RELATIONSHIP BETWEEN LIVE WEIGHT, BODY CONDITION SCORE AND ULTRASOUND ESTIMATES OF BODY COMPOSITION IN EWES OFFERED DIFFERENT LEVELS OF DIETARY PROTEIN

By

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Being an Honours Research Project submitted in partial fulfilment of the requirements for the BSc (Honours) Degree in Agriculture

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## Contents page

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>III</td>
</tr>
<tr>
<td>LIST OF PLATES</td>
<td>III</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>IV</td>
</tr>
<tr>
<td>ABBREVIATIONS</td>
<td>V</td>
</tr>
<tr>
<td>POSTER</td>
<td>VI</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>VII</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>VIII</td>
</tr>
<tr>
<td>CHAPTER ONE: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER TWO: LITERATURE REVIEW</td>
<td>2</td>
</tr>
<tr>
<td>2.1 EWE NUTRITION MANAGEMENT</td>
<td>2</td>
</tr>
<tr>
<td>2.1.1 Mating</td>
<td>2</td>
</tr>
<tr>
<td>2.1.2 Pregnancy</td>
<td>2</td>
</tr>
<tr>
<td>2.1.3 Lactation</td>
<td>4</td>
</tr>
<tr>
<td>2.1.4 Weaning</td>
<td>5</td>
</tr>
<tr>
<td>2.2 METHODS OF MONITORING BODY COMPOSITION:</td>
<td>5</td>
</tr>
<tr>
<td>2.2.1 Body Condition Scoring</td>
<td>5</td>
</tr>
<tr>
<td>2.2.2 Weighing</td>
<td>6</td>
</tr>
<tr>
<td>2.2.3 Drafting</td>
<td>7</td>
</tr>
<tr>
<td>2.3 ALTERNATIVES</td>
<td>7</td>
</tr>
<tr>
<td>2.3.1 Ultrasound</td>
<td>7</td>
</tr>
<tr>
<td>2.3.2 X-ray Computer Tomography (CT)</td>
<td>7</td>
</tr>
<tr>
<td>2.4 OTHER SECTORS</td>
<td>7</td>
</tr>
<tr>
<td>2.4.1 Pigs</td>
<td>7</td>
</tr>
<tr>
<td>2.5 PROTEIN SUPPLY</td>
<td>8</td>
</tr>
<tr>
<td>2.5.1 Calculating requirements</td>
<td>8</td>
</tr>
<tr>
<td>2.5.2 Sources</td>
<td>8</td>
</tr>
<tr>
<td>2.6 IMPROVING PROTEIN SUPPLY</td>
<td>8</td>
</tr>
<tr>
<td>2.6.1 Xylose treatment</td>
<td>8</td>
</tr>
<tr>
<td>2.6.2 Heat treatment</td>
<td>8</td>
</tr>
<tr>
<td>2.6.3 Micronisation</td>
<td>8</td>
</tr>
<tr>
<td>2.7 CONCLUSION OF THE LITERATURE REVIEW</td>
<td>9</td>
</tr>
<tr>
<td>CHAPTER THREE: MATERIAL AND METHODS</td>
<td>10</td>
</tr>
<tr>
<td>3.1 EXPERIMENTAL DESIGN</td>
<td>10</td>
</tr>
<tr>
<td>3.2 EWE NUTRITION</td>
<td>10</td>
</tr>
<tr>
<td>3.3 BODY CONDITION SCORING AND WEIGHING</td>
<td>13</td>
</tr>
</tbody>
</table>
3.4 Ultrasound scanning for backfat and muscle depth determination ........................................ 13
3.5 Statistical analysis of data ........................................................................................................ 14
3.6 Laboratory analysis ...................................................................................................................... 14

