the Afro-type sheep breeds which have a higher wither height and have a higher tendency to birth multiple lambs per lambing opportunity. Age has a significant influence (P<0.001) on all the body measurements of the Meatmaster, except for neck- and tail length. The environment has a significant influence (P<0.001) on all the body measurements of the Meatmaster, except for tail length.

Chapter 1

Introduction

1.1 Introduction

1.1.1 Early Evolution of Ruminants and Sheep

About 32- to 39 Million years ago the ruminants as species emerged, a study done in 2019 comparing about 40 trillion base pairs of DNA information sequences had been generated and this huge amount of DNA information was assembled into the genomes for 44 different ruminant species. When put into a coherent set, this creates a phylogenic family tree for ruminants, placing species such as the *Giraffe* (Largest) and the *Lesser mouse deer* (Smallest) on some of the earliest diverging branches. The data from a study like that produce a fundamental genomic roadmap for a group of mammals with such important ecological and economical roles (Chen *et al.*, 2019).

Ruminants as a species have a unique and highly specialized digestive system, which allows them to have a diet high in cellulose plants which are otherwise indigestible for other animals. They all have multi-chambered stomachs that create the ideal environment for a symbiotic relationship with microbes that help ferment and break down the plant materials; and also allow them to regurgitate materials for further chewing. Ruminants have 295 unique newly- evolved genes that are mainly associated with the digestive system. These genes describe the structure and function of this complex multi-chambered stomach. Also, a number of genes have been identified that are mainly related to antlers and horns. The use for horns and antlers in ruminants can mainly be seen in mating behaviour or/and a protection role from predators (Chen *et al.*, 2019).
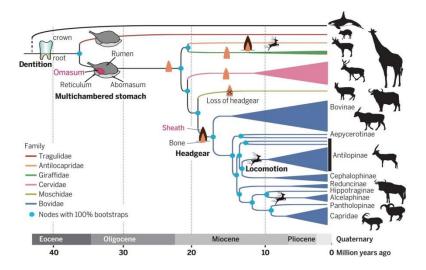
Figure 1: Phylogenetic tree for ruminant evolution (Chen *et al*., 2019)

The unique mutations that separate sheep and goats from their common ancestor and each other indicate that the divergence happened about four million years ago. Information about the genomic and transcriptomic event in the evolutionary history of sheep shows specific rumen and lipid metabolism adaptations that are unique to sheep which have a relevance to both diet and wool (BGI Shenzhen Group, 2014). The Rupicaprini that is likely represented by the Capriconis of Southeast Asia seems to be an example of a goat-antelope ancestor from which sheep evolved (Geist, 1971).

Sheep is a part of the extensive ruminant species, and therefore they have the unique ability (shared by all ruminant species) to produce animal protein from lignocellulose plant materials. Mutton and wool are examples of the animal protein produced by sheep, with its main interests in agriculture. Wool is a very interesting feature; because it is linked to the divergence between the sheep and goat species, as the syntheses have a strong linkage to the fatty acid metabolism process (BGI Shenzhen Group, 2014).

RNA- sequencing was done on 94 tissue samples from six Texel individuals. Within this study on the development of the rumen, skin and wool, a gene-encoding protein was identified which helped with keratinized epidermal structures within the animal. The gene-encoding protein identified as Trichohyalin-like 2 (TCHHL2) a non-annotated gene, is hypothesized a gene specific to the mammalian group. The main role of the gene (TCHHL2) within sheep would be the cross-linking of keratins on the rumen surface.

Another family gene was identified, known as *PRD-SPRR2*. This gene is likely to be a ruminant specific gene. This specific family of genes (*PRD-SPRR2*) seems to have been uniquely modified by the ruminant evolutionary process; it might have been the result of a sequence divergence and amplification of the SPRR2 gene. The function portrayed by the gene (PRD-SPRR2) is that of the cornification of the keratin-rich surface within the rumen (BGI Shenzhen Group, 2014).

Further research into gene-sequencing of sheep has provided evidence of a unique sub-family of genes. These genes are known as Late Cornified Envelopes (*LCE*) and within sheep, goat and cattle species, as *LCE7A*. What makes *LCE7A* unique is that if put under positive selection pressure within the sheep species, the gene will be expressed within wool formation, but no longer in the rumen. This gives an indication of the expansion of the specific gene (*LCE7A*) for unique wool formation within sheep. Speculatively, this could have resulted in unique selection paths in the early domestication of sheep, resulting in the woollen breeds as we know them today. The *MOGAT* gene pathway gives us another perception into what might facilitate wool production within sheep. Researchers found that the genes-MOGAT2 and MOGAT3 had both undergone a tandem gene expansion, where both are expressed in the sheep's skin but not in the liver. Whereas within humans the MOGAT3 is a gene responsible for enzyme-encoding within the liver, this evolutionary change points to changes within ruminant metabolisms. That would suggest that the loss of the MOGAT2 and MOGAT3 genes in the liver of ruminates, may reduce the significance of long chain fatty acid metabolism if contrasted to non-ruminants (BGI Shenzhen Group, 2014).

Wild sheep mainly lived in the mountain ranges of Central Asia, but during the Pleistocene period they spread to Europe and North America. These animals thrived despite the existence of man, mainly due to their mountainous habitat (Ryder, 1993). The debate about the origins of domesticated sheep is still an open one, and currently there are six wild species of sheep which could have been the origin to our domestic breeds. The important wild ancestral breeds are Argali (Ovis Ammon), the Mouflon (Ovis Musimon), the Urial (Ovis Orientalis) and the Bighorn (Ovis Canadensis). The Mouflon wild sheep seem to have been the parental breed from which all domestic sheep descended,

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although there is evidence that the Urail breed could have contributed to the European breeds (Ryder, 1993; Ryder, 1984).

The chromosome count of domestic sheep is 2n = 54. This number is also found in the Asian Mouflon, the European Mouflon, the Bighorn sheep and the Dall sheep. The other breeds such as the Siberian snow sheep only have a chromosome count of 2n = 52, with the Argali a count of 56 pairs and the Urail 58 pairs (Ryder, 1984). The studies by Heindleder *et al.*, (1998; 2002) focused on investigating mitochondrial DNA (mtDNA) of 243 domesticated sheep from Asian-, Central Asian- and European descent. Sixteen mtDNA haplotypes were identified, but none of these haplotypes were present within the Argali or Urail breeds; thus, providing evidence that these two species were probably not under the ancestors of today's domestic sheep. However, the wild Mouflon tested positive for some of these haplotypes, which is a strong indication that the Mouflon is one of the two breeds that has contributed to the creation of the domesticated sheep. The chromosomal and mtDNA evidence points us away from the Urail breed as a possible parental breed and gives even more weight to the argument that the Mouflon would have been the ancestral predecessor to the domestic sheep.

This research suggests not only the uniqueness of ruminants as a whole, but also the importance of the emergence of sheep as a species. Sheep has a unique metabolism and wool formation, to name a few, when compared to its closest evolutionary ancestor, the goat. These divergences have been focused through millions of years of natural selection, not to mention the thousands of years of human selection, creating the domestic sheep as we know it. Through agricultural selection humans have created a plethora of sheep breeds, each distinct in their own way, from the high production wool sheep of Europe to the highly resistant sheep breeds of the tropics, to the extremely well adapted breeds of extreme desert climates. Human beings were able to select the appropriate breed for each climate and time; and confronted with the problems of the modern era, we must also adapt our breeds for better survival in the present and the future. This research hopes to shed light on one of these modern synthetic breeds and position it in the centre as a modern well-adapted sheep breed, namely the Meatmaster.

1.1.2 Sheep production in the South-African context

Sheep production in South Africa is a highly competitive business. Most of South Africa's sheep are farmed within the Eastern Cape (30%), Northern Cape (25%), Free State (20%) and Western Cape (11%) provinces. The other 14% is divided between the other five provinces, with Mpumalanga the highest at 7%. A total number of 24, 5 million sheep are distributed among all nine provinces in South Africa. Most of the sheep production in South Africa is done in arid areas with the Northern Cape and Eastern Cape as good indicators. This arid production environment is the ideal area for a highly adapted sheep breed like the Meatmaster (DAFF, 2011).

The Eastern Cape and Northern Cape (and Free State, but to a lesser extent) is known for long droughts, followed by short periods of heavy rainfall. This arid environment serves as the platform on which adapted sheep breeds are tested. For example, in large areas of the Karoo rainfall can range from 100mm/annually to 400mm/-; but varies from 20mm to 290mm per year. The Karoo has an average altitude of 1200 metres above sea level on the central high plateau (thegreatkaroo, 2017; Mucina & Rutherford, 2006), but can also fall to below 800 metres. Two further examples are given to create an ecological idea of South-Africa's main sheep production areas: Firstly, the Karoo National Park which is situated 12km outside the town of Beaufort West (within the Northern Cape Province) with day temperatures ranging from 15°C in winter to 40°C in summer and an annual yearly rainfall of 190mm (safaribookings, 2020; Mucina & Rutherford, 2006). Secondly, Grootfontein Agricultural Collage (31.4709°S, 25.0286°E) in the Eastern Cape with day temperatures ranging from 35°C in summer to 14° in winter and an average of 372mm (measured from 1888 to 2012) (Du Toit *et al*., 2014). The Karoo area is too dry for profitable extensive cattle production, but suitable as small stock production area (mainly sheep or goats). With its main vegetation being dwarf and succulent shrubs, grasses are rare and are mostly focused in sandy areas. Larger shrubs and trees are sporadic and mostly grow in seasonal riverbeds (sanbi, 2020). Thus, the need for an adapted, hardy and low maintenance sheep breed was evident.

Changes in South Africa's political and socio-economic scene over the past years, created an agricultural environment where low-cost livestock would be more beneficial.

The growing population and increasing demand for food necessitated the intensification of production systems. All over the world and in South Africa, there has been a growing need for low-cost, low-input production systems (Köster, 2001).

1.1.3 Meatmaster breed background

The Meatmaster sheep breed is a composite breed between mainly the Dorper and Damara sheep breeds. It is a low input/ high output, mutton, hair- and non-fat tailed sheep breed. Mainly bred for the harsh environmental pressures of the arid South-African production areas, it distinguishes itself under extensive production environments (Meatmaster Journal, 2019). To describe the average Meatmaster, one must firstly look at both sexes independently and secondly at the characteristics that they inherited from both the Damara and the Dorper. The ideal Meatmaster ewe must be feminine, well-developed in the hind quarters for reproduction purposes and should preferably be polled. The average ram must be masculine, with a well-developed forequarter, large well-developed testes and must preferably be polled, but horns are allowed. Both males and females must have good skin pigmentation, but any coat colour is allowed. The covering of the coat should comprise short and shiny hair with a covering (mostly on the back) of fluffy fine wool. The tail should have a wedge shape with a moderate length, preferably hanging not lower than the hock. The tail should have a moderate fat covering and be well integrated with the hind quarter. Good meat production characteristics and the ability to produce a larger carcass in a relatively short time are inherited from the Dorper, while a strong herd instinct, good adaptability, functional efficiency, fertility, good grazing ability, resistance to local diseases and parasites; and low maintenance are inherited from the Damara. A good layer of fat distributed, over the whole body is preferred (Peters, 2011).

The Meatmaster breed was developed out of the need for an adapted, easy- care and low-cost sheep breed. This happened independently at different localities all over South-Africa and was noticed by Hofmeyer (2001) in an article published in the Farmers Weekly. All of these breeders had more or less the same idea in mind and that was the creation of a new easy- care mutton breed and used the Damara as their genetic base in all of their breeding programmes. The following is a list of the initial breeders that started in the early 1990's (Peters, 2011):

- The Meyerton population (Gauteng Province) of Bosrander sheep (early variants of the Meatmaster) was bred utilizing Ile de France and Darmara constituents. This flock numbered about 460 sheep. Dr. FW Peters was the creator of this synthetic breed during the early 1990's; and this specific breed ultimately became known as the Meinfred Meatmaster sheep stud (Muller, 2007).

- On the farm La Rochelle in the Northern parts of the Eastern Cape near Venterstad, CRC Collett was also establishing his own variant of the Meatmaster breed. The main components of his synthetic breed were Dorper and Damara sheep, with a large flock of 3000 sheep. His selection was fast and inbreeding values were left to a minimum.

- Another large flock of about 5000 Meatmaster sheep consisting of components of Dorper, Van Rooy and Damara breeds were created in the Hopetown area (Northern Cape). This specific synthetic breed was the responsibility of Dr. PW Vermeulen and his family.

- In the Prieska area (Northern Cape) Ms. CM du Toit created her own synthetic Meatmaster breed, utilizing the Mutton Merino and Damara as constituents. This flock of 1060 sheep was then subsequently crossed, using Meatmasters that had a Dorper and Damara origin, thereby creating an animal that had the genetic components of all three: Mutton Merino, Dorper and Damara.

- A flock of 500 Meatmasters, consisting of Dorper and Damara were bred in the Bloemfontein area (Free State); and later a Wiltshire Horns component was also introduced into this synthetic breed. The creators of this synthetic breed were Dr. JJ Steyn and R Liebenberg, with later stakeholders J Morrison, F Steyn and JW Swanepoel also becoming part of this specific breeding programme.

- JAS Zwiegers from the Hopetown area (Northern Cape) used a combination of Dorper and Damara as parental breeds for his flock of about 500 Meatmasters. The other initial members JP du Plessis and R Wiid were also from the Hopetown area.

- In the Kenhardt district of the Northern Cape, DH Visser established his own synthetic Meatmaster breed from Dorper and Damara components. His flocks of

250 Meatmasters were put to the test in some of the driest areas in South-Africa, with an average rainfall of 100-120mm/year.

- Also in the Northern Cape, in the Williston district, D and J Steenkamp have bred their synthetic Meatmaster flock since 1992. This flock was also primarily selected from Dorper ✕ Damara as parental breeds.
- P Spangenberg, J and H Kearney from the Loeriesfontein area in the Northern Cape also formed part of this initial family of early Meatmaster breeders. As a basis they utilized components of the Dorper and Damara breeds to form their particular synthetic Meatmaster breed.

As these separate breeders became known to one another, the pressure also mounted to establish a formal breed, with similar breeding values and ideas. On 23 May 2000 CR Collett organized a formal meeting with the aim of establishing a formal Breeders' Society for the new Damara cross breed. At that meeting a temporary Breeders' Committee was created. The name Meatmaster as the official breed's name was also formally recognized during that meeting. On 15 and 16 February 2005 the very first Meatmaster production sale was held on the farm La Rochelle in the Venterstad district (Eastern Cape). In addition, the first general meeting of the newly- established Meatmaster Sheep Breeders' Society of South-Africa was held, followed by the election of the first Executive Committee. During April 2006 a 60- page application was submitted by Dr. FW Peters to the Registrar of Animal Improvement at the National Department of Agriculture in Pretoria. This document served two purposes; first as the proclamation of the Meatmaster sheep to be formally recognized as a breed and second, a submission for the formal registration of The Meatmaster Sheep Breeders' Society of South Africa. The Meatmaster breed was then registered in 2007, with the Breeders' Society being approved in 2008. Although the breed is still young, it has already proven itself as a valuable and productive breed in South Africa's highly competitive market. Developed in the harsh environments of South Africa (from Kenhardt to Venterstad), the Meatmaster is a well-adapted and low-input cost breed, without sacrificing good carcass quality (Peters, 2011).

The Meatmaster breed was created with the idea of combining high production with high adaptability and that had been proven. The breed has a high lambing percentage in

extensive environments, combined with a low mortality rate (Meatmastersa, 2018). A cardinal concept of selection within the breed is the focus on balance between the selection criteria. The breeders stipulate the idea very clearly, not leaning too much to either tipping point of the scale. Balance must be found between the following discussion points (Meatmaster Journal, 2019): the sheep should not be too fat (moving to a fat-tailed type breed, which will have a negative effect on carcass characteristics) or too dry (moving to breeds that have too little body fat to be effective in all environments). The breed should have the correct body-form and ability, and therefore phenotype and production/reproduction characteristics (selection based on Estimated Breeding Values) should be selected in unison. The correct balance should be determined between how an animal should appear phenotypically to be effective in its environment, in other words the animal should be functionally efficient (for instance, a camel is phenotypically effective for the demands of a desert environment).

Originally, the main parent breeds of the Meatmaster in South Africa were the Dorper, Ile de France, SA Mutton Merino, Wiltshire Horn, Van Rooy and Damara. The Dorper sheep breed was developed at Grootfontein Agricultural College. It is a composite breed that mainly consists of Dorset Horn and Black-head Persian (Dorpersa, 2018). The Ile de France is a well-developed dual- purpose sheep breed and has the potential to create excellent cross breeds. It is the result of the cross between the English Leicester and Rambouillet (Iledefrancesheep, 2018). The SA Mutton Merino, originally known as the German Mutton Merino, was first introduced into South Africa around 1932. The SA Mutton Merino is a dual- purpose breed, focusing 80% on mutton and 20% on wool. It produces heavy slaughter lambs at a very young age (Savleismerino, 2018). The Wiltshire Horn is one of the oldest British sheep breeds, as the breed reached its prominence between the 17th and 18th century. All the Wiltshire Horn sheep in America were imported from the Piel Farm Flock in Canada, and currently there are three purebred flocks within Canada. The sheep were exported to Australia in the 1950's and 70's and are mainly used for cross- breeding purposes (Fitzhugh *et al.*, 1983). The Van Rooy sheep breed is a fat-tailed sheep, bred from the cross between "Blinkhaar Ronderib Afrikaner" and Rambouillet. The Van Rooy was bred in South Africa in 1906 and is an extremely hardy and well-adapted breed (Vanrooysa, 2018). The Damara sheep breed

migrated through Africa to South Africa around the period of 200 to 400 A.D. During that time the Damara sheep were used by the Herero, Namaqua and the Kam Karrin Khoisan tribes for farming and trading (Damarasheep, 2018). The Damara can be described as a highly adaptable, fat-tailed, long-bodied sheep. It is the only breed that is present in all the Meatmaster crosses (Ramsay, 2001).

Development of the Meatmaster happened by crossing different breeds, retaining effective crosses, and refining them through the selection of favoured characteristics. After various cross breeds were tested, the conclusion was that a Meatmaster must contain a certain percentage Damara blood, and it may include a varying component from the Dorper, Ile de France, Wiltshire horn, Van Rooy and the South African Mutton Merino, Dormer and other sheep breeds (Snyman, 2014).

However, a divergence occurred from the manifold different breeds and a decision was made that the Meatmaster's parental breeds would mainly include the Damara and the Dorper sheep breeds. The reasons why the Damara and Dorper were chosen as the main parental breeds for the Meatmasters boils down to the characteristics that is essential to the Meatmaster as a well-adapted composite breed. These include the selection for a low input/cost breed. The Meatmaster is a hair breed, because of the expenses that must be made in the shearing woollen sheep and the fact that wool shorn from the Meatmasters has little to no value, thus it will logically conclude that the shearing of wool will only be an expense. That is why the Dorper is preferred to the other woollen breeds, because it is mainly a hair sheep breed that sheds most of its wool naturally. Breeds had to be selected that were non-seasonal maters, because most parts of South-Africa tend to be temperate to warm throughout the year. This eliminates the need for sheep breeds to be seasonal in their mating habits. A problem was identified with the Wiltshire Horn breed when it was introduced into the Meatmaster breeding programme, mainly because of its tendency to be very seasonal in its mating habits. Thus, the Dorper and Damara as non-seasonal breeders were selected. An optimal sheep breed within the modern South-African context has to walk a thin line between adaptability and the production of an optimal carcass. This very strict selection ideal has the inclination to exclude most of the fat-tailed sheep breeds from obtaining the best slaughter prices. This is the main reason

why the Van Rooy breed was excluded as part of the main parent breeds *(i.e.,* the Dorper and Damara). Thus, excluding the Van Rooy from the Meatmaster breed was mainly since it did not create an optimal breed in terms of carcass characteristics. The combination of Dorper and Damara as parental breeds seems to produce the optimal balance between adaptability and the production of an optimal carcass.

Genetic diversity provides material for breed improvement and for the adaptation of livestock populations to changing environments and changing demands (Mohammed *et al.*, 2017). Body size and body shape can be described by means of measurements and visual assessment. How these measurements of size and shape relate to the functioning of the individual is of paramount importance to livestock production. Therefore, constant checks on the relationship between body measurements and performance traits are vital in selection programmes (Maiwashe, 2000). Therefore, the usefulness of characterization of the phenotypic traits is not contested.

1.2 Problem statement

The vital questions to be answered are:

- Is the Meatmaster a unique breed?
- Can the Meatmaster be described as a unique breed on the basis of its phenotypic data?
- Does the breed have any significant variations within its own parameters?

There is a great demand from within the breed to determine what the driving forces for selection are, specific to the morphological characteristics of the breed. This study proposes to answer the above-mentioned questions. Information has already been collected by Peters (2010) on the genetic uniqueness of the Meatmaster breed. H researcher proposes to support this argument by means of providing Phenotypic and Performance data.

1.3 Motivation

The utilization of an accurate phenotypic characterization system will enable breeders to describe the Meatmaster breed correctly, which will not only create the opportunity to

categorize and improve the breed within sound parameters; but may also promote functional efficiency further. Furthermore, it can be used to identify the phenotypical differences between sex and age (due to hormone functions) for the Meatmaster breed. The project can also support the breed standards by creating objective benchmarks, *e.g.* maximum mature weight and minimum scrotal circumference for animals at specific ages.

1.4 Aim

The aim of this study is to determine if the Meatmaster sheep breed can be classified as its own unique phenotype and also how it varies within the breed. The argument in this study rests on three legs: the Meatmaster is phenotypically unique both in its morphology and performance characteristics; it is genetically unique, thereby proving empirically that the Meatmaster is in fact a unique breed.

1.5 Study objectives

- To examine if the Meatmaster breed is morphologically unique within the South-African context.
- To determine the phenotypical differences within the Meatmaster breed, regarding gender, age and area.
- To create a phenotypical framework for the Meatmaster breed that can be used in conjunction with breed standards.
- To create a morphological framework for the Meatmaster breeders to use in the process of establishing selection criteria.
- To set a benchmark for certain parameters that can be used in the breed standards.

1.6 Hypotheses

- The Meatmaster is a unique breed phenotypically.
- There is significant variation within the breed (sex, age and area), when using body measurements as a method of determination.
- The breed has made progress when compared to the morphological and performance characteristics, as posed by Peters (2011).

- The body measurements of the Meatmaster breed will compare well with some of the mutton sheep breeds in South Africa and Internationally.

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Chapter 2

Literature study

2.1 Introduction

In the past few years body size and shape (general conformation) of the Meatmaster have not been described objectively by means of body measurements. The way in which these measurements of size and shape relate to the functioning of the individual is of paramount importance to the livestock producer.

2.2 Linear Body Measurements and Production Phenotypic Traits

Linear body measurements are the objective and subjective measuring of certain body parts of an animal. The measurements can be divided into two categories, namely skeletal and tissue (Essien *et al.*, 2003). Linear body measurements as a tool can be used for the assessment of the carcass characteristics, feed utilization and growth rate of animals (Brown *et al.*, 1973). Livestock breeds possess unique physical characteristics, ranging coat colour, tail length to characteristics that are deemed commercially important. These traits, both physical and performance- driven, are an important genetic resource (Blott *et al.*, 2003). The measurement of morphological characteristics of the different livestock breeds and populations produce very useful information for animal selection. Recording of morphological traits like coat colour, shape of horns, animal shape, body length, body width and historical data of the breed is very important, with the goal in mind of describing the phenotype of the specific breed. These elements are essential in the creation of breed standards, which culminates in the description of the uniqueness of the breed (McManus *et al.*, 2010). Every animal species and individual have a unique genotype and phenotype. The phenotype is the genotype being mapped into a specific environment and that process follows specific genetic and environmental laws (Pigliucci, 2001).

