An efficiency and economic comparison of conventional and radio frequency identification slaughter readiness methodology in commercial lamb feedlots

By

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Declaration

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Abstract

Title: An efficiency and economic comparison of conventional and radio frequency identification slaughter readiness methodology in commercial lamb feedlots.

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Lamb feedlots are closed intensive systems that takes advantage of high growth rates to rear lambs for carcass production and consumption. Different feedlots use different methods to select slaughter ready animals. Incorporating modern technology into feedlots implies a shift from traditional subjective methods to objective precision methods. When selecting animals for optimal production and margin, individual data is required. After finishing, animals selected for slaughter are transported to the abattoir where after slaughter the carcasses are classed. A heavier carcass with optimal class will lead to higher carcass income. The current study seeks to investigate the effect of selection method on growth, slaughter and profitability parameters while investigating break-even point unit turnover to justify investment in technology to effectively select animals of slaughter from a commercial feedlot.

Ninety-eight Merino wether store lambs were allocated to seven different groups. The seven methods evaluated were lambs selected with ultrasound scanning (RTU), fixed feeding period of 42 days (42 days), visual observation by an experienced person (E-VS), visual observation by an inexperienced person (I-VS), manual palpation of the loin region by an experienced person determining body condition (E-BCS), manual palpation of the loin region by an inexperienced person determining body condition (I-BCS) and using Radio Frequency Identification(RFID) technology auto drafter (Fixed body weight - FBW). Significant differences were observed between the different methods on the respective parameters measured.

In the first study, the effect of the different methods of slaughter readiness selection were evaluated on growth parameters of feedlot lambs including daily dry matter intake (DMI),

cumulative dry matter intake (CFI), days spent in the feedlot, live weight gain (LWG), average daily gain (ADG), feed conversion ratio (FCR) and real time ultrasound scan (RTU).

The cumulative feed intake (CF)I differed (P < 0.05) as the animals differed (P < 0.05) in the number of days spent in the feedlot between treatments. The FBW group resulted in increased (P < 0.05) time spent in the feedlot, increased (P < 0.05) feed intake and cost with the heaviest (P < 0.05) final live weight with the least (P < 0.05) variation. The FBW group had the highest RTU measurement and differed (P < 0.05) from all the other treatments. No differences were observed between the subjective methods of the experienced and inexperienced assessors for either BCS or visual selection at any parameter investigated. The result could be explained by the high level of variance. The use of RFID technology and hardware made data recording easier and more accurate to determine results and monitor the lambs.

In the second study, slaughter, profitably and investment parameters were investigated for the seven slaughter readiness selection methods evaluated and included final live weight, cold carcass weight (CCW), dressing percentage (DP%), and margin above feed cost. Capital investment break-even unit turnover over 1-, 3- and 5-year amortization scenarios were also evaluated while accuracy of carcass income prediction options were determined.

The dressing percentage of the animals selected by the inexperienced and experienced group was lower (P < 0.05) compared to the 42 days and fixed body weight (FBW) groups. The cold carcass weight between the FBW group and the 42-day group differed (P < 0.05) in carcass weight. The cold carcass weight of the FBW group was heavier (P < 0.05) than all the other groups. The FBW group produced the highest numeric margin above feed cost of all the methods evaluated and differed (P < 0.05) from the 42 days, the I-BCS and the I-VS. Real time ultrasound measurement was found to be an accurate technique to predict carcass class, however due to the lack of final body weight data, were less accurate to predict carcass income. Despite a lack of significance of differences in carcass margin between the experience level of subjective evaluation methods of selection, the inexperienced assessor led to major variation that affects repeatability. The longer the payment period, the more animal units are required to justify investment in technology (P < 0.05). The FBW group required the least (P < 0.05) number of animal units per period to break even.

Margin above feed cost showed the highest correlation with ADG (P < 0.01), carcass weight (P < 0.01),final weight (P < 0.01) and dressing percentage (P < 0.05) respectively. It was determined that all these parameters need to be considered to optimize profit, however it was concluded from this study that despite the importance of several parameters, final BW played a significant role in profitability given that carcass class remains a constant.

Opsomming

Titel:	‘n Doeltreffendheid en ekonomiese vergelyking van tradisionele en radio frekwensie identifikasie metodes om die slaggereedheid van kommersiële voerkraallammers te voorspel.
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Lamvoerkrale is ‘n geslote intensiewe stelsel wat voordeel trek uit hoë groeitempo's om lammers af te rond vir karkas produksie en verbruik. Verskillende voerkrale gebruik verskillende metodes om slaggerete diere te selekteer. Die inkorporering van moderne tegnologie in voerkrale lei tot 'n verskuiwing van tradisionele subjektiewe metodes na objektiewe presisie meting metodes. Wanneer diere vir optimale produksie en marge geselekteer word, word individuele data egter vereis. Na voerkraalafronding word diere wat slaggereed diere geselekteer en na die slagpale vervoer waar die karkas na slagting geklassifiseer word. Swaarder karkasse met optimale klas sal lei tot hoër karkasinkomste. Die huidige studie poog om die effek van seleksiemetode op groei-, slag- en winsgewendheidparameters te ondersoek, terwyl ‘n ondersoek na gelykbreekpunt onderneem is om investering in tegnologie te regverdig om slagdiere effektief uit 'n kommersiële voerkraal te selekteer.

Agt-en-negentig Merino hamellammers is in sewe verskillende groepe verdeel. Die sewe metodes wat geëvalueer was, was lammers geselekteer met ultraklankskandering (RTU), vaste voerperiode van 42 dae (42 dae), visuele waarneming deur 'n ervare persoon (E-VS), visuele waarneming deur 'n onervare persoon (I-VS), hand palpasie van die lendestreek deur 'n ervare persoon wat liggaamstoestand (E-BCS) bepaal, hand palpasie van die lendestreek deur 'n onervare persoon wat liggaamskondisie bepaal (I-BCS) en die gebruik van radio frekwensie identifikasie (RFID) tegnologie automatiese sorteer skaal (Vaste liggaamsgewig - FBW). Beduidende verskille van die onderskeie parameters wat gemeet is, is waargeneem tussen die verskillende metodes.

In die eerste studie is die effek van die verskillende metodes van slaggereedheid seleksie op groei parameters van voerkraallammers geëvalueer en het daaglikse droë materiaal inname (DMI), kumulatiewe droë materiaal inname (CFI), dae gespandeer in die voerkraal, lewende

massatoename, gemiddeld daaglikse groei (ADG), voeromset verhouding (FCR) en intydse ultraklankskandering (RTU) ingesluit.

Die CFI het betekenisvol verskil ($P < 0.05$) aangesien die diere verskil het ($P < 0.05$) in die aantal dae wat tussen behandelings in die voerkraal deurgebring is. Die FBW-groep het gelei tot verlengde ($P < 0.05$) tyd in die voerkraal gespandeer, verhoogde ($P < 0.05$) voerinname en hoër voerkoste met die swaarste ($P < 0.05$) finale lewende massa met die minste variasie. Die FBW-groep het die hoogste RTU-meting ($P < 0.05$) teenoor al die ander behandelings behaal. Geen verskille is waargeneem tussen die subjektiewe metodes van die ervare en onervare assessore vir óf BCS óf visuele seleksie by enige parameter wat ondersoek is nie. Die resultaat kan verklaar word deur die hoë vlak van variansie. Die gebruik van RFID tegnologie en hardeware het datainsameling makliker en meer akkuraat gemaak.

In die tweede studie is slag-, winsgewendheids en beleggingsparameters vir die sewe slaggereedheid seleksie metodes wat geëvalueer is ondersoek en het finale lewende massa, koue karkasgewig (CCW), uitslag persentasie (DP%) en marge bo voerkoste ingesluit. Kapitaalbelegging gelykbreek-eenhede oor een, drie en vyf jaar mortifikasie scenarios is ook geëvalueer terwyl akkuraatheid van karkas inkomste voorspelling opsies bepaal is.

Die uitslag persentasie van die diere wat deur die onervare en ervare beoordelaars geselekteer is, was laer ($P < 0.05$) in vergelyking met die 42 dae en FBW groepe. Die koue karkas gewig tussen die FBW groep en die 42-dae groep het verskil ($P < 0.05$) in karkasmassa. Die koue karkasmassa van die FBW groep was swaarder ($P < 0.05$) as al die ander groepe. Die FBW-groep het die hoogste numeriese marge bo voerkoste van al die metodes wat geëvalueer is gelewer en het verskil ($P < 0.05$) van die 42 dae, die I-BCS en die I-VS. Daar is gevind dat intydse ultraklank skandering 'n akkurate tegniek is om karkasgradering te voorspel, maar weens die gebrek aan finale liggaamsmassadata was dit minder akkuraat om karkasinkomste te voorspel. Ten spyte van 'n gebrek aan betekenisvolle verskille in karkasmarge tussen die ervaringsvlak van subjektiewe evalueringsmetodes van seleksie, het die onervare beoordelaar gelei tot groot variasie wat herhaalbaarheid negatief sal beïnvloed. Hoe langer die betalings tydperk, hoe meer diere-eenhede word benodig om investering in tegnologie te regverdig ($P < 0.05$). Die FBW groep het die minste ($P < 0.05$) aantal diere-eenhede per periode nodig gehad om gelyk te breek.

Marge bo voerkoste het die hoogste korrelasie met GDT ($P < 0.01$) en karkasmassa ($P < 0.01$) en finale gewig ($P < 0.01$) en uitslagpersentasie ($P < 0.05$) onderskeidelik getoon. Daar is vasgestel dat al hierdie parameters oorweeg moet word om wins te optimaliseer. Daar is egter vanuit hierdie studie tot die gevolgtrekking gekom dat ten spyte van die belangrikheid van verskeie parameters, finale liggaamsmassa 'n beduidende rol in winsgewendheid speel mits karkas klas konstant bly.

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Note

This thesis is presented as a compilation of five chapters. Each chapter is introduced separately and is written according to the style of the South African Journal of Animal Science.

List of Abbreviations

%	Percentage
A2 lamb	Lamb with no permanent incisors and fat cover of two
ADG	Average daily gain
BCS	Body condition score
BEA	Break-even analysis
BEP	Break-even point
BFT	Backfat thickness
CCW	Cold carcass weight
CFI	Cumulative feed intake
CP	Crude protein
DMI	Dry matter intake
DP%	Dressing percentage
EID	Electronic identification
FBW	Final body weight
FCR	Feed conversion ratio
FIN	Standard commercial finisher feed
FBW	Fixed body weight
RFID	Radio frequency identification
ROI	Return on investment
RTU	Real time ultrasound measurement
SAMM	South African Mutton Merino
SE	Standard error
VID	Visual identification

Table of Contents

List of figures

List of Tables

Chapter 1

General introduction

1.1 Background and problem statement

The purpose of this study is to highlight different factors that influence slaughter readiness in a lamb feedlot, how RFID technology can be incorporated into a feedlot system, as well as different methods of slaughter readiness selection that is currently used in South Africa. New technology is currently developed and used in virtually every sphere of life (Lee and Trimi, 2018). Technology can be used in an intensive feedlot system, however the economic and profitability impact is not fully documented. The main goal was then to determine which method would result in the best margin above feed cost and which method is practical in comparison to ultrasound measurement which has been previously identified as an accurate method.

South Africa consists of different environments supporting a variety of different agricultural practices including cash crops, horticulture, and animal production (Stats Biz, 2021). In several areas, farmers diversify and combine more than one of the production enterprises on a single farming unit (Waha *et al*., 2018). Crop and beef production for example is often combined due to the synergetic nature of the enterprises. According to DAFF (2020) only 20% of the agricultural land available in South Africa is suitable for non-extensive livestock farming. According to Cloete and Olivier (2010), 80% of the geographical regions of South Africa are therefore only suitable for small and large stock production and are often confined to the more arid regions. Sheep are able to convert low quality forage, normally unusable to humans, into high quality protein for human consumption as well as the production of valuable hides and wool (DAFF, 2008). Red meat makes a valuable contribution towards the dietary protein requirements of humans (Geiker *et al.,* 2021).

Small stock operations can be divided in two distinct operations including breeding and the production of lambs via lamb and ewe operations and finishing weaned lambs in feedlots to be slaughtered for the market (Bryceson, 2019; Schoeman *et al.,* 2010). The objective of the latter industry is to achieve optimal slaughter characteristics as fast as possible with the lowest possible cost (Coetzee, 2020). To shorten this feeding period, high energy containing diets are normally fed (Van der Merwe *et al.*, 2020b; De Wet *et al.*, 2021). A lamb is defined as an animal that does not yet have permanent incisors. With the incidence of more frequent drought periods due to the global warming phenomenon (Tabari, 2020), intensive finishing of animals in a feedlot is gaining more popularity (Mare, 2020) as this practice allows more breeding ewes to be kept while reducing financial risk to the producer (Landman, 2013).

Different breeds and crossbreeds including Dorper, Meatmaster, Dohne Merino, South African Mutton Merino, Dormer and Merino can be effectively finished in feedlots (Brandt *et al.,* 2017). A common commercial practice is to exploit hybrid vigor by cross breeding purebred lines as terminal crosses with high meat producing breeds like the Dormer, Ile de France or Mutton Merino (DAFF, 2008; Louw, 2021). According to recent data DAFF (2020), South Africa has currently an estimated 19.9 million sheep. The current South African per capita red meat consumption according to Mare (2020) is 3.2 kg. Red meat can further be regarded as a very good protein source to humans (Schonfeldt *et al.*, 2013).

According to DAFF (2020) South Africa annually produces 1 660 000 tons of lamb/mutton meat. Accurate slaughter time is important as this will affect carcass classification and weight which in turn will affect income. Carcasses classification is determined by the level of fat cover and age according to the Government notice R863 (Government Gazette, 2006). These carcass classes in combination with age and carcass weight will therefore determine income. Optimal carcass weight and classification is required as the consumer demand and preference determine carcass prices (Taljaard *et al*., 2006). In South Africa a lamb carcass weight of ±20 kg and a classification of A2 are considered optimal (RPO, 2021; Department for Environment Food and Rural Affairs, 2020). The duration of the feeding period will also affect feed intake and subsequently cost. Both feed cost and carcass income have a significant effect on profitability in the feedlot. According to Vollgraaff (2018) five factors including, buying price, slaughter or selling price, average daily gain (ADG), dressing percentage and feed cost will determine profitability.

Considering commercial feedlot management practices, different approaches are being followed to determine slaughter readiness of lambs. These include a set period feeding period, visual assessing, palpation of the loin region and more advanced objective weighing systems (Taylor, 1980; Bell *et al*., 2018; Van der Merwe, 2020; Posbergh & Huson, 2021). Some commercial feedlots also use a minimum weight per breed approach (Van der Merwe, 2020). Van der Merwe (2020) determined optimal slaughter weights per breed for optimal carcass classification. Investigating optimal slaughter weights of different ovine breeds, Brand *et al.* (2018) determined the optimal slaughter weight of Dorper lambs to be 36 kg and South African Mutten Merino (SAMM) and Merino at 42.7 kg respectively. Some commercial feedlots also evaluate body condition score by manual palpation between the 13th and 14th rib (Phythian *et al.*, 2012). Other feedlots only subjectively select slaughter ready animals visually. In practice often one or a combination of these methods are employed by a feedlot to determine slaughter readiness (MLA, 2018).

Currently the availability of technology plays a major role in advancement and this phenomenon does not exclude the agricultural sector (Patel & Sayyed, 2014) and more specifically the ruminant livestock sector (Groher *et al.,* 2021; Neethirajan & Kemp, 2021) and iswell documented. The use of radio-frequency identification device (RFID) technology to automate livestock and specifically sheep feedlot systems are increasingly gaining interest (De Wet, 2018; Barnes *et al.,* 2018). According to Shin and Eksioglu (2014) any feedlot capital expenditure should be measured against a break-even unit throughput to assist in any capital expenditure decision justification. De Wet *et al.* (2021) also highlights additional non-monetary advantages including the availability of improved information which could aid in decision making to optimize daily costs and ultimately improve margin.

The focus of this study is to evaluate common commercial methods to determine the accuracy of the selection of animals ready for slaughter in a sheep feedlot. The usefulness of ultrasound scanning (Hopkins, 1990a) as predicter and if semi- or fully automated systems can be incorporated in a commercial feedlot environment as a measure for objective selection methods. Ultrasound fat measurement can be used as reference method to predict carcass class as this method have long since been shown by several researchers as very accurate to predict carcass class (Stouffer & Wellington, 1960; Van der Merwe, 2020; Gomes *et al.,* 2021). Commercial use of ultrasound technology is however limited due to the required level of expertise to interpret the data, cost and the time-consuming nature of the analysis (Van der Merwe, 2020). Regarding visual and palpation assessment, it can be assumed that an experienced assessor would outperform an inexperienced assessor, of which the latter leading to poorer carcass characteristics and ultimately lower margins. Due to variability of animals between and within breeds (Diez-Tascón *et al.,* 2000; Cloete *et al.,* 2014) and different maturity types (Van der Merwe, *et al*., 2020), it is essential to select slaughter ready animals on an individual basis.

Given the differences in methodology currently used in commercial feedlots and due to the known variability between and within breeds a study was designed at the University of Stellenbosch to investigate the production-, carcass- and financial effects of the several commonly used commercially methods of selection for slaughter readiness for commercial lamb feedlots.

The specific objectives of this study were:

- Determine differences in the growth parameters of feedlot lambs between selection methods.
- Determine differences in slaughter parameters of feedlot lambs between selection methods.
- Determine the differences in the margin above feed cost between selection methods.
- Evaluate the accuracy of predicting carcass quality against ultrasound scanning as a reference method.
- Determine the break-even throughput units to quantify the capital investment into technology.

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Chapter 2

Literature review

2.1 General

Currently forty-eight present of the South African agricultural income originates from livestock, where sheep contributes 3% of the total (Figure 2.1). This sheep production contribution represents R9.5 billion annually. In 2018, South Africa slaughtered 166 000 tons of lamb and mutton (DAFF, 2019). According to the latest statistics (DAFF, 2020), South Africa currently has 19.9 million head of sheep.

Figure 2.1. Total sales from agricultural production in South Africa (Stats biz, 2021).

Livestock production is a system where breeding and rearing of cattle and sheep predominantly are extensively on veld in South Africa. According to DALLRD (2020) mutton and lamb production are enterprises in South Africa where meat is produced for local consumption as well as live and carcass exports. Mutton or lamb can be produced extensively on the veld, but the most popular method is to intensively finish the lambs in a feedlot (Van der Merwe *et al.,* 2020b). The choice of different options of producing and finishing lambs are based on the availability of pasture and veld and the store lamb price in conjunction with feed prices (Webb, 2015). With droughts occurring more frequently, the shift to more intensive farming is becoming increasingly popular (Mare, 2020). A sheep feedlot is defined as a closed intensive system to finish lambs and mutton for slaughter (Van der Merwe, 2020). When feeding lambs in a feedlot, an advantage is taken from naturally high growth rates (Van der Merwe *et al.*, 2020a) and the goal is to achieve an optimal carcass weight and classification at slaughter. Optimal carcass weight and class is critical to income per kg carcass (Coetzee, 2020). These market prices are determined by consumer preference and supply and demand (Griffith, 2009). According to Van der Merwe *et al.* (2020b) two main drivers to consider feed lotting includes:

- finishing lambs for slaughter is quicker compared to grazing or veld finishing.
- relieving of grazing pressure takes place when the lambs are removed from the pasture/veld. This normally improves productive ewe carry capacity.

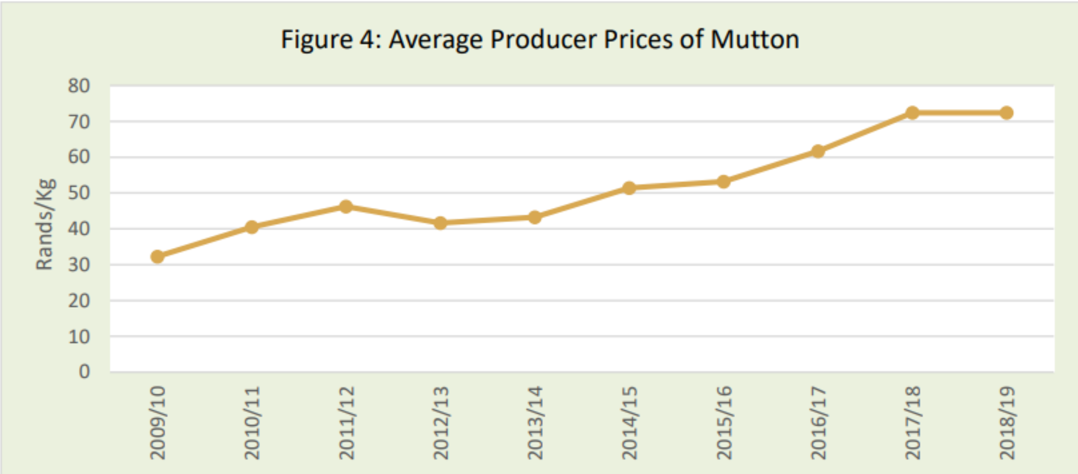
Muscle growth and fat deposition are promoted when feeding lambs a balanced feedlot diet (Van der Merwe, 2020). The principle is to achieve the desired carcass class and weight in the shortest possible time to maximise income while minimising cost (Coetzee, 2020). Feedlot diets are known to contain high levels of readily fermentable carbohydrates (Van der Merwe *et al.*, 2020b; De Wet *et al.*, 2021). As management can play a vital role in feedlot profitability the use of new technology to aid in artificial decision making is becoming more apparent (De Wet *et al.*, 2021).

2.2 Feedlot finishing of animals

According to the economist, Adam Smith, consumption or product demand is the sole end and purpose of all production (Taljaard *et al.*, 2006). A demand of consumers for consistent high-quality lamb and mutton therefore initiated the global phenomenon of sheep feedlots. Van der Merwe *et al* (2020b) summarized the feedlot practice as the practice of purchasing young, weaner animals, improving their market value through intensive feeding and management to produce a carcass that meets the market specifications. When rearing lambs in such a system, a high efficiency is a requirement because profit margins are normally narrow in a feedlot system, mainly due to fluctuating market prices (Janse van Rensburg *et al.,* 2020). Modern precision feedlot rearing and management technology is therefore a requirement to obtain optimal efficiency, sustainability and profitability (De Wet, 2018; Van der Merwe *et al.*, 2020a).

Wathes *et al.* (2008) describe precision livestock farming as managing livestock production by employing principles and technologies normally associated with process engineering that will allow the producer improved monitoring of the system resulting in faster and improved decision making. When fattening lambs in a feedlot, the aim is to provide a consistent and continuous supply of a high-quality product that meets the market demand (Van der Merwe *et al.*, 2020c).

Recently the prices of lamb in South Africa showed an upwards trend (RPO, 2021). This is displayed in Figure 2.2. Figure 2.2 show mutton slaughter prices from 2009/10 to 2018/19 and it can be seen that thenominal producer price has more than doubled during this period.



Source: Statistics and Economic Analysis, DALRRD

Figure 2.2 Increase of mutton prices from 2009/10 till 2018/2019 (DALLRD, 2020).

Shifting of non-reproductive animals (store lambs) earlier to feedlots allows producers to increase stocking levels of reproductive animals on grazing. Commercially in South Africa, lambs are typically moved to a feedlot when having a love weight of between 25 and 32 kg where they are fed for a fixed period or until a desired slaughter weight is obtained (Coetzee, 2004). This weight depends largely on the breed of the lamb as breed differences occur due to maturity variation (Gavojdian *et al.,* 2013). According to Sanson *et al.* (1993) live weight of ovine before slaughter is highly correlated (R^2 = 0.84) to the amount of body fat.

The increasing price phenomenon can be explained by relative lower total numbers of marketable lambs owing to higher incidences of droughts. These unfavourable environmental conditions are owed to the global warming phenomenon (Naumann *et al.,* 2018). Although Figure 2.3 illustrates the effect of global warming on the incidence of drought for several macro regions, Southern Africa is of most importance for this study.

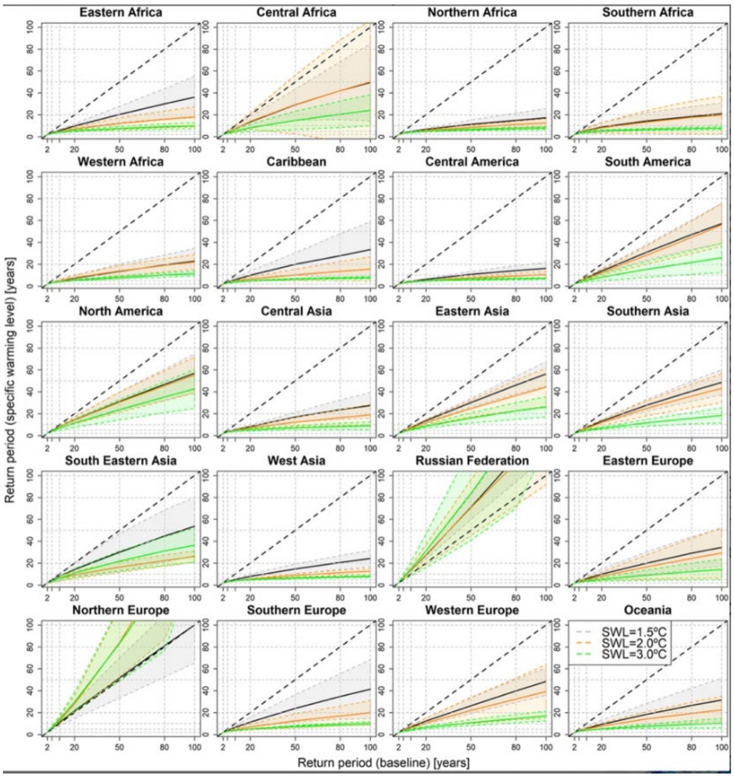


Figure 2.3 Changes in return periods of droughts in global different macro regions for 1.5°C (grey), 2°C (orange), and 3°C (green). The dashed black line represents the no-change curve and intermodal median absolute deviation (shaded areas) (Naumann *et al.,* 2018).