CHAPTER FOUR: RESEARCH RESULTS .................................................................................. 15
4.1 Animal health ............................................................................................................................. 15
4.2 Analysis of feed ........................................................................................................................... 16
4.3 Ewe live weight pre and post-partum ....................................................................................... 16
4.4 Ewe condition score pre and post-partum ............................................................................... 19
4.5 Fat depth pre and post-partum .................................................................................................. 22
4.6 Muscle depth pre and post-partum .......................................................................................... 24
4.7 Correlation between traits ......................................................................................................... 26
   4.7.1 Body condition score and Fat depth .................................................................................... 26
   4.7.2 Body condition score and Muscle depth ............................................................................ 27
   4.7.3 Live weight and Body Condition Score .............................................................................. 27
   4.7.4 Fat depth and Muscle depth ............................................................................................. 28

CHAPTER FIVE: DISCUSSION AND INTERPRETATION .......................................................... 29
5.1 Effect of level and source of protein on ewe performance pre-partum ................................... 29
5.2 Effect of level and source of protein on ewe performance post-partum ................................. 29
5.3 Relationships between traits ..................................................................................................... 30
   5.3.1 Body condition score and Fat depth .................................................................................... 30
   5.3.2 Fat depth and Muscle depth ............................................................................................. 31
   5.3.3 Live weight and Body condition score .............................................................................. 32
5.4 Utilisation of body reserves ....................................................................................................... 32
5.5 Limitations and further research ............................................................................................. 32

CHAPTER SIX: CONCLUSION ................................................................................................. 34

CHAPTER SEVEN: REFERENCES ............................................................................................. 35

CHAPTER EIGHT: APPENDICES ............................................................................................. ERROR! BOOKMARK NOT DEFINED.

APPENDIX 1. BODY CONDITION SCORING STANDARDS ........................................... ERROR! BOOKMARK NOT DEFINED.
List of Tables

TABLE 1: EFFECTS OF SOURCE AND LEVEL OF PROTEIN ON EWE PERFORMANCE ........................................ VII
TABLE 2: EXPERIMENTAL DIETS ............................................................................................................. 10
TABLE 3: CHEMICAL COMPOSITION OF EXPERIMENTAL DIETS .......................................................... 12
TABLE 4: RAW COMPOSITION OF EXPERIMENTAL DIETS ..................................................................... 12
TABLE 5: SUMMARY OF REASONS FOR REMOVING EWES FROM TRIAL ............................................. 15
TABLE 6: CHEMICAL ANALYSIS OF DIETS (Week+3) .............................................................................. 16
TABLE 7: LIVE WEIGHTS OF TWIN BEARING EWES FED ONE OF SIX EXPERIMENTAL DIETS PRE AND POST-PARTUM ................................................................. 17
TABLE 8: BODY CONDITION SCORES OF EWES FED ONE OF SIX EXPERIMENTAL DIETS PRE AND POST-PARTUM .......................................................... 20
TABLE 9: FAT DEPTHS OF EWES OFFERED ONE OF SIX EXPERIMENTAL DIETS PRE AND POST-PARTUM .......................................................... 22
TABLE 10: MUSCLE DEPTHS OF EWES OFFERED ONE OF SIX EXPERIMENTAL DIETS PRE AND POST-PARTUM .......................................................... 24

List of plates

PLATE 1: SCREEN OF ULTRASOUND SCANNER USED ................................................................................ 13
PLATE 2: EXAMPLE OF MEASUREMENTS TAKEN .................................................................................... 14
List of Figures