The performance traits of an animal are usually described in terms of productivity; while adaptations to an environment is another tool of variation which is very useful to identify unique breeds in the process of selection (McManus *et al.*, 2010). The collection of data

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from individual animals (morphological, pedigree and performance) could be used within management systems for selection purposes and could thus lead to the improvement of the productive/economic traits of the breed (Gabina, 2002).

Although molecular techniques have enabled us to identify different species, breeds and individuals; phenotypic characterization is just as important when describing a specific animal or breed and is essential when creating conservation projects (FAO, 2010). In the South African context, the Agricultural Research Council (www.arc.agric.za.) carries the responsibility for the documentation of production performance data and to a lesser extent morphological data for all goat and sheep breeds participating in the National Small Stock Performance and Recording Scheme. The performance characterizations usually recorded within a sheep breed are birth weight for both genders, age at sexual maturity, age at first parturition, length of productivity through an animal's life, fecundity, carcass weight, dressing percentage and fleece weight (Qwabe, 2011).

2.2.1 Other livestock linear body measurements and traits

Bosman (2011) refers to cattle as being divided into two separate phenotypic categories, namely the "metabolic type" and the "respiratory type". The latter type tends to be deeper in its front quarter, has longer legs, being slightly flatter over the ribs, with the ribs angling slightly backwards, with a droopier rump and a larger than average hump. *Bos-Indicus* types also have 15% more skin than the *Bos-Taurus* (Euro types), which assists with temperature regulation, which is an instance of Bergmann's rule. Conversely, the Euro types are more muscled, broader over the back with a rounder conformation, and adapted to retain heat in the cooler climates of Europe. These two examples provide perfect examples of an instance of Bergmann's rule. Figure 1 below explains these differences. An investigation into the phenotype and traits of the Meatmaster indicates a tendency towards a respiratory type rather than a metabolic type. The analyses of the other livestock species (apart from sheep) are mainly done to show the comparison of linear body measurements among those of different species and then comparing them to those of sheep.

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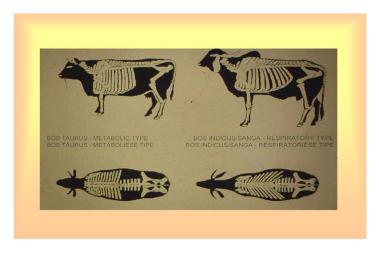
Figure 2.1: Differences between the metabolic and respiratory type (Bosman, 2011)

2.2.2 Rohilkhand Local Goats Linear Body Measurements

One genotype within the goat species (Capra Aegagrus Hircus) will be discussed below as an example of the meat producing type, namely the Rohilkhand Local Goat.

Discussion of morphological data, the model of least square means was used to determine correlational data. The least square means for body weight (kg) of the different age groups differed significantly (P<0.01) between one another; however, they tended to be non-significant between 2- and 3 months of age. The results clearly point to the proposition that body weight increases with age. Body length (cm) between different age groups differed significantly, except between age groups 3 and 3-6 months. Chest girth (cm) between different age groups differed significantly, except between age groups 2 and 3 months. The average ear length stabilized after 3 months of age, thus above 3 months of age there were no significant differences (P>0.05). Neck length (cm) between different age groups differed significantly; the length becomes almost fixed after the age of 12 months. Pelvic width (cm) differed significantly (P<0.01) between age groups. With an average pelvic width of 8.56 cm, this trait seemed to increase with age. Wither height (cm) between different age groups differed significantly (P<0.01), except between age groups 3 and 3-6 months (Fahim *et al.*, 2013).

A positive and significant correlation (P<0.01) between body weight and chest girth, body length, wither height and pelvic width was found, except for neck length, which was non-significant (0.010 respectively). Good results were obtained by Mohammed and Amin

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(1997) on the significant correlation between body weight and chest girth of birth weight to 6 months of age. A positive and significant correlation (P<0.01) between chest girth and the other phenotypic traits was also found, except for neck length, which had a negative correlation (-0.051 respectively). The correlation measured between body length and the two parameters, neck length and pelvic width, was non-significant (P>0.05). Wither height produced a non-significant correlation (P>0.05) with neck length. The measurement of pelvic width tended to have a negative correlation with neck length (-0.121 respectively) (Fahim *et al.*, 2013).

2.2.3 Sheep Linear Body Measurements

The studies examined here will be used to illustrate the correlations found within this specific study (Meatmaster Phenotype); with the aim of determining if the morphological measurements taken from the Meatmaster breed correlate with those found among other sheep breeds. It is important to use other sheep breeds to form a baseline and to see what effect certain body measurements has on the sheep as a species; thereby improving the chances of selecting the right traits, while maintaining a functionally efficient animal.

2.2.4 Mouflon body measurements

The Mouflon (*Ovis Gemelini Musimon*), as described in the introduction, is the ancestral breed (with a possible combination with two other ancestral breeds) from which all the domestic breeds as we know them derived. Cognizance of the primal phenotype of this specific breed may give us insight into what traits are favourable for selection in extensively farmed areas and is fundamental in understanding the sheep phenotype.

The Mouflon male has an average weight of 40-50 Kg while the female weighs between 30-40 Kg. The body length of the male ranges from 125 to 140cm, while the female's body length ranges from 115 to 125cm in length. Wither height ranges between 75 to 85cm for the males and 65 to 75cm for the females (Garel *et al.*, 2003). The Mouflon's fur is very short and straight, and the wool tends to become more prominent around winter and is goffered. Coat colour is reddish-brown on the back and white at the bottom; and during the mating season males' coats tend to be darker at the neck, shoulders and back, but brighter on the saddle. Males have long convoluted horns, around 50-85cm in length,

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while the females' short horns are not convoluted. The horns of the males are perennial and grow throughout the life of the animal; although growth tends to slow down as the animal gets older. Females usually become sexually mature around the age of 2, while males reach sexual maturity at the age of 3 to 4 years (Tosi *et al.*, 1997).

Figure 2.2: Mouflon ram and ewe

2.2.5 Yankasa Sheep

The Yankasa Sheep is a breed native to Nigeria. It is a hardy hair breed, adapted for most ecological regions of the country. The breed is the most numerous sheep breed in Nigeria and the main areas of production include the savannas near Sudan (Afolayan *et al.*, 2006).

Table 2.1: Linear Body Measurements of the Yankasa sheep

Linear Body Measurements	Birth Weight (Kg)	Body Weight (Kg)	Body Length (cm)	Chest Girth (cm)	Rump Height (cm)	Rump Width (cm)
Breed Average	2.91	22.1	38.27	70.86	62.72	17.35
Male Average	2.92	22.55	39.67	70.50	62.80	15.82
Female Average	2.64	21.48	36.87	71.22	62.65	18.88

The results indicate that age plays a significant (P<0.001) role in the variation between morphological traits. The females in the study were lighter than their male counterparts,

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but not significantly, except for the birth weight measurement (2.92 kg for males and 2.64 for females). The male lambs tended to be 17% more muscular and 8% longer than the female lambs. This difference was also recorded by Iyeghe *et al.* (1996) while examining Yankasa sheep in more intensive systems. Males were also inclined to retain this growth advantage over females for all body measurements (except chest girth and rump width) at later ages. Type of birth also played a tremendous role in the lamb developmental values, with single-born lambs 31% heavier (body weight), 10% taller (rump height) and had 11% larger chest girth circumferences. Chest girth correlated the highest of all the body measurements with body weight, with a correlation of 0.94. This means that chest girth can easily be used to determine body weight in areas where weight measurement tools are scarce (Afolayan *et al.*, 2006).

2.2.6 Namaqua Afrikaner

The Namaqua Afrikaner is a sheep breed indigenous to Southern Africa, and in many aspects, it is very similar to the Damara. It is a fat-tailed hair sheep, adapted to the harsh, warm and dry conditions of the Western parts of Southern Africa.

Table 2.2: Linear Body Measurements of the Namaqua Afrikaner Sheep

Morphological trait	Body length (cm)	Chest girth (cm)	Wither height (cm)	Tail length (cm)	Scrotal circumference (cm)	Birth weight (Kg)	120 Day weight (Kg)	12 months weight (Kg)
Rams	71.2	100.6	74.2	43.7	32.2	4.43	28.78	53.59
Ewes	68.7	95.8	67.6	41		4.21	26.23	44.26

Qualitative data were collected from the same group of 386 animals' describing characteristics, such as if the tail had a twist or not, coat colour, head colour and if they had horns or were polled (Qwabe, 2011). The tail phenotype for the Namaqua Afrikaner produced the following results: 97.2% of all rams had a twisted tail, while 90.9% of all ewes had a tail that twisted. Animals that had colour present on their bodies and not just on their heads amounted to 30.5% of rams and 31.1% of ewes. The colour of the head was examined and 71.8% of rams had black heads and 28.2% had brown heads, while

65.1% of ewes had black heads and 34.9 had brown heads. All the rams had horns (100%), while 84.1% of the ewes had horns.

The data suggest that rams have a higher value in every morphological measurement. Rams tend to have a higher body weight in all categories than the ewes, and this tendency increases as the animals get older. It is therefore clear that age and sex play a significant role in the determination of body weight (Qwabe, 2011).

Performance traits recorded from 1993 to 2009 showed that sex, year of birth, birth status of the lamb and age of the dam (mother) had a significant ($p < 0.001$) influence on body weight at all ages of the animal's life. The year in which the animal was born had a significant influence on all traits, except with regards to birth- and weaning weight. Age influenced all traits significantly ($p < 0.01$), except for 11- and 12-month body weight. Males tended to have higher values in body length, chest girth and tail length (Qwabe, 2011).

The reproductive performance of the Namaqua Afrikaner showed an average of 1.45 lambs born per year and an average of 1.31 lambs weaned per year. The average number of lambs produced through the animal's lifetime was 4.49, while the average number of lambs weaned per ewe during her lifetime was 4.05 with a total kilogram/lamb produced over the ewe's lifetime of 112.9 kg. The total number of lambs born, number of lambs weaned, and the overall lamb weight produced over the ewe's lifetime increased with the age of the dam; with the heaviest lambs being born of ewes between the ages of three and six years. Body weight recorded from birth to 12 months of age showed that birth status had a significant role in determining this phenotypic trait, with triplets being the lightest and single born lambs being the heaviest. Differences in weight of 3.56 kg at birth to 1.02 kg at 12 months of age were recorded, proving that the effect of birth status decreases with age (Qwabe, 2011).

2.2.7 Zulu (Nguni) Sheep

Nguni sheep are usually allocated into three different breed categories, namely the Swazi sheep of Swaziland, the Pedi sheep of Sekukunniland and the Zulu sheep of KwaZulu-Natal; but for purposes of this discussion the focus is on the Zulu sheep breed only. It is a fat- tailed breed, which can either have hair, wool or a combination of the two. The breed is very well adapted to the humid and hot areas of KwaZulu-Natal, South Africa. They have a high degree of tolerance to internal- and external parasites (including tick-borne diseases) and have very well- developed mothering abilities (Ramsey *et al.*, 2000). Table 2.3 provides a better image of the linear body measurements (Kunene *et al.*, 2007).

Table 2.3: Linear Body Measurements of the Zulu (Nguni) Sheep

Morphological Trait	Body weight (Kg)	Chest Girth (cm)	Wither Height (cm)	Scrotal Circumference (cm)
0-Incisors (Lamb)	19.14	62.13	54.03	18.00
2-Incisors	27.25	72.23	60.32	24.32
4-Incisors	30.62	74.18	61.92	24.26
6-Incisors	33.46	77.65	63.51	27.34
8-Incisors	34.72	77.22	63.66	27.58
Males	30.88	73.62	61.30	24.3
Females	27.20	71.75	60.07	
University of Zululand	22.76	68.67	58.04	22.11
Makhathini Research station	34.28	75.48	64.58	27.35
Enqutshini	28.54	72.58	59.84	23.32
Owen Sithole College of Agriculture	30.58	74.01	60.72	25.37

Linear body measurements that were collected were influenced greatly by the sex of the animal, as well as the location where the sheep were raised and the age of the animal.

Males tended to have higher values in each of the body measurements. The lowest square analysis of the interaction between the sex of the animal and the location where it was raised amplified the differences between male and female linear body measurements, with males having higher values than females. The lowest square analysis done on the interaction between the age of the animal and the sex of the animal proved that there was a significant difference ($P<0.001$) between males of a certain age and females of a certain age, except for males and females at the 0-Incisor (milk teeth) age. Hassan *et al.* (2002) also found similar results in lambs from the age of 30 days to 90 days, with rams and ewes only starting to differ in later stages of their lives. The scrotal circumference increased with age; thus, older rams had a larger scrotal circumference. Scrotal circumference also differed between locations, with Makhathini Research Station having the largest (27 cm) and the University of Zululand and Enqutshini having lower results (Kunene *et al.*, 2007).

The most dominant colours among the Zulu sheep breed were brown representing 19%, brown and white representing 18% and black and brown representing 16%. Horned males numbered 41% of the total males and horned females 10% of the total females, indicating that males have a higher genetic tendency to have horns than females have (Kunene *et al.*, 2007).

2.3 Phenotypic description of the two parental breeds used in the creation of the Meatmaster sheep breed (i.e., the Dorper and the Damara)

This section will discuss the phenotypic description of the two fundamental parent breeds of the Meatmaster. These two breeds have been used for the development of the Meatmaster breed for their unique traits and for their ability to produce the most productive/least cost-intensive breed combination, as described in Chapter 1 (Low cost/input breed, a breed that is a non-seasonal mater through-out the year with optimal carcass characteristics). In- depth knowledge of these two breeds is essential to describe the Meatmaster as a breed. The Dorper performs the role of the Euro-type parental breed and contributes most of the performance traits, as it contributes five of the Meatmaster's essential traits. The Damara, on the other hand, performs the role of the Afro-type parental breed and contributes most of the reproductive and adaptive traits seen within the Meatmaster breed. The Damara contributes 18 essential traits to the Meatmaster breed. The importance of selecting for traits are of primary concern in the Meatmaster breed, and therefore the two breeds were originally crossed to incorporate the best of both and then selection for the advantageous traits gained the central stage. As seen in Table 2.4, the Damara contributes most of the phenotypic traits, and those have proven to be the most important aspects of the Meatmaster breed. The selection of a more hardy and well-adapted breed was the primary focus in the creation of the Meatmaster breed.

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Table 2.4: Phenotypic traits of the Meatmaster's parental breeds

Phenotypic Traits	Dorper	Damara
Carcass Quality	*	
Muscling	*	
Early lamb growth	*	
Total growth	*	
Milk production till weaning	*	
Mothering ability		*
Quality of milk		*
Resistance against parasites		*
General health of the Animal		*
Reproductive traits		*
Easy lambing ability		*
Herd instinct		*
Traversing large distances		*
Seasonal sheading of the fleece		*
Adaptability		*
A natural intelligence		*
Optimal grazing qualities		*
Sexual dimorphism		*
Short lambing intervals		*
Ram fertility traits		*
Less prone to bloating		*
Pigmentation		*
Low input/Low cost		*

Source: (Meatmaster Breeders' Society, 2017)

2.3.1 The Dorper

The Dorper is a composite South-African breed that is derived from the cross between the Black-headed Persian and the Dorset Horn, created in the 1930's at the Grootfontein Agricultural Collage. In 1942 Round-ribbed Afrikaner crosses were added to the breed, but it was only in 1947 that the Dorper name was associated with the breed. The breed was mainly developed as the effects of the Great Depression forced breeders to look outside of the woollen breeds for a well-adapted mutton breed that can be exported to the British market, as the British market would not accept fat-tailed sheep carcasses. The need for a well-adapted mutton hair breed was created and as a natural result, the Dorper came to fill the gap (dorpersa, 2020). It is a well-adapted breed for the conditions of South-Africa, because the breed has the ability to adapt to a variety of environments and is the second most numerous breeds within South-Africa. It combines the attributes of a very adaptive breed with those of very good carcass quality. The above-mentioned attributes made it an obvious choice as one of the possible parental breeds for the Meatmaster; and it is not considered a fat-tailed breed when marketed for its carcass and thus is not penalized (in the South-African context).

Figure 2.3: Dorper ewes in the Free State Province South Africa

The Dorper has two divergent genotypes: one is a hair type sheep and the other has a woolly fleece covering. An extensive experiment was conducted to see if there were performance differences between the two genotypes, but none could be found (Cloete *et al.*, 2000).

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The Dorper is well adapted to the harsh conditions of Southern Africa and can withstand dehydration well past the normal European sheep breeds' capacity and then replenishes itself when water becomes available, regaining body weight losses (Degen, 1992). This trait enables the breed to thrive under the dry conditions of Western South Africa. A large and comprehensive survey was done in the dry Karoo region of South Africa in which a total amount of 115314 Dorper ewes from 130 different farms, all under distinct managerial regimes, were included in this survey. The measured results indicated that an average of 1.038 lambs was born per ewe mated. The distinct districts also performed differently from one another, ranging from 0.924 lambs born per ewe mated in Prieska, to 1.123 in Calvinia (Ackermann, 1993).

Sexual maturity

At 213 days of age and 39 kg weight a Dorper maiden-lamb showed first oestrus (Greeff *et al.*, 1988). Basson *et al.* (1970) reported a study of maiden-ewes born in autumn which conceived for the first time at an age of 328 days and a weight of 45.9 kg, while ewes born in winter conceived for the first time at the age of 252 days and at a weight of 44.7 kg. Schoeman *et al.* (1993b) reported the oestrus of maiden-ewes at an average age of 8.14 months and an average weight of 50.8 kg. In a study done by Greeff *et al.* (1998), it was reported that the first lambing of Dorper ewes occurred at an average age of 346 days, while Romanov ewes lambed at an age of 363 days. Schoeman *et al.* (1992), monitoring ewes under a system designed for accelerated lambing, found that the date of first lambing was approximately 19.6 months.

Oestrus cycle

The Dorset Horn ✕ Black-headed Persian cross also showed a decrease in seasonality, with the annual number of oestrus cycles at 16.6 for the Dorset Horn ✕ Black-headed Persian cross and 8.1 for the Merinos per annum. The Black-headed Persian and Namaqua Afrikaner proved to be more aseasonal when comparing oestrus cycles, than the Merino and Karakul ewes whose cycles formed a more seasonal pattern (Boshoff *et al.*, 1975). An average of 17.4 days for Dorper maiden-ewes and a 17.6 day oestrus cycle for mature Dorper ewes was observed (Pretorius *et al.*, 1968). Other studies performed

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by Elias *et al.* (1985) also recorded an average oestrus cycle of 16.6 days for Dorper maiden-ewes and 17.6 for mature Dorper ewes. Dorper ewes showed a tendency to have an increased number of oestrus periods during nighttime than day time, with an average length of 36 hours for mature ewes and an average of 28 hours for primiparous ewes (Elias *et al.*, 1985). In a study between Dorper and Romanov sheep breeds by Greeff *et al.* (1990), a difference in ovulation rate and embryo loss between the breeds was found to be a 1.50 ovulation rate and 0.66 embryo loss for Dorper ewes with the Romanov ewes being observed at 3.33 and 1.5 respectively.

Post-partum anoestrus

Joubert (1962) observed that the Dorset Horn × Black-headed Persian crosses had an average return to oestrus cycling of 51 days after parturition, with a large range from 2 to 149 days. Joubert (1972) also later observed a seasonal tendency for Dorper ewes to have a longer post-partum anoestrus after lambing in the winter or spring (a length of 123 days), while ewes that lambed in summer months took 89 days and ewes lambing during autumn averaged 62 days before cycling again. Difference in feed ratios did not seem (a higher ration of 0.10 kg of digestible protein and 14.6 MJ of digestible energy and a lower ration of 0.05 kg of digestible protein and 6.1 MJ of digestible energy) to have an effect on post-partum anoestrus length. This was also proven earlier by Vosloo *et al.* (1969) that feed intake does not seem to have an effect.

Ewe fertility and mothering ability

Conception rates in Dorper ewes tended to be very constant in all the consulted literature, converging on an average of 90% (Cloete *et al.*, 2000). Ewe conception rates compared very well with those of other breeds, including New Zealand Romney sheep, South African Merinos, Döhne Merinos and Australian Merinos (Dalton *et al.*, 1978; Fourie *et al.*, 1993; Jordan *et al.*, 1989). With regards to gestation length, the results were also very similar, averaging around 146.5 to 147.9 days (Joubert, 1962; Joubert *et al.*, 1964). Elias *et al.* (1985) reported the same mean of between 146.2 to 147.9 days, but also noted that the gestation length was dependent on factors of ewe age, litter size and lamb sex. There were large differences recorded in the characteristics of litter size, ranging from 1.45 to

1.60 (Cloete *et al.*, 2000). The average Dorper lamb survival rate indicated an average of about 90%; a figure which is also very constant in the literature (Cloete *et al.*, 2000). Lamb survival also seemed to be negatively correlated with litter size; as observed in a study conducted by Schoeman (1992) which puts single births at 96% and multiple births at 93%. Taking the average litter size into account, the Dorper is a high lamb producer, given the survival rates recorded. The Dorper breed has an average to high overall reproduction rate, weaning 0.99 to 1.40 lambs per ewe mated. This rate can be maintained even under extreme environmental conditions but can also be improved under accelerated lambing systems (of ≥ 1.48 lambs weaned per ewe mated), to which the Dorper sheep can adapt comfortably (Cloete *et al.*, 2000).

Ram fertility

An experiment done by Schoeman *et al.* (1987) indicated that Dorper rams had larger testes from 3 to 10 months of age compared to those of Döhne Merino rams, but similar to those of the crossed rams (Meatmaster). The mean values were: testis weight 303.8 g, epididymis weight 54.1 g and the diameter of the seminiferous tubules 209.4 mm when taken at the age of 365 days in Dorper rams (Schoeman *et al.*, 1987). When joining 14 young Dorper rams to 50 oestrus ewes and observing them over a period of 24 hours the following conclusions were made by Schoeman *et al.* (1987): the rams served an average of 19.7 times, ranging from 12 to 30 times/ram.

Pre-weaning daily gain and Post-weaning performance

The genetic variety for pre-weaning daily gain within the Dorper breed is large, which is mostly due to environmental factors, as most of the Dorper breed is located within very harsh and extensive environmental conditions. The average pre-weaning daily gain for the Dorper breed amounts to 0.24 to 0.28 kg per day, which are optimistic values, taken into consideration that these figures are recorded in numerous studies l and under mainly extensive environmental conditions (Cloete *et al.*, 2000). There are also numerous factors that influence pre-weaning daily gain in Dorpers, which will be discussed in the rest of this paragraph. The age of the ewe giving birth has a large effect on the growth through the lamb's lifetime. Evidence indicates that an increase in daily gain manifests in ewes from

4-6 years, which is then followed by a decline (Schoeman *et al.*, 1992). Ram and wether lambs are inclined to have a higher pre-weaning daily gain and be heavier than the ewe lambs (Schoeman *et al.*, 1992). Single born lambs tend to be heavier and have a higher pre-weaning daily gain than multiple born lambs (Schoeman *et al.*, 1992).

With reference to the concept of post-weaning performance in the Dorper breed, two things must be considered in extensive production systems. First, Dorper ewes are usually mated annually, and the lambs are sold directly from being weaned from their mother. Second, in accelerated lambing systems the purpose is to produce more lambs during an ewe's lifetime, thus most lambs are weaned at an age of 2-3 months. As reported by Basson *et al.* (1970), Dorper lambs weaned at 2 to 3 months of age had an average post-weaning daily gain of 0.230 kg/day, which is compared to the post-weaning daily gain of Döhne Merino lambs at 0.220 kg/day and Merino lambs at 0.170 kg/day. In another study performed by Schoeman *et al.* (1993a), the data showed that Dorper lambs that were weaned at the age of 100 days had an average daily gain of 0.180 kg/day from day 100 to day 200, which decreased from day 200 to day 300 to an average daily gain of 0.160 kg/day. When compared to Damara and Karakul lambs from birth to slaughter, Dorpers had an average daily growth of 0.180 kg/day; the Damara lambs were measured at 0.150 kg/day and the Karakul at 0.148 kg/day (Von Seydlitz, 1996).