In the South Africa, meat is a major component of South African cuisine. The annual per capita consumption of mutton or lamb meat decreased from 6.3 kg in 1980/81 to 3.2 kg in 2018/19, which is a reduction of almost 50% (Mare, 2020). Consumed red meat in South Africa includes lamb, mutton, beef and venison. Meat consumption behaviour is influenced by availability, price and culture (Erasmus & Hoffman, 2017). Lambs are specifically reared for slaughter to meet the demand of consumers since consumers will only purchase and consume products that fulfil their specific requirements and demand (Taljaard *et al.*, 2006). Consumer demand is further increasingly becoming more health orientated (Soji *et al,* 2015) while consumers have also amplified the demand for information about the specific product and its quality, also known as traceability (Calitz, 2016; Suhandoko *et al.,* 2021).

Figure 2.4 depicts the typical value chain of lamb or mutton. From Figure 2.4 it can be seen that lambs are either finished in a feedlot system or by the producer himself. The end goal will always be consumers and therefore the carcass is produced to satisfy consumer demand as this will ensure optimal revenue to the livestock production stakeholders (Taljaard *et al.*, 2006).

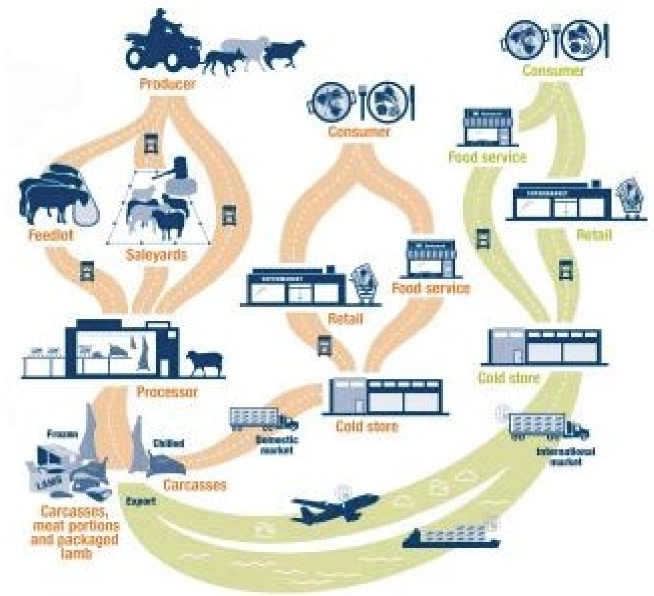


Figure 2.4 Red meat value chain (Bryceson, 2019).

According to a study by Schonfeldt *et al.* (2013) at the University of Pretoria, in conjunction with the Agricultural Research Council (ARC), South African mutton and lamb can be regarded as a good source of recommended protein intake, a good source of bioavailable haem iron and a natural source of conjugated linoleic acid (CLA) to humans. Conjugated linoleic acid has been shown by several studies (Kennedy *et al.*, 2010: Jutzeler van Wijlen, 2011; Ing & Belury, 2011; Dilzer & Park, 2012) to protect the body from heart disease and lowering cholesterol levels. The Schonfeldt (2013) study was based on carcasses with optimal fat cover (A2 class), according to the current South African carcass classification and grading system (Schonfeldt *et al*., 2013). Considering feedlot costs, livestock and meat prices is exposed to more volatility compared to cost of production, processing, management and marketing (Van Rensburg *et al.*, 2020). Due to this high fluctuation of livestock and meat prices, the manageable and fixed costs need to be kept as low as possible while income is maximised (Van Rensburg *et al.*, 2020). The ingredient commodity cost of the diet is also exposed to a high degree of volatility as normal economic supply and demand forces will determine feed commodity pricing (Wu *et al.,* 2020). Periodic and seasonal droughts as well as other environmental factors will therefore influence diet cost (Leister, 2015). Currently in South Africa bovine carcasses represent the dominant amount (number and weight) with ovine carcasses contributing significantly lower levels (Van Rensburg *et al.*, 2020). When prices are however considered, lamb and mutton carcass value add to almost double that of bovine carcase per unit of weight (Van Rensburg *et al.*, 2020; RPO, 2021).

2.3 Different tendencies and methods in countries

The South African lamb market demand young animals with no permanent incisors (age class A) and a relative lean fat cover (backfat depth of 1–4 mm; fat class 2), marked as a carcass with an A2 classification (DAFF, 2006). According to Van der Merwe *et al.* (2020a) approximately 72% of lamb carcasses currently slaughtered in South Africa is classified as A2 as a price premium is offered for this class due to high consumer demand. Upon purchase by the consumer, the requirements surveyed are fatness, tenderness, colour and freshness while it is expected to remain consistent over time. When producing meat, the preference of the end-user needs to be kept in mind throughout the production process as they demand consistency in quality. Mutton and lamb slaughter statistics of week 53 during 2020 in South Africa is shown in Table 2.1.

Table 2.1 indicate that 74.2% of sheep/lambs slaughtered during the reported period was classified as A2. While these numbers confirm what is reported in literature (Van der Merwe *et al.,* 2002a), the highest price per kg (R90.51/kg) was also paid for A2 classified carcasses (Table 2.1). These high A2 classified lamb carcass numbers and price can therefor be directly related to consumer demand.

Table 2.1 Example of week 53 (2020) mutton and lamb slaughtering volumes and prices (RPO, 2020).

Class	Units	Avg carcass mass (kKg)	Avg purchase price (R)	Avg selling (R)	Selling min - Weighted 20%	Selling max - Weighted 20%
A0	9	9.88	78.5	35.73	35.73	35.73
A1	331	15.8	87.35	86.93	79.79	89.33
A2	8018	20.05	88.38	90.51	86.19	93.28
A3	818	22.32	86.95	88.91	87.24	94.11
A4	154	22.6	80.7	78.86	77.57	80.88
A5	7	23.69	76	66.91	66.91	66.91
A6	34	23.03	75.9	67.92	67.86	68.3
AB2	96	22.4	77.61	81.49	75	94.37
AB3	9	24.9	77.45	78.47	75	82.71
B2	133	25.05	66.13	70.16	68.29	75.82
B3	19	29.29	64.98	69.27	68.07	73.75
C2	1054	24.88	67.24	69.46	65.65	74.5
C3	121	27.99	67.39	69.76	65.99	74.84
Total	10803					

Comparing the Australian, New Zealand and United Kingdom (UK) markets to the South African market, different carcass sizes and fat cover is however preferred (Van der Merwe *et al.,* 2002a). Lambs for slaughter are normally selected on weight and age. Animals in Australia with two permanent incisors is still classified as lamb (Pannier *et al.,* 2018) where in South Africa they would be considered as mutton (Van der Merwe *et al.,* 2002a). Australian and New Zealand lamb carcasses at 25 kg dressed weight and a fat score of three, meets nearly all their market requirements in Australasia compared to South Africa where an optimal carcass weight is on average 20 kg (MLA, 2018). A recent UK study on slaughter statistics, reported the average lamb carcass weight of ± 20 kg; similar to the South African market (Department for Environment Food and rural affairs, 2020). According to Kintzel (2014) in New Zealand acceptable lamb carcass weights is between 15 to 20 kg.

2.4 Factors affecting feedlot profitability

When finishing lamb in a feedlot, various vectors play a role in the profitability of the enterprise. Five major vectors have been identified that influences feedlot profitability. These five factors include store lamb cost, slaughter price or selling price, average daily gain (ADG), dressing percentage and feed cost (Vollgraaff, 2018).

The main factors affecting feedlot profit margins include the purchase price of store lambs, the price of meat produced, along with the dressing percentage of the carcass, the price of feed consumed by the animal, as well as the efficiency of growth achieved (Lima *et al.,* 2017). According to Coyne *et al.* (2019) dressing percentage is directly related to the revenue per lamb and therefore also has a significant impact on overall profitability. All these factors need be considered to ensure optimal profitability as all contribute towards profit (Ahola & Hill, 2012). To manage all these factors precision management is indispensable. Of these profitability drivers only dressing percentage and ADG can be managed by the feedlot operator (Van der Merwe, 2020). The optimal slaughter weight and growth will differ between breeds due to different maturity levels (Court *et al.,* 2010). The dressing percentage of carcasses increases with the level of subcutaneous fat, similarly to early maturing breeds being slaughtered at lower live weights, ewe lambs are typically slaughtered at lighter body weights compared to rams due to them maturing earlier than rams, thus depositing fat at a lower body weight (Owens *et al*., 1993 Brand *et al*., 2018; Hanel, 2021). The slaughter lamb price (R/kg) is however partly under producer control as carcass revenue are directly influenced by carcass class and weight. It is important to realize that slaughter lamb prices are however also influenced by the economic forces of supply and demand which is not under the control of the operator (Oosthuizen, 2016).

2.4.1 Store lamb cost

In South Africa the store lamb cost is determined by market price per weight unit; animal live weight and age. The weekly unit cost is determined by supply and demand forces and is therefore influenced by the availability of store lambs. According to Langford (1969) demand can be defined as the various quantities of the particular product or service which consumers will take off the market at all possible alternative prices in a given unit of time, with all other factors unchanged. Within the South African commercial livestock environment, this price is determined weekly and therefore prices fluctuate as supply and demand between lamb producers and feedlot operators intertwine. Although animals are bought per unit of weight based on live weight, prices also differ between shorn and unshorn animals. Normally all animals are sheared at arrival at the feedlot to take advantage of the opportunity income of the wool and also to increase dry matter intake (DMI) (Keady & Hanrahan, 2014). Increased DMI lead to higher ADG and less time spent in the feedlot. In a study comparing DMI and ADG in beef cattle, Zinn *et al.* (2008) reported a clear relationship ($R^2 = 0.77$, $P < 0.05$) between the latter parameters. Shorter cycles will lead to an annual increase in animals through the facility and therefore increased return on investment. A Brazilian study by Raineri *et al.* (2015) suggests that fixed capital in facilities amount to a significant portion of production cost. The latter authors established that facilities represent approximately 60% of the cost of depreciation, over 26% of the costs of maintenance and over 82% of remuneration on fixed capital, respectively. It is therefore important to optimize facilities efficiency (Raineri *et al.,* 2015). Due to the value proposition of wool, feedlot operators are prepared to pay more for store lambs with wool on (Figure 2.5). Figure 2.5 depicts an example of different price scenarios based on weight, age and wool cover.

Figure 2.5 Differences in weight, age and wool effect store lamb price (BKB, 2021).

The South African feedlot industry prefer store lambs to be between 27 and 34 kg live weight when entering the system (Van der Merwe, 2020). In South Africa during 2021, the demand for store lambs increased significantly and resulted in store lamb prices that increased to R57.00 per kg of live weight (RPO, 2021), but as demand in South Africa reduced also during

2021, store lamb prices reduced significantly (R38.00/kg) per kg of live weight (RPO, 2021). This illustrates the volatility of store lamb cost owing to supply and demand forces (BKB, 2021) and is largely not under the feedlot operator's control (Raineri *et al.,* 2015).

2.4.2 Feedlot income

From a lamb producer perspective, lambs can either be sold as per fattened live weight or as per carcass weight after slaughter (Bryceson, 2019) (Figure 2.4).

2.4.2.1 Live weight income

The selling price is the monetary value at which abattoirs buy lambs that are slaughter ready from producers. This value is determined from final live weight and price per kg live weight as vectors. As indicated, these prices are also dependant on demand of the abattoir for immediate slaughter production which in turn is determined by consumer demand (Bryceson, 2019). According to the RPO (2021) these prices ranged between R38.00 to R57.00 per kg live weight; representing a 50% fluctuation in only 2021.

2.4.2.2 Carcass income

The slaughterer carcass price is influenced by the market price of the specific class of the carcass and the carcass weight. These vectors will determine the value of the carcass while carcass classification will be determined by age and subcutaneous fat cover (DAFF, 2006). The goal in a feedlot is to finish lamb to consistently produce optimal classified carcasses to realize the highest price per unit of weight while keeping cost as low as possible in the shortest possible turnaround time (Duddly *et al.,* 2016). Table 2.2 summarises the carcass classification fields of sheep and cattle (DAFF, 2006). The carcass classification reflects specific qualities of the carcass of desire to the consumer and is based on the interpretation of carcasses, by using clearly defined characteristics that are of high importance throughout the red meat value chain (Webb, 2015). The classification is normally done by a qualified classifier in the abattoir (Webb, 2015). During 2021 these prices ranged between R79.00 to R101.00 per kg carcass for A2 classified lambs (RPO, 2021).

From 1944 to 1992 a grading system was employed for lamb carcases in South Africa and this was replaced by a carcass classification system from 1992 to date (Strydom, 2011; Webb, 2015). Multiple factors influence classification and includes sex, breed, subcutaneous fat cover, conformation and age (Figure 2.2). According to Webb (2015) carcass classification is required to classify carcasses based on clearly defined quality attributes to ensure more consistent meat quality and consumer satisfaction. It is therefore a requirement that animals selected for slaughter from a feedlot also reduce carcass variation as far as possible.

Table 2.2 Current South African red meat carcass classification system (Webb, 2015).

South African Red Meat Classification System				
Age category	A 0 Permanent incisors	AB 1-2 Permanent incisors	B 3-6 Permanent incisors	C >6 Permanent incisors
Rollermark code	AAA	ABAB	BBB	CCC
Colour of roller mark	Purple	Green	Brown	Red
Carcass fat codes: 0 - no fat; 1-Very lean; 2-lean; 3-medium; 4 - fat; 5 - slightly over fat; 6 - excessively overfat				
Conformation scores: 1- very flat to 5 very round				

The South African red meat industry has essentially three steps in the marketing process of lamb and mutton carcasses. The classification process commences with meat inspection, followed by carcass classification which allocates the relevant classification markings to the carcasses. The carcass inspection is based on a subjective, visual consideration by trained and experienced meat classifiers who are audited regularly [Strydom *et al.,* 2005; South African Meat Industry Company (SAMIC), 2006]. The classification system ensures that the consumer can buy according to his/her personal preference to a known consistency (Soji *et al.*, 2015). The South African red meat classification system is governed by government notice No. R. 863 (DAFF, 2006). Age is determined on the number of permanent incisors of the animal (Figure 2.2) and the subcutaneous backfat thickness is measured by millimetre back fat at the 13th rib of the relevant animal (Van der Merwe, 2020). Consumer purchasing behaviour when buying meat is dependant by eating quality. Eating quality is significantly influenced by animal age, with increased age resulting in decreased eating quality (Pethick *et al.,* 2005; Thompson *et al.,* 2005). This is mostly due to increases in collagen concentration and crosslinking that occur as animals mature, which decreases muscle tenderness (Bouton *et al.,* 1978; Shorthorn & Harris, 2006; MLA, 2020). Early work by Weller *et al.* (1962) however did not indicate any relationship between age and tenderness when number of chews and shear force values of legs of lamb of different ages were compared. Resent work by Claire *et al.* (2020) also indicated little age effect on eating quality when lamb of different ages were evaluated by a sensory panel. The latter study however did not include objective Warner-Bratzer shear force analysis. Despite some inconsistency in results, currently most research accepts that meat tenderness decreases as the animal ages. Due to its negative impact on eating quality, animal age is factored into price grids and grading systems at slaughter. Soji *et al.* (2015) summarizes the four major benefits of the classification systems as follows:

- It creates a platform for meat traders to describe their requirements when acquiring carcasses.
- It creates variety in the market intending to optimise consumer satisfaction/demand.
- It enables the use of different prices.
- Classing determines the price per kg of carcass which determines the price for cuts.

According to the fatness classification (DAFF, 2006), an A2 lamb carcass should have between 1 and 4 mm and more than 5.6%, but not more than 8.5%, subcutaneous fat (SCF) (average of 7% SCF) (Van Heerden *et al.,* 2007). The fat cover of A3 carcass should be between 4 to 7 mm (DAFF, 2006). Carcass damage is evaluated on a scale ranging between 1 to 3 (DAFF, 2006). The price will decline with more damages to the carcass (Grandin, 1980). Regarding sex, only males that have reached maturity will be marked as males (Government Gazette, 2006). Juvenile lambs of different sexes will therefore not be marked for sex (Casburn *et al*., 2013). The reason why mature males are marked is due to masculinity (Webb, 2015).

2.4.3 Dressing percentage

The dressing percentage of an animal is the carcass weight expressed as a percentage of live weight, prior to slaughter (Rahman *et al*., 2013). The cold carcass weight of the slaughtered lamb is the weight after having been bled, skinned and eviscerated, and after removal of the head, feet, tail and genital organs and chilled, while kidneys and kidney fat are however included in the carcass weight (Schweihofer, 2011). The higher the muscle and bone ratio compared to the offal, the higher the dressing percentage (Shahbandeh, 2021).

$$Dressing\ percentage\ (DP\%) = \frac{Carcass\ weight}{live\ weight} \times 100$$

In general, Australian lamb have an average dressing percentage of 45% to 48%, with a variation between 54% and 40% (Casburn *et al*., 2013). Factors that influence dressing percentage includes the degree of fatness, time off feed and water prior to final live weighing, feed conditions, sex, breed, hide weight and wool length (Casburn *et al*., 2013; McLeod, 2003). Due to differences in maturity rates and the associated allometric of growth, dressing percentage will differ between breeds and sexes at a set age (Van der Merwe, 2020). Faster growth rate and the deposition of localized fat variances between different sexes are well documented where males grows faster than castrated males which in turn grows faster than females (Lloyd *et al.,* 1979; Petrović *et al.,* 2015) and females accumulating fat faster than males (Lloyd *et al.,* 1979; Santos & Azevedo, 2007). The differences can be explained by the difference in hormonal secretions between the sexes. Testosterone enhances muscle growth in rams (Schanbacher *et al.*, 1980), however when rams are castrated, it slows the growth rate and fat is also deposited earlier (Field *et al.*, 1993). When dressing percentage is compared, rams will have lower dressing percentages due to horns (in some breeds) and the testes that are removed which form part of the offal. Ewes normally therefore have the highest dressing percentage (Casburn *et al.*, 2013).

Whether lambs dresses about 1.5% lower than ewe lambs (Casburn *et al.*, 2013). Van der Merwe *et al.* (2020) therefor suggests that with feedlot finishing, breed and sex needs to be considered, as it will influence growth rate and profitability. In a study by Van der Merwe (2020), the dressing % (DP%) for Merino lambs were 42.5 ± 0.28% and for South African Mutton Merino (SAMM) lambs 45.5 ± 0.21% respectively (Brand *et al.*, 2018).

Lambs grow according to the allometric scaling of growth, which indicates that the growth of specific body tissue or organs is dependent on the growth phase and physical maturity of the animal (Swatland, 2020). Animal growth further follow a sigmoidal curve, that does reach a flat asymptote and is symmetrical, when weight against time is plotted (Swatland, 2020). The initial phase is known as the lag phase, whereafter accelerated growth takes place whereafter a plateau is reached when the animal nears maturity (Figure 2.6). The rate at which the growth rate of the animal starts to slow is determined by the relative maturity rate of the breed (Tatum *et al.,* 1998) with smaller breeds tending to mature earlier (Kennedy, 2019).

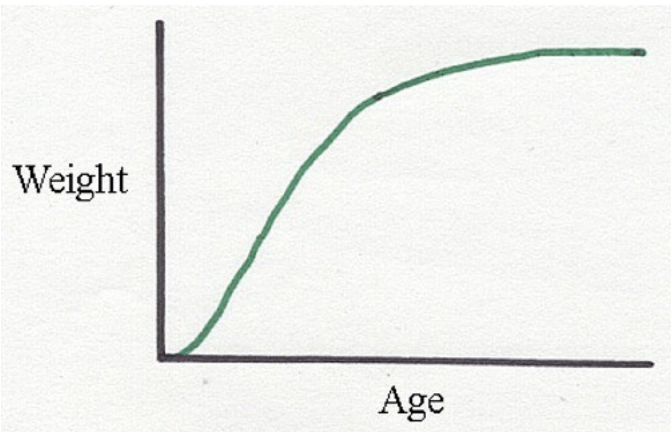


Figure 2.6 Sigmoidal curve of weight against age of ruminant livestock (Swatland, 2020).

When animals are slaughtered too early, the dressing percentage will tend to decrease (Van Koevering *et al.,* 1995). Under such conditions, the degree of fatness of the carcass will also tend to be too low, contributing to not only a lower dressing percentage, but also poor classification while too late slaughtering will also lead to poorer classification of the carcass, as fat cover will be excessive, despite a higher dressing percentage (Van Koevering *et al.,* 1995; Brand *et al.,* 2017). According to Brand *et al.* (2018), in South Africa, over-conditioned carcasses often will struggle to sell due to negative consumer preference, as the high fat is considered unhealthy. The most appropriate slaughter weight and time are reached when muscle weight is at the biggest relative to the total live body weight while offal is at the lowest and this will differ between breeds (Van der Merwe *et al.*, 2020a). Physiologically muscle is deposited second last, while adipose tissue is deposited last (Savell, 2021). When different breeds with different maturity ages are incorporated in a commercial feedlot (almost always the norm), the animals should therefore be managed according to breed. It is therefore clear from literature that slaughtering at the correct physiological stage will have considerable financial implications on feedlot profitability. Higher growth is achieved with a higher plane of nutrition, thus a shorter feed period to reach the desired goal (Savell, 2021). This is illustrated [redacted] the feedlot cycles. Thus with a high growth rate more animals can be accommodated in the infrastructure as animal will exist the feedlot quicker. According to Savell (2021) more muscle to bone and fat is deposited as time progresses when an animal is fed (Figure 2.8).

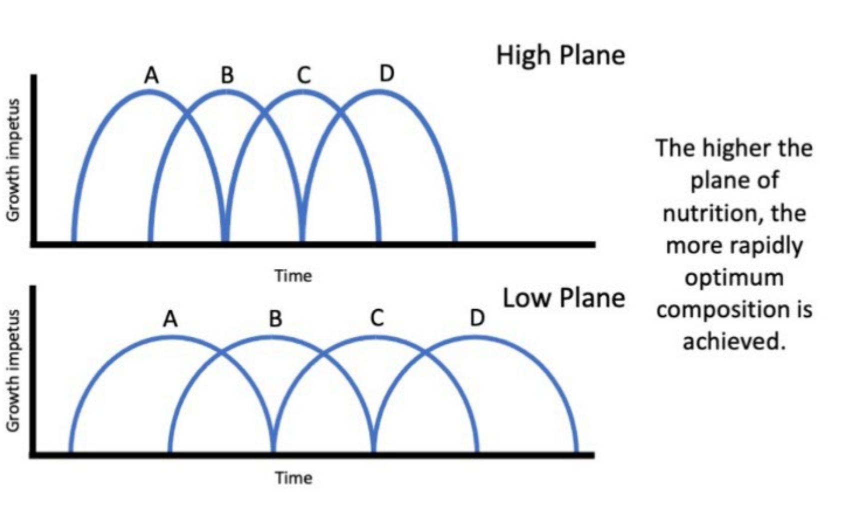


Figure 2.7 Differences between high and low plane nutrition on growth (Savell, 2021).

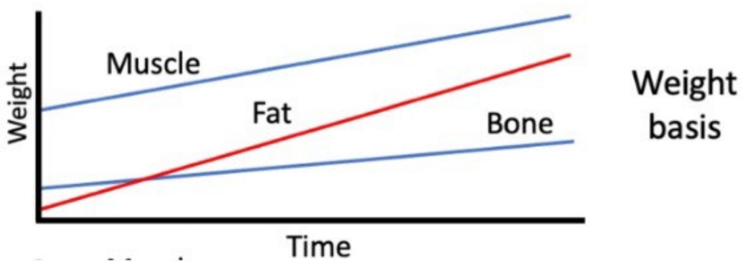


Figure 2.8 Muscle, fat and bone deposition over time in a feedlot animal (Savell, 2021).

Despite similar live and carcass weights and dressing percentages, classification may differ resulting in differences in income, which in turn will affect feedlot profitability. Detailed research have been published to predict fat coverage and dressing percentage of feedlot lambs (Kennedy, 2019) with complex algorithms to determine the optimal slaughter weight accompanied by the desired fat coverage per breed (Van der Merwe, 2020). These studies, however, are costly and the results are only available after slaughtering. Many of these techniques involve costly equipment, are time consuming and require a high skill set and not suited to be implemented at feedlot level in practice. Often the measurements lack critical data to predict carcass income accurately, i. e. ultrasound scanning does not predict carcass weight as live weight before slaughter is not recorded.

2.4.4 Average daily gain and feed conversion ratio

Essential production parameters are evaluated in a commercial feedlot which can influence profitability. Two of the most important drivers that determine feedlot profitability is ADG and FCR. The higher the ADG the better the growth rate and this indicates that the optimal weight of an animal given the maturity, would be achieved faster. In the South African commercial lamb feedlot industry a minimum ADG of 300 g/lamb/day growth rate is considered to ensure profitability (Coetzee, 2004). This growth rate is, however dependent on breed and maturity (Van der Merwe, 2020). Coetzee (2004) described an individual growth of 350 g/day and FCR of 4.5 kg feed/kg as remarkable.

Combined with ADG, FCR is another important profitability factor as it describes the amount of feed required to increase the weight of the animal per unit of gain (Xu *et al.,* 2014; Yi *et al.,* 2018). A FCR value of smaller than 5 should be pursued by the feedlot operator (Coetzee, 2020). To ensure optimal growth, feedlot lambs are supplied a diet high in energy and protein content to meet the requirements of a growing lamb (NRC, 2007). The primary objective of the feedlot operator is to reduce feed cost while increasing live weight gain, thereby decreasing the FCR. A FCR of 1:1 is expected during infancy increasing over time as the animal matures (Vosloo, 1982). Table 2.3 indicates the increase of FCR over time. By feeding weaned lambs between 25 and 30 kg liveweight, the feedlot operator takes advantage of the better FCR at a younger age.