FIGURE 1: PLACENTAL AND FOETAL GROWTH DURING GESTATION ........................................ 4
FIGURE 2: MILK PRODUCTION THROUGHOUT LACTATION ............................................... 5
FIGURE 3: TARGET BODY CONDITION SCORES THROUGHOUT THE PRODUCTION CYCLE .......... 6
FIGURE 4: EFFECT OF PROTEIN SOURCE TWO WEEKS POST-PARTUM ON LIVE WEIGHT. ERROR BARS REPRESENT SED .......................................................... 17
FIGURE 5: EFFECT OF PROTEIN SOURCE AND LEVEL ON LIVE WEIGHT TWO WEEKS POST-PARTUM. ERROR BARS REPRESENT SED ...................................................... 18
FIGURE 6: EFFECT OF PROTEIN SOURCE AND LEVEL ON PRE-PARTUM LIVE WEIGHT GAIN. ERROR BARS REPRESENT SED ............................................................... 18
FIGURE 7: EFFECT OF PROTEIN SOURCE AND LEVEL ON POST-PARTUM LIVE WEIGHT LOSS. ERROR BARS REPRESENT SED .............................................................. 18
FIGURE 8: EFFECT OF PROTEIN SOURCE AND LEVEL ON LIVE WEIGHT THROUGHOUT THE TRIAL PERIOD. ERROR BARS REPRESENT SED .................................................. 19
FIGURE 9: EFFECT OF PROTEIN SOURCE AND LEVEL ON BODY CONDITION SCORE LOSS THROUGHOUT THE WHOLE TRIAL PERIOD. ERROR BARS REPRESENT SED ........................................ 20
FIGURE 10: EFFECT OF PROTEIN SOURCE ON BODY CONDITION SCORE LOSS POST-PARTUM .... 21
FIGURE 11: EFFECT OF PROTEIN SOURCE AND LEVEL ON BODY CONDITION SCORE CHANGE THROUGHOUT THE TRIAL PERIOD. ERROR BARS REPRESENT SED ....................... 21
FIGURE 12: EFFECT OF PROTEIN SOURCE ON BACKFAT DEPTH EIGHT WEEKS POST-PARTUM. ERROR BARS REPRESENT SED .......................................................... 22
FIGURE 13: EFFECT OF PROTEIN SOURCE AND LEVEL ON BACKFAT DEPTH LOSS THROUGHOUT THE TRIAL PERIOD. ERROR BARS REPRESENT SED .................................... 23
FIGURE 14: EFFECT OF PROTEIN SOURCE AND LEVEL ON BACKFAT DEPTH THROUGHOUT THE WHOLE TRIAL PERIOD. ERROR BARS REPRESENT SED ..................................... 23
FIGURE 15: EFFECT OF PROTEIN SOURCE AND LEVEL ON MUSCLE DEPTH LOSS THROUGHOUT THE WHOLE TRIAL PERIOD. ERROR BARS REPRESENT SED .................................. 25
FIGURE 16: EFFECT OF PROTEIN SOURCE ON MUSCLE DEPTH EIGHT WEEKS POST-PARTUM. ERROR BARS REPRESENT SED .......................................................... 25
FIGURE 17: EFFECT OF PROTEIN SOURCE AND LEVEL ON MUSCLE DEPTH THROUGHOUT THE WHOLE TRIAL PERIOD. ERROR BARS REPRESENT SED ..................................... 26
FIGURE 18: RELATIONSHIP BETWEEN BODY CONDITION SCORE AND FAT DEPTH OVER THE WHOLE TRIAL PERIOD. ................................................................. 26
FIGURE 19: RELATIONSHIP BETWEEN BODY CONDITION SCORE AND MUSCLE DEPTH OVER THE WHOLE TRIAL PERIOD ................................................................. 27
FIGURE 20: RELATIONSHIP BETWEEN BODY CONDITION SCORE AND LIVE WEIGHT OVER THE WHOLE TRIAL PERIOD ................................................................. 27
FIGURE 21: RELATIONSHIP BETWEEN FAT DEPTH AND MUSCLE DEPTH OVER THE WHOLE TRIAL PERIOD ................................................................. 28
Abbreviations
AIA – Acid Insoluble Ash
ASH – Ash Content
B – Beans
BCS – Body Condition Score
BH – Beans High
BL – Beans Low
CP – Crude Protein
CT – Computer Tomography
DM – Dry Matter
DUP – Digestible Undegradable Protein
EBVs – Estimated Breeding Values
EE – Ether Extract
ERDP – Effective Rumen Digestible Protein
FME – Fermentable Metabolisable Energy
GE – Gross Energy
H – High
Kg - Kilogram
L – Low
ME - Metabolisable Energy
MP – Metabolisable Protein
NDF – Neutral Detergent Fibre
R – Rape
RH – Rape High
RL – Rape Low
S – Soya
SED – Standard Error of the Difference of the means
SH – Soya High
SL – Soya Low
SRS – Sire Reference Scheme
UDP – Undegradable Dietary Protein
Relationship between liveweight, body condition score and ultrasound estimates of body composition in ewes offered different levels of dietary protein