The total weight of lambs weaned per year/ewe is also a very interesting phenotypic measurement. In a study conducted by Basson *et al.* (1969), the Dorper breed was compared to Döhne Merinos and Merinos. In this experiment the Dorpers did very well weaning 39.7 kg of lamb per ewe/year; followed by the Döhne Merinos at 25.5 kg/year and Merinos at 21.2 kg/year. Dorper rams and ewes weighed at the age of 6 months and 11 months showed the following results: 6-month-old rams 54.6 kg and ewes 47.8 kg, 11-month-old rams 80.0 kg and ewes 65.2 kg (Campbell, 1989). Mature Dorper ewe weight leaned towards around 72.3 kg under natural pasture conditions (Cloete *et al.*, 1987).

Slaughter traits

Within the South-African context the premium price is paid for lambs of a cold carcass weight between 18 to 22 kg, with a carcass conformation of A2 to A3 (A1 being excessively thin and A6 being excessively fat). Dorper lambs, because of maturing early and thus putting on fat from an early age, were usually slaughtered at an earlier age, reaching an average slaughter weight of 30-33 kg (Basson *et al.*, 1970). This changed as the breed got older, as later studies indicated that the average slaughter weight had changed to 40 kg (Snyman *et al.*, 1996). This probably indicates that the selection for a 'drier' type of Dorper was underway, resulting in a faster growing and less localized fat breed (Campbell, 1995). The dressing percentage of Dorper lambs stayed relatively constant at 50% between different environmental conditions, as recorded in the by Cloete *et al.* (2000).

Leather qualities

The Dorper skins are highly sought after and are classified as Glover skin quality. In a study comparing the skins of 10 different breeds, the Dorper breed performed just as well as the other indigenousness breeds and surpassed the woollen breeds in skin quality. Hair-type Dorper skin has textile strength of 18.72 Mpa, slit tear strength of 47.24 N/mm, an extension to grain crack of 70%, an extension to grain break of 82.2% and a Lastometer reading of 11.52 nm. The woollen-type Dorper skin has textile strength of 14.84 Mpa, slit tear strength of 43.22 N/mm, an extension to grain crack of 72.80%, an extension to grain break of 83% and Lastometer reading of 11.62 nm. There were no significant differences between the two types of Dorpers (Snyman *et al.*, 2000).

Linear Body Measurements of Dorper sheep

In three studies conducted by Fourie *et al.* (2002), Fourie *et al.* (2013) and Van Rooyen *et al.* (2012), the body measurements of Dorper sheep were obtained. These studies will be utilized to present a picture of the morphological characteristics of the Dorper breed. Table 2.5 represents the Linear Body Measurements of the Dorper rams, while Table 2.6 represents the Linear Body Measurements of the Dorper ewes:

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Table 2.5: Linear Body Measurements of the Dorper rams

Morphological trait	Mean
Body weight (kg)	54.15
Body length (cm)	71.35
Chest girth (cm)	90.55
Wither height (cm)	63.3
Chest width (cm)	23.655
Chest depth (cm)	28.7
Rump width (cm)	25.95
Rump length (cm)	23.4
Scrotal circumference (cm)	32.55
Skin thickness (cm)	3.1
Pelvic width (cm)	5.56
Pelvic height (cm)	6.44
Pelvic area (cm²)	28.22

Table 2.6: Linear Body Measurements of the Dorper ewes

Morphological trait	Mean
Body weight (kg)	48.0
Body length (cm)	Not measured
Chest girth (cm)	Not measured
Wither height (cm)	60.9
Chest width (cm)	21.5
Chest depth (cm)	29.1
Rump width (cm)	18.3
Rump length (cm)	20.4
Skin thickness (cm)	Not measured
Pelvic width (cm)	6.6
Pelvic height (cm)	6.9
Pelvic area (cm²)	35.4

A high correlation was found in Dorper rams between body weight and chest girth of 0.80 and also between body weight and body length of 0.76-0.79 (Fourie *et al.*, 2002). Reliable correlations were also found in a study conducted by Campbell (1983) on the high correlations between body weight and chest girth (of 0.72); and body weight and body length (of 0.74). Shoulder height, which is sometimes regarded as a reliable indicator of the animal's frame size, had a medium correlation with body weight of 0.55-0.58 (Fourie *et al.*, 2002). Chest girth had an overall high influence on all the growth parameters of the rams, while scrotal circumference had a medium to low correlation with animal performance (particularly growth) parameters (Fourie *et al.*, 2002). Coat type had a low correlation when compared to the ram's overall performance (of 0.04 and 0.11), which builds on the evidence collected from Snyman *et al.* (2002); in addition, there was no significant difference (P>0.05) for skin thickness between rams of different coat types (Fourie *et al.*, 2002).

Pelvic area seems to have a high genetic inheritance of 50-60%, which has a high heritability when spoken of in genetic terms. A pelvic meter was used to measure the pelvic height and width of both Dorper rams and ewes, and it was found there were no significant correlations ($P>0.05$) found between pelvic measurements and linear body measurements. Ewes in this experiment had an average body weight of 48 kg, while pelvic height was observed to be 4.5% larger than pelvic width (Fourie *et al.*, 2013). Van Rooyen *et al.* (2012) recorded an average pelvic area of 35.4 ± 4.9 cm^2 in Dorper maiden ewes. Briedenhann (2010) also observed this strange phenomenon that pelvic height tended to have a larger effect in *Bos Indicus* cattle breeds, while on the other hand pelvic width tended to have larger effect in *Bos Taurus* cattle breeds. Ewes tended to have a larger pelvic area than that of rams, which averaged around 5.33cm² larger. Low correlations were found between the measurements of rump width and pelvic width, but also between rump width and pelvic area. This indicates that rump width is not a reliable measurement for discerning lambing ease. The weight and condition score had little effect on the pelvic area, both with low correlations. A low correlation was also found between the slope of the rump and pelvic area; ewes with 0.25 ($P <0.05$) and rams with 0.019 ($P <0.05$) (Fourie *et al.*, 2013).

2.3.2 The Damara

The Damara sheep breed migrated through Africa to Southern Africa around the period of 200 to 400 A.D. Part of the Middle Eastern sheep breeds, the Damara migrated through Africa and settled in the South-Western parts of Africa (now Northern Namibia), where the sheep were highly valued under the indigenous people of that region (Coleman, 2012). The Herero, Namaqua and the Kam Karrin Khoisan tribes used them for farming and trading purposes during those times (damarasheep, 2018). The Damara can be described as a highly adaptable, fat-tailed and long-bodied sheep. It is the only breed that is present in all of the Meatmaster crosses (Ramsay, 2000). The breed has been in competition with more exotic breeds since the creation of exotic crossed breeds in Southern Africa, but because it is classified as a fat-tailed breed and the slower growth rate of its lambs, its popularity declined under farmers who started to farm more and more with the high production exotic breeds (i.e. Dorper). Genetic progress has been made in

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the direction of better 100- day lamb growth, because in 1956 the average weight was 22.8 kg for ewe lambs and 24.0 kg for ram lambs. This was improved to 24.6 kg for ewe lambs and 28.5 for ram lambs in the year 2000 (Von Wielligh, 1998).

Figure 2.4: Damara sheep

Feeding behaviours

The breed is a well-adapted (even more than the Dorper) and has exceptional feeding abilities in order to survive. Damaras are known for their non-selective feeding behaviours, with a diet consisting of 40% grass and up to 60% of trees and forbs (Von Wielligh, 1998). It is also known for standing on its hind legs to browse in trees, a behaviour more indicative of goats, which is a strong indicator that the Damara is extremely well- adapted to semi-arid environments. Observations have been made that Damaras even tend to browse on invasive species like wattle and even toxic species like milkweed (Coleman, 2012). This correlates with observations made by Clynton Collet on Meatmasters; that when introduced into a paddock that contained a small element of Thorn Apple (*Datura Ferox*), the sheep browsed the plant and it seemed to have no effect on them. The Damara breed also seems to have a feed conversion ratio of 5.90 kg fodder needed to produce 1 kg of live body weight which compares very well to Boer goats at 4.95:1 and Dorpers at 6.35:1 (Von Wielligh, 1998).

Adaptations to Disease and parasites

The literature on disease and parasite resistance in tropically- adapted sheep breeds clearly describes that these animals tend to show a higher degree of tolerance than that of the exotic and European breeds such as the Dorper (Wanyangu *et al*., 1997; Mugambi

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et al., 2005) and Romnay Marsh (Mugambi *et al.*, 1997). This is a normal trend within indigenous breeds throughout Africa, for example the resistance shown to *Trypanosomiasis* by the West African Dwarf sheep (De Almeida *et al.*, 2008a, b). In addition, the Red Maasai breed displays high levels of resistance to internal- and external parasites (Mugambi *et al.*, 2005). The Damara breed is no different, with a high resistance to internal and external parasites and especially well adapted to myiasis- causing flies (Almeida, 2008).

Heat adaptations

The ability to retain thermo-equilibrium under very high ambient temperatures has been under natural selection for millions of years within the different fat-tailed and fat-rumped breeds. The East African fat-rumped sheep is a good example whose physiological performance to withstand heat stress is very similar to that of the wild ruminants like the oryx and gazelle species (Maloy *et al.*, 2008). In a study conducted in Queensland (Australia) by Quigley *et al.* (2000), six sheep breeds, namely the Australian Meat Merino, Damara, Dorper, Poll Dorset-Horn, Rambouilett and the South-African Mutton Merino were measured for their ability to withstand high ambient temperatures. In this experiment the rectal temperatures of all the animals increased with the increase of ambient temperatures, except for the Damara which had a constant rectal temperature. The Damara also seemed to have a lower absolute respiratory rate, while in the heat of the day the other breeds' respiratory rate inclined to increase. Assumptions can therefore be made that the specific localization of fat deposits in fat-tailed and fat-rumped sheep breeds seems to create an advantageous adaptation to regulate body temperature under high ambient temperatures, as evident when comparing Bos Indicus cattle to Bos Taurus (Gaughan, 2010). Another assumption can be made by means of Bergmann's rule (Bergmann, 1847), namely that the area of skin in contact with the outside environment is larger in comparison to the animal's total body weight. Animals that are adapted to high ambient temperatures tend to be smaller and also more circular in shape than those adapted for colder climates. Bergmann's rule was proven to be correct by Gohli *et al.* (2006).

Performance and phenotypic description

Production and performance records about the Damara breed are scarce and much research should still be done on this breed. The literature concerning the performance phenotypic description of this breed indicates the following, as described in the rest of the paragraph. An average birth weight is 4.2 kg for female lambs and 4.5 kg for male lambs. The average weight at 80 days of age is 19.8 kg which is an average for both sexes. An average weight at 6 months of age is 32.3 kg, which is applicable to both sexes. The average weight of both sexes at 12 months of age is 46.6 kg. Sexual maturity for ewes tends to present from the age of 10 to 12 months while age of first lambing tends to be 14.6 to 17.3 months (Du Toit, 1995). An inter-lambing period of 30 to 34 weeks (210 to 238 days) was measured (Coleman, 2012). Conception rate ranges between 89-95%. The mortality rate at birth is between 2-4%. The frequency of multiple births is 35%. The survival percentage of lambs that made it to weaning ranges around 96-98% (Du Toit, 1995).

Carcass traits

The Damara breed has a unique carcass quality, with most of its fat localized in its tail. It has a soft rich meat, mostly due to the long distances it travels daily. In a study conducted by Van Seydlitz (1996), in which the daily average gain and carcass characteristics of the Karakul, Damara and Dorper breeds were compared, a daily average gain of 180 g/day was recorded for the Dorper lambs and 150 g/day for the Damara lambs, which was very similar to the Karakul lambs measured. The Damaras' fat thickness was double that of the Dorper lambs at 3.03 mm thick, while the rib eye area was measured at 1.195 mm². The tenderness and flavour of the Damara lambs were very similar to those of the Dorper lambs but compared more favourably to those of the Karakul. Tshabalala *et al.* (2003) conducted a study comparing Dorper, Damara, Boer goat and other indigenous goat species (indigenous to South Africa) in terms of carcass yield, fatty acid composition of the *Longissimus dorsi*, proportions of dissected carcass tissues and the sensory characteristics of minced meat. The evidence proved that the Damara had an average cold carcass weight of 18.6 kg and a dressing percentage of 60%. The Damara breed has a larger fifth quarter than the other breeds which is mainly due to the fact that the

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Dorper and other goat breeds do not have a large tail. Percentages of the Damara sheep's fifth quarter (when compared to the total body weight of the animal) were as follows: Skin 9.7%, Head 5.77%, Liver and Spleen 2.14% and Tail 12.2%. When comparing the Damara and Dorper, the Damara indicated a higher bone content of 17.72% and a lower meat content of 69.9%; but the other characteristics such as the protein, fat, moisture and ash percentages between the breeds were very similar (Tshabalala *et al*., 2003). When the percentages from specific cuts are determined and the Damara and Dorper are compared, the Dorper is inclined to have higher percentages in its ventral trunks, whereas the Damara is just the reverse, with higher percentages in its dorsal trunks. The two breeds (Damara and Dorper) also have very different fatty acids present in the *Longissimus dorsi* composition the Damara has higher percentages of poly-unsaturated, unsaturated, oleic, linoleic and stearic fatty acids, while the Dorper is likely to have higher percentages of saturated, palmitolec, mystiric and plamitic fatty acids. The sensory tests conducted on the meat showed very similar opinions in flavour, but the Dorpers were deemed chewier (Almeida, 2011).

Leather qualities

According to a study done by Snyman *et al*. (2000), all indigenous sheep, including the Damara have similar properties. The Damara skin is classified as Glover quality. The Damara skin has textile strength of 22.56 Mpa, slit tear strength of 44.98 N/mm, an extension to grain crack of 80.6%, as well an extension to grain break of 89%.

2.4 An overview of the Meatmaster phenotype

Other recent experiments concerning the phenotype of the Meatmaster mainly focused on the performance phenotypic expressions of the Meatmaster; and to a lesser extent, the linear body measurements of the breed. Records were collected from three different areas (Meyerton in the Gauteng Province, La Rochelle farm in the Eastern Cape Province and Keetmanshoop in Namibia) using two different breed combinations (Damara × Dorper and Damara × Ile de France). These studies provide a good indication of where the breed had been and to which extent selection had an influence on its phenotypic

values now. In 2006 the linear body measurements of the Meyerton Meatmaster were examined and the following averages were recorded (Peters, 2011):

Table 2.7: Meyerton Meatmaster Linear Body Measurements

Morphological Measurement	Rams	Ewes
Body Weight (kg)	58.1	52.2
Chest Girth (cm)	92.6	94.2
Wither Height (cm)	74.6	69.6
Head Length (cm)	24.4	23.0
Head width (cm)	14.6	13.8
Tail length (cm)	40.6	38.4
Canon bone Circumference (cm)	10.0	9.2
Canon bone Length (cm)	15.7	14.4
Scrotal Circumference (cm)	33.4	N/A

Observations were also made in terms of the coat colouring and hoof colouring. These indicated that the Meyerton Meatmaster had a wide range of coat colouring in terms of colour scheme (Multi-coloured, speckled, patched and uni-coloured) and the colour itself (Red, Red and White, Chocolate, Chocolate and White, Black, Black and White, White and Pink). Hoof colouring was dark, which was observed in all the animals measured, which is a good indication of protective pigmentation (Peters, 2011).

Performance traits recorded from three different areas (Meyerton in the Gauteng Province, La Rochelle farm in the Eastern Cape Province and Keetmanshoop in Namibia) exhibited a very fertile and well-adapted breed. Table 2.8 shows the averages recorded and condensed, ranging from 1990 to 2009 (Peters, 2011).

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Table 2.8: Performance and Phenotypic traits of the Meatmaster sheep breed in 2009

Performance Phenotypic Trait	Measurement
Age at First Lambing	13.0 Months
Average Litter Size (Fecundity %)	120%
Lambing Interval	273 days
Lambing Percentage	86%
Survival Rate (Lamb survival from birth till weaning age)	97%
Birth Weight	3.8 kg
100-day Weight	26.0 kg
270-day Weight	47.0 kg
Mature Ram Weight	65 kg
Mature Ewe weight	52.2 kg
Live Slaughter Weight	38 kg at 5 months of age
Cold Carcass Weight	17.5 kg
Carcass Grading	80 to 90% of the lambs will produce a A2 and A3 grading.

Research conducted in Keetmanshoop in Namibia on the Gellapper Meatmasters flock produced interesting results in terms of birth weights and lamb carcass characteristics. When examining birth weight, Meatmasters had an average of 3.35 kg, which compared to the Dorpers (3.7 kg) and Damaras (3.7 kg) which were also present at the same research station (Peters, 2011). This compares very well to other breeds in the literature, like the hair and wool type Dorper at 4.06 kg; and 4.12 kg (Snyman *et al.*, 2002); Sabi lamb birth weights at 2.63 kg (Matika *et al.*, 2003) and Namaqua Afrikaners at 4.43 kg for rams and 4.21 for ewe lambs (Qwabe, 2011). The Meatmasters had an exceptional fecundity (Lambs born from ewes) of 153.5% for the year 2004 when the research was done; especially when taking into account the other two breeds: Damaras producing a fecundity of 107.89% and the Dorpers a percentage of 115.79% (Peters, 2011).

Carcass characteristics produced by the Gellap-Ost Research Station in Keetmanshoop also showed promising results; with Meatmaster lambs reaching an average weaning weight of 24.89 kg and an average daily gain of 149.54 g/Day. At the time of slaughter, the live slaughter weight recorded on average was 35.95 kg, resulting in a Cold Carcass weight of 15.64 kg. This meant that the Gellapper Meatmaster had an average slaughter percentage of 43.51%. About 50.94% of all slaughtered lambs were awarded the carcass grading of A2, with the second highest being A1 at 20.75% (Peters, 2011).

2.5 The Genetic analysis of the Meatmaster when compared to other breeds

As defined by the FAO, a specific breed is a grouping of uniquely identifiable animals, recognizable on the grounds of external morphological characteristics. This form of identification is used to differentiate the breed from other breeds within the same species (FAO, 2012). While this definition is fine on its own, the complexity of the modern sciences demands a higher degree of evidence. If the breed differentiation is only based on morphological data, as a means of classifying sheep breeds, it is not consistent with the data we see from genetic and historical analysis (Rendo *et al.*, 2004). The indigenous and locally developed sheep breeds pose huge opportunities for breeders, because of the breed's genetic adaptation to a specific (namely the local) environment. Thus, animals selected artificially or naturally for a specific environment, create a unique combination of adaptive traits and provide the breeder with a good combination of survival and productive abilities (Buduram, 2004). Subsequently the genetic uniqueness of the Meatmaster breed as the third leg of this research study (Morphological, Genetic and Performance Phenotype) is discussed, proving that the Meatmaster is unique and should be treated as a separate breed on its own.

In a study conducted by Peters *et al.* (2010), genetic material from four different populations of Meatmasters were collected and analyzed and results were compared to seven other sheep breeds (Damara, Dorper, Ile de France, Namaqua Afrikaner, Ronderib Afrikaner, SA Mutton Merino and Van Rooy). The research of frequency- and multilocus-based measures proved that the Meatmaster should be recognized as a distinctive breed. Four alleles were found that were unique to the Meatmaster, although these were at very-low frequencies (0.013-038) within the breed's genome. Utilising the Bayesian-based

assignment test (Pritchard *et al*., 2000) can add great value in determining if the breed has unique units. This test was able to assign these breeds to breed- specific clusters with an accuracy of 78.7 to 92.9 %. A percentage of 69.4% of all the Meatmasters showed three (out of 10) distinct cluster formations that were unique to the breed; notably none of these clusters retained only the genomic information from a specific breeder. It should also be noted that the three clusters (that is cluster 4, 6 and 9) did not contain more than 3.6% of the parental breeds individual SNP's and contained 69.4% of the Meatmaster genotypic information. This provides convincing evidence to the concept of the Meatmaster being a unique breed (Peters *et al.* 2010).

Another piece of evidential information is the trend of the R(st) values, which are very good at determining correlations between breed genomes. It showed a considerably high R(st) value between the Meatmaster breed and the non-related breeds (Namaqua Afrikaner *etc.*); a high R(st) value between the Meatmaster and its parental breeds (Damara, Dorper *etc.*), and a low R(st) value between the four different Meatmaster populations (Peters *et al.*, 2010). The F(st) value produced the same conclusion, but at a lower value: the F(st) value of 0.012-0.033 was still very low when compared to other studied that also tried to determine the uniqueness of specific breeds, for example Quiroz *et al.* (2008) reported a F(st) value of 0.1 and Rendo *et al.* (2004) a F(st) value of 0.07.

A hierarchical analysis was conducted on the total genetic diversity among the 11 groups. The data predicted a 2.315% variation between the four Meatmaster groups, but a variation of 11.445% between Meatmaster and other breeds (including their parental breeds) (Peters *et al.*, 2010) was recorded. These data further support the thesis that the Meatmaster is a unique breed.

2.6 The Carcass classification system within a South African context

Carcass classification is a system based on the descriptive elements of the carcasses by clearly- defined predetermined rules that are of great importance to the meat industry and consumers for identifying classical differences between carcass compositions and quality (Kempster *et al.*, 1982). The classification of carcasses is of essential importance in an efficient animal production system, the fixing of prices and in the end the meeting of

consumer demands. Significant variation exists within carcass composition and quality of the animal due to the effects of species, breed within a species, sex, maturity type, age and the effects of interaction within production systems (Webb *et al.*, 2013). The purpose of a system like the carcass classification system is to classify carcasses based on clearly-defined rules to ensure that the consistency of meat quality is properly identified and consumer satisfaction is met. Carcasses of equal composition and quality are then classified into the same category to reduce the differences between carcasses and guarantee a more consistent end product. A carcass classification system shift is emphasized from a grading system (which is an indication provided of a standard, prime and superior carcass grades) to classifying carcasses in order to allow the meat industry and consumers with a better choice regarding different types of carcasses to which their preferences may sway in terms of carcass composition and physical characteristics. The theoretical basis of the carcass classification system is therefore based on the standard that producers, retailers and customers differ in terms of their attitudes and expectations of carcass and meat quality, and the experience of eating a certain type of meat (Webb, 2015).

A comprehensive knowledge of the South African sheep classification system is of great importance to improve competitiveness, increase economic efficiency and ensure the same degree of quality that the customers have come to enjoy. This information is used to adjust production practices and livestock breeding policies to produce carcasses and meat that comply with consumer prerequisites (Webb, 2015). The systems have hence moved to a more market- orientated idea of carcass classification, where the consumer determines widely which type of carcass is more preferable and which is less. According to the consumers' demand prices are assigned to different carcass classifications and different cuts of meat. Thus, it is supply and demand that creates the prices of the different classifications. The Meatmaster breed has found its niche right here, while being a highly adaptive breed with an above average fecundity, it also has a very good carcass classification standard.

The carcass classification system was introduced in 1992 and replaced the carcass grading system in South African. The carcass grading system focused on denoting the

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quality and value of the carcass by the grades; Standard, Prime and Super. The best argument against the former South African red meat grading system is that it was not a customer-orientated system but catered mainly for the government and retailers. This system was relatively reliable at that time but could not survive the free-market systems which were more effective in determining price (Webb, 2015). The carcass classification system of South Africa is formulated around a classification system based on their compositional and physical traits, which include carcass fatness (carcass fat codes 0 - 6), age (age categories A, AB, B, C), carcass conformation (carcass conformation codes 1 - 5), and damage (1 to 3) (Webb, 2015).

Principles of the South African Carcass Classification System

The age of the animal plays a primal role in determining tenderness, and therefore age forms the foundation of the current South African carcass classification system. The older an animal gets, the tougher its meat becomes (Dreyer *et al.*, 1977); which is caused because the connective tissue like collagen and elastin becomes more predominant in the meat (Lawrie, 1998). Younger livestock tends to have more collagen in their meat; which creates a tenderer meat profile. The tenderness of the meat is considered to be the primary important attribute regarding its quality (Issanchou, 1996; Boleman *et al.*, 1997).