Table 2.3 The influence of lamb age on FCR (Vosloo, 1982)

Age (days)	Live weight (kg)	Feed conversion ratio (kg DM intake/kg live weight gain)
0 - 42	4.5 – 15	1.0:1
42 – 60	15 – 20	3.0:1
60 – 80	20 -25	3.5:1
80 -100	25 -30	4.0:1
100- 120	30 -35	4.5:1
120 – 140	35 – 50	5.0:1
140 - 160	40 -45	5.5:1

High environmental temperatures (heat stress) influence ADG by reducing DMI as the environmental temperature increases (Bhattacharya & Uwayjan, 1975). Table 2.4 illustrates the effect of temperature and feed density on DMI.

Table 2.4 Effect of lucerne hay-to-concentrate ratio on feed intake of sheep under cool and hot conditions (Bhattacharya & Uwayjan, 1975).

	Intake (g/day)	
Hay:Concentrate Ratio	Cool (11-22°C)	Hot (27-32°C)
23:75	1000	820
50:50	1180	1032
75:25	1050	1016
75:25 + fat	879	868
Average	1027	934

Strategies to mitigate heat stress includes the availability of clean cool drinking water, adequate space and effective ventilation (Krishnan *et al.,* 2017). As store lambs entering the feedlot normally are reared on pasture prior to entering the feedlot, deworming is essential as they therefore were exposed to higher endoparasite infection (Andrioli *et al.,* 2017). According to Whittier *et al.* (1995) deworming improves lamb performance significantly in the feedlot as competition for nutrients between the host and the parasite is eliminated.

2.4.5 Feed cost

Feed cost normally contribute between 70% and 75% of total cost in the feedlot (Retallick, 2012; Lima *et al.*, 2017) and is mainly determined by grain cost as 50 to 60% of the diet consists of grain (De Wet, 2018). Commercially, feeds are normally formulated according to the least cost principle; therefore, keeping feed cost to a minimum without compromising on quality to ensure optimal growth of the animals (Roush *et al.,* 1996; Patil *et al.,* 2019). Prior to growth of an organism, maintenance requirements need to be met first (Mendes *et al.,* 2021). In formulation, the cost and availability of a feed ingredient will determine inclusion in the final feed formula (Kleyn, 2013). Under commercial environments feed is supplied in pelleted form to prevent selective eating behaviour and improves utilization of the feed while reducing waste (Van der Merwe *et al.*, 2020). To meet the high energy requirements of growing lambs (NRC, 2007), ingredients high in readily fermentable carbohydrates (starch) content such as maize are normally used (De Wet, 2018) while fibre content is minimized. High starch containing diets combined with minimal fibre, however, poses a risk of sub clinical rumen acidosis or even clinical acidosis when lactic acid production overpowers the buffering capacity of the rumen (Hernández *et al.,* 2014). This risk is the main reason why feedlot lambs are gradually adapted to feedlot diets for 10 to 14 days (Smith, 2008; Frassen *et al.,* 2018). This adaptation period has been adopted by most producers to allow adequate time for development of lactate-utilizing bacteria (Tajima *et al.,* 2000), and ruminal papillae (Schurmann *et al.,* 2014). In practice often ionophores (Price *et al.,* 2009) such as, probiotic yeast (Lockard *et al.,* 2020) with buffers (Smith, 2008) are included to aid with the adaptation of the rumen to the higher starch diets. The main objective is to shorten the adaption period while still allowing lamb growth without the occurrence of metabolic risks (MLA, 2007; Pienaar *et al.*, 2012). The diet normally contains grain, protein concentrate as well as forage like lucerne hay or silage (Van de Vyver *et al.*, 2013). Table 2.5 shows a typical lamb feedlot diet (Van der Merwe *et al.,* 2020) while Table 2.6 indicate the nutritional requirements of feedlot lambs (NRC, 2007).

On average, lamb daily DMI range between 3.8 and 4.2% of body weight (MLA, 2007, NRC. 2007; Van der Merwe, 2020). More accurate DMI prediction models (i.e. Brody and Gompetz) have been investigated by Van der Merwe (2020); however being more accurate, is much more complicated and more difficult to implement in practice. A wide range of feed management options and feed equipment is available for lamb finishing operations. Different categories of feeding systems used include self-feeders/troughs, troughs and choice feeding (MLA, 2007). Feed is normally *ad libitum* offered in either pelleted or loose total mixed ration (TMR) processed feed formats (Li *et al.,* 2021).

Table 2.5 Example of a commercial feedlot diet composition (Van der Merwe *et al.,* 2020).

Ingredients	As fed (g/kg)	Nutrients	As Fed
Lucerne hay	485.10	Energy (MJ *ME/kg feed)	9.41
Maize	394.90	Crude protein (g/kg)	160.00
Cottonseed oilcake meal	57.90	Non degradable protein (g/kg)	34.60
Calorie 3000	25.00	Rumen degradable protein (g/kg)	125.40
Salt	10.00	Total digestible nutrients (g/kg)	630.00
Urea	5.00	Crude fibre (g/kg)	160.90
Ammonium sulphate	5.00	Acid detergent fibre (g/kg)	209.80
Slaked lime	5.00	Neutral detergent fibre (g/kg)	286.80
Ammonium chloride	5.00	Calcium (g/kg)	14.70
Limestone	5.00	Phosphorus (g/kg)	3.00
Mono calcium phosphate	2.10		
Total	1000.00		

*ME – Metabolizable energy

Table 2.6 Nutritional requirements of growing lambs between the age of 4 and 7 months. Adapted from the National Research Council (NRC, 2007; Van der Merwe, 2020).

Body weight (kg)	ADG (g/kg)	Daily feed intake (kg/day)	Total digestible nutrients (kg/day)	Metabolizable energy (MJ/day)	Crude protein (g/day)	Rumen un-degradable protein (g/day)	Ca (g/day)	P (g/day)
20	200	0.83	0.66	22.0	101	40.4	3.4	2.7
	300	1.20	0.95	31.7	142	56.8	4.9	4.0
30	200	1.20	0.79	26.4	119	47.6	3.7	3.0
	300	1.25	0.99	32.9	148	59.2	4.9	4.0
	400	1.62	1.28	42.7	189	75.6	6.4	5.4
40	200	1.29	1.00	33.2	148	59.2	4.6	3.8
	300	1.50	1.02	34.0	153	61.2	5.0	4.1
	400	1.66	1.32	43.9	195	78	6.4	5.4

[a] Rumen undegradable protein requirement calculated as 40% of crude protein requirements

According to Savell (2021) to produce a desirable carcass three factors are required:

- animals must be fed *ad libitum*
- animals must be marketed when ready
- animals should not be kept after readiness is reached

2.5. Practices of selecting animals for slaughter

Different practices between feedlots to select slaughter-ready lambs are used and are determined by personal preference based on speed, labour intensiveness, variability in the animals, breed variability in matureness and the end-market of the animals in the feedlot. These strategies include:

- fixed number of days (normally 42 days) (Van der Merwe *et al.,* 2020b).
- minimum weight (depend on breed; normally 36-45 kg live weight) (Brand *et al.*, 2018).
- body condition scoring (normally done with palpation; >4) (Kenyon *et al.*, 2014).
- visual assessment.
- objective technology use (RFID, 2021).

2.5.1 Fixed number of days

Most commercial feedlots in South Africa use a predetermined slaughter weight or a fixed period of days in the feedlot (Van der Merwe *et al.,* 2020b). The length of the feeding period to finish the lambs is determined by the desired final weight and subcutaneous fat cover of the lamb along with the growth rate of the lambs (Van der Merwe *et al.,* 2020). This is different for the respective breeds due to differences in maturing rates (Taylor, 1980; Van der Merwe, 2020; Posbergh & Huson, 2021). When comparing the South African market to the European market, the South African market demand a heavier carcass of between 18-22 kilograms, compared to the European market of a carcass between 10-13 kg (Brand *et al.,* 2018). In Light lamb “ternasco”, “recental” or “pascual” is the most frequent product (68-75%) in the Spanish market with a typical carcass weight between 8.5 and 13 kg (Alfonso *et al.,* 2001). New Zealand and Australian markets, despite still acknowledging meat from sheep with two permanent incisors, produce similar carcasses as in South Africa (Flakemore *et al.,* 2015; Ladaniwsky, 2020; Van der Merwe *et al.,* 2020a). Another popular commercial practice by feedlots in South Africa is to feed lambs for only 42-49 days, whereafter they are all slaughtered, irrespective of all other factors (Van Heerden, 2007). This practice, despite being simple and easy to manage, can however lead to reduced revenue as animal variation will lead to variation in the classification, particularly when large variation of breeds and weights of animals fed exists (Bowman, 2010). Under these conditions some animals will be under conditioned and some over-conditioned. In a study to determine the length of the feed period of different breeds, Van der Merwe (2020) determined rearing periods of 43 days for Merino lambs, 37 days for SAMM lambs, 32 days for Dormer lambs and 26 days for Dorper lambs, respectively, to reach the respective ideal slaughter weights and classification. These results highlight the differences in maturing rates of different breeds (Van der Merwe, 2020). It has been demonstrated that subcutaneous fat increases as the rearing period progress and as carcass weight of the lambs increase (Brand *et al.,* 2018). This does not consider that each animal within a breed can have a different growth rate due to underlying genotype (Van der Merwe, 2020). From literature it is therefore evident that when different breeds are being fed in the same feedlot, specific managerial inputs are required and that a single defined period on feed cannot be used without a reduction in profitability.

2.5.2 Minimum weight

A popular commercial practice is to slaughter animals when a specific weight is reached. This practice is however problematic as maturity rates and weights differs between breeds (Taylor, 1980; Posbergh & Huson, 2021). Ideal slaughter weights for South African lamb were determined by Brand *et al*. (2018) as 42.7 kg for Merino and SAMM lambs and 36 kg for Dorper lambs. Van der Merwe (2020) also reported similar numbers. As this practice designates that an animal should be slaughtered as the desired weight is reached, bearing in mind the maturity differences, it in practice will therefore require different final weights. However from a commercial perspective this is , almost impossible to manually manage effectively (Duddy *et al.,* 2016).

2.5.3 Body condition score (BCS)

Various methods are currently available to determine BCS in animals. Predicting fat cover while lambs are still alive can be done by BCS via visual observation, palpation or ultrasound scanning (Bell *et al*., 2018).

In Australia, the traditional approach of visually assessing lambs when the lambs go through the drafting race, results in variation of between 5-8 kg per carcass combined with significant variation in fat scores (Casburn *et al.*, 2013). Visual assessment of sheep combined with physical palpation assessment, is a method used by livestock managers to monitor energy status of animals (Brown *et al.,* 2014). Monitoring liveweight in sheep is a valuable management strategy (Brown *et al*., 2014). According to Jones *et al.* (2011), who assessed managerial feedlot practices, reported that 41% to 50% of livestock mangers indicated they use such systems. When only using visual assessment, rumen fill and wool can perceive a misconception of the actual body condition of the specific animal (Brown *et al.*, 2014). Although single flock variation could be minimal when only visual assessment is used, large variation in cross flock assessment is still evident (Kenyon *et al.,* 2014). As consumers demand uniformity, the use of only visual assessment as a decision tool could therefore be limited.

Determining BCS by palpating between the 12th and 13th rib in the loin region, is a conventional method that has disadvantages and advantages. This technique was developed in 1961 by Jeffries when he first described the body condition scoring technique based on a scoring system from one to five where one is very thin and five very fat (Kenyon *et al.*, 2014). A degree of sharpness (spinous) and roundness (transverse) is assessed when palpating the loin. Russel *et al.* (1969) later modified the BCS by inserting 0.25 increments. When palpating the loin region on the back of the lamb at the 13th rib, the longissimus dorsi muscle is palpated (Phythian *et al.*, 2012). The degree of dorsi muscle and fat cover is assessed with palpation, as this region is last to develop and is thought to reflect rapid gains or losses in body fat (Jeffries, 1961). A body condition score (BCS) ranging from 1 to 5 can be assigned through this subjective manner of assessment (Standford *et al.,* 1998).

Figures 2.9 and 2.10 illustrates the practice of palpation, both evaluating the transverse and spinous fat cover (Wright & Genever, 2019). Figure 2.11 depicts a BCS sheet. Clavas *et al.* (1998) concluded that the palpation BCS technique is easy for a person to master in a single flock, however assessment is not accurate across flocks. Different persons will therefore render different scores (Kenyon *et al.*, 2014). Furthermore, according to Russel *et al.* (1961) the reliability of body condition scoring in sheep resulted in conflicting results that ranged from excellent to poor. A high variation of repeatability of determining the BCS by palpation can range from 52% to 100% (Keinprecht *et al.*, 2016). It is therefore clear that the level of experience and consistency of the adjudicator plays a major role in repeatability and variation in BCS assessment (Evans, 2010; Kenyon *et al.*, 2014). Both these methods of BCS can yield a high variation within group (Kenyon *et al.,* 2014).

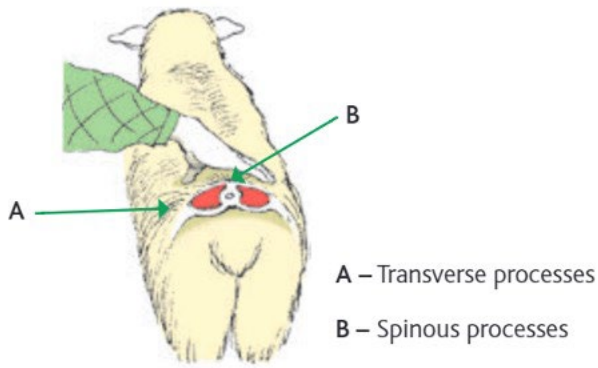


Figure 2.9 Position of manual palpation to determine BCS in lamb (Wright & Genever, 2019).

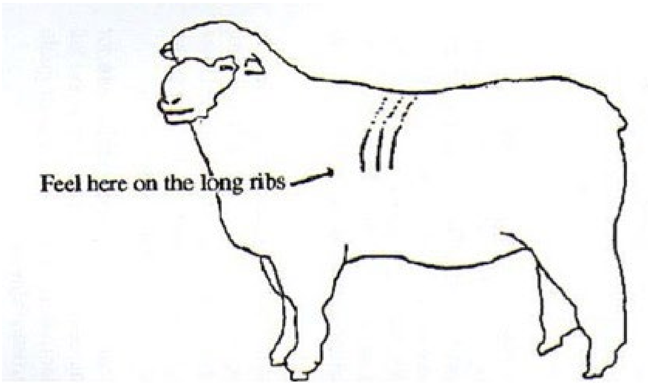


Figure 2.10 Palpation of the loin at the 13th rib on the longissimus muscle (Wright & Genever, 2019).

Several authors; Silva *et al.* (2016) in equids, Anderson & Wahlstrom (1969) in swine, Keinprecht *et al.* (2016) and Van der Merwe *et al.* (2020) in lambs, Williams (2002) and Suguisawa *et al.* (2003) in beef steers and Domecq *et al.* (1995) in dairy cows all reported ultrasound scanning as an effective and accurate method of predicting BCS by accurately and objectively measuring subcutaneous fat cover. Ultrasound scanning as a standard practise in commercial feedlots dealing with large animal numbers, might have limited use due to cost, availability, animal ethic issues and the speed of use (Bell *et al.,* 2018). Modern technologies can therefore assist in more objective and accurate predictions with higher repeatability and less variation (Van der Merwe, 2020). Earlier Hopkins (1990) also showed a strong correlation between ultrasound fat depth measurement and carcass fat depth, after lambs were slaughtered. The method of ultrasound measurement scanning however takes more than a minute as the scanner head needs to be against the skin surface for an accurate measurement and the animal needs to be held still. Thus, animals with wool on need either to be sheared or the wool need to be opened up to make the skin visible (Teixeira *et al.,* 2006). Basic training is needed to operate the ultrasound scan equipment for animals for correct interpretation of the scan result (ASUM, 2017). With lambs, ultrasound fat scanning is done at the 13th rib between the third and fourth lumbar vertebrae at the point of the transverse muscle (Van der Merwe *et al.*, 2020a). Figure 2.12 shows an ultrasound scan image compared with a normal digital image at the 13th rib. The correlation between the fat level and the classification of the carcass has been shown by Van der Merwe (2020a) as an effective method to quantify the ideal time of slaughter. The measurement of fat depth over the eye muscle showed a correlation coefficient in two experiments by Hopkins (1990) of 0.93 and 0.95, respectively. The above data is verified in a comprehensive review article by Tait (2016).

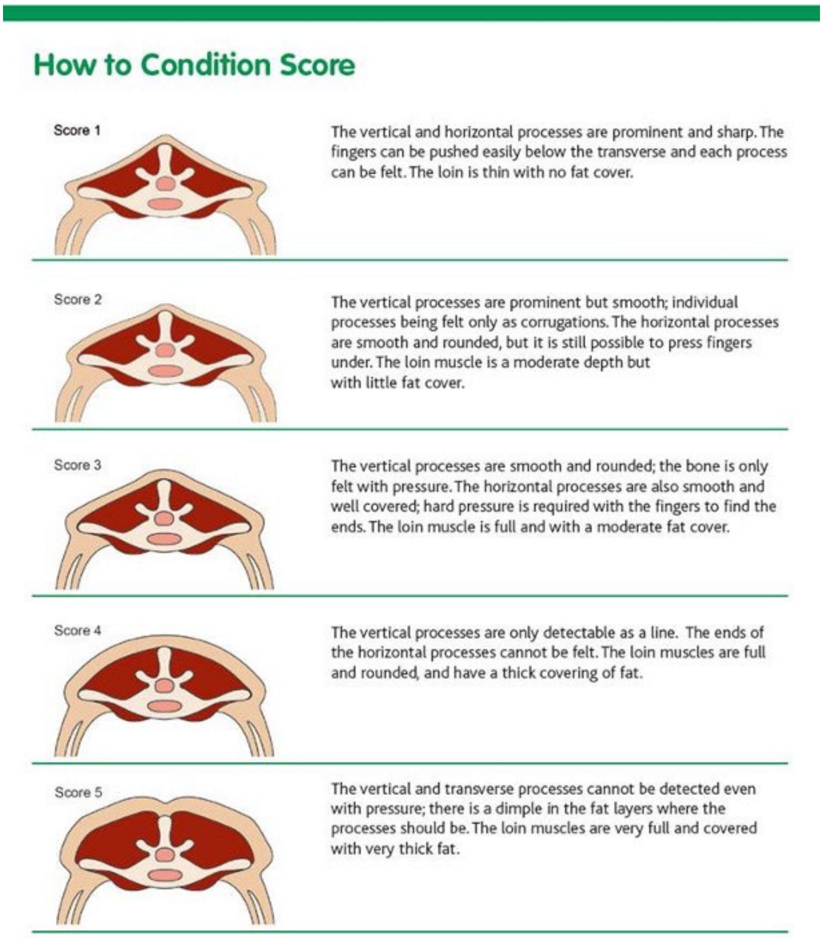


Figure 2.11 Body condition scoring of lambs (Wright & Genever, 2019).

Ultrasound technology has been shown to be effective to select slaughter ready lambs to optimise carcass fat classification (Van der Merwe, 2020). The technology is considered a non-invasive technique to predict the fat cover of an animal without damaging the meat (Silva *et al.,* 2006; Agamy *et al.,* 2015). Ultrasound can provide breeders, producers and researchers the ability to estimate carcass composition traits (Agamy *et al.,* 2015). However, ultrasound scanning is time-consuming, as the best image needs to be frozen for measurement (Van der Merwe, 2020) and is less accessible to farmers and feedlots due to relative high equipment cost (Mindaray America, 2021). Furthermore the scanning area of each animal needs to be clear of wool or hair to make direct contact with the skin, thus the technique is not practical in large commercial environments (Van der Merwe *et al.,* 2020a; Teixeira *et al.*, 2006). Ultrasound also does not take body weight into consideration and therefore despite being accurate to predict carcass class, does not predict carcass weight and hence is a poor predictor of carcass income. Table 2.7 indicates the correlation of fat cover to classification (SAMIC, 2011).

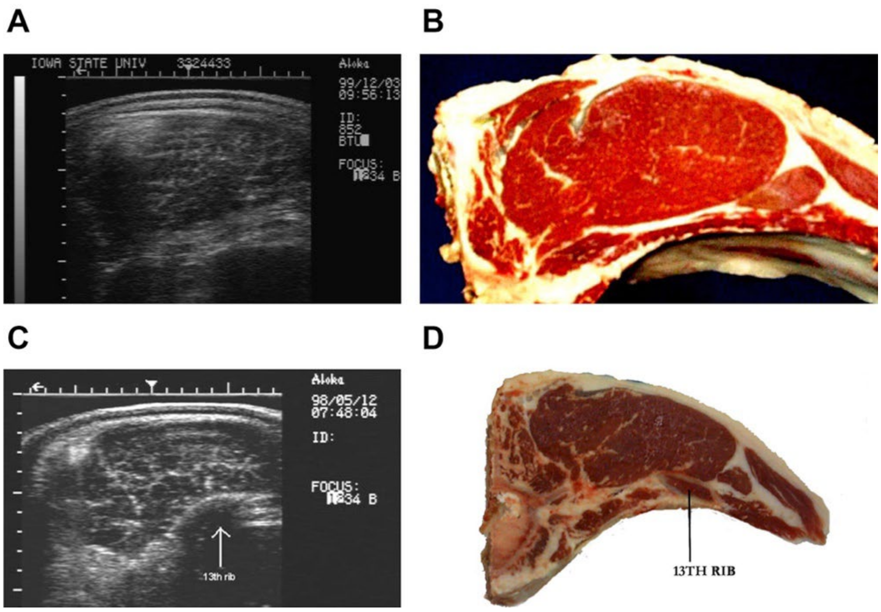


Figure 2.12 Ultrasound scanning and the relationship of fat cover to classification (Tait, 2016).

Table 2.7 Backfat thickness for fat classification evaluation (SAMIC, 2011)

Fat cover	Fat score	Description of fat cover
0	0	No fat
<1 mm	1	Very lean
1.1-4 mm	2	Lean
4.1 – 7 mm	3	Medium
7.1 – 9 mm	4	Fat
9.1 – 11	5	Slightly overfat
>11.1	6	Excessively overfat

Figure 2.13 is a typical example of an ultrasound device. It consists of a probe and computer that has a screen and keyboard. These devices can be either fixed or portable. Figure 2.14 shows how and where on the sheep it is done in practice. Figure 2.14 illustrates how the wool have to be opened so that the probe of the ultrasound device can be pressed against the skin (Teixeira *et al.,* 2006). Figure 2.15 visualizes the results of an ultrasound snapshot indicating muscle, fat and skin. The skin is the most outer layer with the fat layer between the muscle

and skin layer (Figure 2.15). Both muscle measurement and pregnancy detection are possible with a single ultrasound device given different probes are available (Mindaray America, 2021).

Figure 2.13 Ultrasound device (Mindaray America, 2021).

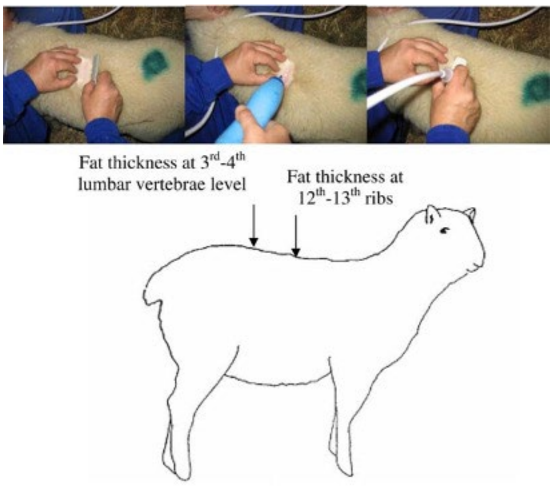
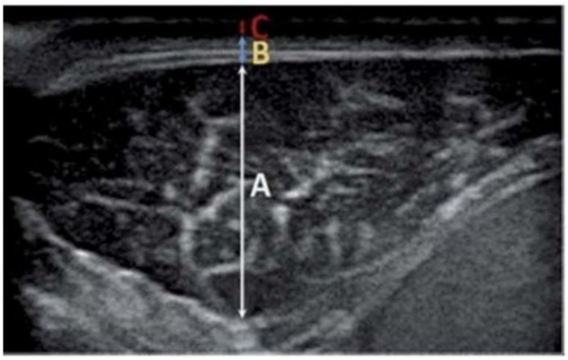


Figure 2.14 Position of ultrasound scanning (Teixeira *et al.*, 2006).



A – Muscle; B- Fat; C- Skin

Figure 2.15 Results of an ultrasound scan (Teixeira *et al.,* 2006).

2.6. Precision livestock farming and technology

Until recently, ruminant precision livestock farming has been limited to the dairy industry. In modern dairies, milk production is measured individually, and feed allocation is done according to yield, milk solids, days in milk, body weight changes and BCS and other parameters via sophisticated integrated software and censors (Trevarthen & Michael, 2008). As this technology are becoming more available and affordable, it is being incorporated more often in other intensive and extensive livestock production systems (Banhazi *et al.*, 2012). Precision livestock farming is commonly utilized to increase the efficiency of production, while also improving animal and human welfare, by applying advanced information and communication technologies, targeted resource use and exact control of the production process (Banhazi *et al.*, 2012). The demand for individual animal management, identification and traceability is guided by the need for quality control and welfare management and drives PLF (Voulodimos *et al.*, 2010). In PLF the individual animal data is recorded more accurately compared to a more traditional group measurement approach (Bolte, 2006).

Radio frequency identification (RFID) technology is one method available to achieve PLF. These systems make use of individual animal performance rather than group performance. Group management systems can only be successful when all animals are moved to different phases together. When groups are non-homogenous, individual identification is required for successful tracking and management of the animals. According to Bolte (2006), the National Animal Identification System aims to individually identify animals in which interest recently has grown significantly. Radio frequency identification can aid in this electronic animal identification service at livestock markets (Bolte, 2006). In the modern era of precision farming, technology can be used to generate more accurate data including growth rate and feed intake to aid in rapid and databased decision making. The use of RFID systems is commercially used to evaluate animals, based on individual performance rather than group performance by collecting individual data (Datamars, 2021). Since the wide adoption of RFID technology globally, ranging from groceries to laundry, it has been established that the use of RFID technology can provide the technological framework, over which accurate and highly sophisticated management of animals can be performed (Voulodimos *et al.*, 2010). Current commercial RFID systems enables farmers to weigh and draft animals automatically using several different criteria (RFID, 2017). The use of this technology often leads to a decrease in time spent on specific activities, like precise data collection, improved management decisions, reduced labour costs, better genetic selection and an increase in efficiency and accuracy, ultimately resulting in a higher revenue (Sabbaghi *et al*., 2008).