Joseph Williams and Dr John Donaldson
BSc Hons Agriculture

Introduction/Background
- Nutrition is key to successful productivity in ewes (Mcdonald et al., 2007).
- Nutritional adequacy is assessed through a range of measures most usually visually, by liveweight or commonly through body condition score.
- Body condition score is highly subjective and techniques used in other livestock, take a more objective approach, namely through back-fat scanning.

Methodology
- This study will utilise an ongoing research trial looking at ewes on a range of protein treatments from 6 weeks pre lambing week (-6) through to 4 weeks post-parturition week (+4)
- The ewes will be housed from the 3rd January 2014, with a mean lambing date of 14th February 2014 and through to 14th March 2014
- As part of the study ewe liveweight and body condition score will be measured weekly.
- Ultrasound scanning will be undertaken on a weekly basis to measure back fat levels

Null Hypotheses
There is no relationship between liveweight, body condition score and ultrasound estimates of body composition in ewes during late pregnancy and early lactation

Aims and Objectives:
- This study aims to assess the relationship between liveweight, body condition score and back-fat measures
- To compare ultrasound estimates of body composition with the more objective measure of body condition scoring
- The trial intends to find out which level of dietary protein more economically viable whilst providing the optimum level of production and performance within the ewes

Benefits/wider implications of the research
- Gives a greater understanding of ultrasound scanning estimates of body composition of ewes
- Will be beneficial to producers during this important nutrition management period of the ewe’s annual cycle
- Will help EBLEX, with their understanding of the technology

References
Relationship between live weight, body condition score and ultrasound estimates of body composition in ewes offered different levels of dietary protein

J.G. Williams, J. Donaldson
BSc (Hons) Agriculture

Introduction
The UK sheep industry uses Soya as its main protein source however, due to the fact that it is mostly imported, it is an unsustainable product. Therefore, if a home-grown source could prove to be more efficient then, the reliance on soya could be reduced. Measuring body composition in the UK tends to be a visual assessment or using body condition scoring (BCS). However, being a subjective measurement, there is the opportunity to use a more objective measure and improve the assessment of body composition and therefore, improve the level at which nutrient requirements can be assessed (AFRC, 1993).

Materials and methods
Forty eight Suffolk x North Country mule ewes carrying twin lambs were allocated to one of six dietary treatments according to live weight, parity and body condition score.
1. Soya bean meal (Low) (SL)
2. Soya bean meal (High) (SH)
3. Rape seed meal (Low) (RL)
4. Rape seed meal (High) (RH)
5. Field beans (Low) (BL)
6. Field beans (High) (BH)

Ewes were housed six weeks pre-partum (3/1/2014) and individually penned until four weeks post-partum (14/3/2014). Following this they were penned within their treatment groups for another four weeks (11/4/2014), which was the date that the trial finished. The ewes were fed a concentrate level in relation to their live weight at the beginning of the trial, this increased until parturition. In addition, ewes were offered 0.5 Kg DM/day of grass silage pre-partum which was increased to 1.0 Kg DM/day post-partum. Live weight and body condition scoring was carried out fortnightly while ultrasound measurements were taken in weeks -6, -2, +2, +4 and +6. Feed analysis was carried out in to confirm the chemical composition of the treatments. Data analysis was done using Genstat (version 16) as a randomly blocked 2x3 factorial experiment.

Research results:
The only significant effect of treatment in regards to change over time was overall BCS change (P=0.018) in relation to protein source. Ewes on diets sourced from rape lost on average 0.815 BCS whereas, ewes on soya based diets lost just 0.217 BCS over the whole trial period. There were no other significant effects of treatment on change within the measured traits over the time (Table 1).