The market forces seem to prefer a leaner carcass which in turn resulted in farmers selecting for a carcass grading of an A2 to A3 (Webb *et al.*, 2008). The emphasis has shifted to a leaner type of meat, which has had a tremendous influence on the red meat industry. South-Africa's drier climate (which created the need to raise adapted animals to) and other financial forces (for example increased yield) tended to produce a higher number of fatter carcasses. The power of the customer to select has driven the production of a leaner type of red meat (Webb *et al.*, 2013). This forms a crucial part of the Meatmaster's selection and consequent success, because market forces clearly indicated a preference for a leaner red meat. The adaptability of the fat-tailed sheep breeds with a carcass quality of the drier sheep breeds produced the Meatmaster.

2.7 Phenotypic adaptations

The adaption of animals over time is a dynamic process, wherein living organisms react to environmental stimuli and are modified phenotypically. The effect is a modulation of the genomic expression to fulfil the needs of the time (Naqvi *et al.*, 2013).

One of the expressions of change to environmental stimuli is adaptation to heat stress and drought stress, which form the most important factors if semi-arid and arid production zones are considered. Tropical degradation is known to alter the physiology of livestock and has as an effect on mortality rates and decreases both reproduction and production in male and female animals (Hoffman, 2010).

If heat stress is combined with nutritional paucity an environment is developed where only well-adapted animals are able to survive. Research has proven that the native sheep breeds of India take different physiological and blood biochemical adaptive actions to fight against nutritional stress (Sejian *et al.*, 2014).

Phenotypic modification as an evolutionary adaptation to harsh climate can be seen in sheep breeds that are adapted to semi-arid and arid environments. These breeds typically have morphological adaptations like long legs for the purpose of long migrations in search of better vegetation. Their body shapes and sizes have also adapted to deal with water loss and heat tolerance, and they are inclined to be smaller in size than European breed counterparts (Naqvi *et al.*, 2013). Adapted sheep breeds tend to show fat localization, specifically to the tail, which helps with heat conductance to the periphery for dissipation and the tail also serves as an energy reserve in periods of food scarcity (Atti *et al.,* 2004).

In the battle for survival in arid and semi-arid environments animals need to conserve water. Sheep breeds show some amazing physiological adaptations in the attempt to conserve water in harsh environments. They have the ability to reduce fecal moisture and urine volume. The Henlé loops, situated in the medulla of the kidney, are mainly responsible for the retention of water from urine. The medulla region in the adapted sheep breeds tend to be much thicker and produce more concentrated urine (McNab, 2002).

The same phenotypical adaptations are observed in the Hassawi cattle from Saudi-Arabia. They are small in size; the mature body weight of bulls is 210kg to 270kg, and the cows only weigh 150kg to 200kg. The adaptation to smaller sizes helps them in times of food scarcity, as a smaller animal requires less food. These cattle have long legs with fine and light bones, which assist to move over long distances in search of food. The colour of the coat is light red with dark pigmented skin and glossy hair, which protects against solar radiation. The eyelids, muzzle and external genitalia are pigmented. The ears of the cattle are large even in comparison with Indian breeds, leading to the conclusion that larger ears are an adaptation for extreme warm climates. The necks of the Hassawi breed are short in both male and female, but thick in the male animals and thin in females. They have a reduced dewlap with a large and well-defined hump (Mohammed, 1997).

2.8 Selection for functional efficiency

The genetic make-up of any animal is determined during conception. This statement which is usually regarded as correct carries with it a large amount of truth. Although complex genetic laws such as phenotypic plasticity, horizontal gene transfer, epigenetics, transposition, hybridization, symbiogenesis and genome duplication have a large effect on the animal at conception and even during its lifetime, the largest amount of information is determined during conception. This genetic potential of the animal determines how it will interact with its environment. The genotype-environment interaction will determine how the morphological form (phenotype) of the animal will appear (Pigliucci, 2001). This knowledge is used as a guide to determine if this animal is functionally efficient in its environment, or if it is adapted to its environment. A simple and correct definition of mammal adaptation is: the animal is able to go through the four stages of its life cycle (growth, reproduction, lactation and fattening) in its natural environment with little or no intervention by human beings and to produce a marketable product at the end (Mentz, 2016). We thus select for functional efficiency in animals on the grounds of being morphologically sound for its environment (no genetic defects), being able to grow (to mature acceptably from birth to weaning), being able to reproduce (to reproduce at an acceptable rate per annum), being able to lactate (have an acceptable milk yield to

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support its growing young) and being able to fatten (have an acceptable growth rate from weaning to sale) in its present environment. The term *acceptable* is used to describe a large range of production specific to an environment; for example, livestock in temperate climates has the potential of having a much higher rate of production than livestock in a desert climate. It is then up to the person in charge of selection to find the most functionally efficient breeds for his specific environment; or as put by Steyl (2018), the term functionally efficient is determined by the animal's capability to perform and reproduce in its environment with as little as possible intervention and input costs.

2.8.1 Body profile and general conformation of ewe

The right phenotypic description of any ewe must always start from the knowledge claim of fertility. We should first examine what the phenotypic characteristic is that makes a ewe fertile by examining large numbers of fertile and sub-fertile ewes, and then create a phenotypic image of the fertile ewe. This should be the aim of any breeder to strive towards breeding and maintaining this image. Fertility should be the main focus of any sheep enterprise, because it is the highest contributor to a profitable margin (Meatmaster Breeders Society, 2017). Second, selection for functional efficiency is the best way of attaining this goal, for an ewe that cannot produce and reproduce in her environment is not functionally fit. Thus, the environment becomes the authority of which phenotypes work and which do not.

Environment can be divided into two categories: first the external environment into which the animal is born, and which comprises the environment outside the animal's own body, second the other is the internal environment which is the body of the animal. In determining the right body profile of an ewe the second environment plays an important role and that is by regulating the hormonal balance of the ewe with finely tuned feedback mechanisms (Bonsma, 1983). Hormones play a pivotal role in how the phenotype of the animal will be presented and also the fertility status of the animal. Hormonal imbalances must be detected as early as possible, for it will have grave consequences in the functional efficiency of an animal and eventually the herd.

The femininity of an ewe can be described as the interplay between sex and growth hormones. Thus, the phenotype of a fertile ewe will appear to wedge to the rear quarter (to her rump) where her reproductive organs are situated. When viewed from behind the largest diameter seen on the ewe will be the mid-rib region, and this huge capacity forms a vital part during pregnancy and grazing. On the other hand, the forequarters can be described as light and sleek, with the brisket not being overly developed and the shoulder blades tend to be free from coarse muscling, loose and lean (Bonsma, 1983). She will have a thin, long neck (in most cases longer than those of rams), with a refined head free from over- muscling. Collette, (2019) warns against the Euro type breeds with round muscles as it does not lead to more meat production but definitely to lower fertility, lambing problems and a less functional and efficient sheep.

Figure 2.5: Highly fertile feminine Meatmaster ewes demonstrating the rear quarter wedge shape

2.8.1.1 The external genitalia

Functional infertility in ewes can represent from a young age but can be primarily identified by their phenotypic appearance (having a more masculine appearance). Further inspection can be done concerning her genitalia. Signs of under-developed external genitalia are usually presented as a prominent clitoris with coarse hair growing in her genital area, and a small genital opening that is surrounded by perineum fat deposits. A well-shaped, well attached and functional udder is the ideal with two normally shaped teats with one opening each (Meatmaster Breeders Society, 2017).

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2.8.2 Body profile and general conformation of the ram

As for males, the idea of functional efficiency is just as important, thus selecting for masculinity in rams will prove to be one of the most important aspects in the long run. Fertile rams will appear to wedge to the forequarters, with well-developed forequarters and strong masculine necks and heads. Rams will represent well-defined withers, accompanied by coarser hair growth and even a skirt growth of coarse long hair on the brisket-neck area. In a study conducted by Fourie *et al.* (2004), testosterone levels had a significant correlation ($P<0.05$) with masculinity. Rams with a more prominent forequarter wedge shape (wedge shape score of 5 and 7) also tend to be significantly ($P<0.01$) heavier than rams with wedge shape scores of 4 and below (as can be seen in Figure 2.3.). Chest girth is one of the body measurements that present an objective picture of forequarter size in rams. The literature is very clear about a high correlation between chest girth and total body weight in rams; as Yankasa sheep 94% correlated (Afolayan *et al.*, 2006) and Dorper rams 80% (Fourie *et al.*, 2002). The literature is also clear that rams have a larger chest girth circumference than ewes (Afolayan *et al.*, 2006; Fourie *et al.*, 2002; Kunene *et al.,* 2007; Qwabe, 2011). Fertility in rams goes hand in hand with good masculine muscular development, specifically in the forequarters.
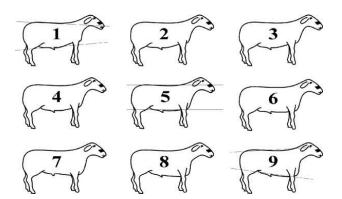
Figure 2.6: Linear scores for the wedge shape of rams on a scale of 1−9 (Fourie *et al.,* 2004)

Figure 2.7: Highly fertile masculine Meatmaster ram demonstrating the forequarter wedge shape

2.8.2.1 The external genitalia

Rams should present a well-attached scrotum, with well-developed and evenly shaped testicles (Meatmaster Breeders Society, 2017). Sub-fertility in the external genitalia of rams can manifest in a multitude of ways, namely hypoplasia of one or both testicles, a scrotum which has the inability to regulate temperature, a separation of the testes by the scrotum and pendulousness of the scrotum. The sheath of the ram should be well developed with coarse hair at its opening, and protruding prepuce should be selected against (Fourie *et al.,* 2004). Any form of hormonal imbalance in rams must be selected against and can be easily detected by paying attention to the phenotypic body shape of a ram and its external sexual organs.

2.8.3 Coat type in selecting for functional efficiency

The coat type followed by coat and skin colour in sheep evolved over a large period of time, which excludes human selection, and this evolutionary process can be seen in the difference between those sheep adapted for desert and tropical environments and those adapted for more temperate climates (Gootwine, 2011). The structure of the coat (namely coat type) must be examined in conjunction with coat colour, because they are two parts of one organ. The coat colour and structure affect the penetration of light, as well as the absorption of radiation on top and within the coat (Finch *et al.,* 1984). Take for example

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the Awassi sheep with its white fleece of open and loose combinations of hair and wool: its fleece is highly adapted to a desert environment with high ambient temperatures and sandstorms (Gootwine, 2011).

Coat colour in sheep can be described as one of the characteristics by which a specific breed can be most easily identified. It is also an important phenotypic trait in determining the average heat load and how much of the solar radiation the animals absorb and/or reflect (Daramola *et al.,* 2009). Coat colouring has a measurable effect on heat absorption, with lighter coat colourings absorbing less heat than darker coats (Asres, 2014). Finch *et al.* (1980) found that heat gain by radiation and convection of the black coat goats was twice as high as those of the white-coloured goats when both was exposed to the sun. Black coloured goats seemed to have no significant difference in heat storage or metabolic heat production when compared to those of white coat colour, although the black goats had a higher rate of evaporation to get rid of the extra heat. Coat colour effects seem to have a correlation with climatic-stress-tolerance traits as observed by Fadare *et al.* (2013) when studying the West African dwarf sheep. It was observed that sheep with lighter pigmentation were less prone to heat stress. Effects such as packed red cell volume, rectal temperature, pulse rate, respiration rate and plasma potassium and sodium levels are all influenced by coat colour.

The smooth, straight and short hair of the West African dwarf goats is an efficient adaptation to their hot and humid tropical climate (Daramola *et al.,* 2009). This coincides with observations made by Finch *et al.* (1984) who found a negative correlation between the woollier coat type (which was made worse if the coat colour is darker) and phenotypic traits such as weight gained, the time per day spent grazing and tolerance to sun light. Afrikaner cattle seem to have similar traits, as they are highly resistant to high ambient temperatures and solar radiation. Their smooth coats produce more serum which has tick- repellent attributes during the summer months. These coats tend to have a lot less static electricity and thus do not matt easily, which makes it difficult for ticks to infest, because ticks do not like direct sun light. This adaptation of smooth coated animals seems to provide an advantage of fewer ticks (Bonsma, 1983).

2.8.4 Animal behaviour and functional efficiency

Ruminants have various ways of protecting themselves from extreme environmental factors by means of adapting their behaviour. For instance, ruminants tend to be diurnal (active during the day), but when water is scarce and daily temperatures are high, they limit their movement during the day to conserve water (Nejad *et al.,* 2017). Small ruminants also take advantage of their hairless body parts, by shedding unnecessary hair, reducing feed intake and increasing their water intake to dissipate body heat (Attia, 2016). One form of heat production in ruminants takes place through feed intake, and therefore ruminants adapted a behaviour for reducing feed intake during extreme heat to decrease metabolic heat production (Attia, 2016). The goat species are extremely well adapted in overcoming heat stress, although selective breeding for other more production-orientated traits seemed to have had a negative effect on their adaptive traits. In a study conducted by Koluman *et al.* (2016) in which the German Improved Fawn goats were compared to the Saanen hair goats it was found that the Saanen goats performed a lot better than the German Improved Fawn goats when put under extreme heat stress. The Saanen adapted to eat a smaller number of meals while still having a larger meal size, a longer meal length and an increase in time between each inter-meal interval. These behavioral adaptations were not found among German Improved Fawn goats.

2.8.5 Pedigree performance testing

Most common forms of breeding are based on truncation selection, in which focus is placed on the best performance between parental groups when determining who will be mated to whom. These forms of selection are divided into three categories: using gene markers (that is using a genomic-assisted selection), pedigree performance-orientated selection (using breeding value-assisted selection) or phenotypes (phenotypic selection or using index assisted selection) (Akdemir *et al.*, 2016). Each of these forms has their advantages and disadvantages; however, the focus in this study is on pedigree performance testing.

Pedigree performance testing is a powerful selection tool that utilizes the animal's own performance data in combination with the performance records of its ancestors, the

animal's own progeny and full- and half sibling information. This enables commercial as well as seed-stock producers to make more accurate decisions regarding their replacement stock (Bourdon, 2000).

Another important part of Pedigree performance testing is the values known as Expected Progeny Differences (EPD). These values convey an objective quantifiable meaning to a specific genetic value of the animal (for example it is expressed in either a plus or a minus for weaning weight, fertility index, average inter- lambing period, etc.). This informs the reader to the quantity assigned to the genetic merit of what that animal will pass on to its offspring and if the animal is superior or inferior to others of that specific value (Bourdon, 2000). EPD's can be used very effectively within a specific breed, as they are very accurate and have the ability to limit the effect of different contemporary groups. EPD's do have a limitation: they are very effective in measuring differences between animals of the same herd and even breed and in ranking them accordingly, but their accuracy declines drastically when comparing one breed to another. EPD's increase in accuracy and reflect an accuracy value of a specific trait. The more information of a specific animal becomes available, the more accurate the EPD for that trait becomes. Take for example a young maiden ewe with no lambs, her EPD for weaning weight index is less accurate than for a ewe which has raised two lambs; because we can use her progeny to increase the accuracy of the EPD (Bourdon, 2000). The only information we can discern on the maiden ewe with no lambs is that of her ancestry and siblings; thus the more measurements we have, the more accurate her EPD's become (Boggess *et al.* 2019). EPD's are used in statistical models such as BLUP (Best Linear Unbiased Prediction) which is widely used in the livestock industry.

The Meatmaster breed uses a combination of pedigree performance testing and phenotypic selection. This is used not just to identify the animals with the best EDP's, but also to balance it with a functional efficient phenotype.

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Chapter 3

Materials and Methods

3.1 Introduction

The Meatmaster breeds' phenotypic analysis was conducted over five different areas within South-Africa, from 2019 to 2020 to eliminate seasonal bias. A total number of 409 animals were measured, which included 187 Rams and 222 Ewes.

3.2 Environments

The environments chosen for this study are mainly divided into two biomes: the Nama-Karoo and the Grassland Biome (Kenhardt being the exception, with both the Savanna and the Nama-Karoo Biome), which provided a good overview of two extreme environments and the Meatmaster's ability to adapt to both. Three of the five breeders were part of the original founding Meatmaster breeders, which provides important information concerning the original bloodlines of this breed. It is important to note that during the collection of the data, the Northern Cape was still in the grasp of a drought that had been raging for seven years. The study areas were the following:

1. Bethulie (Free State)

   Bethulie is situated in the South Western part of the Free State province. It is situated within the Grassland Biome of South-Africa (Mucina & Rutherford, 2006). It receives an average annual precipitation of 481 mm. The average temperature is 16.1 °C, but ranges from 22.7 °C (January) in its warmest month to 8.3 °C (July) in its coldest month (climatedata, 2020).

2. Calvinia (Northern Cape)

   Calvinia is situated in the South-Western part of the Northern-Cape and is located within the Succulent-Karoo Biome of South-Africa (Mucina & Rutherford, 2006). An average annual precipitation of 216 mm is recorded which is seasonally bounded (to the winter months). It has an average temperature of 16.4 °C, but ranges from 22.4 °C (February) to 10.1 °C (July) (climatedata, 2020).

3. Kenhardt (Northern Cape)

Kenhardt is situated in the Northern central part of the Northern Cape, and forms part of the Nama-Karoo Biome of South-Africa (Mucina & Rutherford, 2006). This is a very dry region with an average annual rainfall of 148mm. The temperatures range from 36 °C in of January to 2 °C in July, with an average of 28.1 °C (climatedata.eu, 2020).

4. Wesselsbron (Free State)

Wesselsbron is situated in the Northern central part of the Free State province and is positioned within the Grassland Biome of South Africa. It receives an average annual precipitation of 451 mm, mostly occurring in summer with an average temperature of 16.4 C° recorded in this area. Temperatures range from 32 °C in January to 1 °C in July (Mucina & Rutherford, 2006).

5. Williston (Northern Cape)

Williston is situated in the South-Central part of the Northern Cape, within the Nama-Karoo Biome of South-Africa (Mucina & Rutherford, 2006). This is a typical Karoo area with a low average annual rainfall of 179mm. The temperatures range from 33 °C in January to 1 °C in July, with an average of 24.9 °C (climatedata.eu, 2020).

Keys:

Purple: Bethulie

Blue: Calvinia

Red: Kenhardt

Yellow: Wesselssbron

Green: Williston

Figure 3.1: Representation of research sites in South-Africa

3.3 Animals

Four hundred and nine (409) animals were measured: 187 rams and 222 ewes. The breeders and areas were chosen for specific reasons: first, the animals of that specific area had to be registered to ensure that the animals have been bred purely (that is Meatmaster bred to a Meatmaster) for at least 5 generations. Second, it was attempted to represent registered breeders from as many areas as possible, as the ecology of the regions differs from one another. Data were collected by conducting different body measurements on both ewes and rams. All measurements were taken by the same person, to minimize variability and measuring bias (Mohammed, 2018). Two methods of recording age were used; namely dentistry (identifying the number of incisors an animal possesses from 0-Incisors to 8-Incisors) and the other being production records (birth records), the latter being more accurate. Twelve body measurements, including body weight were recorded, from the male sheep (rams) and fifteen body measurements including body weight, from female sheep (ewes). These excluded the six Qualitative traits that were measured for both rams and ewes. Furthermore, seven phenotypic performance traits were measured from each ewe (these data were retrieved from the production records held by the owners).

3.4 Linear body measurements

Linear body measurements were chosen as method, with body weight included in the measurements, as these seemed to be the most accurate way of determining a general phenotype for the Meatmaster breed and is widely used in the literature when describing morphology (Afolayan *et al.*, 2006; Kunene *et al.*, 2007; Qwabe S.O., 2011). Linear body measurements were recorded according to the guidelines of Fourie *et al.* (2002).

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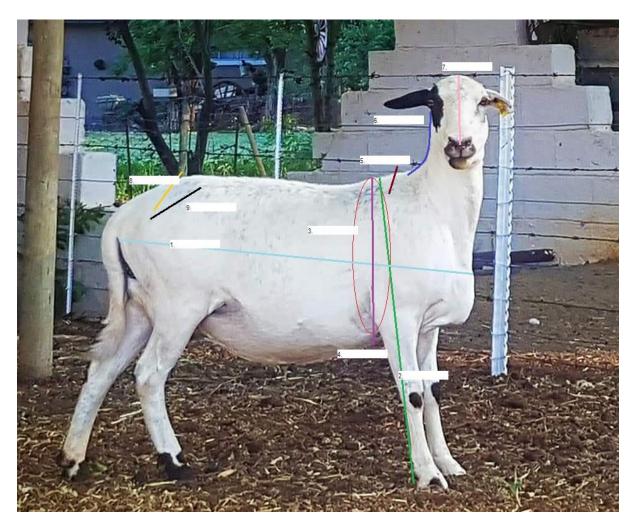
Figure 3.2: Indication of where on the animal the linear body measurements were taken

1. Body Length (Light blue)
2. Wither Height (Green)
3. Chest Girth (Red)
4. Chest Depth (Purple)
5. Chest Width (Maroon)
6. Neck Length (Dark Blue)
7. Head Length (Pink)
8. Rump Width (Yellow)
9. Rump Length (Black)

The measured quantitative variables used the linear body measurement method (measured by a measuring tape), body weight (determined by means of an electronic

scale) and the pelvic measurements (a pelvic meter). The following measurements were recorded:

Table 3.1: Quantitative and Qualitative variable measurements

Quantitative variable	Symbol	Definition
Body Weight (kg)	BW	Live animal weight (kg)
Head Length (cm)	HL	The distance between the tip of the nose and the most upper point of the forehead.
Neck Length (cm)	NL	The distance from the first neck vertebrae to the tip of the shoulder.
Wither Height (cm)	WH	The height from the ground to the top of the withers.
Chest Width (cm)	CW	The maximum intercostal diameter from the position of the sixth rib, from behind the animals' elbows.
Chest Girth (cm)	CG	The perimeter of the chest at the position of the sixth rib.
Chest Depth (cm)	CD	The vertical distance between the xiphiod processes of the sternum to the top of the withers.
Tail Length (cm)	TL	The distance of the caudal vertebrae (from the first caudal vertebra to the tip of the tail).
Body Length (cm)	BL	The distance between the base of the neck and the base of the tail.
Rump Length (cm)	RL	The distance between the pin and hip bone.
Rump Width (cm)	RW	The distance between the right and left thurls.
Pelvic height (cm)	PH	The distance between the sacrum and the dorsal pubic

		tubercle located at the bottom of the pelvis.
Pelvic Width (cm)	PW	This measurement is taken at the widest two points between the right and left ilium shafts.
Pelvic Area (cm²)	PA	The width and length of the pelvis as measured internally. Those two measurements were then read into an equation which determines the area of the pelvis. It is the shape and size measured in cm² of the entire area within the pelvic chamber.
Scrotum Circumference (cm)	SC	The circumference of the scrotum as measured at its widest points.
Qualitative variable	**Symbol**	**Definition**
Back Profile (on a scale of 1 to 3)	BP	Is the back straight or concave?
Rump Fall (on a scale of 1 to 3)	C/RF	Is the rump straight or at a 30-degree angle?
Colour	C	The colour of the coat.
Horn Presence (on a scale of 0 to 2)	HP	Where 0=polled, 1= small knobs, 2= defined horns.
Wool Fleece Extent (on a scale of 1 to 3)	FE	In what phenotype does the fleece present itself: 1= Hair type (low density), 2= mixture of hair and wool (medium density), 3= mixture of hair and wool, but more wool dominated (high density)

Table 3.2: Phenotypic performance traits

Trait	Description
Age at first lambing	The age (in months) at which the ewe gave birth for the first time.
Number of times lambed	The number associated with the ewe having produced a lamb/lambs during her lifetime.
Number of lambs born	The number associated with number of lamb/lambs that the ewe has given birth to during her lifetime.
Number of lambs weaned	The number associated with number of lamb/lambs that the ewe has weaned during her lifetime.
Average inter-lambing period	The average period (in days) between each successive lambing session.
Cold carcass weight	The weight of the carcass after slaughter after 3% had been deducted from the warm carcass weight.