2.7 RFID hardware

RFID uses electromagnetic fields to automatically identify, and track tags attached to animals (Brown-Brandl, 2019). Radio-frequency identification technology consists of several different components including a small radio transponder, a radio receiver and transmitter (Barge *et al.,* 2013). When triggered by an electromagnetic interrogation pulse from a nearby RFID reader device, the tag transmits digital data, usually an identifying number, back to the reader (Ajami & Rajabzadeh, 2013; Akbari & Ajami, 2015). This technology makes use of low frequency signals to exchange data between subjects such as tags and readers and computers (Ruiz-Garcia & Lunadei, 2011). A passive RFID tag is placed on the animal and these tags are used in different applications ranging from ear tags (Figure 2.17), boluses and injectable tags. In the livestock sector however, ear tags are most commonly used (Barge *et al.,* 2013). This management practice improves economic efficiency as these tags can be re-used up to five or six times or even more (RFID Experts Africa, 2021). The RFID ear tag is small and ultra-lightweight and is attached to the animal similarly to conventional identification ear tags (Ajami & Rajabzadeh, 2013). Each RFID ear tag can be uniquely number stamped to allow the stockman to either read it manually or scan electronically via the reading panel or a hand-held (mobile) wand (RFID Experts Africa, 2021). Figure 2.16 show a reading panel while Figure 2.18 show a hand-held wand.

A common misconception that the tags “store” the animal’s data and when read and can convey all this information exists. In reality data is actually stored on the reader's database and conveys the data stored on the database of the reader when the animal tag is detected (Ilie-Zudor *et al*., 2011). Each of these tags has a unique identification number containing 15 digits. This electronic identification (EID) number is linked to a visual identification number (VID) as well (RFID, 2021). Different types of readers exist to read these electronic ear tags including handheld, panel readers or walk by readers (RFID Experts Africa, 2021). These readers exchange information with the electronic tags by radio frequency and stores it on a database. These databases can then be uploaded to cloud storage or transferred to computers via cables. Finally, the data is transformed into information, which can be used to calculate and determine individual animal efficiency and production parameters. From this information, objective data-based management decisions can then be made. Real-time decision making is possible, as these readers have the ability to organize data into useable information in real-time. This modern technology therefore can effectively replace manual data capturing and processing often delaying decision-making and forcing multiple handling of animals. The technology also allows for more frequent weighing, as it is less labour intensive as data is automatically captured while efficiency calculations is also automated (Wang, 2008).

An auto drafter and scale are components of a semi and fully automated system (RFID, 2021). An auto drafter ensures quicker sorting of lambs with less handling, compared to conventional methods (Trevartthen & Michael, 2008). According to the RFID Experts Africa (Gqeberha, South Africa), a sheep auto drafter enables a farmer to draft 500 sheep per hour while captured data can be transferred directly to external feedlot management software (RFID Experts Africa, 2020). This auto drafter and scale uses automated flow control and weigh-identification-sorting to reduce the time of handling and increase ease of movement (Mutenje, 2013). A unique electronic identification number linked to the specific RFID tag is used to identify animals. These systems normally consists of a pre-holding crate, weigh crate, 3/5-way sorting gates and a panel RFID reader (RFID Experts Africa, 2020). Figure 2.16 shows an autodrafter with the different components. In a study on cattle handling, comparing a conventional manual system against a RFID system (auto drafter and scale), Mutenje (2013) reported a 63.2% reduction in handling time, 5.5% reduction in incorrect sorting and 14% less animal stress. The incorrect sorting compared to hand sorting decreased from 8 to 2.5% resulting in a reduction of 13.6% from 15.2% to 1.6% in cattle stress. The negative effect of stress on animal production and reproduction has been well documented (Voisinet *et al.,* 1997a; Voisinet *et al.,* 1997b; Sordillo & Aitken, 2009; Gouveia & Hurst, 2013; Grandin, 2016). In another Australian study, the advantage of having individual data per animal that could be used to identity fast and slow growers and shy feeders, as growth rate is known as a good indicator of profitability (MLA, 2020).

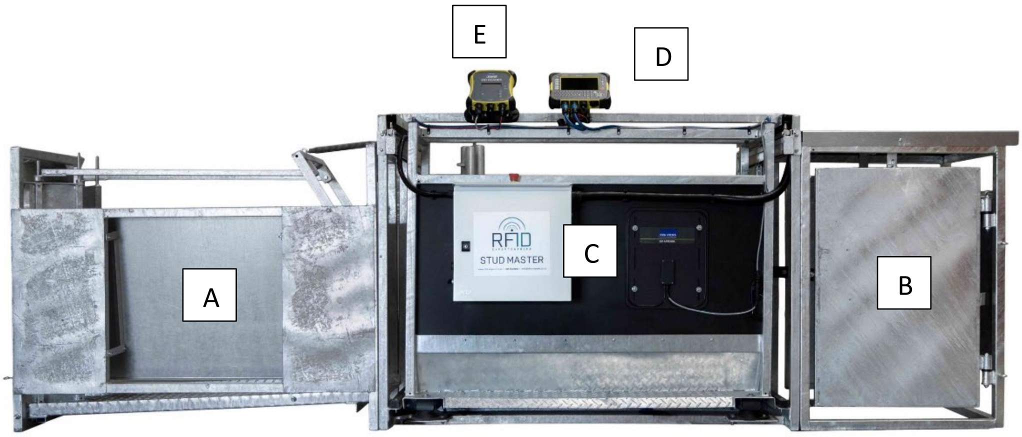


Figure 2.16 The components of an auto drafter scale (RFID Experts Africa, 2020).

A – Pre holding crate
B – Drafting gates
C – Fixed panel reader
D – Scale head
E – Reader computer

Figure 2.17 Example of an electronic identification tag (RFID Experts Africa, 2020; Datamars, 2021).

Figure 2.18 A hand-held reader (RFID Experts Africa, 2020; Datamars, 2021).

According to Shin & Eksioglu (2014), the greatest inhibitor to use these RFID systems is the initial capital investment requirement. Current initial capital investment requirement for an auto drafter is ±R200 000 while the current pricing of tags is ±R16.55 per animal (RFID Experts Africa, 2021). The automated system also allows for repeated measurements with minimal human intervention (Richards, 2014). Client-specific drafting parameters can be pre-programmed by most auto drafter units (RFID Experts Africa, 2021). This system also employs Tempel Grandin's principle as the sides are solid thereby reducing stress when handling the animals (Grandin, 1998). Although more frequent handling can lead to elevated animal stress that could possibly impact negatively on performance (Grandin, 1998), body weight monitoring is however a key management tool (Wells, 2020). More frequent handling introduced over time also reduce animals stress (Grandin & Shivley, 2015). It is however critical to determine the minimum critical number of animals to ensure return-on-investment. From an economical perspective, some advantages of these systems cannot be purely measured in direct monetary value therefore monetary and non-monetary factors should be considered when investment is evaluated (De Wet *et al.,* 2021).

Van der Merwe (2020) modelled different South African purebred breeds in feedlot conditions. In the latter study, optimal live weight per breed to ensure optimal slaughter classification and carcass weight were determined. This data can be used as criteria to effectively draft slaughter ready animals with an auto drafter. This makes it possible to remove individual animals from a mixed group according to weight and breed, using enhanced technology like the TruTest® (Datamars livestock, USA) devices combined with auto drafter scales (RFID experts, 2021). According to Brand *et al.* (2018) early maturing breeds should be slaughtered earlier to ensure uniformity with the fat cover and carcass quality of later maturing breeds. By minimising animal handling and being able to distinguish between fast and slow growers earlier and more precisely while managing early and late maturing breeds, management decisions can be used to ensure proper animal welfare while still collecting the required data.

2.8 Practical application of technology in the industry

Current methods to identify individual animals includes hot branding, visual tags, and RFID tags. The Blackwell farming enterprise in Australia investigated the use of RFID tags on their farm and reported three valuable lessons (MLA, 2020):

- It not only saved time, but also improved the accuracy and efficiency of data collection. With automatic drafting, the farmer can separate the animals automatically that require particular attention apart from the rest of the flock. This saves time and effort and provides almost 100 percent reliability (Trevarthen, 2007).
- "Be strategic with the choice of data collected – do not collect data that would not assist in decision making."

- Compared to traditional condition scoring, they have found it easier to get the labour to push the animals through the RFID scale than to get an experienced classer for condition scoring accurately and consistently. According to (MLA, 2020), the main objective is to use something that can be consistent.

Considering traceability, EID tags and databases allow multiple amounts of data recording per animal. This recorded data includes drenching and vaccination information while proximity information of the animals can also be tracked. The availability of such information allows feedlot operators and abattoirs to compile a supplier database which can be used to determine which producers' animals produce optimally under specific conditions. While RFID has been successfully used for cattle identification in several countries including the USA, Australia, Canada, Uruguay, South Korea, New Zealand and the European Union (EU), it is also more recently used in Australia, South Africa and the EU in the small stock industry (Hossain, 2012).

According to Doğan *et al.* (2016) the main advantages of RFID in livestock use can be summarized as animal identification, on-farm identification, and animal traceability. Different countries have different systems for this traceability system. In Great Britain, traceability is reported by the Cattle trace system (CTS), in Australia the National Livestock identification system (NLIS), in the United Stated of America the National animal identification system (NAIS) and in South Africa the Livestock identification traceability system (LITS) is currently being developed (Vlad *et al.,* 213).

Carcass feedback is a major benefit of adopting a RFID-based animal identification system. Carcass feedback is provided by the end of the value chain to the producer so that he/she can use it to effectively adapt management practices (De Wet, 2021).

2.9 Economy of RFID technology in a lamb feedlot

The transformation from conventional methods to modern objective data-based decision-making methods with the incorporation of technology, is a shift from subjective or group measurements and management practices towards precision and individual evaluation (Morris *et al*., 2020). This paradigm shift however, requires significant capital investment. These systems are generally expensive to introduce, however it can have a positive effect that may increase profitability over the longer run. Maintenance expenses and servicing of such systems also need to be considered and need to be inspected and serviced annually (RFID Experts Africa, 2021). Currently the cost of a complete new modern system composing of pens, auto drafter scale and sorting facilities based on Australian designs with solid sides and rounding is ±R500 000.00 (RFID experts Africa, 2021). Investigation into return on investment on this capital input is needed. The minimum unit throughput to justify the capital expenditure should also be established. Return on investment can be divided into monetary and non-monetary returns. De Wet (2021) described monetary and non-monetary evaluation on categories of RFID and are summarized in Table 2.8.

Table 2.8 Monetary and non-monetary advantages of RFID systems in a feedlot (De Wet, 2021).

Monetary	Non-monetary
Saving on feed	Better decision making according to market needs
Availability of supplier data	Improved animal welfare
Saving on time	Decreased stress on animals
Saving on labor	Less danger for working personnel
	Tag reading errors are non-existent

As feedlots are constantly investing ways to improve profitability and efficiency and with this technology, feedlots can distinguish between different suppliers by having performance data of each animal from each supplier (De Wet, 2021). Sorting animals to the same weight groups for optimal social behaviour and more precise feeding due to body weight is also possible (Coetzee, 2020). Problems and poor performing animals can be identified early and managed accordingly (De Wet *et al.,* 2021). Individual animal performance and management can have a significant impact on profitability (Hannon & Murphy, 2019). Consideration should additionally be given to the opportunity cost of not individually identifying and weighing lambs. When lambs are considered as groups rather than individuals, many poor-performing lambs are concealed by the averages and possibly carried by the top performers (MLA, 2017). The efficiency of such a system will be determined by the accuracy of data and is underlined by fewer errors due to lower human intervention and human responsibilities manual data recording (Mutenje, 2013). De Wet *et al.* (2021) reported six out of 100 data errors with conventional methods while 1 out 1000 errors were observed when RFID technology was used.

The breakeven point in a break-even analysis (BEA) is the calculation and inquiry of the margin of safety for an enterprise based on the revenues collected and costs associated with the production (Sintha, 2020). In basic terms, the analysis indicates the number of units of a specific value required to cover investment cost (Dean, 1948.) Figure 2.19 depicts BEP and indicate the break-even point. Figure 2.19 shows a description of a break-even point graph where the horizontal-axis (X) indicates the sales volume (expressed in units of quantity) and were the vertical axis (Y) shows margin and cost of sales (Sintha, 2020). The break-even point is located at the point of intersection of the sales revenue and coast lines. The area to the left of the breakeven point, that is the area between the total cost line and the sales revenue line is the area of loss, because sales revenue is lower than the total cost, while the area to the right of the breakeven, the area between sales revenue and total the costs lines is the profit area because sales revenue is higher than the total costs (Sintha, 2020).

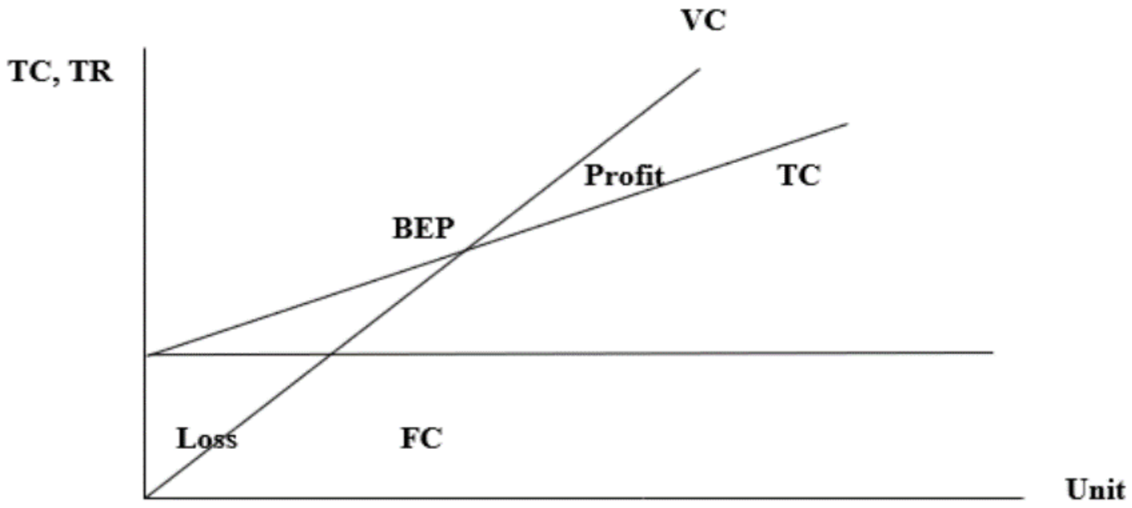


Figure 2.19 Break-even point graph (Sintha, 2020).

FC – Fixed cost
VC – Variable cost
TC – Total cost
BEP – Break-even point

Return on investment (ROI) is a performance measurement used to determine the efficiency or profitability of an enterprise and attempts to directly measure the amount of return on a particular investment, relative to the cost of the investment (Fernando, 2021).

In both BEA and ROI calculations, the operational scale of the enterprise will be important in the determination of investment (Sintha, 2020). With feedlot investments, the number of animals required over a specific period to cover the investment cost is determined by break-even analysis. According to Gutierrex & Dalsted (2020) the break-even point is the point where an enterprise's revenue is equal to the cost. There are two possible ways that this can be determined:

- the number of units that need to be sold need to be increased.
- the unit income needs to be increased.

The number of units required for break-even can be calculated (Gutierrex & Dalsted, 2020) by:

$$Units = \frac{Fixed\ costs}{Sales\ price\ per\ unit\ -\ variable\ cost\ per\ unit}$$

When the full RFID system capital expenditure in a feedlot is considered, the break-even point therefore should be determined where the required units obtained through the system per unit of time is of importance. A study by De Wet *et al.* (2021) evaluated the financial viability of implementing RFID technology in a South African feedlot. By using return on investment, simple payback method internal rate of return and the net present value the viability were investigated. The authors concluded that the RFID investment qualified if it was used for more than just non-performers after 14 days, but to use the data to identify which individual animal performs superior and use the data for strategic management decisions.

2.10 Conclusion

Profit margin in a sheep feedlot remain narrow with high variable cost such as feed and variable income such as slaughter prices. Different decision approaches to slaughter ready selection, both traditional and more modern exist. Body condition scoring, visual assessment and ultrasound scanning are accepted methods of predicting slaughter readiness and can also be combined to be more precise. The use of technology such as RFID technology allows predictions and precise observations for real time decision making. An investigation to the effect of implementing strategic management on slaughter readiness of feedlot lambs in South Africa using RFID technology on profitability is therefore important. The biggest inhibitor of new systems is however the associated cost thereof, as investment in technology normally is associated with high initial capital input. While precision livestock rearing is being incorporated into many production systems, the South African lamb feedlot industry still largely relies on basic feedlot assumptions and subjective management strategies.

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Chapter 3

The effect of subjective and objective decision-making tools on production parameters and slaughter readiness of lambs under feedlot conditions

3.1 Abstract

Commercial feedlots use different methods to select animals for slaughter readiness. Incorporating modern technology into feedlots implies transferring from traditional subjective methods to objective precision methods. Individual animal data is needed when selecting animals for optimal production and margin. In this study, different methods of slaughter readiness selection were evaluated on growth parameters of feedlot lambs. The seven methods evaluated was lambs selected with ultrasound scanning (RTU), fixed feeding period of 42 days (42 days), visual observation by an experienced person (E-VS), visual observation by an inexperienced person (I-VS), manual palpation of the loin region by an experienced person determining body condition (E-BCS), manual palpation of the loin region by an inexperienced person determining body condition (I-BCS) and using radio frequency identification (RFID) technology auto drafter (Fixed body weight - FBW). Ninety-eight Merino store lambs were randomly allocated to the seven different groups. The cumulative feed intake differed (P < 0.05) as the animals differed in the number of days spent in the feedlot. The FBW group had the highest cumulative feed intake (P < 0.05) and differed from all the other treatments measured, while the E-VS and I-VS differed (P < 0.05) from the 42-day and FBW groups. The I-BCS group (6.67 ± 1.38) had the highest FCR and differed (P < 0.05) from E-BCS (4.70 ±0.55) which had the best FCR but did not differ from the other treatments. The FBW group of animals resulted in the highest RTU measurement (0.50 ± 0.02) and differed (P < 0.05) from all the methods evaluated. The FBW group also had the highest (P < 0.05) final weight (42.92 ± 0.47kg) and spent the longest time in the feedlot (58.50 ± 2.50 days) which differed (P < 0.05) from all the other methods. The RTU group had better RTU measurements compared to both inexperienced groups and the E-VS group[redacted]

3.2 Introduction

A sheep feedlot is defined as a closed intensive system to finish ovine animals for slaughter (Endres & Schwartzkopf-Genwein, 2018). Intensive feeding of lambs in a feedlot allows advantages of naturally high growth rate (Van der Merwe *et al*., 2020a) and improved feed conversion ratio (FCR) (Sultana *et al.,* 2010). The goal of an intensive feed system is to achieve optimal carcass weight and a desired carcass classification at slaughter at the least cost, which is normally at the shortest time in the system (Greenwood, 2021). According to De Wet *et al*. (2021), feedlot profitability is underpinned by the accumulation of muscle tissue weight as quickly as possible at the least cost without compromising feed quality. As feedlot management affects profitability directly (De Wet *et al*., 2021), the use of new technologies might improve management decisions and profit. High efficiency is often obtained with the use of precision technology (Monteiro *et al.,* 2021; Onyango *et al.,* 2021). Wathes *et al.* (2008) describe precision livestock farming as: “Managing livestock production by employing principles and technologies employed by process engineering that will allow the producer improved monitoring of the system which will allow for better decision making.”

The livestock and meat prices in a feedlot and abattoir environment normally vary more than the cost of production, processing, and marketing (Spies, 2011). The primary South African ovine meat market demand is for lamb with no permanent incisors (age class A) and a lean fat cover (backfat depth of ±4 mm; fat class 2), summarized as a carcass with an A2 classification (Government Gazette, 2006).

According to Swatland (2020), lambs grow according to the allometric scaling of growth, which indicates that the growth of specific tissues or organs is dependent on the growth phase and physical maturity of the animal. Animals furthermore grow in a sigmoidal curve when weight is plotted against time (Brunner & Kühleiter, 2020). When animals are slaughtered too early, fat deposition is often not adequate while the opposite holds true as over conditioned carcasses are downgraded due to excessive fat. Optimal slaughter weight and feedlot feeding period are normally reached when muscle weight is highest relative to total body weight while offal percentage are at the lowest and according to Van der Merwe *et al*. (2020a) this will significantly differ between breeds. According to Van der Merwe *et al*. (2020a) the determination of the optimal slaughter weight combined with the desired fat coverage per breed need to be considered when predicting fat coverage and dressing percentage of lambs. Research in this regard is however costly and the results are further only visible after slaughtering.

According to Vollgraaff (2018), five major drivers determining feedlot profitability across the entire process play a role. These five factors include buying price, slaughter price or selling price, average daily gain (ADG), dressing percentage and feed cost. Feed conversion ratio is a function of gain and growth and needs to be considered (Lima *et al.,* 2017). The ADG is an indication of the weight increase of the animal over a set period and is generally expressed per day. According to Coetzee (2020), the higher the ADG, the better since the animal grow faster and would reach optimal weight earlier. In a feedlot finishing system, a minimum ADG of 300 g/lamb/day is desired (Dickson, 2020; Van der Merwe, 2020). Coetzee (2004) describes individual growth of 350 g/day and FCR of 4.5 kg feed/kg as remarkable. In conjunction with ADG, the FCR is an important profitability factor as it describes the amount of feed required to increase the weight of the animal by 1 kg.

To ensure optimal growth, feedlot lambs are supplied with a diet high in energy and protein content to meet the requirements of a growing lamb (NRC, 2007; Coetzee, 2020). Feeding cost attribute about 70% of the production cost (Ford, 2011; Lima *et al.,* 2017; Dickson, 2020). When feedlot conditions are not optimal, animals will take longer to reach the desired slaughter weight. Average daily gain is normally indicative of the well-being of an animal as they can only perform when feed and health status are optimal (Reinhardt *et al.,* 2012). Ovine feedlot diets are normally supplied as pellets to prevent any selective eating and improves utilization of the feed while minimizing waste (Van der Merwe *et al*., 2020). To meet the high energy requirements of the growing lambs, ingredients with high starch and low fiber is commonly used (NRC 2007). High levels of grain including maize (Zietsman, 2008) and small grain (>50% of diet DM) and high-quality forage such as lucerne hay (Macdonald *et al.,* 2021) are common in South African lamb finishing diets. Lambs in a feedlot consume 3.8 – 4.2% of their body weight as is daily (MLA, 2007; NRC, 2007; Dickson, 2020; Van der Merwe, 2020).

When selecting slaughter-ready lambs from a feedlot, different practices are used. These practices depend on the feedlot operation, the breeds in the feedlot and the target market of the carcasses produced. Commonly used selection methods in South Africa includes a fixed number of days in the feedlot, minimum weight, body condition score and or visual assessment (Van Zyl, 2022). According to Van Der Merwe *et al*. (2020b), most commercial feedlots in South Africa however use a predetermined slaughter weight combined with visual evaluation or a fixed period of days. The length of the feeding period to finish the lambs is determined by the desired final weight and subcutaneous fat cover of the lamb along with the growth rate of the lambs (Van der Merwe *et al*., 2020). These variables are however different for each breed due to different maturing rates (Van der Merwe, 2020). A popular commercial feedlot practice is to feed lambs for a set period of 42-49 days only, irrespective of other factors, whereafter they are all slaughtered. It has been shown that subcutaneous fat, among other adipose tissue deposits, increases with the rearing period and carcass weight of lambs (Brand *et al*., 2018). This, however, does not account for interbreed variation (Van der Merwe, 2020). Both these commonly used decision-making methods are also significantly influenced by market demand drivers (Janse van Rensburg *et al.,* 2020).

Another popular commercial practice is to slaughter animals as soon as they reach a specific target weight (Shiningavamwe, 2009). Different breeds will have different optimal live weight targets prior to slaughter as they differ in the rate of maturing. Some breeds, like the Dorper, are early maturing (Cloete *et al.,* 2000) relative to late-maturing breeds such as the Merino (Brand *et al.,* 2018) and the South African Mutton Merino (SAMM; Burger *et al.,* 2013). Ideal live weights prior to slaughter for South African lambs were determined by Brand *et al.* (2018) as 42.7 kg for Merino and SAMM lambs and 36 kg for Dorper lambs, respectively. Slaughter at the designated live weight is considered a common commercial practice. According to Bell *et al*. (2018) and Van der Merwe (2020) both visual body condition score (BCS) evaluation and ultrasound scanning is used to predict fat cover while lambs are still alive. Ultrasound scanning however are considered to be the most accurate objective prediction method (Keinprecht *et al*., 2016; Van der Merwe *et al*., 2020). In the commercial environment however, the latter method is less widely used due to lack of availability and being expensive. According to Casburn *et al*. (2013) in Australia the traditional approach of visually assessing sheep when the lambs are put through a drafting race often results in a 5-8 kg carcass weight variance combined with a significant variation in fat scores between lambs. Visual assessment of ovine, both on its own and combined with some form of 'hands-on' assessment, is the most common commercial method used by livestock managers to monitor energy status. Results of a study of Jones *et al*. (2011) amongst livestock managers show that 41% and 50% of livestock managers respectively indicated that they use one of the two systems. When only using visual assessment however, rumen fill and wool coverage can lead to subjective misconceptions of the actual body condition of the specific animal (Brown *et al*., 2014). These difficulties contribute to the wide variance observed with these subjective practices (Casburn *et al*., 2013).

To determine the subjective BCS of the animal by palpating between the 12th and 13th rib in the loin region is a conventional method. This technique was developed in 1961 by Jeffries when he first described a body condition scoring technique on a system from 1 to 5 (Russel *et al.,* 1969; Kenyon *et al*., 2014). With this technique, one is considered very thin and five very fat (Jeffries, 1961; Kenyon *et al*., 2014). A degree of sharpness (spinous) and roundness (transverse) is assessed when palpating the loin (Kenyon *et al*., 2014). Russel *et al.* (1984) later modified the BCS technique by inserting 0.25 increments. When palpating the loin region on the back of the lamb at the 13th rib, the longissimus dorsi muscle is palpated (Phythian *et al*., 2012). Clavas *et al*. (1998) concluded that the palpating BCS technique is easy for a person to master in a single flock, however assessment is not accurate across flocks. According to Russel *et al*. (1961), the reliability of body condition scoring in sheep resulted in divergent results that range from excellent to poor while the repeatability of BCS determining by palpation can range from 52% to 100% (Keinprecht *et al*., 2016).

Ultrasound scanning can measure different information such as rib eye depth, muscle length, pregnancy status and subcutaneous backfat thickness. Ultrasound scanning was initially developed just after the 2nd World War mainly for medical purposes (BMUS, 2021). For over 50 years however, ultrasound techniques have been used to predict carcass composition and meat traits *in vivo* (Silva, 2012). The use of ultrasound scanning in animal science started in 1956, where subcutaneous backfat thickness of beef cattle was measured at the now Colorado State University with a “Somascope” by Howery Douglas (Stouffer, 2004). The first real time ultrasound (RTU) application for carcass traits evaluation commenced in 1976 by Hans Busk who used the RTU scanner in breeding programmes with swine, cattle and sheep (Silva, 2012). Since these early applications, various improvements and modernisation of the technology to make data more accurate and easy to operate has been made. Ultrasound scanning is however a time-consuming process and not always accessible to farmers and feedlots (Van Der Merwe *et al*., 2020a). Backfat ultrasound scanning of lambs is done at the 13th rib between the third and fourth lumbar vertebrae at the point of the transverse muscle (Van der Merwe *et al*., 2020a). Figure 3.1 visualizes this. The correlation between the fat level and the classification of the carcass has been shown by Van der Merwe (2020a) as an effective method to predict carcass class.

Considering subjective human assessing of animals, an experienced observer is regarded as a person that is properly trained and skilled for the specific task. According to the Oxford English dictionary (2022), experience is defined as having gained knowledge or skill in a particular field over time. In the context of the current study, the experienced observer was a person that performs daily work with animals. As part of their daily work they frequently use BCS techniques or visual observations to select and class live animals. In the South African context experienced professional livestock individuals includes sheep and wool technical advisors or livestock agents. In contrast, an inexperienced observer is a person with little knowledge or skill of a particular field (Oxford English dictionary, 2022). During an assessment, inexperienced individuals based decisions on guessing with relative low repeatability (Gallagher, 2010). A comparison of these two different levels of experience observers was used to distinguish the effect that skill and training has on outcomes (Garcia *et al*., 2015).

Radio frequency identification (RFID) is technology that is used to record individual data of an animal with the use of and electronic identification tag (EID) tag in combined with hardware devices that are able to scan these tags (RFID experts Africa, 2021). Commercially available hardware (i. e. TruTest®, Datamars, Switzerland) can be used to record this data (Datamars, 2021). In combination with this hardware, automated drafting gates can be added to sort animals based on the specific data recorded per individual animal, allowing more accurate individual monitoring with less effort (RFID experts Africa, 2021).

The aim of the proposed study was to determine the accuracy of seven? different methods to determine slaughter readiness of feedlot lambs. Seven different methods evaluated included lambs selected with ultrasound scanning (RTU), fixed feeding period of 42 days (42 days), visual observation by an experienced person (E-VS), visual observation by an inexperienced person (I-VS), manual palpation of the loin region by an experienced person determining body condition (E-BCS), manual palpation of the loin region by an inexperienced person determining body condition (I-BCS) and using RFID auto drafter technology (Fixed body weight - FBW). The specific objectives of this chapter were to:

- Determine differences in growth parameters of feedlot lambs between selection methods.
- Compare a fixed number of days against minimum weight methods in a feedlot.
- Compare subjective methods selection between experienced and inexperienced assessors.

3.3 Materials and methods

This study was granted ethical approval (ACU-2020-14965) from the animal care and use committee of the University of Stellenbosch.

3.3.1 Trial animals

Ninety-eight similar sex, age and weight Merino (*Ovis Aries*) wether lambs were sourced from a commercial supplier in the Trompsburg area in the Southern Free State of South Africa. Upon arrival, the lambs weighed an average of 28.01 kg and were six months of age. They were born in lambing pens whereafter they were reared extensively on natural veld before they entered the trial.

3.3.2 Housing

All lambs were housed under feedlot conditions at the sheep division on the Welgevallen experimental farm of the University of Stellenbosch (33°56’45.7”S 18°52’02.2”E). A specifically designed sheep barn equipped with wooden slatted flooring was used. Seven different pens of 20 m^2 were used to accommodate the lambs. Commercial feedlot conditions were mimicked as closely as possible.

3.3.3 Processing of lambs

The 98 lambs were all shorn prior to commencement of the trial. All lambs received vaccinations and drenching to ensure they are free from parasites and are protected against common feedlots diseases. The veterinary products administered according to manufacturer recommendations and were Mulitvax P® supplied by MSD, Multimin +Se® supplied by Virbac, Maxilint® supplied by Ascendis Animal Health Ivermectin® supplied by Ivomec and Vitamin ADE supplied by Cipla. Lambs were weighed upon arrival and used as the start weight. Each pen represented a group that was subjected to a different selection method for slaughter readiness and all groups received the same commercial feedlot diet as presented in Table 3.1. Each pen was equipped with an automated RFID self-feeder (RFID Experts, South Africa) and a ball-valve water trough ensuring daily *ad libitum* feed and clean *ad libitum* water. All trial animals were equipped with an on-ear RFID tag (FDX 25 mm, RFID Experts, South Africa) inserted by the lamb supplier at birth. Each RFID tag had a unique electronic identification (EID) number accompanied by a visual identification number (VID). The visual identification number and first weight were recorded at commencement of the trial and linked to the EID for all further recording and identification purposes through a Stud Master® (RFID Experts, Datamars, Switzerland) auto drafter equipped with a TruTest® scale to measure lamb live weight accurate to 0.5 kg (RFID Experts, Datamars, Switzerland).

3.3.4 Methods and experimental design

Ninety-eight animals were randomly assigned to seven treatments as indicated a few lines later. Each of the seven treatment groups were subjected to a different method of selection for slaughter readiness. These methods were implemented from day 28 in the feedlot on a weekly (once every 7 days) basis. All animals were weighed weekly on the same day at the same time. Some animals were removed from the trial due to ethical reasons and 90 results were obtained that were used.

The seven treatments (represented by 7 methods of decision) used for slaughter readiness were:

1. Lambs selected by real time ultrasound scanning. A measurement of at least 4 mm used to slaughter (RTU) – This method was used as reference method.
2. Lambs slaughtered after 42 fixed days in the feedlot – (42 days).
3. Visual observation by an experienced person (E-VS).
4. Visual observation by an inexperienced person – (I-VS).

5. Manual palpation of the loin region by an experienced person determining body condition – (E-BCS).
6. Manual palpation of the loin region by an inexperienced person determining body condition –(I-BCS).
7. Using RFID auto drafter technology to select slaughter ready animals according to weight. Based on the Merino growth curve work of Van der Merwe (2020), a minimum live weight of 42 kg was used as slaughter ready (Fixed body weight – FBW).

The trial was terminated at day 70 in the feedlot as all animals that were still not selected for slaughter at this time, were slaughtered.

The 42 days and FBW selection methods were used to simulate commercial feedlot conditions as these are the most widely used methods used in the South African lamb feedlot industry. All treatments were measured against RTU to determine the differences in accuracy as this technique has been previously shown as a very accurate method to predict carcass classification (Van der Merwe, 2020). The assessor that assessed the E-VS and E-BCS was the same person while a different individual assessed Treatments I-VS and I-BCS. To prevent any prejudice, the respective two assessors had no contact with each other. Care was taken to assure the selections of the assessors were always completely independent without any external influence. No feedback was supplied to any of the assessors to prevent experience gain over time during the trial. No training, apart from own experience, was supplied during or prior to commencement of the study to any of the assessors.

All animals selected for slaughter were ultrasound scanned whereafter they were immediately transported to the abattoir (84 km) where they stood in lairage (16 hours) until the next morning for slaughter.

3.3.5 Diet

All lambs were adapted for 10 days upon arrival, where they received an adaption phase diet with hay roughage fed *ad libitum*?. The adaption diet was stepwise replaced with the feedlot finisher diet. All feed was pelleted to reduce selection and feed wastage while also allowing RFID feeder use. The feedlot finisher diet used closely represented that of a commonly used commercial lamb feedlot in South Africa. The commercial feedlot diet composition and nutrient composition is shown in Table 3.1.

Table 3.1 Composition and proximate analysis of the finishing feed.

Ingredient	kg
Barley	200
Calorie 3000[1]	12
Molasses syrup	30
Yellow maize meal	343
Canola oilcake meal	23
Extrublend[2]	50
Wheat straw	205
Lucerne hay	100
Mutton Gainer 125 [3]	19
Salt	3
Feed lime	15
Total	1000
Composition	g/kg
Fat	31.0
Protein	145.0
Moisture	107.3
Ash	49.5
NDF	11.97
Fibre	97.8

[1]CP=40 g/Kg, ME = 10 MJ/Kg
[2]CP=360 g/Kg, ME=12.4MJ/Kg
[3]CP = 1250 g/Kg, P = 2.30 g/Kg

3.3.6 Hardware/infrastructure/human influence needed for each method

3.3.6.1 RTU

An ultrasound scanning device, (Mindray DP 30V® ultrasound scanner, IMV imaging South Africa) was used to measure the backfat thickness of all animals on the last day before slaughter. A visual explanation of where on the body of the animal ultrasound scanning is measured is displayed in Figure 3.1 From Figure 3.1, it can be seen that the placement is between the 12-13th rib of the animal (Teixeira *et al.,* 2006). The wool was gently combed at the scanning position and ultrasound gel was used as a coupling agent to improve conductivity between the transducer probe and the skin (Teixeira *et al.,* 2006). Once the best image was obtained, it is frozen and on-screen measurements of the cross section subcutaneous fat depth was taken. All animals in the RTU group with a measurement of 4 mm and more was subjected to slaughter.

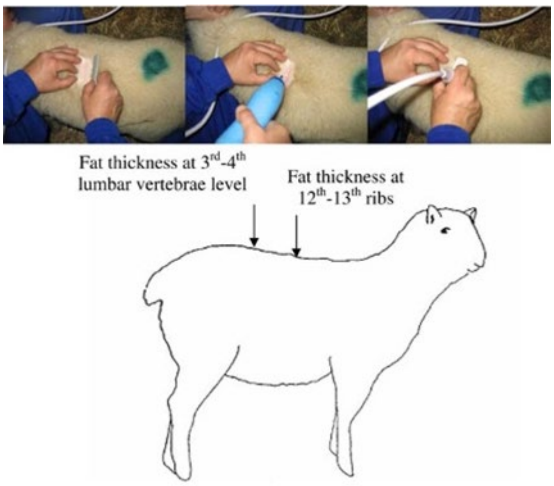

Figure 3.1 Position of ultrasound scanning probe (Teixeira *et al.*, 2006).

3.3.6.2 Fixed 42 -day

Calculation of day of slaughter was determined at 42 days after the 10 days of adaption period. According to Van Zyl (2022), most commercial feedlots in South Africa finish lambs within 6 weeks.

3.3.6.3 E-VS and E-BCS

A person with experience in classing animals and that has been trained to select animals based on palpation or visual appearance and is working in the industry was used. In the current study a trained experience BKB representative was used.

3.3.6.4 I-VS and I-BCS

A person with no experience or training to select animals for slaughter was used. In the current study an administrative official at the University of Stellenbosch without livestock experience was used.

3.3.6.5 FBW

An auto drafter scale with a TruTest® indicator (RFID Experts, Datamars, Switzerland) equipped with an air compressor to automatically draft the animals based on weekly body weight, was used. The minimum weight was set at 42 kg as determined by Van der Merwe (2020) to be an optimal live weight for slaughter for Merino lambs.

The BCS of animals evaluated according to E-VS and I-VS was subjectively recorded as described by Kenyon *et al.* (2014). The BCS of the lambs was assessed by the palpation of the lumbar region specifically on and around the backbone in the loin area, immediately behind the last rib and above the kidneys to examine the degree of sharpness or roundness (Jeffries, 1961; Phythian *et al.,* 2012). Animals according to subjective opinion of the respective observer that were ready to slaughter were then sent to slaughter.

3.3.7 Laboratory analysis of the feed

Proximate analysis was performed on the feed sample (weekly pooled). The dry matter (DM) crude protein (CP), crude fat (EE), acid detergent fibre (ADF), neutral detergent fibre (NDF), crude fibre (CF) and ash content were determined as depicted in Table 3.1. All samples were milled through a standard laboratory mill (Scientec RSA Hammer mill Ser. Nr 372; Centrotec) to pass through a 1.5 mm screen prior to analysis and stored in airtight honey jars until further use. Dry matter was determined by forced air oven drying at 100°C for twenty-four hours according to method 934.01 of the AOAC (AOAC, 2002). Crude protein content was determined with a Leco N-analyser (model FP 528, St Joseph, Michigan, USA), according to method 990.03 of the AOAC (AOAC, 2002). Ash content was determined by incineration at 500°C for six hours according to method 942.05 of the AOAC (AOAC, 2002). Ether extract content was determined according to AOAC method 920.39 (AOAC, 2002). All NDF and ADF, as well as CF content, was determined with an Ankom^{220} Fiber Analyzer (ANKOM Technology, Fairport, NY, USA). For the latter analysis, all samples were weighed in triplicate (300 +/- 10 µg) and heat-sealed in fibre filter bags (Ankom F57) of 25 µm porosity. The NDF content of the bag residues (Amok, 2016) was then determined using α-amylase and sodium sulfite (Na_2SO_3) as described by Van Soest *et al.* (1991).

3.3.8 Data recording

All animals were weekly weighed on the same time using the TruTest® scale, irrespective of the selection method. The weekly body weight data was only used with the FBW group of animals while the remaining weight data was not made known to the assessors or used in any of the other selection methods evaluated. The RTU treatment group was ultrasound scanned weekly to determine backfat thickness for slaughter. Irrespective of the selection method, all animals selected for slaughter were ultrasound scanned for backfat thickness before transportation to the abattoir to determine correlation between parameters recorded and carcass classification. A Mindray DP 30V® ultrasound scanner (IMV imaging South Africa), with a 7.5 MHz linear transducer was used to scan individual subcutaneous backfat depth at the 13th vertebra. The weight before transportation to the abattoir was considered as the final live weight of the animal. The ADG was determined by subtracting the initial weight from the final weight divided by the number of days in period. The average daily feed intake (DM) was determined by considering the cumulative feed intake divided by the number of days being fed. Table 3.2 summarises the data recorded during the study.

Table 3.2 Summary of data recorded.

Period	Type of record
Weekly	• Live weight
	• ADG
Day before slaughter	• Final live weight
	• Ultrasound scanning measurement
Continuous	• Daily dry matter feed intake

3.4 Statistical analysis

Microsoft excel and files obtained from the TruTest XR5000® was used to capture the data. Statistica (TIBCO Software) version 13 was used to analyse the data statistically. Summary statistics were used to describe the variables dry matter intake (DMI), RTU measurement, days in feedlot, ADG, FCR and final live body weight. Means were used as the measures of a central location for ordinal and continuous responses and standard deviations and quartiles as indicators of spread. Relationships between two continuous variables was analysed with regression analysis and the strength of the relationship measured with Pearson correlation or Spearman correlation if the continuous variables were not normally distributed. Continuous response variables over time between treatments were analysed with repeated measures analysis of variance (RANOVA). Mean differences was considered significant at $P < 0.05$. For all measurements, the null hypothesis was that there were no significant differences between the factors investigated and the alternative hypothesis were that there are significant differences between factors investigated.

3.5 Results and discussion

The traditional methods for selection of lambs for slaughter from a feedlot were compared to more modern techniques by incorporating RFID technology and the known accurate ultrasound scan approach (Van der Merwe, 2020). The determined production parameters in the feedlot, convey the results of growth and the rate at which the desired goal, depending on the method, can be reached.

Table 3.4 shows the means with standard errors of means (SE) of growth parameters in comparison to the different methods evaluated over the total growth period. As expected, the start weight of the seven groups showed low variation (Table 3.4) and reflect effective allocation to treatments. The mean starting weight of the whole group of 28.01 ± 12.5 kg favorably corresponds to commercial start weights seen in the commercial sector (Van Zyl, 2022). Under commercial feedlot conditions lambs received from producers are however rarely as uniform as was used in the current study. The automated pre-sorting of animals in peer groups of similar weight is one of the advantages of the auto drafter scale (Morgan-Davies *et al*., 2018). This will reduce social bullying and enhance more efficient and uniform feeding to meet the nutrient requirements of the animals since intake is determined by body weight (Barnes *et al*., 2018; Van der Merwe, 2020). The higher the uniformity of the lambs fed the higher the uniformity of carcasses will be when fed the same diet for the same time (Van der Merwe, 2020). Consumers preference also demanded uniformity of carcasses (Whaley *et al.,* 2019). According to Coetzee (2020) social behavior in the group is improved when the animals are grouped according to similar age, weight, and sex. Even within a same breed uniform animal group at commencement in the feedlot, considerable variation in the final results is possible due to differences in growth rate within a breed (Oldenbroek & Van der Waaij, 2014).

The ADG results of the current trial are shown in Table 3.4 and are comparable to that reported by Van der Merwe (2020). No significant differences between treatments were observed (Table 3.4). This was expected as the animals were similar in start weight, sex and breed and received the same diet. Van der Merwe (2020) reported an ADG of 0.284 kg/day for Merino lambs under feedlot conditions. According to Coetzee (2020), the mean ADG across all treatments of 0.265 kg/day, can be considered as acceptable, although ADG >0.300 kg/day is more desired. Across all treatments, the highest individual ADG achieved was 0.460 kg/day while 0.060 kg/day was the lowest ADG achieved over the total feedlot period. Figure 3.2 illustrate the ADG distribution of all the animals. Clear growth differences within a breed under similar conditions is therefore evident and results of the current study supports that of Oldenbroek & Van der Waaij (2014). Considering the days in feedlot compared to the ADG of the animals, it was significant time ($R^2 = 0.41$; $P < 0.01$) in Table 3.3. This is seen in Table 3.4

and 3.5 and follows a similar trend as determined by Brand *et al* (2007) and Van der Merwe (2020) in their respective studies. The FCR and ADG is highly negatively correlated (R^2 = -0.79; P < 0.01; Table 3.3). This was expected and indicates that the larger the ADG the smaller the FCR. In essence this implies that the faster growing animals need lees feed to increase weight.

It is clear from Table 3.5 that, after an initial period of slower growth rate, the rate increases over time whereafter the rate of growth tends to decrease as the animals progressed in the feedlot. The data therefore exhibit the typical sigmoidal growth curve described by Verhulst (1838) and Swatland (2020). The maintenance requirement of the animal increases with age and more tissue maturing takes place with more adipose tissue is deposited at a later stage (Swatland, 2020). In the current study, this descending growth rate is a result of constant removing of the faster growing individuals. According to Strydom *et al*. (2008), faster growing animals (higher ADG) will have a shorter rearing period compared to slower growing animals. From Table 3.3 it can be seen that the longer the animals are in the feedlot the smaller the ADG (R^2 = -0.41; P < 0.01).

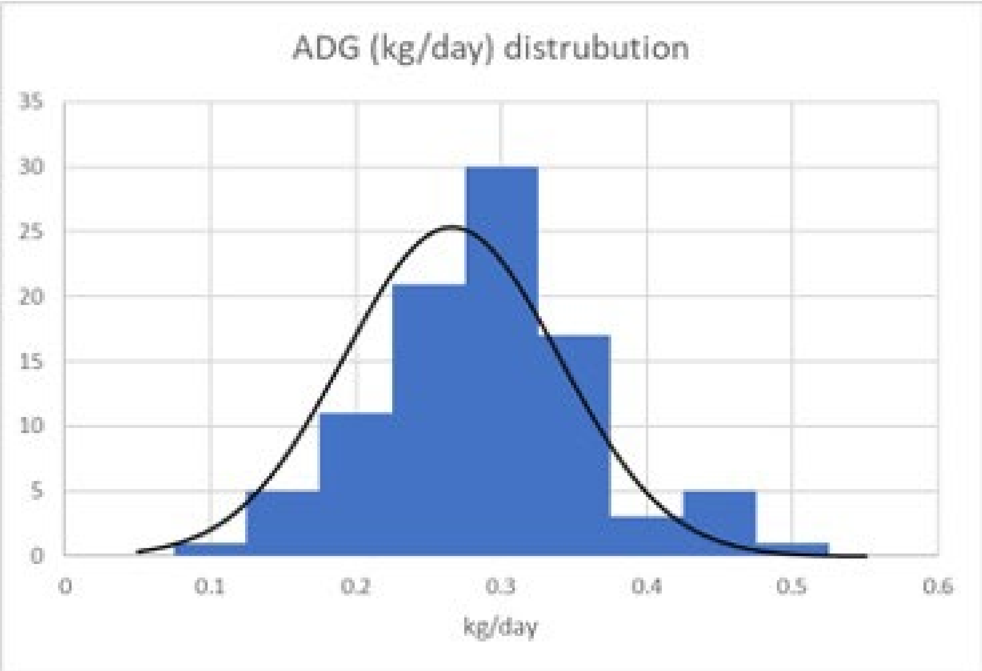

Figure 3.2 Distribution of ADG across all treatments.

Only visually evaluating animals can lead to misconceptions of the real condition of the animal due to stomach fill and wool cover (MLA, 2020). Furthermore, the ADG can be used as an indicator to the health status of the animal (Irsik *et al.,* 2006). Sufficient nutrient intake is further required for growth rate (NRC, 2007). Environmental factors also affect the growth rates as animal intake tends to decrease with higher temperature (Dmitriew, 2011). In addition, reduced nutrient utilization will increase days in the feedlot which increases the cost of rearing (Bello *et al.,* 2016). For the current study, the correlation between days in feedlot and FCR was R^2 = 0.31 (P < 0.01; Table 3.3). Considering a set final weight, the ADG of lambs in a feedlot can also be used to predict slaughter readiness as these parameters are corelated R^2 = 0.49 (P < 0.01; Table 3.3). On day 70 of the current study, irrespective of selection method, there were still lambs that did not meet the requirements for slaughter. To terminate the trial, all remaining animals were slaughtered at day 70, irrespective of being selected for slaughter. At termination, four animals were slaughtered at lower than desired outcomes and originated from the I-VS, FBW group and RTU groups. According to Brown *et al*. (2014), identifying the poor performers (less than 0.100 kg/day) at an earlier stage in the feeding period, allows the manager to remove the animals sooner, thereby reducing unnecessary feed costs. Although all lambs received feed *ad libitum*, significant differences (P < 0.05) in the average daily DMI between the different groups were observed (Table 3.4). This was unexpected as all the animals were kept under identical conditions and had similar starting weights (Table 3.4). These differences can be attributed to genetic variance within breed (Oldenbroek & Van der Waaij, 2014).

Table 3.3 Correlation matrix between feedlot parameters.

	Days in feedlot	ADG	Final weight	RTU	DMI	CFI	FCR
Days in feedlot	1.00	-0.41**	0.20	0.41**	0.23*	0.97**	0.31**
ADG		1.00	0.49**	0.03	-0.09	0.39**	-0.79**
Final weight			1.00	0.56**	0.04	0.21*	-0.50**
RTU				1.00	0.09	0.40**	-0.12
DMI					1.00	0.44**	0.27**
CFI						1	0.35**
FCR							1

*P < 0.05
**P < 0.01

RTU - Real time ultrasound
ADG - Average daily gain
DMI - Dry matter intake
CFI - Cumulative feed intake
FCR - Feed conversion ratio

Cumulative DM feed consumption (CFI) between different methods of slaughter readiness selection showed significant differences (P < 0.05) due to the FBW group spending more time in the feedlot (Table 3.4). Further reasons to justify differences can be due to variation within groups and different FCRs (Oldenbroek & Van der Waaij, 2014). The average animal consumed 54.24 kg of feed, compared to the FBW group that consumed 78.80 kg of feed before being slaughtered (Table 3.4). The cost of feed used has been described as a major feedlot input cost, representing approximately 70% of the variable cost for intensive systems (Lima *et al.,* 2017). Daily DMI of animals and duration in the feedlot is therefore important factors in determining total dietary costs. Chiba (2009) emphasizes the importance of providing animals with quality feed at the lowest possible cost, implementing the shortest possible time spent in the feedlot at the least possible cost per ton of feed. With increased daily DMI and days in the feedlot, finishing feed costs in the feedlot will increase (Van der Merwe, 2020; Coetzee, 2020). The relative higher DMI observed of the FBW group is due to increased days spent in the feedlot to achieve the required fixed live weight of 42 kg. The average days for the FBW group was 58.5 ± 2.50 days in the feedlot (Table 3.4). The RTU measurement group on average spent 42 ± 3.44 days in the feedlot, significantly ($P < 0.05$) less compared to that of the FBW group (Table 3.4). Dry matter intake for the FBW group were also numerically the highest. Despite not differing significantly from any of the other selection groups, the DMI of the RTU group differed ($P < 0.05$) from the I-VS group (Table 3.4). The days spent in feedlot results found in the current study agrees to that observed by Van der Merwe *et al.* (2020), who reported the number of days to reach the optimal weight of 42.7 kg, with Merino lambs which required 43 ± 2.7 days starting at a live weight of 30.6 kg. Brand *et al.* (2018) at a starting weight of 33 kg, reported a targeted 42 kg live weight within 42 days. Brand *et al.* (2018) indicated that 98 days are required when a heavier carcass of 51 kg is required.