3.5 Instruments

Pelvic meter

Pelvic area measurements are taken using a pelvic meter, which is an instrument designed by Fourie and Van Rooyen at the CUT (Central University of Technology Free State, Patent P59736ZP00). The pelvic meter has been found to be a useful and reliable instrument for measuring the dimensions of the pelvic area (Fourie *et al.*, 2013).

Figure 3.3: The pelvic meter created for the use in small stock

As represented in Figure 3.4, two pelvic measurements. Pelvic width (PW) was taken from the widest two points between the right and left ilium shafts. Pelvic height (PH) was measured as the distance between the sacrum and the dorsal pubic tubercle located at the bottom of the pelvis. (Cloete *et al.*, 1998; Fourie *et al.*, 2002; Fourie *et al.*, 2013; Jacobsz *et al.*, 2019; Kilgour & Haughey, 1993; Patterson & Herring, 1997; Van Donkersgoed, *et al.*, 1990; Van Rooyen *et al.* 2012; Walker *et al.*, 1992). The equation used to calculate pelvic area is represented by Morrison *et al.* (1986): Pelvic area = π (PH/2)*(PW/2).
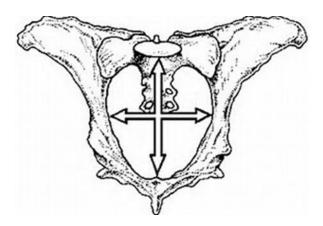
Figure 3.4: The area being measured for pelvic measurements (Anderson & Bullock, 1994)

The right procedure entails accurate measurement. The following guidelines to take accurate pelvic measurements were employed: restrain the animal with ropes, or if possible, in a chute utilizing a light squeeze, try to let the animal stand as normal and

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comfortably as possible. Remove the excess faeces from the animal's rectum to improve accuracy and then enter the animal rectally with the instrument (Deutscher, 1975). When you have entered the animal rectally, open the instrument and apply just a little bit of pressure on the handles of the instrument. Move the instrument around inside the rectal cavity, not entering too deep, as the objective is to try and locate the ossified joint on the pubic symphysis. Once you have located it, it will serve as a reference point to measure the pelvic height between the dorsa pubic tubercle on the bottom of the pelvis and the sacrum at the top (Figure 3.4). The width of the pelvic is then measured by turning the instrument 90° (clockwise or anti clockwise) holding a constant light pressure to the outside of the pelvis to measure the widest points between the right and left shafts of the ilium bones, which I offers the horizontal measurement of the pelvis (Figure 3.5). Pressure on the handles of the instrument can then be released, so it can return to its normal state, and the instrument can be slowly removed from the rectal cavity so not to harm the animal. After each measurement the instrument must be cleaned with a wipe, then water and finally a disinfectant mixture to prevent pathogens being transferred between animals (Cloete *et al.*, 1998; Fourie *et al.*, 2002, Fourie *et al.*, 2013; Haughey & Gray, 1982; Jacobsz *et al.*, 2019; Morrison *et al.,* 1986; Van Rooyen *et al.* 2012).

Figure 3.5: Measuring pelvic height

Measuring skin thickness with a caliper

Skin thickness was measured by means of calipers on the double fold skin between the brisket and the left foreleg, as described by Fourie *et al.* (2002). The measurement of skin thickness holds numerous benefits in wool production (Brown *et al.,* 2000) and in utilizing as a measurement for tick resistance. The pictures below illustrate the operative technique to measure skin thickness.

Figure 3.6: Securing the ram in a seated position

Figure 3.7: Measuring skin thickness between the brisket and the left foreleg

Operative Technique

Secure the animal in a seated position (Figure 3.6). While firmly secure, open calliper toe wide enough so it can easily move over the skin. Close the calliper's adjustable bottom part with your thumb so the skin of the animal is between the pincers of the calliper. Remember to push firmly with your thumb, but not too hard as to compress the skin and alter your measurements. Remove the calliper from the animal to observe the measurement. This technique might change when utilizing electronic callipers.

Statistical Models

A stepwise regression was carried out using SPSS (Version 26) to determine the individual influence of body measurements on performance. An F to enter level of 0.05 was used to determine the significance of the partial contribution of each effect. Pearson correlations were conducted on the body measurements in both rams and ewes, following the guidelines of Field (2009). In order to investigate the difference between various age and area categories the Hochberg's GT2 post hoc test was conducted. A Multiple Regression Analysis was conducted on five models using LBM as the variables. In the next step of the multiple regression analysis the tool of Model Summary boxes were used. The Durbin-Watson statistical test was used for the assumption to be made that the residuals are independent (or uncorrelated).

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Chapter 4

Results and Discussion

4.1 Introduction

The phenotypic description of an animal's morphological characteristics includes the physical appearance, productive parameters, adaptive traits and environmental factors under which performance measurements have been recorded (Rege *et al.,* 1992). The variance within production and phenotype of a specific breed should be conducted over a range of varying environments, which is essential for creating a credible phenotypic mean (Yakubu *et al.,* 2010). Linear body measurements can provide useful information in genetic improvement programmes, whereas the basis of using morphological traits in selection is sustainable and improves animals on a functional evolutionary path (Janssens *et al.,* 2004).

There is ample evidence to support the Meatmaster as a unique breed, both genetically, by authors like Peters *et al.* (2010); as well as by the large amounts of production data collected by farmers and stored at sites like Stamboek. Nevertheless, the need for a phenotypic description of the breed has grown from within the breed, especially for accurate selection data and externally to establish an objective way of determining variance between different sheep breeds.

As a result, a description of both the physical and performance phenotypic traits was executed in 409 Meatmaster individuals in five different areas (environments). Body weight is one of the traits mostly used in the literature, because of its ability to evaluate growth and its prevalence in the livestock production business (Otte *et al.,* 1992). Body weight tends to be the dominant indicator of growth, but it lacks a description of the morphological composition of an animal. Chest girth, wither height and body length can also be included as good indicators of growth and size. Chest girth tends to have the highest correlation with body weight and growth (Benyi, 1997; Fourie *et al.,* 2002); whereas wither height seems to be a reliable estimate of growth in cattle (Swanepoel, 1984). Fourie *et al.* (2002) also found body length to be a very reliable measurement when determining the growth and size of a sheep. Scrotal circumference is a very

accurate measurement for describing the actual size of the testes and has the added bonus of being highly correlated with sperm production (Hoogenboezem, 1995). Thus, the different morphological compositions of an animal play a crucial role in describing specific phenotypic traits and allow for a more accurate picture /concept of specific traits of different animal species.

4.2 Linear Body Measurements

Table 4.1: Means±SD Body weight, Head length, Neck length, Chest girth, Tail length, Wither height, Chest depth, Chest width, Body length, Rump length, Rump width of the Meatmaster rams and ewes

Variables	Rams	Ewes
Body Weight (kg)	80.47±13.33[a]	57.51±12.43[b]
Head Length (cm)	23.93±1.55[a]	22.68±2.05[b]
Neck Length (cm)	28.35±5.16[a]	29.61±3.82[a]
Chest Girth (cm)	102.45±8.42[a]	92.95±8.08[b]
Tail Length (cm)	38.24±4.88	36.64±4.70
Wither Height (cm)	63.91±4.04[a]	58.99±4.86[b]
Chest Depth (cm)	37.51±2.97[a]	34.47±2.97[b]
Chest Width (cm)	23.47±2.56[a]	21.24±2.85[b]
Body Length (cm)	78.95±5.59[a]	72.67±6.06[b]
Rump Length (cm)	21.82±3.29[a]	20.77±1.93[b]
Rump Width (cm)	23.87±2.82[a]	21.36±3.15[b]
Skin thickness (mm)	2.85±0.5	2.81±0.5

Means with different superscripts within the same row differ significantly (P <0.001).

All body measurements had a significant difference (P<0.001) between the genders, except for neck length (P>0.001) and tail length (P>0.001). Neck length seems to be the only measurement in the Meatmaster breed that has a larger value in ewes (1.27 cm larger) than in rams. Neck length is the measurement with the smallest t-value, indicating that the two genders are very similar in this aspect. Body weight seems to be the measurement that differs most between the two genders, with rams being 22.96 kg

heavier than the ewes. Body weight also is the measurement with the largest t-value, indicating that the two genders are very different in this measurement. These results relate well to what was found in a study conducted on Zulu sheep by Kunene *et al.* (2007), who found that gender plays a significant role in determining body weight, with rams inclined to be heavier. Chest girth is also a measurement that differs significantly (P>0.001) between the two genders. These results relate well with studies done by Qwabe (2011) and Kunene *et al.* (2007), who also found that gender plays a significant role in chest girth between rams and ewes, with rams having the larger value. Wither height is also a measurement that differs significantly (P>0.001) between the two genders. These results correlate well with a study done by Kunene *et al.* (2007), who also found that gender plays a significant role in wither height between rams and ewes, with rams having the larger value. The Meatmaster breed as a whole seems to have thinner skin than that of the Dorper breed. This can be seen in the Meatmaster rams' skin measuring, 2.85±0.5 cm, compared to the 3.1±0.4 cm, of Dorper rams (Fourie *et al.,* 2002).

When comparing the Linear Body Measurements to older Meatmaster studies such as that of Peters (2011), we are able to form a more objective picture of the current status of the breed. The rams and ewes of this study seem to be heavier than those of Peters (2011): 80.47±13.33 kg for rams and 57.51±12.43 kg for ewes compared to 58.1 kg for rams and 52.2 kg for ewes in this study. The most significant difference is the weight difference of 22.96 kg between the rams of the two studies. This could be due to the large difference in chest girth in the rams, namely a value of 102.45±8.42 cm compared to 92.6 cm, as measured by Peters (2011). This equates to a 9.85 cm difference between the two; and because chest girth correlates so highly with body weight (89.5%), it may be the reason for the increase in body weight since 2011. The chest girth for ewes has decreased slightly by 1.25 cm from the study conducted by Peters (2011).

The wither height of ewes and rams seems to have decreased from those recorded by Peters (2011), who recorded a height of 74.6 cm for rams and 69 cm for ewes. This is a difference of 10.69 cm in rams and 10.01 in ewes. This could mean that the breed is moving further away from an Afro-type breed which tends to have higher wither height

measurements, as evident in the Namaqua Afrikaner breed with rams measuring 74.2 cm and ewes 67.6 cm tall (Qwabe, 2011). This is also true about wild sheep breeds, such as the Mouflon, whose wither height ranges between 75 to 85cm for the rams and 65 to 75cm for the ewes (Garel *et al.,* 2003). An increase in average body weight and a decrease in average wither height might be a phenotypic selection for a more all-rounder/Euro-type Meatmaster.

Table 4.2: Mean±SD of Pelvic height, Pelvic Width, Pelvic Area and Scrotal Circumference of Meatmaster ewes and rams

Variables	N	Mean±SD
Pelvis Height (cm)	222	7.66±9.8
Pelvis Width (cm)	222	7.66±9.0
Pelvis Area (cm^2)	222	46.69±10.62
Scrotum Circumference (cm)	187	35.12±3.03

The mean values recorded for all four measurements tend to be higher than those of the Dorper breed, as represented in studies by Fourie *et al.* (2002) and Fourie *et al.* (2013). In those studies, the measured values for maiden Dorper ewes were as follows: Pelvic height= 6.9 cm, Pelvic width= 6.6 cm, Pelvic area= 35.55 cm² and the Scrotal circumference of one incisor-aged rams was 32.55 cm. The set of milk teeth Meatmaster ewes in this study had the following values: Pelvic height= 6.49±0.7 cm, Pelvic width= 6.48±1.0 cm, Pelvic area= 33.30±6.5 cm² and a one incisor-aged rams had a Scrotal circumference= 35.050±2.9 cm. As reported by Cloete *et al.* (1998), up to 80% of all lamb deaths happen within seven days after birth and approximately 60% of those are attributed to dystocia. According to Jacobsz *et al.* (2019), a larger pelvic area to birth weight ratio reduces the degree of assistance ewes require during lambing. Scrotal circumference seemed to be higher in the Meatmaster when compared to the Zulu sheep breed with a mean of 24.3 cm. The measurement of scrotum circumference is very important to improve the total fertility of the breed/herd (Keeton *et al.*, 1996). Scrotal circumference is also used in determining the breeding potential of bulls. As indicated in the literature, scrotal circumference seems to be phenotypically and genetically correlated with body measurements and growth traits that breeders use as part of their selection criteria (Kriese *et al.*, 1991; Keeton *et al.*, 1996). The Scrotal circumference measured in

this study is also higher when compared to the data collected by Peters (2011) on Meatmasters, which were 33.4 cm.

Table 4.3: Mean±SD of Age at first lambing, Number of times lambed, Number of lambs born, Number of lambs weaned, Average inter-lambing period of Meatmaster ewes

Performance traits:	N	Mean±SD
Age at first lambing (as measured in months)	177	15.242±3.8
Number of times lambed	177	3.33±1.8
Number of lambs born	177	4.36±3.4
Number of lambs weaned	177	3.44±2.5
Average inter-lambing Period (as measured in days)	177	258.64±151.3

The Meatmaster breed is known as an early maturing breed, as perceived in the data, with the youngest ewe in the study lambing at the age of 10 months and which produced three lambs at an age of 1118 days (she is still in production). The average age at first lambing for the breed ranges around 15.24 months. This seems to be common, as recorded by P.W. Van Heerden in an article about his Meatmasters stud that had an average age at first lambing of between 12 and 15 months (Coleman, 2015). Conversely, Schoeman *et al.* (1992) monitored ewes under a system designed for accelerated lambing and found that the age at first lambing was approximately 19.6 months. In this study an average inter-lambing period of 258.64 days was recorded, which seems to be a lot shorter than the 319 days recorded in another article about Meatmasters (Coleman, 2015). The Meatmaster has a very high fecundity, with a mean number of lambs born of 4.36±3.4; a significant figure when considering that the average lambing opportunities per ewe are 3.33±1.8. Qwabe (2011) reported that the Namaqua Afrikaner sheep had similar performances with the average number of lambs born of 4.49 from 3.10 lambing opportunities. In a study conducted on Meatmasters in 2009, performance data were collected over a 19-year period and the following figures were recorded: average inter-lambing period of 273 days and age at first lambing 13 months (Peters, 2011). This compares well to the data of this study; with the modern Meatmaster having decreased

its average inter-lambing period by 14.36 days and increased its age at first lambing by two months.

Table 4.4: Mean±SD Carcass Grade of Meatmaster sheep

Carcass Grade	N	Mean Cold Carcass Weight
A0	5	16.388±4.2
A1	127	16.098±3.1
A2	1605	16.949±3.2
A3	427	18.138±3.5
A4	18	15.33±5.6
A5	1	14.80±0
A6	4	16.30±8.2
Mean of A-grades	**2187**	**16.77±4.1**
AB1	1	22.10±0
AB2	12	27.117±7.2
AB3	1	22.90±0
Mean of AB-grades	**14**	**24.039±13.8**
B1	2	25.01±14.8
B2	13	26.656±5.2
B3	2	28.15±16.3
B4	1	27.80±0
Mean of B-grades	**18**	**26.904±13.3**
C2	23	25.127±4.3
C3	9	24.633±7.1
Mean of C-grades	**32**	**24.88±4.9**

The most common carcass grade is that of an A2 lamb, for it is the most sought-after by the market. In a Free-market system, in which the price is determined by supply and demand market forces, consumers portray higher demand for lambs with a lower body fat grading. Thus, the highest prices are paid for lambs with gradings of A1 and A2 (Webb, 2015). In this regard the Meatmaster is doing very well and produces the most sought-after carcass in terms of weight and grading. The Meatmaster achieves a mean weight of 16.77±4.1 kg for the A-grade category (Lamb) which is a very average weight grading. In a study conducted by Van der Merwe *et al.* (2020) in which lambs of different breeds were

finished in a feedlot system, the following carcass weights were recorded: South African Mutton Merino at 22.0 kg, Dorper at 18.9 kg, Meatmaster at 16.6 kg and Namaqua Afrikaner at 15.1 kg.

Table 4.5: Coat Colour Representation

Coat Colour	Number of Animals	Percentage
Red	118	28.9%
Red &White	160	39.1%
Chocolate	37	9.0%
Chocolate & White	39	9.5%
Black/Seal	10	2.4%
Black & White	15	3.6%
White	23	5.6%
Pink	7	1.7%
Total Number:	409	

In this study the most dominant colour represented in the Meatmaster breed is that of Red and White (39.1%). In a study conducted on Zulu sheep by Kunene *et al.* (2007), brown represented the dominant colour at 19%. The Damara breed is a multi-coloured breed (Von Wielligh, 1998); whereas the Dorper is renowned for its black head and the White Dorper is only white. The Meatmaster gets its multi-coloured phenotype primarily from the Damara.

4.3 Correlations between the different morphological measurements

Table 4.6: Correlation between Linear Body Measurements for Rams

	Body Weight	Head Length	Neck Length	Chest Girth	Tail Length	Wither Height	Chest Depth	Chest Width	Body Length	Rump Length	Rump Width	Scrotum Circum.
Body Weight	1											
Head Length	.203**	1										
Neck Length	-0,082	.362**	1									
Chest Girth	.895**	0,094	-.209**	1								
Tail Length	.265**	.227**	.220**	.167*	1							
Wither Height	.543**	0,121	-0,058	.503**	.177*	1						
Chest Depth	.670**	0,082	-.144*	.745**	.151*	.498**	1					
Chest Width	.747**	0,039	-0,047	.672**	.144*	.328**	.488**	1				
Body Length	.735**	0,112	-.197**	.729**	.155*	.588**	.632**	.498**	1			
Rump Length	.245**	0,089	.249**	.236**	.193**	0,066	.176*	.243**	.218**	1		
Rump Width	.677**	-.174*	-.397**	.702**	0,045	.509**	.498**	.581**	.604**	.189**	1	
Scrotum Circum.	.473**	-0,039	-.298**	.534**	.172*	.339**	.469**	.378**	.506**	.222**	.460**	1

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

As can be deduced from the correlational matrix, body weight and chest girth had the highest correlation in both rams (89.5%) and ewes (89.7%). This significant correlation (P<0.01) seems to be the trend in a representation of the literature; Yankasa sheep (94%) correlated (Afolayan *et al.*, 2006), Dorper rams (80%) correlated (Fourie *et al.*, 2002), while Ankole cattle correlated very high with bulls (98%) and cows (92%) (Kugonza *et al.*, 2011). This seems to indicate that selection for increased body weight in sheep should rather be more focused on chest girth than measurements taken from the rump. Meatmaster rams have an average chest girth of 102.45±8.42 cm while ewes' chest girth is 92.95±8.08 cm. A lot of emphasis is put on selection of larger rump measurements in sheep, but their correlation to total body weight is a lot lower than those of chest girth. The argument is understandable, because the more expensive cuts tend to be situated in the rump area. As can be seen in Figure 4.1, chest girth seems to rise as masculinity increases.

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Scrotal circumference seems to be another body measurement that correlates significantly (P<0.01) with chest girth. The body measurement that has the highest correlation with scrotal circumference is chest girth (53.4%), with body length being second at 50.6%. This is a good indication that masculine traits in rams coincide with a larger chest girth circumference. This trend was also observed in a study by Fourie *et al.* (2002), in which two different Dorper populations were measured, and a correlation between scrotal circumference and chest girth of 47.95% were recorded for rams from the Northern Cape and a correlation of 25.90% for rams from the Free State. Fourie *et al.* (2004) found a significant (P<0.001) correlation between scrotal circumferences and masculinity, depicted in Figure 4.2, which indicates that scrotal circumference increases with masculinity.
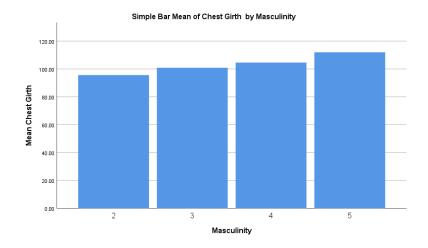
Figure 4.1: Chest girth by Masculinity
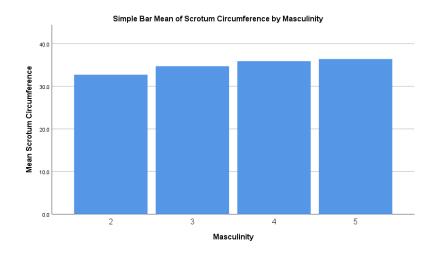
Figure 4.2: Scrotum Circumference by Masculinity

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Table 4.7: Correlation between Linear Body Measurements for Ewes

	Body Length	Body Weight	Chest Depth	Chest Girth	Chest Width	Head Length	Neck Length	Pelvis Area	Pelvis Length	Pelvis Width	Rump Length	Rump Width	Tail Length	Wither Height
Body Length	1													
Body Weight	.778**	1												
Chest Depth	.703**	.685**	1											
Chest Girth	.706**	.897**	.712**	1										
Chest Width	.548**	.811**	.524**	.706**	1									
Head Length	.249**	.195**	.405**	.236**	0,080	1								
Neck Length	0,030	-0,099	.198**	-0,011	0,028	.487**	1							
Pelvis Area	.404**	.305**	.524**	.282**	0,045	.445**	.246**	1						
Pelvis Length	.373**	.274**	.467**	.224**	-0,003	.365**	.188**	.961**	1					
Pelvis Width	.453**	.370**	.575**	.365**	0,131	.518**	.281**	.947**	.832**	1				
Rump Length	.523**	.521**	.458**	.537**	.504**	.184**	.135	.183**	0,123	.257**	1			
Rump Width	.665**	.791**	.601**	.716**	.768**	0,028	-0,037	0,104	0,086	.156*	.470**	1		
Tail Length	.168*	.176*	0,106	.184**	0,048	0,101	0,056	0,105	0,086	0,121	.157*	0,114	1	
Wither Height	.700**	.625**	.708**	.553**	.493**	.389**	.258**	.448**	.412**	.486**	.480**	.581**	.182**	1

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Ewes' body weight (79.1%) tends to correlate higher with rump width than those of rams (67.7%). As can be seen in a study by Fourie *et al.* (2004), rams with a larger chest girth and a masculine wedge shape (where the forequarters of the ram are larger than those of its the hind quarters) tended to be significantly heavier ($P<0.05$) than those rams with a more feminine wedge shape. The contrary is also true selecting for ewes with a more feminine shape (where the hind quarters are larger than the forequarters) will create better results, because the ewe has a higher correlation between body weight and rump width. Neck length seems to be the only body measurement that correlates negatively with body weight in both rams (-0.082) and ewes (-0.099).

Pelvic measurements in ewes seem to predict the following high correlations: pelvic height correlates 96.1% with pelvic area, pelvic width correlates 94.7% with pelvic area. This can also be seen in the literature as in a study of Van Rooyen *et al.* (2012), in which he describes a 4.5% difference between pelvic height and pelvic width in Dorpers (with pelvic height being the greater one). Briedenhann (2010) also made an interesting discovery that pelvic height plays a more important role in the Bos Indicus cattle breeds,

while the converse is true in Bos Taurus breeds, with pelvic width being the more important one. In the Meatmaster it seems that pelvic height also plays a more important role than pelvic width.

Table 4.8: Correlation between ewe productive traits

	Age at first lambing	Number of times lambed	Number of lambs born	Number of lambs weaned	Average inter-lambing period	Age (Days)
Age at first lambing	1					
Number of times lambed	-.178[*]	1				
Number of lambs born	-.215[**]	.847[**]	1			
Number of lambs weaned	-.154[*]	.863[**]	.855[**]	1		
Average inter-lambing period	-0,059	.601[**]	.435[**]	.451[**]	1	
Age (Days)	-0,001	.867[**]	.744[**]	.771[**]	.623[**]	1

**Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level

Age seems to play a significant role ($P<0.001$) in determining average inter-lambing, with a correlation of (62.3%). Therefore, as age increases, the average inter-lambing period also increases, as seen in Table 4.15. Ewes that have had more opportunities to produce a lamb also have a higher average inter-lambing period, which makes sense, for ewes that have just produced one lamb have an average inter-lambing period of 0. That is why number of times lambed has the highest correlation with age (86.7%): the older an ewe gets the more opportunities she has had to produce a lamb. This can also be seen in the Namaqua Afrikaner sheep, older ewes had more opportunities to lamb and also have had a greater number of lambs born (Qwabe, 2011).

4.4 Regression models

Table 4.9: Regression model for Average inter-lambing period (Days)

Model	R	R Square	Adjusted R Square
1	.387[a]	.150	.140

a. Predictors: (Constant), Wither Height

Regression equation for predicting the Average inter-lambing period variable = (16.94 x Wither Height) -724.94

The Average inter-lambing period variable resulted in a significant model of R^2= 0.150, P<0.001; adjusted R^2= 0.140. The adjusted R^2 value of 0.140 indicates that approximately 14% of the variability in the Average inter-lambing period variable could be predicted by the Wither Height variable. The following guidelines, presented by Evans (1996), were used to interpret R^2: very weak (0-4%); weak (4-16%), moderate (16 – 36%); strong (36-64%) and very strong (64-100%). From these guidelines, it can be deduced that the model that was constructed had a weak predictive power towards the average inter-lambing period variable. The only predictor of average inter-lambing period was the wither Height (β = 0.387) variable. The results appear to suggest that an increase in wither height seems to correlate with an increase in average inter-lambing period, as can be seen in wither height β = 0.387 value.

Age seems to play a significant role (P<0.001) in determining average inter-lambing period, as can be seen in Table 4.15. Older ewes tend to have a higher average inter-lambing period. Wither height only increases partially with age, as depicted in Table 4.15 with ewes with one pair of incisors not differing significantly (P>0.001) from ewes with four pairs of incisors. This seems to indicate that wither height is affected to a lesser degree by age, but this does not seem to be the primary reason for it being a predictor of average inter-lambing period.

Another argument could be made, based on the assumption that within a decade the Meatmaster breed has slowly been moving toward a more Euro-type breed. This

argument rests on two pieces of evidence: earlier linear body measurements conducted on Meatmaster by Peters (2011) indicated that they had larger wither height values, and Afro-type breeds tend to have higher Wither height measurements, including wild breeds such as Mouflons (Qwabe, 2011; Garel *et al.,* 2003). The Afro-type breeds seem to have longer average inter-lambing period with a higher tendency to have multiple-births, which is constant in the literature (Schoeman *et al.*, 1991; Qwabe, 2011). Schoeman *et al.* (1991) recorded an average inter-lambing period in Karakul sheep of 293.60±2.78 days which is higher than that of the Meatmaster at 258.64±151.3 days. The assumption can therefore be made that the Afro-type Meatmaster has a higher wither height and an increase in wither height follows an increase in average inter-lambing period. Very little information about the interplay between wither height and average inter-lambing period is available in the literature. This may be due to the unique characteristics present in the Meatmaster breed and shared by other Afro-type sheep breeds. This argumentation is in line with the intuitive knowledge that different breeds are unique and differ in their phenotype (Gutierrez *et al.,* 2005; Kashan *et al.,* 2005; Okendo *et al.*, 2005).

Table 4.10: Regression model for Age at First Lambing (Months)

Model	R	R Square	Adjusted R Square
1	.293[a]	.086	.075
2	.403[b]	.162	.143
3	.480[c]	.230	.203
4	.518[d]	.269	.234
5	.551[e]	.303	.262

a. Predictors: (Constant), Rump Length

b. Predictors: (Constant), Rump Length, Body Weight

c. Predictors: (Constant), Rump Length, Body Weight, Skin Thickness

d. Predictors: (Constant), Rump Length, Body Weight, Skin Thickness, Femininity

e. Predictors: (Constant), Rump Length, Body Weight, Skin Thickness, Femininity, Chest Width

Regression equation for predicting the Age at first lambing variable = (1.022 x Rump Length) + (-0.235 x Body Weight) + (-2.502 x Skin Thickness) + (1.424 x Femininity) + (0.556 x Chest Width) – 0.612

The second regression model resulted in a significant model R^2= 0.303, P<0.001; adjusted R^2= 0.262. The adjusted R^2 value of 0.262 indicates that approximately 26% of the variability in age at first lambing variable could be predicted by a combination of the rump length, body weight, skin thickness, femininity and chest width variables. The model that was constructed therefore had a moderate predictive power towards age at first lambing variable.

To predict age at first lambing remains a complicated endeavour, which could be one of the reasons why there are many variables that play a role in determining this trait. As can be seen, heavier ewes tended to have a lower age at first lambing variable (Body weight β = -0.235). Ewes need to be of a certain weight before the onset of puberty occurs. This is reflected in the literature that body weight plays a pivotal role in determining when puberty occurs, as determined by Kertz *et al.* (1998) in a study on Holstein cattle. In a study conducted by Pereira *et al.* (2017), Hereford cross-bred heifers had a negative

correlation between weight to height ratio and early puberty. The age at which a ewe produces her first lamb as measured in months is usually an indication of how early the breed becomes sexually matured. The Meatmaster becomes sexually mature at the young age of 10 months. A larger rump length seems to indicate an increase in the age at first lambing variable (Rump length β = 1.022) but has a R² value of 0.075. A study by Fourie *et al.* (2013) indicated that rump length had a very low correlation (0.04%) to pelvic area, and the assumption can be made that rump length has a very low correlation with traits that are deemed to be of productive importance. In a study conducted by Kumar *et al.* (2016) on Harnali sheep, body measurements also correlated to age at first lambing, although none of their results correlates with those of the Meatmaster. The Harnali sheep's highest correlation (0.13±0.02) was between body length and age at first lambing, indicating that breeds differ between what phenotype is most effective.

Table 4.11: Regression model for Number of Lambs Born

Model	R	R Square	Adjusted R Square
1	.404[a]	.163	.154
a. Predictors: (Constant), Wither Height			

Regression equation for predicting the Number of lambs born variable = (0.1934 x Wither Height) -7.910

The third regression model resulted in a significant model R^2= 0.163, P<0.001; adjusted R^2= 0.154. The adjusted R^2 value of 0.154 indicates that approximately 15.4% of the variability in the number of lambs born variable could be predicted by the wither height variable. The model that was constructed therefore had a weak predictive power towards the number of lambs born variable.

Number of lambs born is a measurement of how many lambs are born per ewe if she had 3.33 lambing opportunities. For example, the Meatmaster breed has an average of 4.36 number of lambs born from 3.33 lambing opportunities. This indicates that the Meatmaster has a higher number of lambs born per lambing opportunity; when compared to studies such as that of Duguma *et al.* (2002), that found Merino ewes produced 5.2 lambs in 6 lambing opportunities; and Snyman *et al.* (1997) reported an average of 2.22 lambs born per ewe given 3 lambing opportunities for Afrino sheep.

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Duguma *et al.* (2002) found that the major influences (P<0.01) on the ewe's production over her lifetime (including number of lambs born) was the specific season in which the ewe was born her body weight as well. Number of lambs born seems to be positively correlated with wither height given a β = 0.1934 value which can be due to the fact that older ewes have had more opportunities to lamb and have a higher average wither height than for example those of ewe lambs. Age (measured in days) also plays a significant role (P<0.01) in the trait average inter-lambing period. The correlation between number of lambs born and the age of the ewe as measured in days correlates 74.4% (as seen in Table 4.8). This is also supported by Table 4.15 which indicates that age does play a significant role (P<0.001) in determining number of lambs born, for number of lambs born increases positively with age. Qwabe (2011) found similar conclusions while studying Namaqua Afrikaner sheep: the age of an ewe contributes significantly (P<0.01) to the number of lambs that the ewe has produced. Very little information about the interplay between wither height and number of lambs born is available in the literature. A possible reason for the little information available may be because of the unique characteristics present in the Meatmaster breed and also shared by other Afro-type breeds. This type of argumentation is in line with the intuitive knowledge that different breeds are unique and differ in their phenotype (Gutierrez *et al.,* 2005; Kashan *et al.,* 2005; Okendo *et al.,* 2005).

Age thus plays an important role in determining the number of lambs that an ewe has produced, but why wither height seems to be the only predictor the following could serve as a reason. The argument according to Bergmann's rule that mammals that are adapted to warm semi-arid environment tend to have longer and thinner legs may be entertained (Gohli *et al.,* 2006). This adaptation helps them to move greater distances in search of food and gives the least resistance in difficult terrain (sandy dunes for example). Another argument could be based on the assumption that within a decade the Meatmaster breed has slowly been moving towards a more Euro-type breed. This argument rests on two pieces of evidence: earlier linear body measurements conducted on the Meatmaster by Peters (2011) indicated that they had larger wither height values, and Afro-type breeds are inclined to have higher wither height measurements, including wild breeds such as Mouflons (Garel *et al.,* 2003; Qwabe, 2011). The Afro-type breeds seem to have a higher tendency to have multiple births, which is constant in the literature (Schoeman *et al.,*

1991; Qwabe, 2011). As can be seen by Qwabe (2011), who recorded an average of 4.49 lambs born with only an average of 3.10 lambing opportunities, multiple births are very common among Namaqua Afrikaners. Ewes with the larger wither height values of the Afro-type breeds have a higher number of lambs born over their lifetime. An assumption can also be made that ewes capable of traversing larger areas are able to graze and forage more, thus having more reserves to produce more lambs. This is a phenotypic trait that was inherited from the Damara breed, which is highly adapted for semi-arid environments.

Table 4.12: Regression model for Number of lambs weaned

Model	R	R Square	Adjusted R Square
1	.360[a]	.130	.120
2	.422[b]	.178	.159

a. Predictors: (Constant), Chest Depth
b. Predictors: (Constant), Chest Depth, Chest Width

Regression equation for predicting the Number of lamb's weaned variable = (0.366 x Chest Depth) + (-0.0183 x Chest Width) - 6.395

The fourth regression model resulted in a significant model R^2= 0.178, P<0.001; adjusted R^2= 0.159. The adjusted R^2 value of 0.159 indicates that approximately 15.9% of the variability in the number of lamb's weaned variable could be predicted by the chest depth and chest width variables. These guidelines indicate that the model that was constructed had a weak predictive power towards the number of lamb's weaned variable.

This seems not to be the case of most of the reproductive traits found in the Meatmaster which have relative low correlations. Chest width has a negative R²-value prediction with number of lambs weaned (as can be seen by the β = -0.0183 value). In ewes a large chest width is associated with a more masculine appearance, with rams having a larger chest width than ewes, as seen in Table 4.1. In addition, reproductive measurements in rams such as scrotal circumference correlate higher (37.8%) with chest width than those of ewe reproductive measurements such as pelvic area (4.5%). It can thus be concluded that the more feminine ewes have a smaller chest width and produce more lambs.

This could also be a unique trait to the Meatmaster, for in a study conducted by Al-Abdullah *et al.* (2011), a significant difference (P<0.001) between chest width of the Awassi and Chios ewes in its relation to their number of lambs weaned was reported. This seems to be influenced by the dam breed and not by individual lamb differences; in other words, the specific breed plays a significant role in certain body measurements. Factors that significantly (P<0.01) influence the number of lambs weaned seems to be: birth states of the ewe (ewes with a multiple birth status having a larger number of lambs weaned) and the specific year in which the ewe was born (Duguma *et al.,* 2002).

Table 4.13: Regression model for Body Weight of rams

Model	R	R Square	Adjusted R Square
1	.944[a]	.892	.890
2	.959[b]	.920	.917
3	.968[c]	.938	.935

a. Predictors: (Constant), Chest Girth
b. Predictors: (Constant), Chest Girth, Chest Width
c. Predictors: (Constant), Chest Girth, Chest Width, Wither Height

Regression equation for predicting the Body Weight of rams = (0.956 x Chest Girth) + (2.351 x Chest Width) + (0.639 x Wither Height) - 112.714.

The regression model resulted in a significant model R^2= 0.38, P<0.001; adjusted R^2= 0.935. The adjusted R^2 value of 0.935 indicates that approximately 93.5% of the variability in the body weight of rams could be predicted by a combination of the chest girth, chest width and wither height variables. From these guidelines, it can be observed that the model that was constructed had a very strong predictive power towards the body weight of rams.

The gender and age of the animal have a significant influence (P<0.001) in determining body weight, with rams being heavier than ewes and older rams being heavier than younger rams (Afolayan *et al.,* 2006; Fourie *et al.,* 2002; Qwabe, 2011). Chest girth plays an important role in predicting the body weight of rams and ewes, but specifically in rams. It can be observed that a positive increase in chest girth in rams has a positive increase in body weight (β = 0.956). A ram with a wide chest is regarded as a more masculine ram,

which could be one of the reasons for it having the highest Beta value ($\beta = 2.351$). Wither height is a strong predictor of body weight, especially in cattle. Measurements that are commonly used to determine body weight in cattle breeds are body length, wither height and chest girth, with chest girth being the most reliable measurement (Benyi, 1997). Goe *et al.* (2000) also found an 87% predictive value between chest girth and body weight in working oxen.

With a predictive power of 93.5%, the body weight of a ram can be determined with relative ease without using modern weight measuring equipment. This can be valuable in certain remote and rural areas where electricity and modern equipment are scarce. Generating strongly predictive regression models could in the long run help farmers who are not able to afford electronic weight prediction equipment.

4.5 The Influence of Age on Linear Body measurements and Performance Traits

Table 4.14: Influence of Age on Linear body measurements of rams

	Set of milk teeth	One pair of incisors	Two pairs of incisors	Three pairs of incisors	Four pairs of incisors
Body Weight (in kg)	52.156±2.7[a]	79.313±9.0[b]	85.633±10.2[b]	90.154±17.2[b]	103.071±17.1[c]
Head Length (in cm)	24.162±1.6[a]	23.588±1.2[a]	24.300±2.2[a]	25.777±1.5[b]	24.643±1.5[ab]
Neck Length (in cm)	31.276±4.5[a]	27.409±5.0[a]	28.968±5.4[a]	31.746±4.9[a]	27.857±5.1[a]
Chest Girth (in cm)	86.73±4.6[a]	103.59±5.8[b]	105.46±5.6[b]	106.13±8.6[b]	113.21±9.4[c]
Tail Length (in cm)	37.152±3.8[a]	38.240±5.2[a]	38.977±5.1[a]	38.131±3.5[a]	39.357±1.7[a]
Wither Height (in cm)	60.290±3.5[a]	64.122±3.8[b]	63.164±3.2[ab]	66.508±3.8[bc]	68.471±4.8[c]
Chest Depth (in cm)	33.067±1.8[a]	37.788±2.2[b]	37.714±1.6[b]	39.931±1.8[c]	40.671±1.3[c]
Chest Width (in cm)	20.067±2.3[a]	23.515±1.9[b]	25.077±2.8[bc]	24.146±2.5[b]	26.571±2.7[c]
Body Length (in cm)	70.21±3.5[a]	79.27±4.4[b]	80.46±3.7[b]	82.68±5.7[b]	87.69±5.4[c]
Rump Length (in cm)	20.510±1.7[a]	21.720±3.4[a]	22.155±3.7[a]	23.485±1.7[a]	23.386±3.8[a]
Rump Width (in cm)	20.457±2.7[a]	24.260±2.2[bc]	24.100±2.2[bc]	23.831±4.7[b]	26.414±3.2[c]
Scrotum Circumference (in cm)	30.543±2.8[a]	35.630±2.5[bc]	35.659±2.0[bc]	35.192±2.6[b]	37.857±3.6[c]

Means with different superscripts within the same row differ significantly (P <0.001).

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Table 4.15: Influence of Age on Linear body measurements and Performance traits of ewes

	Set of milk teeth	One pair of incisors	Two pairs of incisors	Three pairs of incisors	Four pairs of incisors
Body Weight (in kg)	45.708±11.3[a]	56.904±11.0[b]	60.154±7.6[b]	60.607±12.8[b]	63.993±10.8[b]
Head Length (in cm)	22.404±1.8[b]	20.580±2.1[a]	23.043±1.7[b]	23.336±1.6[b]	23.197±1.8[b]
Neck Length (in cm)	30.100±3.3[a]	27.995±3.1[a]	28.952±4.5[a]	30.415±3.8[a]	28.100±4.5[a]
Chest Girth (in cm)	85.29±8.6[a]	91.79±7.5[b]	93.85±3.7[b]	94.58±7.4[b]	95.61±7.4[b]
Tail Length (in cm)	35.780±5.0[a]	36.468±5.4[a]	37.545±3.5[a]	36.464±4.9[a]	37.929±4.5[a]
Wither Height (in cm)	53.405±4.1[a]	60.695±5.0[c]	57.072±3.4[b]	60.757±4.0[c]	61.024±3.6[c]
Chest Depth (in cm):	30.449±2.3[a]	34.371±2.2[bc]	33.188±2.8[b]	35.264±2.1[cd]	36.058±1.9[d]
Chest Width (in cm)	19.754±2.2[a]	20.540±2.1[ab]	21.735±2.6[ab]	21.643±3.6[ab]	21.836±2.8[c]
Body Length (in cm):	65.46±5.3[a]	71.99±6.1[b]	74.44±5.1[bc]	74.48±5.3[bc]	77.05±4.3[c]
Rump Length (in cm)	19.715±2.2[a]	19.992±1.8[ab]	20.771±1.7[ab]	21.221±2.0[b]	21.148±1.6[b]
Rump Width (in cm)	19.061±2.8[a]	22.256±2.2[b]	21.455±3.5[b]	20.460±3.0[ab]	22.500±3.0[b]
Pelvic Width (in cm)	6.48±1.0[a]	7.44±1.0[b]	7.75±1.0[bc]	7.99±0.5[c]	8.05±0.7[c]

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Pelvic height (in cm)	6.49 ± 0.7^a	7.50 ± 1.0^b	7.86 ± 1.0^b	7.98 ± 1.0^b	8.01 ± 0.9^b
Pelvic Area (in cm²)	33.30 ± 6.5^a	44.04 ± 6.4^b	48.06 ± 6.9^{bc}	50.35 ± 7.2^c	51.04 ± 9.6^c
Age of First Lambing (months)	12 ± 0^a	14 ± 1.6^a	14.93 ± 3.0^a	15.52 ± 3.5^a	15.47 ± 4.2^a
Number of Times Lambed	1 ± 0^a	1.05 ± 0.2^a	1.71 ± 0.9^a	2.06 ± 0.7^a	4.36 ± 1.5^b
Number of Lambs Born	1.5 ± 0.7^a	1.21 ± 0.4^a	2 ± 1.1^{ab}	2.3 ± 0.9^{ab}	5.88 ± 3.5^b
Number of Lambs Weaned	1 ± 0^a	1.16 ± 0.4^a	1.57 ± 0.9^a	1.7 ± 1.0^a	4.64 ± 2.4^b
Average Inter-lambing Period	0 ± 0^a	18.53 ± 80.8^a	118.64 ± 146.3^{ab}	236 ± 135.2^{bc}	330.08 ± 151.3^c

Means with different superscripts within the same row differ significantly (P <0.001).

Table 4.14 and 4.15 will be discussed under as one heading. Gender and age play a significant (P<0.001) role in determining the phenotypic structure of a sheep (Afolayan *et al.,* 2006; Fourie *et al.,* 2002; Qwabe, 2011). The Meatmaster is not different in this aspect as age plays a significant role, not just between the two genders, but also within the same gender. Neck length and tail length seem to be the only measurements that do not differ significantly (P>0.05) both within rams and ewes, therefore age does not have a large impact on either neck- or tail length. Age seems to have a more significant influence (P<0.001) on body weight in rams than it has in ewes; the reason for this may be the increased selection pressure for rams or the fact that ewes have fewer opportunities to put on body weight as a result of production challenges (a ewe has to produce a lamb every year). Another reason for this could also be the emphasis for a selection of sexual dimorphism between the two genders, with rams being the larger and heavier gender. Fahim *et al.* (2013) reported similar findings that age plays a determined role in body weight, with body weight increasing with age in Rohilkhand goats. The same effect is

present in chest girth, in which age plays a more significant role (P<0.001) in rams than in ewes. Age also contributes a significant role (P<0.001) in pelvic measurements, but pelvic height seems to be the least influenced by the age of the ewe, with only lambs (Set of milk teeth age group) differing significantly. Fahim *et al.* (2013) recorded similar findings concerning pelvic width in which age played a large role. The Rohilkhand ewes' pelvic width also increased with age. Scrotal circumference is also significantly influenced (P<0.001) by age, with a positive increase as the rams get older.

4.6 Influence of Environment on Linear Body Measurements

Table 4.16: Influence of Environment on the Linear body measurements of rams

	Bethulie	**Calvinia**	**Kenhardt**	**Wesselssbron**	**Williston**
Body Weight (in kg):	82.833±10.6[b]	96.800±8.2[c]	75.800±13.3[b]	Not Measured	63.370±11.3[a]
Head Length (in cm):	23.509±1.2[a]	24.700±2.8[ab]	25.208±1.6[b]	24.233±1.6[ab]	24.870±1.5[ab]
Neck Length (in cm):	26.051±4.0[a]	32.060±4.8[b]	32.177±2.5[b]	32.994±5.2[b]	33.191±3.8[b]
Chest Girth (in cm):	105.33±5.3[b]	112.05±5.3[c]	100.87±9.8[b]	91.93±7.5[a]	92.00±6.3[a]
Tail Length (in cm):	38.000±4.9[a]	44.270±6.8[b]	38.500±2.5[a]	38.567±4.7[a]	36.487±3.3[a]
Wither Height (in cm):	64.891±3.8[a]	62.380±2.7[a]	62.131±3.3[a]	62.489±4.9[a]	61.426±3.9[a]
Chest Depth (in cm):	38.220±2.2[bc]	38.930±2.3[c]	36.662±2.4[ab]	34.406±3.2[a]	35.970±2.4[ab]
Chest Width (in cm):	23.935±1.8[bc]	25.650±1.5[c]	23.562±4.0[bc]	22.267±4.1[ab]	20.922±1.8[a]
Body Length (in cm):	81.17±4.5[b]	79.74±3.9[b]	75.10±4.5[a]	72.41±4.7[a]	73.96±4.7[a]
Rump Length (in cm):	21.903±3.6[ab]	24.310±3.6[b]	19.762±2.2[a]	21.522±1.8[ab]	21.691±2.0[ab]
Rump Width (in cm):	25.080±2.1[b]	24.110±1.6[b]	20.900±2.5[a]	23.311±1.7[b]	19.365±1.5[a]

Scrotum Circumference (in cm):	36.185±2.5[c]	35.050±2.9[bc]	33.154±3.7[ab]	32.039±2.5[a]	32.935±2.5[ab]

Means with different superscripts within the same row differ significantly (P <0.001).