Animals are often fed to a fixed body weight since under optimal slaughter conditions, the higher feed inputs can be justified. The relatively small CFI standard error for the fixed 42-day groups (Table 3.4) can be explained by the number of days in the feedlot being the same. Considering days in the feedlot, significant ($P < 0.05$) differences between the FBW group and the remaining groups were observed (Table 3.3).

Considering final weight differences between selection methods, the methods showed a significant ($P < 0.05$) difference between FBW (42.93 ± 047kg) and all the rest of the methods who did not differ between each other (Table 3.4). The heavier the desired final weight, the longer the animal will need to stay in the feedlot at the same ADG, thus a longer feedlot period. In general, an optimal weight of 42 kg was achieved at approximately day 56 in the feedlot in this study. In contrast Van der Merwe (2020) reported a 42-day feedlot period, but the animals in the latter study started at an average body weight of 2 kg heavier compared to the current study. From all selection methods evaluated in the current study, only FBW considered live weight for selection while all the other methods resulted in significantly ($P < 0.05$) lower final body weights (Table 3.4). As the trial was setup in such a way that assessors did not have access to animal weight data, the assessors did not have any other references, hence the lower final weights chosen. The goal in a feedlot operation is to slaughter animals when the muscle to offal (intestines, head, legs, and hide) ratio is at the highest without increased adipose tissue deposition (Jones *et al.,* 1984). In young animals, the proportion of muscle is greater than that of adipose tissue in the body (Owens *et al*., 1993). According to the allometric of growth principle, adipose tissue is normally the last tissue to deposit (Swatland, 1994; Swatland, 2020).

It is well documented that the number of days in the feedlot is also depended on the diet composition as this would affect the speed of growth or ADG (Van der Merwe & Smith, 1991; Hejazi *et al.,* 1999; Price *et al.,* 2009; Coetzee, 2020; Herzog *et al.,* 2021). Both dietary protein and energy supply are required for effective gain (Ebrahimi *et al.,* 2007; Ríos-Rincón *et al.,* 2014). It is therefore evident that starting weight is a critical parameter that influences the number of days required in the feedlot when a fixed number of days criteria for slaughter readiness selection is used. This approach might therefore be problematic when variation in starting weight of animals is high. Additionally, the final required target weight will also affect the days in feedlot. Assuming an ADG of 0.250 kg/day, on average for each 1 kg of live weight gained, 4 days are required in the feedlot. This will lead to an additional 4 days in the feedlot with every 1 kg lower starting weight given the final weight required remain constant. Given the variability of start weights, final weights required and performance variation, no single fixed days in the feedlot for all animals can therefore be applied. This variation of starting weight severely limits the fixed days approach. In the current study all animals have been selected to allow the minimum variation and hence it was not possible to evaluate the latter effect. When correlating the days in feedlot with final weight across all selection methods, a weak correlation $R^2 = 0.20$ ($P < 0.05$) with no definite pattern could be established (Table 3.3). It is therefore concluded that weight is not always a factor of time.

Table 3.4 Means (±SE) of feedlot parameters between different selection methods.

Parameters	RTU	42 days	E- BCS	E- VS	FBW	I – BCS	I – VS
#Lambs	14	13	13	14	14	14	12
Start weight (kg)	27.21 ± 0.71	27.73 ± 0.53	27.81 ± 0.80	28.11 ± 0.62	28.61 ± 0.65	28.71 ± 0.62	27.83 ± 0.95
ADG (kg)	0.29 ± 0.02	0.22 ± 0.02	0.32 ± 0.03	0.27 ± 0.01	0.25 ± 0.01	0.25 ± 0.02	0.26 ± 0.02
CFI (kg)	55.27^{bc} ± 4.24	57.47^{b} ± 0.50	47.30^{bc} ± 3.51	46.04^{c} ± 2.48	78.80^{a} ± 3.41	48.68^{bc} ± 3.16	44.42^{c} ± 3.49
Days in feedlot	42.00^{bc} ± 3.44	42.00^{b} ± 0	34.46^{c} ± 2.17	36.00^{c} ± 1.62	58.50^{a} ± 2.50	35.50^{c} ± 1.87	36.75^{bc} ± 1.95
FCR	5.07^{ab} ± 0.46	6.54^{ab} ± 0.57	4.70^{b} ± 0.55	5.02^{ab} ± 0.36	5.59^{ab} ± 0.31	6.67^{a} ± 1.38	4.93^{ab} ± 0.42
DMI (kg/d)	1.17^{ab} ± 0.02	1.20^{ab} ± 0.02	1.22^{a} ± 0.03	1.14^{b} ± 0.03	1.21^{a} ± 0.01	1.21^{a} ± 0.02	1.06^{c} ± 0.03
LWG (kg)	11.21 ± 0.62	9.50 ± 0.69	10.77 ± 0.72	9.57 ± 0.68	14.32 ± 0.50	8.96 ± 0.92	9.33 ± 0.72
Final weight kg)	38.43^{b} ± 0.71	37.23^{b} ± 0.78	38.58^{b} ± 0.88	37.68^{b} ± 0.48	42.92^{a} ± 0.47	37.68^{b} ± 0.89	37.17^{b} ± 0.90
RTU (mm)	0.44^{b} ± 0.01	0.40^{bc} ± 0.01	0.41^{bc} ± 0.02	0.38^{c} ± 0.01	0.50^{a} ± 0.02	0.38^{c} ± 0.02	0.38^{c} ± 0.02

^{abc} Means within rows with different superscripts differ significantly (P<0.05).

DMI = Daily dry matter intake
RTU = ultrasound scanning
42 days = fixed 42 days in feedlot
E-VS = visual observation (experienced person)
I-VS = visual observation (inexperienced person)
E-BCS = Manual palpation of the loin region (experienced person)
I-BCS = manual palpation (inexperienced person)
LWG = Live weight gain (kg)
FBW = RFID auto drafter to draft at a minimum body weight of 42 kg
CFI = Cumulative feed intake
FCR = Feed conversion ratio

As breeds exhibit different maturing rates (Van der Merwe, 2020), the different desired final weights for optimal carcass weights and time of slaughtering can be explained (Brand *et al.,* 2018; Posbergh and Huson, 2021). Van der Merwe (2020) described models for different breeds that can be used to ensure optimal classification. The 42-day group resulted an average final weight of 37.23 kg ± 0.78 (Table 3.4). Within the group, there were however a difference of 7.50 kg between the numerically heaviest (42.00 kg) and the numerically lightest (34.50 kg) lamb. This variation is however unavoidable. Live weight gain over the period is higher for animals that had to reach a heavier final weight compared to the animals with the same starting weight. The desired live weight gain was determined by the final weight less the starting weight. The lower the starting weight, the higher the weight gain would need to be to reach slaughter weight. Days in the feedlot influenced cumulative DMI, ADG, and average DMI (Table 3.4). More time spent in the feedlot will result in a higher cumulative DMI and a higher daily DMI due to increased weight as DMI is dependent on live weight of lambs (Van der Merwe, 2020; Gurgel *et al.,* 2021). In the current study average DMI and days in feedlot showed correlations of $R^2 = 0.23$ ($P < 0.05$) (Table 3.3).

Feed conversion ratio is defined as a function of the ADG and the feed consumed over a specified time (Yi *et al.,* 2018). According to Coetzee (2020), the lower the FCR value, the more efficient and profitable the animal in a feedlot are as they will require less feed to gain a unit of weight. Jasper (2004) suggested that a FCR of 5 or lower is desired with lambs in the feedlot. In the current study, the average FCR achieved across all animals of 5.50 ± 0.26 suggests that on average every 1 kg of live weight gain required 5.5 kg of DM feed is consumed. The result of this study compares to that of Van der Merwe (2020) who reported a FCR of 5.63 ± 0.51. An average ram and ewe FCR, across all the breeds of 4.32 ± 0.27 and 5.33 ± 0.27 were observed respectively by Van der Merwe (2020). In the current study the FCR ranged between a low of 2.74 and a high of 23.67. The higher ($P < 0.05$) FCR (6.67 ± 1.33) value obtained for I-BCS was not unexpected as the inexperience level of the assessor contributed to feeding non effective animals opposed to the experienced assessor that removed the non-efficient animals more effectively. Surprisingly, neither DMI nor ADG did not differ between the latter selection methods, however the relatively large variation observed by the inexperienced assessor for this parameter could explain the result (Table 3.4).

Feed conversion ratio got larger (less effective) as the animals spent time in the feedlot (Table 3.5). This result could be explained by the significant ($P < 0.05$) reduction in ADG combined by the significant ($P < 0.05$) increase in CFI and DMI as time progressed (Table 3.5). The result of the current study is in support to that of Brand *et al.* (2017) who evaluated the effect of days in the feedlot on production, efficiency, and carcass parameters. Feed conversion ratio increased with time as animals become older (Vosloo,1982; Brand *et al*., 2017).

The latter authors hypothesized that the Merino might not be as effective as exclusive meat breeds like the Dorper which showed no increase in FCR over time. Brand *et al.* (2017) concluded that significant breed effects exists when FCR is evaluated over time in the feedlot. Given the variation in DMI, ADG and maturity (Schoeman, 2000; Cloete *et al.,* 2004), the results of the current study therefore support the latter reasoning leading to FCR variance within breeds.

Given a purchase price of R4450.00 per ton DM and the average DMI of 1.31 kg ± 0.01, the average cost of feed per animal per day (DM) in the current study was R5.79. This implies that to add 1 kg of live weight it would cost on average R31.82. The absence of differences in final weight compared to days in the feedlot indicates the growth rate variance between animals, and thus leading to the phenomenon of reaching similar weights at different durations in the feedlot.

Table 3.5 Effect of days in the feedlot on production parameters irrespective of selection method (means ± SE).

Days in feedlot	28	35	42	49
# lambs	21	20	31	10
RTU	$0.41^{cd} \pm 0.01$	$0.37^{e} \pm 0.02$	$0.40^{de} \pm 0.01$	$0.43^{bcd} \pm 0.03$
Final weight (kg)	38.57 ± 0.53	37.55 ± 0.62	38.32 ± 0.49	37.65 ± 1.60
ADG (kg)	$0.31^{a} \pm 0.02$	$0.28^{ab} \pm 0.01$	$0.25^{bc} \pm 0.01$	$0.24^{c} \pm 0.03$
CFI (kg)	$35.56^{d} \pm 0.83$	$44.57^{c} \pm 0.63$	$57.03^{b} \pm 0.53$	$68.59^{a} \pm 0.67$
DMI (kg)	1.137 ± 0.03	1.13 ± 0.02	1.21 ± 0.01	1.25 ± 0.01
FCR	$4.55^{ab} \pm 0.99$	$4.66^{b} \pm 1.04$	$5.76^{a} \pm 1.03$	$7.62^{ab} \pm 2.41$

^{abcde} *Means within rows with different superscripts differ significantly (P < 0.05).*

RTU – Real time ultrasound
ADG – Average daily gain
CFI – Cumulative feed intake
FCR – Feed conversion ratio
DMI - Dry matter intake

Cumulative feed intake is a function of days in the feedlot and DMI (Cole, 1991). While daily DMI is a function of metabolic weight (NRC, 2007), Van der Merwe (2020) showed that 4% of body weight could be used as an accurate prediction of “as is” intake of lambs in a feedlot. In the current trial all the lambs received *ad libitum* feed and averaged a daily DMI of 3.4% of body weight, slightly lower than the intake predictions of the NRC of between 3.8% and 4.2% (MLA, 2007; NRC, 2007).

The real-time ultrasound measurement is an evaluation of the backfat cover of the animal when still alive (Hopkins *et al*., 1993). Real-time ultrasound scanning was determined as a proven accurate backfat cover prediction method (Van der Merwe, 2020). When live weight is, however not accounted with RTU scanning, it leads to lower than desired final weight despite acceptable fat cover which can lead to significant effects in potential carcass income.

It is necessary to be able to predict backfat cover under feedlot conditions as any over or under conditioning will lead to lower carcass class, lower consumer acceptance and price penalization (Van der Merwe, 2020). The study of Van der Merwe (2020) confirmed ultrasound scanning as an accurate method to predict subcutaneous backfat. The latter author suggested to use ultrasound scanning in combination with live weight to correct for carcass weight limitations. The procedure is however time-consuming, the animal must be sheared (to expose the skin) at the site of scanning and the equipment is expensive. In the current study significantly ($P < 0.05$) higher RTU values were observed for the FBW group of animals compared to all other selection methods evaluated (Table 3.4). This could be attributed to increased time spent in the feedlot that led to elevated live final weights (Brand *et al*., 2018). Further differences ($P < 0.05$) between E-VS, I-VS and I-BCS compared to the reference RTU measurement were also detected. The latter three groups had an average backfat thickness of less than 4 mm (Table 3.4). The South African market has a high demand for lamb (with no permanent incisors, age class A) and a lean fat cover (fat depth of 1–4 mm; fat class 2) (Daff, 2006). According to Van der Merwe *et al.* (2020a) about 72% of all lamb slaughtered in South African registered abattoirs meet these specifications. A premium price is further offered for carcasses that meet these specifications. The higher than 4 mm fat cover observed with the FBW method of selection (Table 3.4) in the current study could therefore reduce income due to the carcasses being considered over fat. Similarly, animals that spend excessively long times in the feedlot (>42 days) might also lead to lower income (Table 3.4). The RTU measurement to live weight correlation was $R^2 = 0.56$ ($P < 0.01$; Table 3.3). With the lower feed requirement and lower final weight, the significant differences can be explained.

The assessing methods of experienced and inexperienced assessors can be considered subjective and are compared in Table 3.6. No significant differences for any parameters measured between the four groups against RTU measurement were observed (Table 3.6). Furthermore, none of the parameters measured differed between subjective observations (Table 3.6). This result was unexpected. Despite the experienced assessor being a professional livestock expert, neither of the two assessors could achieve the accurateness of the objective decision-making techniques. Despite the lack of differences, the experienced assessor selected animals with less variation (Table 3.6). The experienced assessor however did numerically select more efficient animals (Table 3.6). The differences in variation observed with visual selection techniques can be attributed to full belly contents of the animals possibly leading to misinterpretation by the less experienced assessor as body condition. Wool cover further contributed to the variation by the inexperienced assessor. According to Thompson & Meyer (1994) and Neary & Yager (2022), several factors including wool cover could lead to variation and accurateness of subjective BCS determination. Subjective palpation variation can be explained by inexperience and the relatively poor repeatability of accuracy of the palpation technique. A variation of 5 to 8 Kg in body weight was reported by Casburn *et al.* (2013) when palpation of BCS was studied. The lack of differences between the experience level of the assessors was attributed to the high variation and the results could be affected by the relatively small sample size used in the current study.

The FBW group resulted in the highest ($P < 0.05$) final weight (Table 3.4). The slaughter time and final weight of the animals in the FBW group post 42 days in the feedlot is depicted in Figure 3.3**.** Considering an additional weekly feed cost of R46.20 per lamb, any increase in time to reach market weight will increase feed cost and lower margin above feed cost. This will be investigated in Chapter 4.

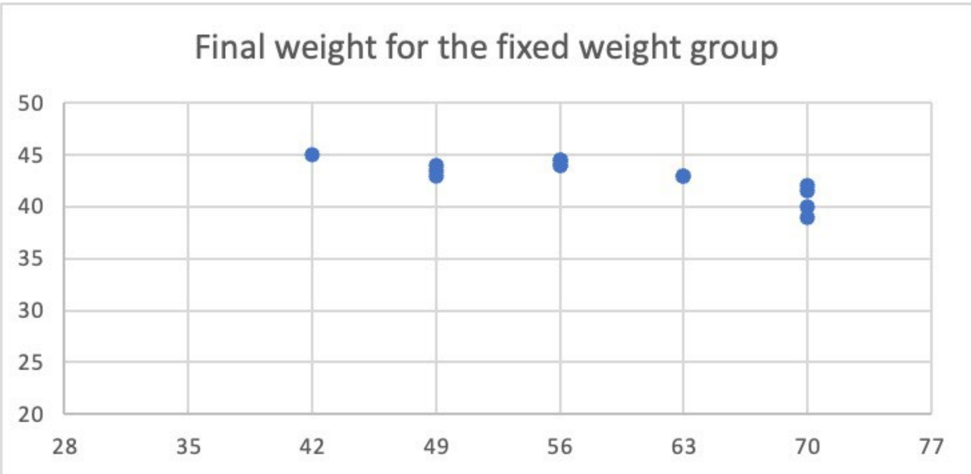

Figure 3.3 Time spent in feedlot to reach a minimum weight of 42 kg of the FBW group of animals.

Table 3.6 Means (±SE) of feedlot parameters of the palpation method (BCS) and visual selection (VS) and between inexperienced and experienced assessors

Method	Experienced	Inexperienced	BCS	VS	P-value (EX vs IN)	P-value (BCS vs VS)
#Lambs	27	26	27	26		
Start weight (kg)	27.96 ± 2.55	28.31 ± 2.78	28.28 ± 0.50	27.98 ± 0.54	0.64	0.69
ADG (kg)	0.294 ± 0.02	0.256 ± 0.01	0.287 ± 0.02	0.262 ± 0.01	0.07	0.24
Days in feedlot	35.26 ± 1.32	36.08 ± 1.33	35.00 ± 1.40	36.35 ± 1.23	0.66	0.47
CFI (kg)	46.65 ± 2.08	46.71 ± 2.33	48.02 ± 2.31	45.3 ± 2.05	0.25	0.32
FCR	4.86 ± 0.32	5.87 ± 0.77	5.72 ± 0.77	4.97 ± 0.27	0.23	0.37
Final weight (kg)	38.11 ± 2.56	37.44 ± 3.16	38.11 ± 0.62	37.44 ± 0.48	0.40	0.40
RTU (mm)	0.40± 0.01	0.38 ± 0.01	0.39 ± 0.01	0.38 ± 0.01	0.24	0.45

ADG – Average daily gain
FCR – Feed conversion ration
RTU – Real time ultrasound
BCS – Body condition score
VS – Visual selection
CFI - Cumulative feed intake

3.6 Conclusion

Differences in the growth parameters of feedlot lambs between selection methods were investigated. Differences between selection methods for FCR, cumulative feed intake, days in the feedlot, daily dry matter intake and RTU measurement in the feedlot were observed. These differences could be attributed to selection method used and the variation within breed. The FBW group resulted in increased time spent in the feedlot, increased cumulative feed intake and cost with the heaviest final weight. The FBW group further resulted in the lowest variation in final weight as animals were slaughtered at the same final weights. The fixed number of days group (42-days) group resulted in lower RTU measurement compared to the FBW group due to lighter final body weight and lower cumulative feed intake.

No differences were observed between the subjective methods of the experienced and inexperienced assessors for either BCS or visual selection at any parameter investigated. The result could be explained by the high level of variance and in future studies it is recommended that larger sample sizes should be used. However, for the current study, it was concluded that these methods result in similar results of the feedlot production parameters.

Although Merinos were used in this study, the findings can be extrapolated to all sheep breeds providing their determined weights and desired final weight and maturity is considered. The degree of wool cover might however affect the results and it is recommended that different breeds are also included in future studies. The use of RFID technology and hardware made data recording easier and more accurate to determine results and monitor the lambs.

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Chapter 4

Effect of subjective and objective decision-making tools in a lamb feedlot on slaughter profitability and capital investment justification

4.1 Abstract

Consumer demand is the main reason why lambs are reared for slaughter in an intensive finishing system. After feedlot finishing, animals selected for slaughter are transported to the abattoir where carcasses are classed after slaughter. Slaughter, profitability, and investment parameters of ninety-eight Merino wether lambs, randomly allocated to seven treatment groups, were determined. The seven different groups were lambs selected with ultrasound scanning (RTU), fixed feeding period of 42 days (42 days), visual observation by an experienced person (E-VS), visual observation by an inexperienced person (I-VS), manual palpation of the loin region by an experienced person determining body condition (E-BCS), manual palpation of the loin region by an inexperienced person determining body condition (I-BCS) and using radio frequency identification (RFID) technology auto drafter (FBW). Slaughter parameters investigated included final live weight, cold carcass weight, dressing percentage, and margin above feed cost while investment break-even over 1-, 3- and 5-year scenarios were evaluated. No differences between subjective groups of experienced and the inexperienced assessors irrespective of palpation or visual selection were observed for all parameters. The dressing percentage of the animals selected by the inexperienced and experienced group was lower ($P < 0.05$) compared to the 42 days group (47%) and FBW group (47%). The cold carcass weight between the FBW group (20.13 kg ± 0.30) and the 42-day group (17.52 kg ± 0.34) differed ($P < 0.05$) in carcass weight. The cold carcass weight of the FBW group was heavier ($P < 0.05$) than all the other groups. The FBW group (R169.59 ± 27.01) produced the highest numeric margin above feed cost of all the methods evaluated and differed ($P < 0.05$) from the 42 days (R95.48 ± 18.96), the I-BCS (R57.97 ± 33.05) and the I-VS (R72.31 ± 28.29). Margin above feed cost showed the highest correlation with ADG (R^2 = 0.65; $P < 0.01$) and carcass weight (R^2 = 0.65; $P < 0.01$) and less with final weight (R^2 = 0.57; $P < 0.01$) and dressing percentage (R^2 =0.21; $P < 0.05$), respectively. The longer the payment period, the more animal units are required to justify investment in technology ($P < 0.05$). The FBW group required the least ($P < 0.05$) number of animal units per period (five years = 1900 ± 303; three years = 1570 ± 251 and one year = 1180 ± 188) to break even.

4.2 Introduction

In South Africa livestock production is based on a system where cattle and sheep are predominantly extensively bred and raised on veld (Mucina & Rutherfrod, 2006; Van Marle-Köster & Visser, 2018). Mutton and lamb production are enterprises in South Africa where meat is produced for local consumption, as well as live and carcass exports (DALLRD, 2020). A sheep feedlot is defined as a closed intensive system to finish lambs and mutton for slaughter (Van der Merwe, 2020). When feeding lambs in a feedlot, advantage is taken from naturally high growth rates (Van der Merwe *et al.*, 2020a) and the goal is to achieve an optimal carcass weight and classification at slaughter to ultimately increase income per kg carcass. Carcass prices are set according to class which is based on consumer preference and this demand determines prices (Van der Merwe *et al.*, 2020; RPO, 2021). Management in a feedlot system can affect profitability and especially with the use of modern technology including radio frequency identification (RFID) (De Wet *et al.*, 2021). In the South African context, consumer demand is the highest for meat from young sheep (lamb) with no permanent incisors (age class A) and a lean backfat cover (backfat depth of 1–4 mm; fat class 2) classified as A2 (Government Gazette, 2006).

Several factors influence lamb feedlot profitability. According to Vollgraaff (2018) the five most important factors includes buying price, slaughter or selling price, average daily gain (ADG), dressing percentage and feed cost. The buying price is determined by market store lamb live weight prices and body weight. The market store lamb price in turn is influenced by the availability of lambs per period. The weekly store lamb price fluctuates according to the ratio of number of lambs available from producers to the demand of feedlots (RPO, 2021). The latter in turn is determined by consumer demand.

The slaughter carcass price is influenced by the slaughter lamb market price of the specific class of carcass in conjunction with the carcass weight (kg x R/kg; Griffth, 2009). Carcass class determine the unit price as demand will determine carcass class (Coetzee, 2020). Carcass classification is based on the description of carcasses, by using clearly defined characteristics that are of prime importance to the meat industry, retailers, and consumers and is performed by qualified classers in the abattoir (Webb, 2015).

The dressing percentage is the amount of carcass weight (muscle and bone) relative to the offal and skin of the animal and is expressed as carcass weight as a percentage of live weight (Coetzee, 2020). If slaughtering occurs too early, the dressing percentage will tend to be lower, due to a higher contribution of offal relative to complete carcass weight (Van Koevering *et al.,* 1995) while the degree of fatness of the carcass will also tend to be relatively low, contributing to not only a lower dressing percentage, but also resulting in poorer classification (Sebsibe, 2008). In contrast, slaughtering too late will also lead to the downgrading of the carcass due to excessive backfat cover, despite a higher dressing percentage (Brandt *et al*., 2017). According to Brand *et al.* (2018) over-conditioned carcasses sell slower due to consumers preference, as the higher fat content is perceived as unhealthy. Optimal slaughter weight and time spent in the feedlot are reached when the muscle is the biggest relative to the complete body and offal after slaughter is at the lowest and this will differ between breeds (Van der Merwe *et al.*, 2020a). A higher dressing percentage and thus higher carcass weight, converts to a higher monetary value, given class is optimal.

Despite possible equal final body weight (BW) of feedlot lambs, both dressing percentage and consequently carcass weight as well as classification may differ, which will affect monetary income value (Coetzee, 2020). Ultrasound scanning have previously been shown to be an accurate method of predicting backfat coverage and therefore class of the carcass as well as dressing percentage of lambs (Van der Merwe, 2020).

To produce the most desirable carcass three factors are important. According to Savell, (2021), this includes that animals should be fed a well-balanced feed *ad libitum* while marketing the animals when ready and avoiding any delay to slaughter when they are ready for slaughter. When animals are fed beyond the point in weight that would produce an optimal carcass, it leads to a decreased rate of gain, poorer feed efficiency and undesirable carcass composition (Strydom, 2002; Leeuw, 2002; Van der Merwe, 2020). With as low as possible buy-in price, high as possible slaughter prices, high as possible ADG, low as possible feed costs and high as possible dressing percentage, profitability can be optimised (Vollgraff, 2018). Of these, only dressing percentage and ADG can be managed by the feedlot operator by slaughtering the animal at the correct physiological stage to optimize class to ensure optimal revenue from a carcass (Van der Merwe 2020). The buy-in price and slaughter price are determined by market forces and cannot be changed by the producer (Bryceson, 2019) while the slaughter lamb price and carcass income are directly influenced by carcass class and weight (DAFF, 2006; Webb, 2015). Thus, by optimizing the carcass weight and classification, optimization of revenue can be achieved. Coetzee (2020) mentioned that the feedlot animal needs to be slaughtered with optimal dressing percentage as soon as possible.

Breeds differ in desired final slaughter weights as they differ in the rate of maturing (Van der Merwe, 2020). Optimal slaughter weights for South African lambs were determined by Brand *et al.* (2018) and later by Van der Merwe (2020) as 42.7 kg for Merino and South African Mutton Merino (SAMM) lambs, where weight of Dorper lambs was determined at 36.0 Kg.

Determining body condition score (BCS) by palpating between the 12th and 13th rib of the loin region, is a conventional method that has disadvantages and advantages (Jeffries (1961). This technique was developed in 1961 by Jeffries when he first described the body condition scoring technique where a BCS of one is considered very thin with five being very fat (Kenyon *et al.*, 2014). A degree of sharpness (spinous) and roundness (transverse) is assessed when palpating the loin (Kenyon *et al.*, 2014). In a previous study, the reliability of the body condition scoring technique in sheep resulted in divergent results that range from excellent to poor (Russel *et al.*, 1961). The repeatability of determining the BCS by palpation is highly variable and can range from 52% to 100% (Keinprecht *et al.*, 2016).

Ultrasound scanning has been proven by Van der Merwe (2020) as an accurate method to predict the level of backfat cover and thus also carcass class. Measuring the backfat thickness cover with ultrasound scanning therefore can be used to select animals to be slaughtered to reach an optimal carcass fat class (Van der Merwe, 2020). Ultrasound backfat measurement is however time-consuming and less accessible to farmers and feedlots as the equipment is expensive (Van der Merwe, 2020). Ultrasound backfat measurement is performed with lambs at the 13th rib between the third and fourth lumbar vertebrae at the point of the transverse muscle (Van der Merwe *et al.*, 2020a). The correlation between the fat level in the live animal and the classification of the carcass has been shown by Van der Merwe (2020a) as an effective method to quantify the ideal time of slaughter. Earlier Hopkins (1990) also indicated a strong correlation between ultrasound fat depth measurement in the live animal and carcass fat depth of the carcass. Hopkins (1990) reported in two experiments correlation coefficients of 0.93 and 0.95 between measurement of backfat depth in the live animal and the *Longissimus thoracis and lumborum* (LTL) muscle respectively.

New radio frequency identification (RFID) technology aim at managing the individual animal compared to group management, allowing managers to make more informed more accurate decisions (Herschel & Rafferty, 2012). Modern RFID systems allows the feedlot operator automatic weighing and drafting of animals using several automated or pre-programmed decision criteria (RFID, 2017). The use of this technology leads to a decrease in time spent on specific tasks including precise data capturing, improved management decisions, reduced labour costs, better genetic selection and an increase in efficiency and accuracy and this leads to improved profitability of the operation (De Wet, 2021). An animal auto drafter and scale form components of a semi and fully automated system (Trevartthen & Michael, 2008) where the scale identifies animals according to a unique electronic identification number linked to the specific RFID tag. Normally animal RFID systems consists of a pre-holding crate, weigh crate, 3/5-way sorting gates and a panel RFID reader (RFID, 2021). In a study on cattle handling comparing a manual system against an RFID system (auto drafter and scale) results showed a 63% reduction in handling time, 5.5% reduction in incorrect sorting and 14% less animal stress (Mutenje, 2013). The greatest inhibitor to use these systems is the initial investment cost as these systems are expensive (Shin & Eksioglu, 2014). The current (2021) initial capital investment for an auto drafter is ± R200 000 while the current pricing of tags is ± R18.00 per animal (RFID Experts Africa, 2021). Client-specific drafting parameters can be pre-programmed to automatically sort the lambs through the auto drafter. The systems are designed according to the Temple Grandin principle as the sides are solid and reduce the stress of handling the animals (Grandin, 1989). The auto drafter forms an integral part of sorting lambs quicker and more accurately in modern commercial feedlots and allows regular weighing (De Wet, 2021). Concerns about heightened stress levels of the animals with more regular weighing and the resultant negative effect on performance (Grandin, 1998), need to be offset against the need for effective decision-making information (Citroen, 2011). According to De Wet *et al*. (2021) the RFID technology allows managers to identify potential problems and poor performing animals early while Banhazi *et al.* (2012) also concludes that the use of precision livestock management techniques improves profitability. Bi-weekly weighing after the adaption period will ensure sufficient information to aid critical decision-making while weekly measurement is recommended during the last 3 weeks of the feedlot period (Coetzee, 2020). Inventory administration is an additional advantage of RFID record-keeping (RFID, 2021). According to RFID Experts Africa (2021) one drafter unit can handle up to 500 animals per hour. Human error is often a common cause of inaccurate gathering of data (Hughes *et al.,* 2021). Accurate RFID data allow the manager to monitor the animals individually. This in turn allows the manager to determine which animals should be removed from the feedlot and also which animals should be ready for slaughter sooner (Citroen, 2011). As the use of RFID technology also improves animal welfare (Grandin, 1998; Aquilani *et al.,* 2022), it is difficult to quantify this technology in pure direct monetary value alone, hence both direct monetary and non-monetary factors should be considered when investment into this technology are evaluated. Grouping animals in the same weight groups improves in-group social behaviour (Coetzee, 2020) and more precise feeding as body weight is an important driver for dry matter intake (DMI) (Van der Merwe, 2020). Consideration should additionally also be given to the opportunity cost of not individually identifying and weighing lambs. When lambs are considered as groups rather than individuals, many poor-performing lambs are concealed by the average of the group and possibly carried by the top performers in the group. Continuous weight data capturing of feedlot lamb performance allow managers improved management as decisions can be made based on data (De Wet *et al.,* 2021; Brown *et al*., 2014). Poor performing lambs with relatively low ADG can be identified early as growth rate and BW at slaughter have a significant effect on lamb profitability (Maxwell *et al.,* 2015; Coetzee, 2020; Van der Merwe, 2020). When lambs are managed as groups compared to individuals, poor performing lambs are concealed by the averages and possibly can erode group profitability (De Wet, 2018).

Van der Merwe (2020) modelled different South African breeds in a feedlot situation to evaluate the differences between breeds. Van der Merwe (2020) modelled optimal live slaughter weight per breed to optimal classification and carcass weight. This information is critical to effective RFID technology implementation in feedlots. Earlier Brand *et al.* (2018) reported that early maturing breed needs to be slaughtered earlier in comparison to later maturing breeds to ensure uniformity of fat cover and carcass weight. The latter report was supported by the work of Van der Merwe (2020). By minimising animal handling, animal welfare is improved while also allowing timeous, rapid decision-making (e.g. removal of any non-performing animals from the environment) with accurate data from the RFID technology.

From an investment point of view, the breakeven point and return on investment (ROI) need to be evaluated. According to Hayes (2021) the breakeven point in a break-even analysis is the calculation and inquiry of the margin of safety for an enterprise based on the revenues collected and costs associated with production. The size of the enterprise and the turnover compared to capital required is important considerations when investment in technology is considered (Sintha, 2020; Fernando, 2021). From a feedlot perspective the minimum number of animals in the feedlot plays a role in capital expenditure decisions and often break-even analysis techniques can assist. The break-even point, measured in physical units of output, is the point where the total revenue of the enterprises is equal to the total cost (Oppusunggu, 2020). To determine the break-even units required to justify capital investment, the number of animal units with a specific margin per unit of time required is determined. This allows the determination of the exact number of units when the enterprise will start making a profit (Hayes, 2021). Feedlot investment cost is normally measured as investment per head and return per head. All animals in a feedlot are fed *ad libitum* daily and thus have a daily feed cost. Feed are being used by the animal for both maintenance and production (McDonald *et al.,* 2022). It is therefore inevitable that the longer an animal spend time in the feedlot, the higher the maintenance feed cost would be. By slaughtering at the optimal time, feed cost can be reduced and thereby increasing profit (Vollgraff, 2018).

A study was conducted at the University of Stellenbosch to investigate the effect of RFID weight measurement and the subsequent decision-making on profitability of feedlot lambs.

The use of this technique was evaluated against traditional subjective tools and ultrasound as a reference.

The specific objectives of this study were to:

- Determine effect of selection methods on slaughter parameters.
- Determine effect of selection methods on the margin above feed costs.
- Determine the minimum number of units in a feedlot required to justify RFID capital expenditure.
- Compare the economic return of subjective methods of selection between experienced and inexperienced assessors.

4.3 Materials and methods

This study was granted ethical approval (ACU-2020-14965) from the animal care and use committee of the University of Stellenbosch.

4.3.1 History of lambs

The lambs used in this study originated from the same as previously described in Section 3.3.1 of Chapter 3.

4.3.2 Housing

The lambs used in this study originated from the same as previously described in Section 3.3.2 of Chapter 3.

4.3.3 Processing of lambs

The lambs used in this study originated from the same as previously described in Section 3.3.3 of Chapter 3 and were therefore similarly processed.

4.3.4 Methods and experimental design

All methods and experimental design followed was similar as described in Section 3.3.4 of Chapter 3.

4.3.5 *Data recording*

The full belly live weight one day before slaughter was considered as the final live weight. The warm carcass weight was recorded while cold carcass weight (CCW) was determined as 3% less than warm carcass weight (Coetzee, 2020; Schweihofer, 2011.)

The dressing percentage was calculated from the final live weight and cold carcass weight according to Rahman *et al*. (2013).

$$Dressing\ pecentage = \frac{Cold\ carcass\ weight}{Final\ live\ weight^{*}} \times 100\%$$

* Final live weight was recorded the day before slaughter

Carcass classification was performed by an experienced, trained classer according to the guidelines for South African small stock (Government notice, 2006). The classification level and conformation of each lamb was recorded at the abattoir as depicted in Table 4.2. The monetary value of each carcass was then determined from the class of the lamb and the market carcass price (per kg) on the day at the end of the trial (RPO, 2021). Thereafter margin above feed cost of each animal were determined as the difference of total revenue less total operating cost (Wolf, 2010; Roberto *et al.,* 2019) with the following formula:

$$Margin\ above\ feedcosts = Carcass\ income^{\wedge} - (Buy\ in\ price^{\#} + feedcosts)$$

#The buy-in price was determined by the live weight of the animal at commencement of the trial and the store lamb price per kg (RPO, 2021). Feed cost was determined from the total amount of feed consumed for the whole feedlot period at a price of R4450.00 per ton dry matter (DM). ^The carcass income was determined by abbatoir assessment.

The break-even determination was calculated from instalments per year and contributions per unit according to Oppusunggu (2020):

$$Units\ needed = \frac{Installment\ per\ year}{Contribution\ per\ unit}$$

All data recorded with timing of recording is presented in Table 4.1.

Table 4.1 Summary of timing and data recorded

Period	Type of record
1 day prior to slaughter	• Live weight (kg) • Ultrasound measurement (mm)
At slaughter	• Warm carcass weight (kg) • Classification • Conformation

Table 4.2 Classification categories of sheep carcasses in South Africa (Government notice, 2006)

Classification category	Classifier	Result	Extra
Age	0 permanent incisors	A	
	2 permanent incisors	AB	
	3 – 6 permanent incisors	B	
	> 6 permanent incisors	C	
Fat	0	0	No fat
	<1 mm	1	Very lean
	1.1-4 mm	2	Lean
	4.1 – 7 mm	3	Medium
	7.1 – 9 mm	4	Fat
	9.1 – 11	5	Slightly overfat
	>11.1	6	Excessively overfat
Conformation	Very flat	1	
	Flat	2	
	Medium	3	
	Round	4	
	Very round	5	
Damage	Slight	1	
	Moderate	2	
	Severe	3	

4.3.6 Statistical analysis

Microsoft excel and files obtained from the TruTest XR5000® was used to capture the data. Statistica (TIBCO Software) version 13 was used to analyse the data statistically. Summary statistics were used to describe the variables days in feedlot, final body weight, cold carcass weight, dressing percentage, classification, feed cost and margin above feed cost. Means were used as the measures of a central location for ordinal and continuous responses and standard deviations as indicators of spread. Continuous response variables over time between treatments were analysed with repeated measures analysis of variance (RANOVA). Relationships between two continuous variables was analysed with regression analysis and the strength of the relationship measured with Pearson correlation (P < 0.05 or P < 0.01). Seven treatments over 94 animals resulting in 12 to 14 repetitions per treatment were compared. The 94 lambs were randomly allocated per treatment resulting in similar initial body weights (Table 3.4?). Repetitions were different due to the removal of injured animals from the trial. Mean differences was considered significant at P < 0.05. For all measurements, the null hypothesis is that there were no significant differences between the factors investigated and the alternative hypothesis were that that there are significant differences between factors investigated.

4.4 Results and discussion

4.4.1 Slaughter parameters

The effect of selection method on abattoir slaughter parameters is presented in Table 4.3. When days spent in the feedlot are investigated, RTU, 42 days and I-VS did not differ while FBW differed (P < 0.05) from all other treatments (Table 4.3). Treatment 42-days however differed (P < 0.05) from E-BCS, E-VS and I-BCS. It was to be expected that RTU and 42 days did not differ as the latter treatment used a fixed time. It was further expected that experience level will have a significant effect in days spent in the feedlot. Holland (1979) reported that experience level of assessors has a significant effect on the decision when to slaughter, days in feedlot and carcass parameters. In the current study this could however not be established as both the visual and palpation methos did not differ between the experience level of the assessors (Table 4.3).

As expected, the fixed body weight (FBW) group resulted in the highest final body weight (BW) as it was a fixed effect in the selection criteria and was significantly (P < 0.05) higher compared to all the other groups. The remaining groups did not differ in final BW between each other (Table 4.3). Numerically the latter groups resulted in final BW ranging between 37 and 39 kg. It is therefore clear that when objective body weight measurement is not a criterion for selection for slaughter readiness, the subjective selection process will lead to lighter animals selected for slaughter. Both rumen fill and wool cover can lead to misinterpretation of the actual body condition of the animal during visual and palpation assessment (Brown *et al*., 2014). All the latter decision tools, including RTU scanning and fixed number of days in feedlot does not take final BW into account during the selection process and therefore lead to lighter animals being slaughtered.

The FBW group resulted in the heaviest (P < 0.05) mean cold carcass weight (CCW). This was expected as the FBW group also recorded the heaviest final BW of all groups (Table 4.3). Brand *et al.* (2017) reported similar CCW of 18.2 kg for similar animals. The RTU group scored the second highest cold carcass weight (17.66 kg ± 0.315) and being ± 2.5 kg lower ($P < 0.05$) than that of the FBW group. Table 4.3 indicate that the CCW of the RTU group however did not differ from the fixed 42 days group nor any of the palpation selection methods (E-BCS and I-BCS). The latter was expected as the final BW also did not differ between the latter treatments. Despite not differing significantly from E-BCS, E-VS and I-BCS groups, the I-VS group recorded the lowest numeric CCW mean of 16.50 kg ± 0.38. This result was expected as it is known that experience play a significant role in the selection process and normally leads to sub-optimal slaughter parameters (Holland, 1979). The significantly ($P < 0.05$) higher CCW of the FBW group compared to the fixed period days in feedlot group, compares much more favorable to current South African consumer demand of a lamb carcasses of ± 20.9 kg (RPO, 2021). The higher CCW of the FBW group can be attributed to the higher final BW (Table 4.3). Market preference is an important factor as a consumer demand play an integral role in price determination (Taljaard *et al*., 2006). Figure 4.1 indicate the CCW of the respective groups.

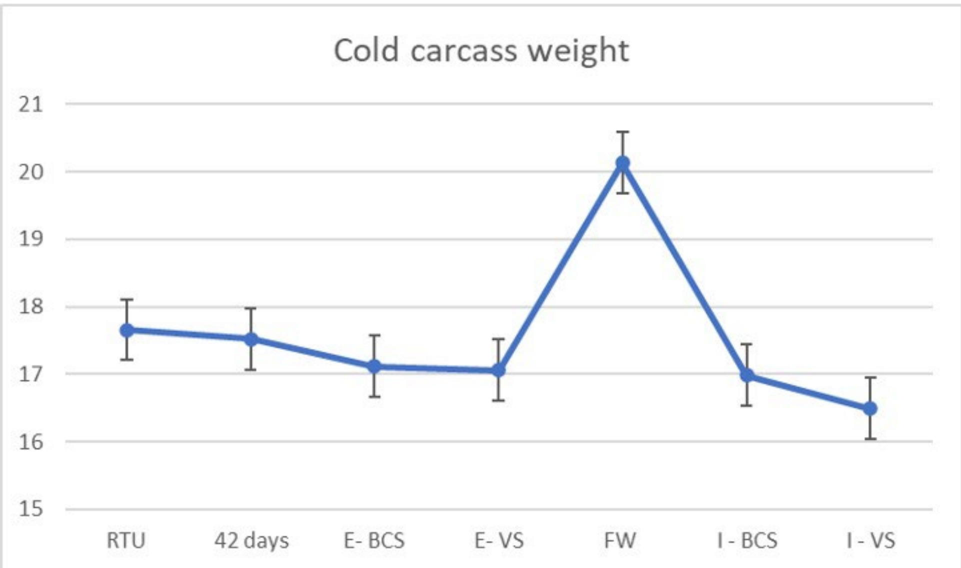

Figure 4.1 Cold carcass weights of the selection methods.

From Table 4.3 the dressing percentage of the FBW group was 47% and did not differ from either the RTU and 42-day groups who reported 46% and 47%, respectively. These results are higher than Brand *et al*. (2017) who reported a dressing percentage of 42.5% with Merino lambs. The higher dressing percentages of the current study can be attributed to dietary (Wang *et al.,* 2020) and length time in the feedlot (Brand *et al.,* 2017) differences. The lowest dressing percentages were consistently achieved by all the subjective methods of E-VS, I-VS, E-BCS and I-BCS who differed ($P < 0.05$) from all other methods of selection (except RTU) but did not differ between each other. These results were as expected given final BW was not known to the assessors. A higher dressing percentage value is associated with a higher fat, muscle and bone ratio compared to the viscera and other offal components including the hide and head (Swatland, 2020; Shahbandeh, 2021). Several factors including degree of fatness, time off feed and water prior to live weighing, feed conditions, sex, breed, skin weight and wool length can all affect dressing percentage of lambs (McLeod, 2003; Casburn *et al.*, 2013). According to Vollgraaf (2018) and Coetzee (2020) dressing percentage have a significant influence on the margin. Lower dressing percentage can be due to too early or too late slaughtering, gut fill at slaughter or feed related factors (Coetzee, 2020). According to MLA (2020) the average dressing percentage of Australian lamb is between 45% to 48% and therefore compare favorable to that in South Africa (RPO, 2021) and to that recorded in the current study.

The FBW group resulted in numerically the highest margin above feed cost (R169.59 ± 27.01) and differed ($P < 0.05$) from the 42- days group, I-BCS and I-VS groups, but not from the remainder of the treatment groups. This result was mostly expected as the accurateness of determining slaughter time of the inexperienced assessor resulted in lighter CCW and poorer dressing percentages. The combined effect led to significantly lower margin over feed cost of the animals selected by the inexperienced assessor. The FBW group in contrast benefited from significantly higher ($P < 0.05$) final BW leading to significantly heavier ($P < 0.05$) CCW combined with superior dressing percentage to eventually result in superior margin above feed cost. Optimal CCW profit is achieved combined with optimal conformation and class to maximize income while simultaneously reducing time spent on feed thereby reducing cost to a minimum (Notter *et al.,* 1991). According to Van der Merwe (2020) to optimize these critical profit drivers in a feedlot, precise management slaughter decisions is required per specific breed. By not considering BW in the decision to slaughter affects not only final BW, but also several of the critical drivers for profitability when animals are either slaughtered too early or too late.

To minimize cost the higher final BW need to be achieved in the shortest possible time thereby maximizing ADG (Wells, 2020). Vollgraaff (2018) and Coetzee (2020) consider ADG and dressing percentage as critical profitability factors within the commercial lamb feedlot environment. In the current study, margin was influenced by live weight, carcass weight and dressing percentage, however, feed cost and time spent in the feedlot did not show the same sensitivity (Table 4.3).

Table 4.3 The effect of selection method on abattoir slaughter parameters and margin per animal (Mean ± SE)

Item	RTU	42 days	E- BCS	E- VS	FBW	I- BCS	I- VS
N	14	13	13	14	14	14	12
Days in feedlot	42.00^{bc} ± 3.44	42.00^{b}± 0.00	34.46^{c} ± 2.17	36.00^{c} ± 1.62	58.50^{a} ± 2.50	35.50^{c} ± 1.87	36.75^{bc} ± 1.95
Final weight (kg)	38.43^{b} ± 0.71	37.23^{b} ± 0.78	38.58^{b} ± 0.88	37.68^{b} ± 0.48	42.93^{a} ± 0.47	37.68^{b} ± 0.89	37.17^{b} ± 0.90
CCW (kg)	17.66^{b} ± 0.32	17.52^{b} ± 0.34	17.12^{bc} ± 0.39	17.06^{bc} ± 0.29	20.13^{a} ± 0.30	16.98^{bc} ± 0.39	16.50^{c} ± 0.38
DP %	46^{ab} ± 0.01	47^{a} ± 0.01	44^{b} ± 0.02	45^{b} ± 0.01	47^{a} ± 0.01	45^{b} ± 0.01	44^{b} ± 0.01
Feed cost (R/animal)	R 276.35^{bc} ± 21.21	R287.36^{b} ± 2.19	R236.50^{bc} ± 17.53	R230.20 ^{c} ± 12.40	R394.00^{a} ± 17.03	R243.40^{bc} ± 15.80	R222.10^{c} ± 17.45
Gross income (R/animal)	R 1447.99^{b} ± 25.87	R 1436.61^{b} ± 27.74	R 1403.63^{b} ± 32.09	R 1398.86^{b} ± 23.76	R 1650.68^{a} ± 24.48	R 1392.5^{b} ± 31.79	R1352.08^{b} ± 31.22
Margin over feed cost (R/animal)	R 137.50^{ab} ± 22.35	R 95.48^{bc} ± 18.96	R 110.43^{abc} ± 20.64	R 100.59^{abc} ± 23.24	R 169.59^{a} ± 27.01	R 57.97^{c} ± 33.05	R 72.31^{bc} ± 28.29

^{abcd} Means within rows with different superscripts differ significantly ($P < 0.05$).

DP % - Dressing percentage (%)
RTU - Ultrasound scanning
42 days - Fixed 42 days in feedlot
E-VS - Visual observation (experienced person)
I-VS - Visual observation (inexperienced person)
E-BCS - Manual palpation (experienced person)
I-BCS - Manual palpation (inexperienced person)
FBW - RFID auto drafter (minimum body weight of 42 kg)
CCW - Cold carcass weight

The lambs with similar cold carcass weight differs in margin due to length of feeding affecting feed cost, ADG, starting weight and dressing percentage (Table 4.3). Despite the importance of dressing percentage (Coetzee, 2020), CCW is also required for efficient income per carcass (Taljaard *et al.,* 2006).

In the commercial environment margin per animal in lamb feedlots is known to be narrow (Janse van Rensburg *et al*., 2020). The use of RFID technology allows producers to automatically group feedlot animals in comparable groups easing managerial burden while also allowing individual selection of animals for slaughter compared to a more traditional group management approach (RFID, 2021). Irrespective of accuracy, due to availability, skill required and time constraints, RTU measurement cannot be considered as a practical precision tool for selection in the commercial environment (Houghton & Turlington, 1992). Ultrasound measurement further does not use BW during the selection process and hence is not an accurate predictor of margin (Table 4.3). From the data of the current study a RFID precision management strategy improves profitability by eliminating subjective decision making and objectively use BW as a decision criterion, while also reducing the labor burden (De Wet *et al*., 2021).

Table 4.4 depicts the effect of days spent in the feedlot on slaughter parameters. As can be seen from Table 4.4 after day 49 in the feedlot the number of animals slaughtered did not have enough repetitions for over time to analyse and therefore were only analysed to 49 days in the feedlot.

No difference over time were observed for RTU (Table 4.4). This was expected as only backfat thickness was used as selection criteria. Backfat cover increases over time with increased levels of adipose tissue deposition taking place (Swatland, 2020). In Brand *et al.* (2018) study the back thickness increased over time. In the current study RTU selected animals were however selected on backfat thickness alone with no consideration to time spent in the feedlot, hence the similar measurement over time.

No difference for margin, daily DMI and final BW over time were observed (Table 4.4). The dressing percentage increased ($P < 0.05$) over time in the feedlot. This was not surprising as several other reports of increased time spent in feedlot are highly correlated to final BW and dressing percentage (Coyne *et al.,* 2019; Coetzee, 2020). Shirima *et al.* (2012) however reports poorer dressing percentages when animals are fed beyond optimal slaughter weight. The latter authors reported increased dressing percentages in ovine from 0 to 56 days in the feedlot with poor dressing percentages at day 70 and 84 in feedlot. This was attributed to too high level of abdominal fat content.

Table 4.4 The effect of days spent in the feedlot on the slaughter and economical parameters (Mean ± SE).

Days in the feedlot	**28**	**35**	**42**	**49**
#Lambs	21	20	31	10
Final weight (kg)	38.57 ± 0.53	37.55 ± 0.62	38.32 ± 0.49	37.65 ± 1.61
RTU (mm)	0.41 ± 0.01	0.37 ± 0.02	0.40 ± 0.01	0.43 ± 0.03
DP %	44^{c} ± 0.003	45^{bc} ± 0.01	46^{a} ± 0.004	46^{ab} ± 0.01
DMI (kg/day)	1.137 ± 0.03	1.13 ± 0.02	1.21 ± 0.01	1.25 ± 0.01
CCW	17.01 ± 0.25	16.95 ± 0.29	17.72 ± 0.24	17.16 ± 0.69
Total feed cost (R/animal)	R 177.80^{d} ± 4.15	R 228.50^{c} ± 3.15	R 285.15^{b} ± 2.65	R 342.95^{a} ± 3.35
Gross income (R/animal)	R 1394.78 ± 20.42	R 1389.9 ± 23.44	R 1452.86 ± 19.78	R 1407.39 ± 56.2
Margin over feed cost (R/animal)	R 78.82 ± 19.36	R 117.31 ± 16.87	R 114.75 ± 15.30	R 72.66 ± 41.66

^{abcd} Means within rows with different superscripts differ significantly (P < 0.05).