Table 4.17: Influence of environment on Linear body measurements of ewes

	Bethulie	Calvinia	Kenhardt	Wesselssbron	Williston
Body Weight (in kg)	55.304±8.0[a]	67.748±2.4[b]	51.285±7.8[a]	Not Measured	48.182±13.6[a]
Head Length (in cm)	19.091±1.0[a]	22.833±1.2[b]	23.788±2.0[c]	21.831±1.6[b]	23.510±2.2[c]
Neck Length (in cm)	34.077±2.9[c]	26.740±2.3[a]	30.175±2.6[b]	26.000±3.7[a]	30.492±3.0[b]
Chest Girth (in cm)	94.46±5.3[bc]	98.59±1.8[c]	91.19±6.2[ab]	87.15±7.7[a]	89.37±9.2[ab]
Tail Length (in cm)	36.555±4.1[a]	38.182±4.1[a]	36.770±3.8[a]	37.867±5.6[a]	35.458±5.3[a]
Wither Height (in cm)	62.293±3.6[c]	57.669±3.0[b]	56.724±4.4[b]	62.027±3.3[c]	52.982±4.5[a]
Chest Depth (in cm)	35.637±2.6[cd]	36.306±1.3[d]	33.923±1.9[bc]	29.336±2.4[a]	33.530±2.9[b]
Chest Width (in cm)	23.079±1.5[b]	24.130±1.0[b]	20.209±1.9[a]	19.738±3.5[a]	19.591±2.2[a]
Body Length (in cm)	78.30±3.5[c]	73.25±3.3[d]	70.93±4.1[bc]	66.52±4.1[a]	69.57±6.2[ab]
Rump Length (in cm)	21.194±2.0[ab]	21.670±1.0[c]	20.021±1.6[a]	20.484±1.6[ab]	21.118±2.1[ab]
Rump Width (in cm)	24.484±1.9[b]	24.030±1.2[b]	19.317±1.6[a]	20.000±1.8[a]	19.082±2.2[a]
Pelvic Width (in cm)	7.82±1.0[b]	6.43±0.4[a]	7.83±1.0[b]	7.54±1.0[b]	7.64±1.0[b]
Pelvic height (in cm)	7.99±1.0[c]	6.59±0.2[a]	7.91±1.0[bc]	7.28±1.1[ab]	7.50±1.1[bc]
Pelvic Area (in cm²)	49.33±7.1[b]	33.34±2.8[a]	49.23±9.9[b]	43.68±11.5[b]	45.80±12.1[b]

Means with different superscripts within the same row differ significantly (P <0.001).

Table 4.16 and 4.17 will be discussed under one heading. As with age, the environment also plays a more significant role (P<0.001) in rams than in ewes, with rams differing more significantly between various environments than ewes do. This could be as a result of different selection standards and pressures between breeders. Tail length seems to be the least affected by different environments, with the only significant differences in rams from Calvinia. This could be due to the fact that the environment plays a lesser role in determining the length of the tail and a stronger genetic component is dominant. Neck length, especially in ewes, seems to be affected more by environment than by age, with ewes having a more significant difference (P<0.001) between neck lengths and rams demonstrating it to a lesser extent. If taking pelvic measurements into account, clarification should be given why they differ significantly. Only ewe lambs were measured in the Calvinia environment; and as evident in Table 4.15 age plays a significant role (P<0.001), especially in pelvic width and pelvic area. It can be argued that the only pelvic measurement with significant (P<0.001) differences between environments is that of pelvic height. The other aspects (that is, pelvic width and pelvic area) reveal no significant (P>0.001) differences, if taking into account the age of the ewes in the Calvinia sample. The evidence indicates that the environment plays a role in determining certain phenotypic expressions, even if it is just to degrees. This can also be seen in a study by Fourie *et al.* (2002), where the body measurements of two different Dorper ram populations were collected. The results showed a difference in morphological measurements. Canché *et al.* (2015) found that certain performance traits differed between Pelibuey ewe populations, for example litter size at birth and litter size at weaning.

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Chapter 5

Conclusions and Recommendations

5.1 Summary

Grounded in the vision of creating a widely adaptable, low input/ low cost, economically viable mutton sheep breed, the dream of a composite breed was established. By combining the adaptability and fertility of the Damara sheep with the highly sought-after carcass and conformation of the Dorper and Ile de France, the Meatmaster was born (Peters, 2011). The Meatmaster is a low input/ high output, mutton, hair- and non-fat tailed sheep breed. Mainly bred for the harsh environmental pressures of the arid South-African production areas, it distinguishes itself under extensive production environments (Meatmaster Journal, 2019). This study clearly indicated that the Meatmaster is a widely adapted and highly fertile breed. It has also been proven that the Meatmaster is a unique breed, based on the foundations of phenotype, productive performance and genetics. These objective grounds clearly indicate that the Meatmaster not only differs from its parental breeds but can be classified as a unique composite breed on its own.

5.2 Phenotype of the Meatmaster

The phenotype of the Meatmaster can be best explained within concepts like an Afro-type breed (breeds adapted to the Southern-African environment, like the Damara), an Euro-type breed (breeds that are adapted to more temperate climates, like Dorpers and Ile de France) and an All-rounder type (this is a mixture between the two types and possibly bests describes the Meatmaster).

All body measurements exhibited a significant difference (P<0.001) between the genders, except for neck length (P>0.001) and tail length (P>0.001). Neck length seems to be the only measurement in the Meatmaster breed that has a bigger value in ewes (+1.27 cm larger) than in rams. The Meatmaster breed has an average pelvic area of (46.69±10.62 cm^2), which ranges from lambs with 33.30±6.5 cm^2 to four incisor ewes with 51.04±9.6

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cm^2. This is in line with the view of Van Rooyen *et al.* (2012) that ewes with larger pelvic areas will eventually have less dystocia.

The Meatmaster breed is known as an early-maturing breed which is evident in the data with the youngest ewe in the study lambing at the age of 10 months and subsequently produced three lambs at an age of 1118 days (she is still in production). The average age at first lambing for the breed ranges around 15.24 months. Multiple births are very common in the Meatmaster breed with a ewe producing 4.36±3.4 number of lambs per 3.33±1.8 lambing opportunities. This is also discernible in breeds like the Namaqua Afrikaner with 4.49 lambs born from 3.10 lambing opportunities (Qwabe, 2011).

5.3 Phenotypic correlations and predictions

The highest morphological correlation (excluding pelvic measurements) is that between chest girth and body weight with an 89.5% correlation for rams and an 89.7% correlation for ewes. The body weight in the ewes also seems to correlate higher with rump width at 79.1% than that of rams, which is 67.7%. The mean scrotal circumference of all rams finds its highest correlation with chest girth at 53.4%. In both rams and ewes neck length is the only measurement that correlates negatively with body weight, namely rams at -8% and ewes at – 9%.

Interesting predictions were found when regression models were applied to the phenotypic performance characteristics. Wither height is the only measurement that has a predictive correlation with performance variability such as average inter-lambing period and number of lambs born, with R² values of 0.14 and 0.15 for average inter-lambing period and number of lambs born respectively. This is an indication that wither height plays a pivotal role in certain productive aspects of the Meatmaster breed. Wither heights lead to an increase in both average inter-lambing period and number of lambs born (multiple births). Thus, moving away from Afro-type breed (that is perceived in the literature as having a higher average wither height) could possibly reduce the Meatmaster's fertility.

The body weight of rams had the highest predictive power with an R² value of 0.94, calculated from the following linear body measurements: chest girth, chest width and

wither height. This is a 94% predictive value that can be determined without the need of modern weight measuring equipment and could possibly play an important role for farmers in rural areas in determining body weight, where electricity is scarce and modern equipment is usually too expensive.

5.4 Influence of Age

Age seems to play a significant role (P<0.001) on most body measurements, which is the case in most of the literature (Afolayan *et al.,* 2006; Fourie *et al.,* 2002; Qwabe, 2011); with the exception of neck- and tail length which do not differ significantly (P>0.001) in both age and gender. Age seems to have a more significant influence (P<0.001) on body weight of rams that it has of ewes; which can be due to the increased selection pressure in rams or to the fact that ewes have less opportunity to increase body weight due to production restrictions (a ewe has to produce a lamb every year). Sexual dimorphism also could play a role in the difference in body weight between the genders.

Within the performance traits age seems to influence average inter-lambing period the most. As age and average inter-lambing period is positively correlated, the older the ewe becomes, the larger her average inter-lambing period becomes. Of all the Performance traits, age at first lambing seems to be the least influenced by age; for its does not differ significantly (P>0.001) between age groups. This is mainly due to the concept of sexual maturity; animals of the same breed usually have a genetically driven element that forces them to become sexually mature at a certain age.

5.5 Influence of Environment

The environment has a more significant role (P<0.001) to play in rams than in ewes, with rams differing more significantly between environments than ewes do. This could be due to different selection standards and pressures between breeders. Tail length seems to be least affected by different environments, which could because of genetic elements that are not greatly affected by the environment. For example, environment has a larger effect on one's body weight than it has on the number of fingers you have. Neck length in ewes seems to be affected more by environment than by age, with ewes having a more

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significant difference (P<0.001) between neck lengths but rams to a lesser extent. This could be due to neck length being a more feminine trait.

5.6 Recommendations

- The high positive correlation between chest girth and body weight emphasizes the importance of selecting rams with a deeper and more robust front quarter. In males this trait seems to be of high importance.

- In ewes, wither height is the measurement that correlates the highest with performance traits. Ewes with higher wither heights has an increase in both inter-lambing periods as well as the number of lambs born per ewe.

- Sexual dimorphism should be one of the corner stones in any sheep production system, for it will increase long-term fertility and functional efficiency of any breed. Rams should be selected for increased chest girth in combination with masculinity while in ewes, selection should focus on rump length and width.

- Pelvic measurements should form part of any selection system, because of its high correlations with reduced dystocia (Van Rooyen *et al.,* 2012). The Meatmaster has a relatively large pelvic area (46.69±10.62 cm²), which may be the reason for the breed's ease of birth.

- Neck length is the only measurement that is larger in ewes than in rams. This seems to be a feminine trait, for ewes should have a longer and thinner neck than rams. The Meatmaster seems to be a unique combination between an Afro- and Euro-type sheep breed, which makes it highly flexible when adapting to new environments. It is recommended that in harsher environments, the focus should be on higher wither height, for it correlates better with the Afro-type Meatmaster. The environment thus plays a decisive role in how an animal's phenotype is eventually presented.

- Visual appraisal directed at functional efficiency in a balanced combination with performance test results, breeding values and pedigrees, has proven to enhance genetic progress and is also recommended for this breed.

- Functional efficiency plays a pivotal role in selecting for the right phenotype for your environment. Functional efficiency should be grounded in the idea of an

animal being morphologically sound for its environment (no genetic defects), being able to grow (to mature acceptably from birth to weaning), being able to reproduce (to reproduce at an acceptable rate per annum), being able to lactate (have an acceptable milk yield to support its growing young) and being able to fatten (have an acceptable growth rate from weaning to sale) in its present environment. The term 'acceptable' is used to describe a large range of production factors specific to an environment; for example, livestock in temperate climates has the potential of having a much higher rate of production than livestock in a desert climate.

- Bergmann's rule (Bergmann, 1847) should also be one of the corner stones in the idea of what creates a functionally efficient animal in a specific environment. Mammals adapted to temperate environments have a square shaped body, with a smaller ratio of skin to body weight. Mammals adapted to arid environments have an oval shaped body, with a larger area of skin in contact with the outside environment compared to the animal's total body weight (Gohli *et al.,* 2006).

- Recommended research on the effect of wither height on reproductive traits in other Afro-type sheep breeds could help us better understand the role this measurement plays in the adaptive phenotype of these breeds.

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Addendum A: Scientific Paper
Phenotypic characterisation of Meatmaster sheep using quantitative and qualitative trait analysis

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Abstract
A phenotypic analysis of the Meatmaster breed was done, using linear body measurements, qualitative assessment, slaughter data, and pedigree performance data. The linear body measurements and pedigree performance data were collected from 187 rams and 222 ewes of all age categories. The following means were recorded in rams and ewes respectively: Body Weight (kg) (80.47±13.33; 57.51±12.43), Head Length (cm) (23.93±1.55; 22.68±2.05), Neck Length (cm) (28.35±5.16; 29.61±3.82), Chest Girth (cm) (102.45±8.42; 92.95±8.08) Tail Length (cm) (38.24±4.88; 36.64±4.70), Wither Height (cm) (63.91±4.04; 58.99±4.86), Chest Depth (cm) (37.51±2.97; 34.47±2.97), Chest Width (cm) (23.47±2.56; 21.24±2.85), Body Length (cm) (78.95±5.59; 72.67±6.06), Rump Length (cm) (21.82±3.29; 20.77±1.93) Rump Width (cm) (23.87±2.82; 21.36±3.15), Skin Thickness (mm) (2.846±0.5; 2.805±0.5), Pelvic Length (cm) (7.66±.98), Pelvic Width (cm) (7.66±.90), Pelvic Area (cm^2) (46.69±10.62) and Scrotal Circumference (cm) (35.12±3.03). The pedigree performance data of 177 ewes showed the following means: Age at First Lambing (15.242±3.8 months), Number of Times Lambed (3.33±1.8), Number of Lambs Born (4.36±3.4), Number of Lambs Weaned (3.44±2.5) and Average Inter-lambing Period (258.64±151.3 days). Slaughter data was compiled from 2251 animals of different genders and ages the means are as follows measured in (kg): A-grade carcass (16.77±4.1), AB-grade carcass (24.039±13.8), B-grade carcass (26.904±13.3) and C-grade carcass (24.88±4.9). A predictive value of R^2= 0.140 was observed between wither height and average inter-lambing period as well as a R^2= 0.154 between the wither height and number of lambs born. This seems to be a characteristic of the Afro-type breeds which have a higher wither height and also have a higher tendency to birth multiple lambs per lambing opportunity.

Keywords: Linear body measurements, Meatmaster, production performance
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Conflicts of interest/Competing interests
The authors declare there is no conflict of interest.

Availability of data and material
Not applicable.

Code availability
Not applicable.

Authors' contributions
The trials were executed by SJB while PJF supervised.

Ethics approval
Not applicable.

Consent to participate
Not applicable.

Consent for publication

Not applicable.

Introduction

The phenotypic description of an animal's morphological characteristics includes the physical appearance, productive parameters, adaptive traits and environmental factors under which performance measurements have been recorded (Rege & Lipner, 1992). The variance within production and phenotype of a specific breed should be conducted over a range of varying environments, this is essential for creating a credible phenotypic mean (Yakubu *et al.*, 2010). Linear body measurements (LBM) have been proven as useful information in genetic improvement programs; the basis of using morphological traits in selection can be sustainable and improve animals on a functional evolutionary path (Janssens *et al.*, 2004). Every animal species and individuals have a unique genotype and phenotype. The phenotype is the genotype being mapped into a specific environment and that proses follows specific genetic and environmental laws (Pigliucci, 2001). The performance traits of an animal are usually described in the terms of productivity, but adaptations to an environment is another tool of variation that can be used to identify unique breeds and is very useful in the proses of selection (McManus *et al.*, 2010). The collection of data from individual animals (morphological, pedigree and performance) could be used within management systems for selection purposes and could thus lead to the improvement of the productive/economic traits of the breed (Gabina, 2002).

This knowledge is then used to provide guidance in determining if the animal is functionally efficient in its environment, or if it is adapted to its environment. A simple and correct definition of mammal adaptation is provided in that the animal is able to transition through these four stages of its life cycle (growth, reproduction, lactation and fattening) in its natural environment with little or no intervention by human beings and to produce a marketable product at the end (Mentz, 2016). It can thus be selected for functional efficiency in mammals on the grounds of being morphologically sound for its environment (no genetic defects), being able to grow (to mature acceptably from birth to weaning), being able to reproduce (to reproduce at an acceptable rate per annum), being able to lactate (have an acceptable milk yield as to support its growing young) and being able to fatten (have an acceptable growth rate from weaning to sale) in its present environment. The term acceptable is used to describe a large range of production specific to an environment for example; livestock in temperate climates has the potential of having a much higher rate of production than livestock in a desert climate. It is then up to the person in charge of selection to find the most functionally efficient breeds for his specific environment. Or as put by Steyl (2018) the term functional efficient is determined by the animal's capability to perform and reproduce in its environment with as little as possible intervention and input costs.

The development of the Meatmaster was characterised by crossing different breeds, retaining effective crosses and refining through the selection of favored characteristics. After various cross breeds were tested the conclusion was that a Meatmaster must contain a percentage Damara blood, and it may include a varying component from the Dorper, Ile de France, Wiltshire horn, Van Rooy, South African Mutton Merino, Dormer and other sheep breeds (Peters, 2011).

The aim of this study was to create a phenotypic picture of the Meatmaster breed in South-Africa using scientific techniques such as linear body measurements (LBM), qualitative assessment (QA), slaughter data (SD) and pedigree performance data (PPD).

Materials and Methods

The Meatmaster breed's phenotypic analysis was conducted over five different areas within South-Africa, from 2019 to 2020 to eliminate seasonal bias. Four hundred and nine (409) animals were measured; this is comprised of one hundred and eighty-seven rams (187) and two hundred and twenty-two ewes (222). Specific breeders were chosen for this study, all of these breeder's farm with Studbook approved animals which give a certainty that these animals are pure Meatmasters and not just randomized crosses. Secondly, it was attempted to represent registered breeders from as many areas as possible as the ecology of the regions differs from each other. Data was collected by conducting different body measurements on both ewes and rams. All measurements were taken by the same person, to minimize variability and measuring bias (Mohammed, 2018). Two methods of recording age were used; one being dentistry (identifying the number of incisors pairs an animal possesses from 0-Incisor to 4-Incisor pairs) and the other being production records (birth records), the latter being more accurate. Twelve LBM including body weight (BW) was recorded from the males and thirteen body measurements including body weight were recorded from the females. This excluded the five qualitative traits (back profile, colour, horn presence, rump fall and wool fleece extent) that

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were measured for both rams and ewes. Furthermore, seven phenotypic performance traits were measured from each ewe (these data were retrieved from the production records held by the owners). The method of LBM was chosen as it is widely used in the literature when describing morphology (Afolayan *et al.*, 2006; Kunene *et al.*, 2007; Qwabe, 2011). LBM were recorded according to the guidelines of Fourie *et al.* (2002).

The environments chosen for this study are mainly divided into two biomes: the Nama-Karoo and the Grassland Biome (Kenhardt being the exception, with both the Savanna and the Nama-Karoo Biome), which provided a good overview of the two extreme environments and the Meatmaster's ability to adapt to both. Three of the five breeders were part of the original founding Meatmaster breeders, which provides important information concerning the original bloodlines of this breed. It is important to note that during the collection of the data, the Northern Cape was still in the grasp of a drought that had been raging for seven years. The study areas were the following:

1. Bethulie (Free State)
   Bethulie is situated in the South Western part of the Free State province. It is situated within the Grassland Biome of South-Africa (Mucina & Rutherford, 2006). It receives an average annual precipitation of 481 mm. The average temperature is 16.1 °C, but ranges from 22.7 °C (January) in its warmest month to 8.3 °C (July) in its coldest month (climatedata, 2020).
2. Calvinia (Northern Cape)
   Calvinia is situated in the South Western part of the Northern Cape and is located within the Succulent-Karoo Biome of South-Africa (Mucina & Rutherford, 2006). An average annual precipitation of 216 mm is recorded which is seasonally bounded (to the winter months). It has an average temperature of 16.4 °C, but ranges from 22.4 °C (February) to 10.1 °C (July) (climatedata, 2020).
3. Kenhardt (Northern Cape)
   Kenhardt is situated in the Northern central part of the Northern Cape, and forms part of the Nama-Karoo Biome of South-Africa (Mucina & Rutherford, 2006). This is a very dry region with an average annual rainfall of 148mm. The temperatures range from 36 °C in of January to 2 °C in July, with an average of 28.1 °C (climatedata, 2020).
4. Wesselsbron (Free State)
   Wesselsbron is situated in the Northern central part of the Free State province and is positioned within the Grassland Biome of South Africa. It receives an average annual precipitation of 451 mm, mostly occurring in summer with an average temperature of 16.4 C° recorded in this area. Temperatures range from 32 °C in January to 1 °C in July (Mucina & Rutherford, 2006).
5. Williston (Northern Cape)
   Williston is situated in the South-Central part of the Northern Cape, within the Nama-Karoo Biome of South-Africa (Mucina & Rutherford, 2006). This is a typical Karoo area with a low average annual rainfall of 179mm. The temperatures range from 33 °C in January to 1 °C in July, with an average of 24.9 °C (climatedata, 2020).

Pelvic area (PA) measurements were taken using a pelvic meter (Patent P59736ZP00). The pelvic meter has been found to be a useful and reliable instrument for measuring the dimensions of the pelvic area (Van Rooyen *et al.*, 2012). Pelvic width (PW) was taken at the widest two points between the right and left ilium shafts. Pelvic length (PL) was measured as the distance between the sacrum and the dorsal pubic tubercle located at the bottom of the pelvis. The equation used to calculate pelvic area is represented by Morrison *et al.* (1986) where PA = π (PH/2)*(PW/2). Following the right procedure will entail an accurate measurement, thus the guidelines for taking an accurate pelvic measurement is as follow. Restrain the animal either with ropes or if possible, in a chute utilizing a light squeeze, try to let the animal stand as normal and comfortably as possible. Remove the excess faeces from the animal's rectum to improve accuracy and then enter the animal rectally with the instrument (Deutscher, 1975). When the animal was entered rectally the instrument can be opened and slight pressure was applied on the handles of the instrument. The instrument was then moved around inside the rectal cavity, not entering too deep with the objective being to locate the ossified joint on the pubic symphysis. Once it was located it served as a reference point in measuring the pelvic length between the dorsa pubic tubercle on the bottom of the pelvis and the sacrum at the top. The width of the pelvic was then measured by turning the instrument 90° (clocks wise or anti-clocks wise) holding a constant light pressure to the outside of the pelvis as to measure the widest points between the right and left shafts of the ilium bones, providing the horizontal measurement of the pelvis. Pressure on the handles of the instrument was then released, and slowly removed from the rectal cavity as not to harm the animal. Between each animal the instrument was cleaned with a wipe; then rinsed with water and finally a disinfectant mixture to avoid pathogens being transferred between

animals. (Cloete *et al.*, 1998; Haughey & Gray, 1982; Kilgour & Haughey, 1993; Morrison *et al.*, 1986; Patterson & Herring, 1997; Van Donkersgoed, *et al.*, 1990; Van Rooyen *et al.*, 2012; Walker *et al.*, 1992).

Skin thickness (ST) was measured using a caliper on the double fold skin between the brisket and the left foreleg as described by Fourie *et al*. (2002). The measurement of ST holds numerous benefits in wool production (Brown *et al.*, 2000) and in utilizing as a measurement for tick resistance. Secure the animal in a seated position. While the animal was firmly secured the caliper toe was opened wide enough so it can easily move over the skin. The caliper's adjustable bottom part was closed using the thumb, so the skin of the animal is trapped between the pincers of the caliper. Constant pressure was then applied using the thumb after which the caliper was removed from the animal as to observe the measurement.

A stepwise regression was carried out using SPSS (Version 26) to determine the individual influence of body measurements on performance. An F to enter level of 0.05 was used to determine the significance of the partial contribution of each effect. Pearson correlations were conducted on the body measurements in both rams and ewes, following the guidelines of Field (2009). In order to investigate the difference between various age and area categories the Hochberg's GT2 post hoc test was conducted. A Multiple Regression Analysis was conducted on five models using LBM as the variables. In the next step of the multiple regression analysis the tool of Model Summary boxes was used. The Durbin-Watson statistical test was used for the assumption to be made that the residuals are independent (or uncorrelated).

Results and Discussion

All body measurements showed a difference (P <0.001) between the genders, except for neck length (NL) (P >0.001) and tail length (TL) (P >0.001). NL seems to be the only body measurement in the Meatmaster breed that has a larger value in ewes (+1.27 cm larger) than in rams. The Meatmaster ewes had an average PA of (46.69±10.62 cm^2); this ranges from (33.30±6.5 cm^2) in lambs to (51.04±9.6 cm^2) in four incisor paired ewes. These measurements are in line with the measurements reported by Van Rooyen *et al.* (2012) in Dorper ewes. The Meatmaster breed as a whole seems to have thinner skin than that of the Dorper breed. This can be seen in the Meatmasters rams skin measuring; 2.85±0.5 cm, compared to the, 3.1±0.4 cm of Dorper rams (Fourie *et al.*, 2002).

Table 1 Mean (± SD) of Age at first lambing, Number of times lambed, Number of lambs born, Number of lambs weaned and mean inter lambing period of Meatmaster ewes

Performance traits:	N	Mean±SD
Age at first lambing (as measured in months)	177	15.2±3.8
Number of times lambed	177	3.33±1.8
Number of lambs born	177	4.36±3.4
Number of lambs weaned	177	3.44±2.5
Mean inter lambing period (as measured in days)	177	259±151.3

The Meatmaster breed is known as an early maturing breed which can be seen in the data with the youngest ewe in the study lambing at the age of 10 months and has produced three lambs at an age of 1118 days (she is still in production). The average age at first lambing (AFL) for the breed ranges around 15.24 months. Multiple births are very common in the Meatmaster breed with a ewe producing 4.36±3.4 number of lambs per 3.33±1.8 lambing opportunities. This can also be seen in breeds like the Namaqua Afrikaner with 4.49 lambs born from 3.10 lambing opportunities (Qwabe, 2011).

Table 2 Means (± SD) Body weight, Head length, Neck length, Chest girth, Tail length, Wither height, Chest depth, Chest width, Body length, Rump length, Rump width, Pelvic length, Pelvic width, Pelvic area and Scrotal circumference of Meatmaster rams and ewes

Variables	Rams	Ewes
Body Weight (kg)	80.5±13.3[a]	57.5±12.4[b]
Head Length (cm)	23.9±1.55[a]	22.7±2.05[b]
Neck Length (cm)	28.4±5.16[a]	29.6±3.82[a]
Chest Girth (cm)	103.0±8.42[a]	92.9±8.08[b]
Tail Length (cm)	38.2±4.88	36.6±4.70
Wither Height (cm)	63.9±4.04[a]	58.9±4.86[b]
Chest Depth (cm)	37.5±2.97[a]	34.5±2.97[b]
Chest Width (cm)	23.5±2.56[a]	21.2±2.85[b]
Body Length (cm)	78.9±5.59[a]	72.7±6.06[b]
Rump Length (cm)	21.8±3.29[a]	20.8±1.93[b]
Rump Width (cm)	23.9±2.82[a]	21.4±3.15[b]
Skin thickness (mm)	2.85±0.5	2.8±0.5
Pelvis Length (cm)		7.66±9.8
Pelvis Width (cm)		7.66±9.0
Pelvis Area (cm^2)		46.7±10.6
Scrotal Circumference (cm)	35.1±3.03	

Means with different superscripts within the same row differ significantly (P <0.001).

When comparing the LBM of this study to older Meatmaster studies such as that of Peters (2011), certain changes became evident. The rams and ewes of this study seem to be heavier than those of Peters (2011); 80.47±13.33 kg for rams and 57.51±12.43 kg for ewes compared to 58.1 kg for rams and 52.2 kg for ewes. A weight difference of 22.96 kg was found between the rams of the two studies. This tendency was also observed in certain body measurements like chest girth (CG) in the rams; a value of 102.45±8.42 cm compared to 92.6 cm measured by Peters (2011) was recorded. That is a 9.85 cm difference between the two and because CG correlates so highly with BW (90%) it may be the reason for the increase in BW since 2011. This may also be an indication of increased emphasis on selection for growth traits within the breed.

Table 3 Mean (± SD) Carcass grade and cold carcass weight of Meatmasters sheep

Carcass Grade	N	Mean Cold Carcass Weight
A0	5	16.4±4.2
A1	127	16.1±3.1
A2	1605	16.9±3.2
A3	427	18.1±3.5
A4	18	15.3±5.6
A5	1	14.8±0
A6	4	16.3±8.2
Mean of A-grades	2187	16.8±4.1
AB1	1	22.1±0
AB2	12	27.1±7.2
AB3	1	22.9±0
Mean of AB-grades	14	24.0±13.8
B1	2	25.0±14.8
B2	13	26.7±5.2
B3	2	28.1±16.3
B4	1	27.8±0
Mean of B-grades	18	26.9±13.3
C2	23	25.1±4.3
C3	9	24.6±7.1
Mean of C-grades	32	24.9±4.9

In a study conducted by Van der Merwe *et al.* (2020) wherein lambs of different breeds were finished in a feedlot system the following carcass weights were recorded: South African Mutton Merino at 22.0 kg, Dorper at 18.9 kg, Meatmaster at 16.6 kg and Namaqua Afrikaner at 15.1 kg. The Meatmaster achieves a mean weight of 16.77±4.1 kg for the A-grade category (Lamb).

Table 4 Coat colour representation

Coat Colour	Number of Animals	Percentage
Red	118	28.9%
Red &White	160	39.1%
Chocolate	37	9.0%
Chocolate & White	39	9.5%
Black/Seal	10	2.4%
Black & White	15	3.6%
White	23	5.6%
Pink	7	1.7%
Total Number:	409	

In this study the most dominant colour in the Meatmaster breed is that of Red and White (39.1%).

Table 5 Correlation between linear body measurements in rams

	BW	HL	NL	CG	TL	WH	CD	CW	BL	RL	RW	SC
BW	1											
HL	.20**	1										
NL	-0.08	.36**	1									
CG	.90**	.09	-0.21**	1								
TL	.27**	.23**	.22**	.17*	1							
WH	.54**	.12	-0.06	.50**	.18*	1						
CD	.67**	.08	-0.14*	.75**	.15*	.50**	1					
CW	.75**	.04	-0.05	.67**	.14*	.33**	.49**	1				
BL	.74**	.11	-0.20**	.73**	.16*	.59**	.63**	.50**	1			
RL	.25**	.09	.25**	.24**	.19**	.07	.18*	.24**	.22**	1		
RW	.68**	-0.17*	-0.40**	.70**	.05	.51**	.50**	.58**	.60**	.19**	1	
SC	.47**	-0.04	-0.30**	.53**	.17*	.34**	.45**	.38**	.51**	.22**	.46**	1

**Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.
BW= Body Weight, HL= Head Length, NL= Neck Length, CG= Chest Girth, TL= Tail Length, WH= Wither Height, CD= Chest Depth, CW= Chest Width, BL= Body Length, RL= Rump Length, RW= Rump Width, SC= Scrotal Circumference.

The highest morphological correlation (excluding pelvic measurements) is that between CG and BW with a 90% correlation for rams and a 90% correlation for ewes. In a study by Fourie *et al.* (2004) rams with a larger CG and a masculine wedge shape (where the forequarters of the ram are larger than those of it's the hind quarters) tended to be heavier ($P<0.05$) than those rams with a more feminine wedge shape. The mean SC of all rams finds its highest correlation with CG at 53.4%. In rams and ewes neck length is the only measurement that correlates negatively with BW (rams at - 8% and ewes at – 9%). Scrotal circumference seems to be another body measurement that correlates ($P <0.01$) with CG. The body measurement that has the highest correlation with SC is CG (53.4%), with Body length (BL) being second at 50.6%. This is a good indication that masculine traits in rams coincide with a larger CG circumference. This trend was also observed in a study by Fourie *et al.* (2002) where two different Dorper populations were measured, a correlation between SC and CG of 47.95% were recorded for rams from the Northern-Cape and a correlation of 25.90% for rams from the Free-state.

Table 6 Correlation between Linear Body Measurements in Ewes

	BL	BW	CD	CG	CW	HL	NL	PA	PL	PW	RL	RW	TL	WH
BL	1													
BW	.78**	1												
CD	.70**	.69**	1											
CG	.71**	.90**	.71**	1										
CW	.55**	.81**	.52**	.71**	1									
HL	.25**	.20**	.41**	.24**	.08	1								
NL	.03	-0.1	.20**	-0.01	.03	.49**	1							
PA	.40**	.31**	.52**	.28**	.05	.45**	.25**	1						
PL	.37**	.27**	.47**	.22**	-0.0	.37**	.19**	.96**	1					
PW	.45**	.37**	.58**	.37**	.13	.52**	.28**	.95**	.83**	1				
RL	.52**	.52**	.46**	.54**	.50**	.18**	.14*	.18**	.12	.26**	1			
RW	.67**	.79**	.60**	.72**	.77**	.03	-0.04	.10	.09	.16*	.47**	1		
TL	.17*	.18*	.11	.18**	.05	.10	.06	.11	.09	.12	.16*	.11	1	
WH	.70**	.63**	.71**	.55**	.49**	.39**	.26**	.45**	.41**	.49**	.48**	.58**	.18**	1

**Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.
BW= Body Weight, HL= Head Length, NL= Neck Length, CG= Chest Girth, TL= Tail Length, WH= Wither Height, CD= Chest Depth, CW= Chest Width, BL= Body Length, RL= Rump Length, RW= Rump Width, PA= Pelvic Area, PL= Pelvic Length, PW= Pelvic Width.

Ewes' BW (79.1%) tends to correlate higher with rump width (RW) than those of rams (67.7%).
Pelvic measurements in ewes showed the following high correlations; PL correlates 96% with PA while PW correlates 95% with PA. Briedenhann (2010) made an interesting discovery that PL plays a more important role in the Bos Indicus cattle breeds, while the converse is true in Bos Taurus breeds with PW being the more important trait. In the Meatmaster it seems that PL also playing the greater role than PW. This may be an instance where animals adapted to warmer environments morphological shapes may be more oval than that of mammals adapted to temperate environments, as proposed by Bergmann's law (Bergmann, 1847). This is then mirrored morphologically in pelvic measurements.

Table 7 Correlation between ewe productive traits

	Age at first lambing	Number of times lambed	Number of lambs born	Number of lambs weaned	Average inter-lambing period	Age (Days)
Age at first lambing	1					
Number of times lambed	-0.18*	1				
Number of lambs born	-0.22**	0.85**	1			
Number of lambs weaned	-0.15*	0.86**	0.86**	1		
Average inter-lambing period (Days)	-0.06	0.60**	0.44**	0.45**	1	
Age (Days)	-0.001	0.87**	0.74**	0.77**	0.62**	1

**Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

Age seems to play a role ($P < 0.001$) in determining average inter-lambing period (AIP), with a correlation of (62%). Thus, as age increases so thus the AIP, as seen in Table 9. For ewes that had had more opportunities to produce a lamb also have a higher AIP. That is why number of times lambed (NTL) has the highest correlation with age (87%), the older a ewe gets the more opportunities she has had to produce a lamb. This can also be seen in the Namaqua Afrikaner sheep, older ewes have more opportunities to lamb and also has had more number of lambs born (NLB) (Qwabe, 2011).

Table 8 Mean (± SD) Influence of age on linear body measurements of rams

	Set of milk teeth	One pair of incisors	Two pairs of incisors	Three pairs of incisors	Four pairs of incisors
Body Weight (kg)	52.2±2.7[a]	79.3±9.0[b]	85.6±10.2[b]	90.2±17.2[b]	103.0±17.1[c]
Head Length (cm)	24.2±1.6[a]	23.6±1.2[a]	24.3±2.2[a]	25.8±1.5[b]	24.6±1.5[ab]
Neck Length (cm)	31.3±4.5[a]	27.4±5.0[a]	28.9±5.4[a]	31.8±4.9[a]	27.9±5.1[a]
Chest Girth (cm)	86.7±4.6[a]	104.0±5.8[b]	105.0±5.6[b]	106.0±8.6[b]	113.2±9.4[c]
Tail Length (cm)	37.2±3.8[a]	38.2±5.2[a]	38.9±5.1[a]	38.1±3.5[a]	39.4±1.7[a]
Wither Height (cm)	60.3±3.5[a]	64.1±3.8[b]	63.2±3.2[ab]	66.5±3.8[bc]	68.5±4.8[c]
Chest Depth (cm)	33.1±1.8[a]	37.8±2.2[b]	37.7±1.6[b]	39.9±1.8[c]	40.7±1.3[c]
Chest Width (cm)	20.1±2.3[a]	23.5±1.9[b]	25.1±2.8[bc]	24.2±2.5[b]	26.6±2.7[c]
Body Length (cm)	70.2±3.5[a]	79.3±4.4[b]	80.5±3.7[b]	82.7±5.7[b]	87.7±5.4[c]
Rump Length (cm)	20.5±1.7[a]	21.7±3.4[a]	22.2±3.7[a]	23.5±1.7[a]	23.4±3.8[a]
Rump Width (cm)	20.5±2.7[a]	24.3±2.2[bc]	24.1±2.2[bc]	23.8±4.7[b]	26.4±3.2[c]
Scrotum Circumference (cm)	30.5±2.8[a]	35.6±2.5[bc]	35.7±2.0[bc]	35.2±2.6[b]	37.9±3.6[c]

Means with different superscripts within the same row differ significantly (*P* <0.001).

Table 9 Mean (± SD) Influence of age on linear body measurements and performance traits of ewes

	Set of milk teeth	One pair of incisors	Two pairs of incisors	Three pairs of incisors	Four pairs of incisors
Body Weight (kg)	45.7±11.3[a]	56.9±11.0[b]	60.2±7.6[b]	60.6±12.8[b]	63.9±10.8[b]
Head Length (cm)	22.4±1.8[b]	20.6±2.1[a]	23.0±1.7[b]	23.3±1.6[b]	23.2±1.8[b]
Neck Length (cm)	30.1±3.3[a]	28.0±3.1[a]	28.9±4.5[a]	30.4±3.8[a]	28.1±4.5[a]
Chest Girth (cm)	85.3±8.6[a]	91.8±7.5[b]	93.9±3.7[b]	94.6±7.4[b]	95.6±7.4[b]
Tail Length (cm)	35.8±5.0[a]	36.5±5.4[a]	37.6±3.5[a]	36.5±4.9[a]	37.9±4.5[a]
Wither Height (cm)	53.4±4.1[a]	60.7±5.0[c]	57.1±3.4[b]	60.8±4.0[c]	61.0±3.6[c]
Chest Depth (cm)	30.5±2.3[a]	34.4±2.2[bc]	33.2±2.8[b]	35.3±2.1[cd]	36.0±1.9[d]
Chest Width (cm)	19.8±2.2[a]	20.5±2.1[ab]	21.7±2.6[ab]	21.6±3.6[ab]	21.8±2.8[c]
Body Length (cm)	65.5±5.3[a]	71.9±6.1[b]	74.4±5.1[bc]	74.5±5.3[bc]	77.1±4.3[c]
Rump Length (cm)	19.7±2.2[a]	19.9±1.8[ab]	20.8±1.7[ab]	21.2±2.0[b]	21.2±1.6[b]
Rump Width (cm)	19.1±2.8[a]	22.3±2.2[b]	21.5±3.5[b]	20.5±3.0[ab]	22.5±3.0[b]
Pelvic Width (cm)	6.48±1.0[a]	7.44±1.0[b]	7.75±1.0[bc]	7.99±0.5[c]	8.05±0.7[c]
Pelvic Length (cm)	6.49±0.7[a]	7.50±1.0[b]	7.86±1.0[b]	7.98±1.0[b]	8.01±0.9[b]
Pelvic Area (cm²)	33.3±6.5[a]	44.0±6.4[b]	48.1±6.9[bc]	50.4±7.2[c]	51.0±9.6[c]
Age of First Lambing (months)	12±0[a]	14±1.6[a]	14.9±3.0[a]	15.52±3.5[a]	15.5±4.2[a]
Number of Times Lambed	1±0[a]	1.05±0.2[a]	1.71±0.9[a]	2.06±0.7[a]	4.36±1.5[b]
Number of Lambs Born	1.5±0.7[a]	1.21±0.4[a]	2±1.1[ab]	2.3±0.9[ab]	5.88±3.5[b]
Number of Lambs Weaned	1±0[a]	1.16±0.4[a]	1.57±0.9[a]	1.7±1.0[a]	4.64±2.4[b]
Average Inter Lambing Period (Days)	0±0[a]	18.5±80.8[a]	119.0±146.0[ab]	236.0±135.0[bc]	330.0±151.0[c]

Means with different superscripts within the same row differ significantly (*P* <0.001).

Gender and age play a role (*P* <0.001) in determining the phenotypic structure of a sheep (Fourie *et al.*, 2002; Afolayan *et al.*, 2006 & Qwabe, 2011). Age has an influence (*P* <0.001) on all the body measurements of the Meatmaster, except for NL and TL. Fahim *et al.* (2013) has had similar findings that age plays a determined role in BW, with BW increasing with age in the Rohilkhand goats.

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Table 10 Mean (± SD) Influence of environment on the linear body measurements of rams

	Bethulie	Calvinia	Kenhardt	Wesselssbron	Williston
Body Weight (kg)	82.8±10.6[b]	96.8±8.2[c]	75.8±13.3[b]	Not Measured	63.4±11.3[a]
Head Length (cm)	23.5±1.2[a]	24.7±2.8[ab]	25.2±1.6[b]	24.2±1.6[ab]	24.9±1.5[ab]
Neck Length (cm)	26.1±4.0[a]	32.1±4.8[b]	32.2±2.5[b]	32.9±5.2[b]	33.2±3.8[b]
Chest Girth (cm)	105.0±5.3[b]	112.0±5.3[c]	101.0±9.8[b]	91.9±7.5[a]	92.0±6.3[a]
Tail Length (cm)	38.0±4.9[a]	44.3±6.8[b]	38.5±2.5[a]	38.6±4.7[a]	36.5±3.3[a]
Wither Height (cm)	64.9±3.8[a]	62.4±2.7[a]	62.1±3.3[a]	62.5±4.9[a]	61.4±3.9[a]
Chest Depth (cm)	38.2±2.2[bc]	38.9±2.3[c]	36.7±2.4[ab]	34.4±3.2[a]	35.9±2.4[ab]
Chest Width (cm)	23.9±1.8[bc]	25.7±1.5[c]	23.6±4.0[bc]	22.3±4.1[ab]	20.9±1.8[a]
Body Length (cm)	81.2±4.5[b]	79.7±3.9[b]	75.1±4.5[a]	72.4±4.7[a]	73.9±4.7[a]
Rump Length (cm)	21.9±3.6[ab]	24.3±3.6[b]	19.8±2.2[a]	21.5±1.8[ab]	21.7±2.0[ab]
Rump Width (cm)	25.9±2.1[b]	24.1±1.6[b]	20.9±2.5[a]	23.3±1.7[b]	19.4±1.5[a]
Scrotum Circumference (cm)	36.2±2.5[c]	35.1±2.9[bc]	33.2±3.7[ab]	32.0±2.5[a]	32.9±2.5[ab]

Means with different superscripts within the same row differ significantly (*P* <0.001).

Table 11 Mean (± SD) Influence of environment on linear body measurements of ewes

	Bethulie	Calvinia	Kenhardt	Wesselssbron	Williston
Body Weight (kg)	55.3±8.0[a]	67.8±2.4[b]	51.3±7.8[a]	Not Measured	48.9±13.6[a]
Head Length (cm)	19.1±1.0[a]	22.8±1.2[b]	23.8±2.0[c]	21.8±1.6[b]	23.5±2.2[c]
Neck Length (cm)	34.1±2.9[c]	26.7±2.3[a]	30.9±2.6[b]	26.0±3.7[a]	30.5±3.0[b]
Chest Girth (cm)	94.5±5.3[bc]	98.6±1.8[c]	91.2±6.2[ab]	87.2±7.7[a]	89.4±9.2[ab]
Tail Length (cm)	36.6±4.1[a]	38.9±4.1[a]	36.8±3.8[a]	37.9±5.6[a]	35.5±5.3[a]
Wither Height (cm)	62.3±3.6[c]	57.7±3.0[b]	56.7±4.4[b]	62.0±3.3[c]	52.9±4.5[a]
Chest Depth (cm)	35.6±2.6[cd]	36.3±1.3[d]	33.9±1.9[bc]	29.3±2.4[a]	33.5±2.9[b]
Chest Width (cm)	23.1±1.5[b]	24.1±1.0[b]	20.2±1.9[a]	19.7±3.5[a]	19.6±2.2[a]
Body Length (cm)	78.3±3.5[c]	73.3±3.3[d]	70.9±4.1[bc]	66.5±4.1[a]	69.6±6.2[ab]
Rump Length (cm)	21.2±2.0[ab]	21.7±1.0[c]	20.0±1.6[a]	20.5±1.6[ab]	21.1±2.1[ab]
Rump Width (cm)	24.5±1.9[b]	24.0±1.2[b]	19.3±1.6[a]	20.0±1.8[a]	19.1±2.2[a]
Pelvic Width (cm)	7.82±1.0[b]	6.43±0.4[a]	7.83±1.0[b]	7.54±1.0[b]	7.64±1.0[b]
Pelvic Length (cm)	7.99±1.0[c]	6.59±0.2[a]	7.91±1.0[bc]	7.28±1.1[ab]	7.50±1.1[bc]
Pelvic Area (cm²)	49.3±7.1[b]	33.3±2.8[a]	49.2±9.9[b]	43.7±11.5[b]	45.8±12.1[b]

Means with different superscripts within the same row differ significantly (*P* <0.001).

The environment has an influence (*P* <0.001) on all the body measurements of the Meatmaster, except for TL. This could be due to different selection standards and pressures between breeders. Fourie *et al*. (2002) reported that the body measurements of two different Dorper ram populations' results showed a difference in morphological measurements.

Interesting predictions were found when regression models were applied to the phenotypic performance characteristics. Wither height (WH) is the only measurement that has a predictive correlation with performance a variable such as AIP and number of lambs born, with R^2 values of 0.14 and 0.15 for AIP and NLB respectively. This is an indication that WH plays a pivotal role in certain productive aspects of the Meatmaster breed. A larger WH value leads to an increase in both AIP and NLB (multiple births). This creates a natural engineering dilemma, which means that as the one increases positively the other also increases, but in a negative way (a lower AIP is advantages and a higher NLB is preferred). Because of the limiting factor of resources in extensive production systems, these animals may have adapted to deal with this complex matter. Thus, the choice should be made which of these will be the most beneficial for the breed in the long run. Thus, moving away from Afro-type breed (that is perceived in the literature

as having a higher average WH) could possibly reduce the Meatmaster's fertility. An argument could thus be made, based on the assumption that within a decade the Meatmaster breed has slowly been moving toward a more Euro-type breed. This argument rest on two pieces of evidence; earlier linear body measurements conducted on Meatmaster by Peters (2011) indicated that they had larger WH values, and Afro-type breed tends to have higher WH measurements, including wild breeds such as Mouflon's (Qwabe, 2011; Garel *et al.*, 2003). The Afro-type breeds seems to have longer AIP with a higher tendency to have multiple-births, this is reliable in the literature (Schoeman & Albertyn, 1991; Qwabe, 2011).

The R^2 value of 0.262 indicates that approximately 26% of the variability in the AFL variable could be predicted by a combination of the rump length (RL), BW, ST, femininity and chest width (CW) variables. The R^2 value of 0.159 indicates that approximately 15.9% of the variability in the number of lamb's weaned variable could be predicted by the chest depth (CD) and CW. The BW of rams had the highest predictive power with an R^2 value of 0.94, calculated from the following LBM; CG, CW and WH. This is a 94% predictive value that can be determined without the need of modern weight measuring equipment and could possibly play an important role for farmers in rural areas in determining BW, where electricity is scarce and modern equipment is usually too expensive.

Conclusion

The high positive correlation between CG and BW emphasize the importance of selecting rams with a deeper and more robust front quarter. In males this trait seems to be of high importance.

In ewes WH is the measurement that correlates the highest with performance traits. Ewes with higher WH have an increase in both AIP as well as the NLB per ewe. Neck length is the only measurement that is larger in ewes than in rams. This seems to be a feminine trait, for ewes should have a longer and thinner neck than those of rams. The Meatmaster seems to be a unique combination between an Afro- and Euro-type sheep breed, which makes it highly flexible when adapting to new environments. It seems that these two phenotypic types could be described in the same manner as that of the differences between Bos-Indicus (respiratory type) and Bos-Taurus (metabolic type) (Bosman, 2011). Thus, body size and shape can be described using body measurements and visual assessment. How these measurements of size and shape relate to the functioning of the individual animal is of paramount importance to livestock production.

As can be observed the Meatmaster breed seems to have been getting heavier. This could be due to the increased emphasis on selection for growth or animals with positive increases in weight related expected progeny differences (EPD). This will move the breed in the direction of a more Euro-type breed. Selection based purely on EPD's could have long term negative consequences for the breed. Therefore, constant checks on the relationships between body dimensions and production performance are vital.

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