RTU – Real time ultrasound
DP % – Dressing percentage (%)
DMI – Dry matter intake (kg/animal/day)
CCW – Cold carcass weight (kg)

Table 4.5 shows the correlation of data measured to slaughter and profitability parameters. Higher final weight resulted in a higher RTU measurement (R^2 = 0.56; P < 0.01) as well as a higher carcass weight (R^2 = 0.86; P < 0.01). According to Samic (2011) RTU measurement predicts classification accurately when fat cover is more than <1 mm. Despite higher inputs of feed costs, time spent in the feedlot predicts CCW (R^2 = 0.41; P < 0.01).

A positive relationship between dressing percentage and CCW of R^2 = 0.42 (P < 0.01) indicate that as dressing percentage increase, CCW also increase. This finding is not unexpected as it is known that a carcass that contains more adipose tissue will also be heavier (Mummed & Webb, 2019).

Margin over feed cost correlated not significant and poorly to days in the feedlot (R^2 = 0.10) while moderately correlating to final weight and CCW with R^2 = 0.57 and R^2 = 0.65, respectively (P < 0.01; Table 4.5). The latter correlations were expected as the BW of the animals will increase the longer it spends time on feed (Table 4.4). The poor correlation of days in feedlot to margin however was not expected and can possibly be explained by increased carcass income despite additional feed cost, indicating that margin is more sensitive to income compared to feed cost. Further margin correlated with DP% ($R^2 = 0.21$; $P < 0.05$) and ADG ($R^2 = 0.65$; $P < 0.01$). From Table 4.5 it can be deducted that the highest correlation to margin is ADG and CCW and can therefore be used as predicator of margin. Vollgraaff (2018) also reported that dressing percentage, CCW and ADG are factors affecting feedlot profitability.

Figure 4.2 illustrates that an animal with a very low CCW results in a loss, although some animals with a slightly higher CCW also recorded negative margins. The latter animals had a relatively low ADG that led to longer time in the feedlot which in turn led to elevated feed costs (Figure 4.2 and Figure 4.3).

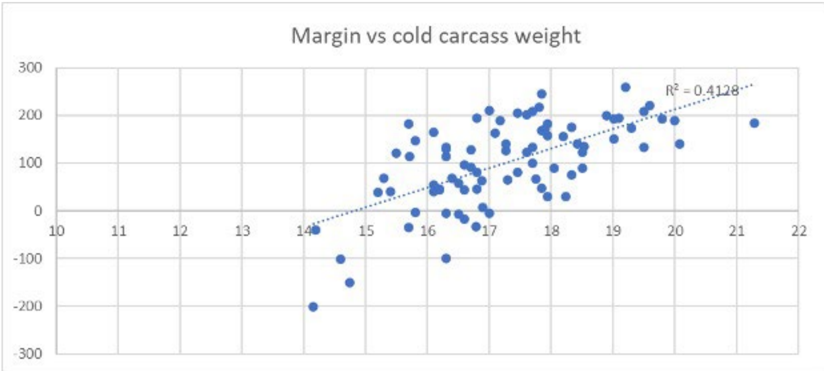

Figure 4.2 Correlation between the margin and cold carcass weight ($P < 0.05$).

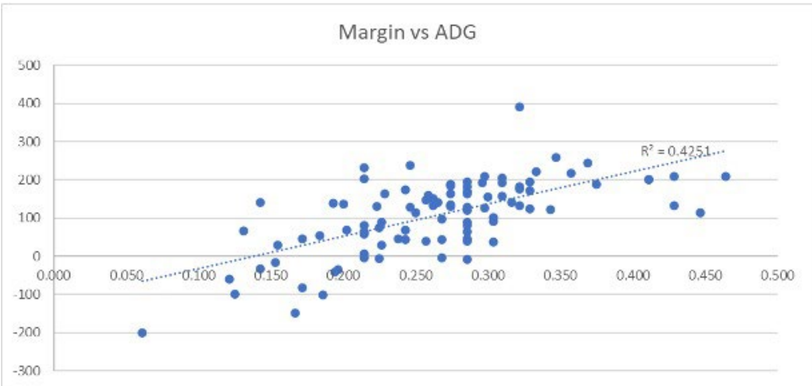

Figure 4.3 Correlation between margin and ADG ($P < 0.01$).

The final BW will have a direct influence on the CCW as the correlation was determined as $R^2 = 0.86$ ($P < 0.01$) and shown in Table 4.5. Higher final BW will thus result in higher CCW due to a more mature animal and the bone and muscle being relative more than the viscera and other offal including blood, head and hide (Swatland, 2020).

Table 4.5 Pearson correlation matrix of production and slaughter parameters.

	Days in feedlot	ADG (kg)	Final weight (kg)	DP % (%)	CCW (kg)	Margin (R/animal)	RTU (mm)	DMI (kg/animal/day)
Days in feedlot	1.00	0.41**	0.20	0.47**	0.41**	0.10	0.41**	0.23*
ADG (kg/animal/day)		1.00	0.49**	0.49**	0.20	0.65**	0.03	0.09
Final weight (kg)			1.00	0.08	0.86**	0.57**	0.56**	0.03
DP % (%)				1.00	0.42**	0.21*	0.25*	0.33**
CCW (kg)					1.00	0.65**	0.63**	0.20
Margin (R/animal)						1.00	0.30**	0.06
RTU (mm)							1.00	0.09
DMI (kg/animal/day)								1.00

*P<0.05
**P<0.01

RTU – Real time ultrasound (mm)
ADG – Average daily gain (kg/day)
DMI – Dry matter intake (kg/day)
CCW – Cold carcass weight (kg)
DP % – Dressing percentage *(%)*

Considering the carcass classification of the animals, most lambs that were slaughtered in the current study were classified as an A2 class (Table 4.6). Although most of the methods resulted in an A2 carcass, not all were in accordance with the optimal carcass weight and margin desired (Table 4.6 and Table 4.3). Current market trends reveal that lambs with no permanent incisors that are classed with a fat score of 2 or 3 (A2 or A3) achieve the highest value at slaughter in South Africa (RPO, 2017).

Table 4.6 Classification results per method of selection.

Group	A1	A2	Total
RTU		14	14
E-BCS		13	13
E-VS	1	13	14
FW		14	14
I-VS		12	12
I-BCS	1	13	14
42 days		13	13

This result was unexpected as it was expected that the animals selected by the inexperienced assessor would result in poorer classification. The results however indicate that class is more easily reached than the optimal carcass weight. After classification, the carcass weight in combination with dressing percentage (Coetzee, 2020) is the most important determinant of carcass income. This emphasizes the fact that slow growers and slaughter ready animals need to be timeously identified. A larger sample size however might have led to different results.

Due to variation within breed (Coetzee, 2020; Van der Merwe, 2020; Hanel, 2022) and group, different growth rates exist between groups of lambs in a commercial feedlot. When only slaughtering at a fixed number of days, some animals will be over conditioned while others will be under conditioned and with the variation of the normal distribution determining the error factor (Kiernan, 2022). The profit of the optimal income animals will therefore be eroded by the less profitable individuals. The reference RTU method showed no significant differences compared to the FBW group, but the latter group yielded the more desired CCW (Table 4.3) according to consumer demand resulting in higher margins over feed cost.

The effect of the subjective evaluation on slaughter and profitability parameters are shown in Table 4.7. Irrespective of method, no differences were observed when the experienced and inexperience assessor was compared. Numerical differences were however present. As body weight was not considered when selecting these animals, the inexperienced assessor randomly chose animals, thus by day 28 when selecting any animal, the most were already A2 and therefore did not affect the classification or final BW which resulted in similar income and profit as the experienced assessor (Table 4.7). Although not significant different the numerical mean of the margin was R40.75 lower when the inexperienced assessor decided to slaughter compared to that of the experienced assessor. The standard error of the inexperienced assessor was also larger than that of the experienced assessor which indicates a higher level of variation in margin results of the inexperienced assessor. Despite not being statistically different, the lack of margin differences between the assessors can also be explained by the experienced assessor that selected the animals slightly earlier (Table 4.7) in an effort to reduce the feed cost. The higher numerical CCW of the animals the experienced assessor selected (0.250 kg) valued to a difference of R20.50 in carcass income as income was calculated at R100/kg A2 carcass. As shown in Chapter 3, a further R13,30 difference can be due to the 0.350 kg numerical difference in starting weight. This, even although carcass weight was not significant different, the numerical difference leads to an income difference. It can therefore be concluded from the results of this study that palpation or visual assessing is equally effective when subjective assessing is used, and animals have been shorn when arrival at the feedlot. Incorporating BW data to subjectively assessing animals, will be beneficial.

Table 4.7 Effect of subjective evaluation on slaughter and profitability parameters (Mean ± SE)

Item	Experienced	Inexperienced	BCS	VS	P-value (EX vs IN)	P-value (BCS vs VS)
#Lambs	27	26	27	26		
Days	35.26 ± 1.32	36.08 ± 1.33	35.00 ± 1.40	36.35 ± 1.23	0.664	0.474
Final weight (kg)	38.11 ± 2.56	37.44 ± 3.16	38.11 ± 0.62	37.44 ± 0.48	0.400	0.400
RTU (mm)	0.4 ± 0.01	0.38 ± 0.01	0.39 ± 0.01	0.38 ± 0.01	0.237	0.445
DP%	45 ± 0.02	45 ± 0.02	49 ± 0.00	45 ± 0.00	0.894	0.884
CCW (kg)	17.09 ±0.24	16.75 ± 0.27	17.05 ± 0.27	16.80 ± 0.24	0.358	0.490
Total feed cost (R/animal)	R 233.23 ± 10.41	R 233.57 ± 11.67	R 240.07 ± 11.55	R 226.47 ± 10.27	0.249	0.315
Gross income (R/animal)	1401.16 ± 19.37	1373.85 ± 22.3	1397.86 ± 22.18	1377.27 ± 19.43	0.358	0.490
Margin over feed cost (R/animal)	R 105.33 ± 15.351	R 64.58 ± 21.69	R 83.26 ± 20.12	R 87.54 ± 17.94	0.129	0.874

CCW - Cold Carcass weight
RTU - Real time ultrasound
DP% - Dressing percentage
BCS - Body condition score
VS - Visual selction

4.4.2 Radio frequency Identification (RFID) technology investment

Break-even analysis techniques can be employed to determine the minimum number of lambs required to be processed through the system to justify a specific capital investment (Louw *et al.,* 2017). In this study, three scenarios were investigated over periods of one year, three years and five years capitalization, respectively. An interest rate of 10% was used (prime +3%) at the time of calculation) on the capital required (R200 000.00) to invest in RFID auto drafter scale technology (RFID, 2021; DALLRD, 2022). Table 4.8 indicates the capital and cost of capital requirement over a five-year amortization.

The break-even number of animals was determined by calculating the number of lambs required when a lamb fully contributes its margin above feed cost for each slaughter ready treatment analyzed. Since the evaluated methods of selection resulted in different margins (Table 4.3) each would require different break-even units at the three chosen scenarios. The number of lambs needed will be to reach break-even point. Commercial feedlots have relative narrow margins ranging between a loss to around R200.00 per animal (Janse van Rensburg *et al*., 2020). Therefore, the result of the current study supports that published by the latter authors (Table 4.3).

Table 4.8 Amortisation of capital and cost for the auto drafter scale over five-year period.

Period	Opening balance	Interest rate (%)	Interest amount	Capital	Capital + interest
1	R200 000.00	10.00%	R20 000.00	R200 000.00	R220 000.00
2	R220 000.00	10.00%	R22 000.00	R220 000.00	R242 000.00
3	R242 000.00	10.00%	R24 200.00	R242 000.00	R266 200.00
4	R266 200.00	10.00%	R26 620.00	R266 200.00	R292 820.00
5	R292 820.00	10.00%	R29 282.00	R292 820.00	R322 102.00

Table 4.9 Determination of capital investment and interest over each period

Parameter	Scenario 1	Scenario 2	Scenario 3
Period (# of years)	5	3	1
Interest rate (%)	10%	10%	
Instalment per year (R)	R64 420.00	R88 733.00	R200 000.00
Total cost of capital (R)	R322 102.00	R266 200.00	R200 000.00

For each scenario, the break-even indicates that any number of lambs above minimum break-even will directly contribute to the profit margin. A shorter payment period requires fewer lambs in the period due to lower interest requirements, however more lambs per year would be required to maintain cash flow. It is evident that the higher the margin the less units are required to break even. Furthermore, since the scale can aid to higher margin due to precise weighing and management to improve selection of slaughter ready lambs, the technology contributes positive to the amortization.

Figures 4.4, 4.5 and 4.6 shows the per treatment minimum unit throughput required of the different amortization periods. Only after the minimum units has been reached, will all excess units directly contribute towards profit.

In Table 4.10 and Figures 4.4, 4.5 and 4.6 the extreme variation in results from I-BCS and I-VS groups indicates how this experience can lead to significant break-even outcomes. Although these two groups did not differ significant from some of the other groups, the variation within the groups were excessively large. The effect of variation of experience was indicated by Holland (1979) in his study.

The FBW group did not differ from the RTU, E-BCS and E-VS group, however the numerical lower required units in all three scenarios could contribute to quicker amortization of debt. As example the difference between the FBW and RTU group in scenario three the numeric difference in units is 275 units (1180 vs 1455). This indicates that the FBW group have to put 275 lambs less through the system to amortize the capital expenditure. The FBW group further results in the least variation since the weight was known and thus margin could be managed. This emphasizes the repeatability of objective data from the use of RFID.

Table 4.10 Mean break-even lamb units (±SE) needed per method per pay-off scenario

Item	RTU	42 days	E-BCS	E-VS	FW	I-BCS	I-VS
Scenario 1	2343^{ab} ± 381	3374^{bc} ± 670	2917^{abc} ± 546	3203^{abc} ± 741	1900^{a} ± 303	5557^{c} ± 3169	4455^{bc} ± 1743
Scenario 2	1936^{ab} ± 315	2789^{bc} ± 554	2411^{abc} ± 451	2647^{abc} ± 612	1570^{a} ± 251	4593^{c} ± 2619	3682^{bc} ±1441
Scenario 3	1455^{ab} ± 237	2095^{bc} ± 417	1812^{abc} ± 339	1989^{abc} ± 460	1180^{a} ± 188	3451^{c} ± 1968	2766^{bc} ±1083

^{abc} Means within rows with different superscripts differ significantly ($P < 0.05$).

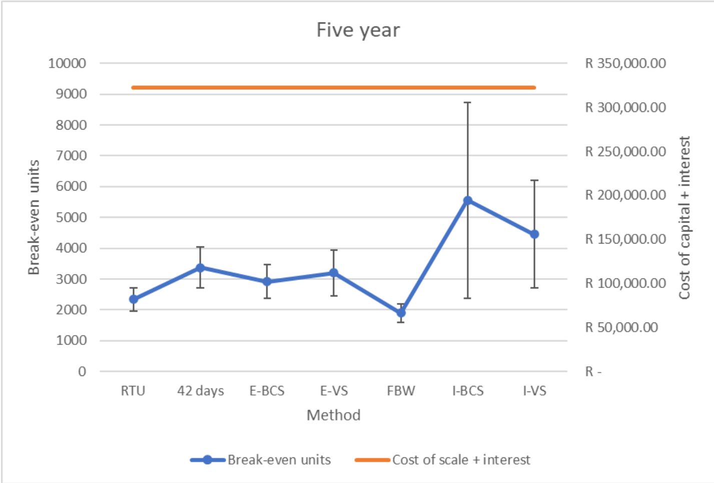

Figure 4.4 Break-even units per method over a five-year period.

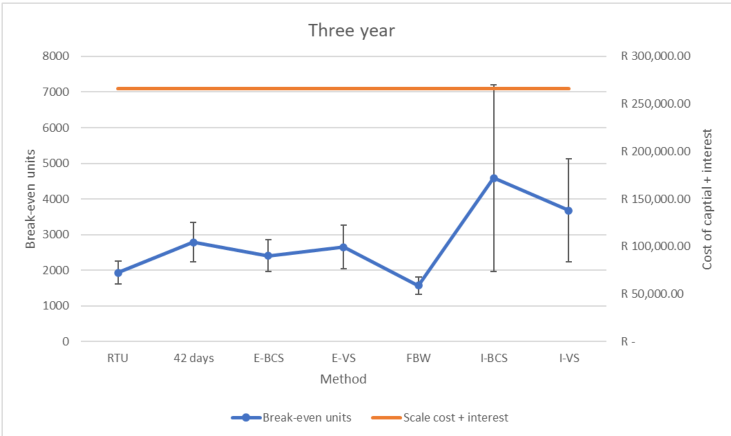

Figure 4.5 Break-even units per method over a three-year period.

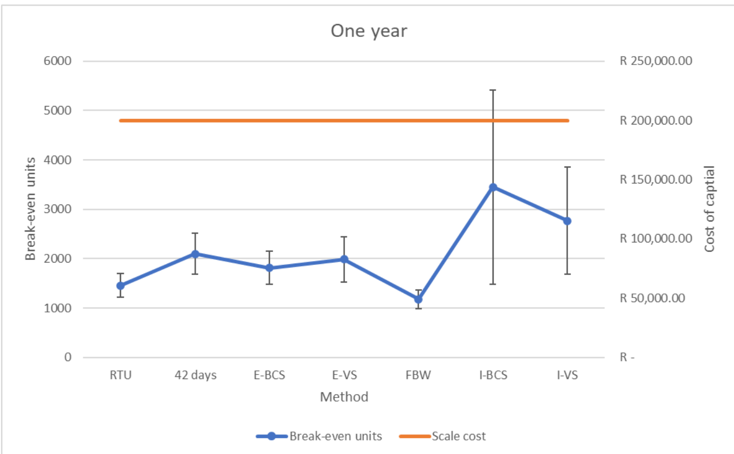

Figure 4.6 Break-even units per method over a one-year period.

Table 4.11 shows the effect of days spent in the feedlot on the minimum required animal break-even units and profitability over 1-, 3- and 5-year amortization scenarios. The days compared are 28, 35, 42 and 49 days in the feedlot respectively.

Table 4.11 uses the margins in Table 4.4. Feed cost increases over time but given the carcass income changes over time margin increase from 28 days to peak at 35 to 42 days whereafter decreasing to 49 days in the feedlot. This was not unexpected as the feed margin until 35 days was under pressure given the relative lighter weights of the animals resulting in lower carcass revenue while at 49 days in the feedlot increased feed cost eroded margin. As expected, the minimum required number of animals for all three scenarios followed a similar trend as margin over feed cost when the time spent in the feedlot is considered. This was not unexpected as revenue is the most important factor that determine the number of units that justify the capital investment. Despite the absence of significance between scenarios, it can be deducted from Table 4.11 that numerically more lambs are required when financing period increase. This can be attributed to the higher impact of interest.

For the current study processing costs and animal buy-in cost remain constant between treatments, however feed cost was minimized by slaughtering the animal when ready. Animals that are slaughtered when ready and thus optimize the carcass weight, contribute positively to debt amortization. While break-even analysis indicates that RFID investment can be justified, payback time is dependent on turnover (Wang *et al.,* 2021). Breed differences in maturity, sex, starting weights of animals in the feedlot and previous diet (Van der Merwe, 2020) will however affect investment decisions.

Table 4.11 The effect of time spent in feedlot on break-even minimum animal units per amortization scenario (Mean ± SE)

Days in feedlot	Margin above operational cost	Scenario 1 BEU	Scenario 2 BEU	Scenario 3 BEU
28	R 78.82 ± 19.36	2538 ± 624	3387 ± 830	4087 ± 1004
35	R 117.31 ± 16.87	1705 ± 246	2270 + 327	2746 ± 395
42	R 114.75 ± 15.30	1743 + 233	2320 ± 310	2807 ± 375
49	R 72.66 ± 41.66	2753 ± 1579	3664 ± 2101	4434 ± 2542

BEU = Break-even animal units

This study evaluated the financial and investment feasibility of an RFID auto drafter scale. It is determined that it is financially possible, however the number of lambs through-put will determine the period that would be most feasible for the enterprise given the turnover.

4.5 Conclusion

The higher the live final BW of the animal, the higher the CCW and the better the class that was reached. A higher dressing percentage combined with the CCW and optimal classification resulted in the highest margin above feed costs. In the current study the group of animals that had to reach a minimum weight therefore resulted in the highest margin, despite having had higher feed inputs and had spent a longer time in the feedlot. Experience was shown as an important requirement when subjective decisions are made as the animals that were sent for slaughter by the inexperienced assessor resulted in the lowest numerical margin above feed cost but did not differ significantly from the experienced assessor and the 42-day group. This lack of significance could be attributed to sample size. Despite being not different in the current study, it is well published that repeatability with inexperienced decision makers might lead to inconsistency in the results in future, especially with larger populations and higher variance amongst animals. By comparing the margin over feed cost of the animals selected by the inexperienced assessor (R64.58) to that of the experienced assessor (R105.33), the numerical margin difference per animal was R40.75. In a commercial feedlot with 1000 animals this accumulate to an additional income of R40 750 per cycle of 6 weeks or R244 500.00 over 6 cycles per annum. From the data it could be determined that final BW played a major role in profitability given that carcass class remains a constant A2 class.

An RFID auto drafter aids in decision making and when utilized correctly can lead to optimization of slaughter time of feedlot lambs. The higher the margin above feed cost the less units are required for the break-even point. Further the shorter the period, the less lambs are required. When FBW resulted in the least units to mortify the capital investment of the auto-drafter scale as the margin above feed cost were the highest for the FBW group of all methods evaluated. This result highlights the effect of precision management of animal in a feedlot on margin and feasibility of an investment.

As with previous studies the backfat thickness measurement (RTU) ensures optimal classing of an A2 classified lamb, but lack BW data and therefore cannot be used alone to determine profitability. Profitability prediction in the feedlot is complex with multiple vectors effecting the outcome.

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Chapter 5

General conclusion and recommendations

5.1 Conclusion

The narrow margins of the feedlot environment have highlighted the importance of precision finishing of lambs for optimal revenue. Feedlot finishing of lambs is a practice that adds value to store lambs. It allows faster finishing of lambs with a high energy density diet while also reducing grazing requirement. The optimization of selection of slaughter-ready lambs is an important precision tool for effective feedlot management and profitability. The study highlighted the importance of objective decision criteria of which body weight at slaughter were found to be the most important. Variation in optimal body weight for slaughter exist due to within and between breed variation owing to different maturity rates. Modern Radio Frequency Identification (RFID) technology, using objective data measurement, was shown to optimize net profit compared to all other selection methods evaluated. Seven different methods including a fixed 42-day period (FBW), ultrasound scanning (RTU) and two subjective methods of visual and palpation with either experienced or an inexperienced assessor to determine slaughter readiness on both the production and slaughter parameters were evaluated. Break-even analysis was used to determine capital investment return of a RFID auto drafter scale.

Due to the selection method, the cumulative feed intake (CFI) differed as the animals varied in the number of days spent in the feedlot. The FBW group had the highest CFI as well as the highest RTU measurement and differed from all the other groups. The FBW group of animals also resulted in the highest final body weight and spent the longest time in the feedlot compared to the other methods. No differences for ADG between the different groups were observed. Despite numeric differences, no significant differences could be established between experience level of the assessors for any parameters measured.

When evaluating the groups, the carcass quality characteristics including class and carcass weight, the FBW group of lambs produced the heaviest carcasses with optimal classification. When considering all parameters combined final weight, dressing percentage and class, the margin of the FBW group was the highest, despite spending longer time in the feedlot and consuming more feed that resulted in higher feed cost. Margin over feed cost correlated positively with ADG, final body weight and carcass weight.

In general, the subjective methods resulted in lower margins, as body weight was not accounted for and selection was based on subjective evaluation. Despite not significant, subjective evaluation was found as numerically less accurate and prone to high variation and error dependant on experience level and consistency that resulted in numerically lower margins over feed cost of the less experienced assessor. Precise management tools generate objective data which allows the feedlot manager precise decision-making information to navigate the multiple factors contributing to the margin over feed cost of the feedlot enterprise.

Ultrasound scanning has been described as an accurate method of predicting carcass fat and class. However, the current study proves that ultrasound scanning cannot be used alone to effectively predict carcass income as final body weight is not considered and the latter directly influences cold carcass weight and income. Further limitations of ultrasound scanning including limited access, measurement speed, need to sheer wooled animals and animal welfare concerns limit to practicality of this method in the commercial environment.

In this study break-even analysis indicates that the higher the margin above feed cost, the less animal units are required too break-even. Higher margin with a shorter amortization period will result in less lambs required to break even. The FBW group required the least units of all selection methods evaluated since it is directly influenced by the margin above feed cost. The FBW group of animals had the highest income per carcass. The inexperienced assessor led to the greatest variation per group.

It can be concluded from results of this study that commonly used selection techniques used within the commercial environment led to different effectiveness in income, variable cost and profit. The ideal method used will however be dependent on availability of resources. Objective data generation and availability however leads to higher margin over feed cost compared to all other methods, but sufficient animal numbers turnover is required to justify the capital investment. . It should further be kept in mind that the feed cost : slaughter price ratio at the time will always have an impact on profitability and break-even scenarios.

5.2 Recommendations

Although this research provided a baseline information for the effectiveness of common methods to decide when to slaughter lambs from a feedlot, further research on combining some of the selection methods would be needed. The days spent in the feedlot should be dependent on the starting weight and the breed of the animal. The profit per enterprise given the turnover of lambs per time unit as determined by time spent by the animals in the feedlot should also be considered in future when evaluating the profitability of decision-making tools.

An evaluation of the effect of experience of the assessor with larger populations with different breeds with differences in wool and hair cover should be conducted.

Future technology advancement where real time ultrasound scanning and combined with real time body weight determination is made possible will improve accuracy, animal welfare and profitability while reducing animal handling in lamb feedlot.