Table 1: Effects of source and level of protein on ewe performance

<table>
<thead>
<tr>
<th>Treatment</th>
<th>SL</th>
<th>SH</th>
<th>RL</th>
<th>RH</th>
<th>BL</th>
<th>BH</th>
<th>s.e.d</th>
<th>Significances</th>
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<tbody>
<tr>
<td>Weight Change (Pre)</td>
<td>11.04</td>
<td>11.51</td>
<td>10.62</td>
<td>12.37</td>
<td>10.31</td>
<td>10.45</td>
<td>1.095</td>
<td>NS NS NS</td>
</tr>
<tr>
<td>Weight Change (Post)</td>
<td>-9.40</td>
<td>-7.44</td>
<td>-12.50</td>
<td>-11.68</td>
<td>-9.53</td>
<td>-7.41</td>
<td>2.776</td>
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<td>BCS Change (Pre)</td>
<td>0.300</td>
<td>0.153</td>
<td>-0.187</td>
<td>0.094</td>
<td>0.125</td>
<td>0.050</td>
<td>0.2218</td>
<td>NS NS NS</td>
</tr>
<tr>
<td>BCS Change (Post)</td>
<td>-0.336</td>
<td>-0.234</td>
<td>-0.739</td>
<td>-0.637</td>
<td>-0.521</td>
<td>-0.871</td>
<td>0.2796</td>
<td>NS NS NS</td>
</tr>
<tr>
<td>Overall BCS Change</td>
<td>-0.208</td>
<td>-0.225</td>
<td>-0.956</td>
<td>-0.815</td>
<td>-0.352</td>
<td>-0.876</td>
<td>0.3807</td>
<td>* NS NS</td>
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<tr>
<td>Fat Change (Pre)</td>
<td>-0.13</td>
<td>-0.14</td>
<td>-0.11</td>
<td>-0.16</td>
<td>-0.16</td>
<td>-0.13</td>
<td>0.070</td>
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<td>Fat Change (Post)</td>
<td>-0.34</td>
<td>-0.26</td>
<td>-0.32</td>
<td>-0.32</td>
<td>-0.34</td>
<td>-0.26</td>
<td>0.073</td>
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<tr>
<td>Overall Fat Change</td>
<td>-0.66</td>
<td>-0.55</td>
<td>-0.57</td>
<td>-0.62</td>
<td>-0.64</td>
<td>-0.65</td>
<td>0.117</td>
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<td>Muscle Change (Pre)</td>
<td>-0.16</td>
<td>-0.23</td>
<td>-0.21</td>
<td>-0.34</td>
<td>-0.21</td>
<td>-0.30</td>
<td>0.101</td>
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<tr>
<td>Muscle Change (Post)</td>
<td>-0.027</td>
<td>-0.061</td>
<td>-0.060</td>
<td>-0.227</td>
<td>-0.179</td>
<td>-0.164</td>
<td>0.107</td>
<td>NS NS NS</td>
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<tr>
<td>Overall Muscle Change</td>
<td>-0.38</td>
<td>-0.35</td>
<td>-0.43</td>
<td>-0.63</td>
<td>-0.58</td>
<td>-0.62</td>
<td>0.143</td>
<td>T NS NS</td>
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N.B: P Values, P=Main effect of protein source, L=Level of protein offered, Int=Interaction between source and level of protein. Pre-partum, Post-partum.
Correlations between traits showed that BCS and fat depth were the most positively correlated (R²=0.367).

Conclusion:
The main findings of this study show that ewes on soya based diets have performed in terms of live weight, BCS and ultrasound measurements. However, ewes on diets sourced from rape, have shown better lamb performance and also produced more milk than both ewes on soya and beans based diets. There was no effect of protein level on ewe performance. Therefore, as an alternative home-grown protein source to soya, rape would be recommended above soya. BCS and fat depth have shown a moderate positive correlation which suggests that while they are both measuring body composition, ultrasound measurements are more accurate and the use of this technology could help the industry to better calculate nutrient requirements of ewes in relation to changes in body composition.

References
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The Harper Adams University farm staff have also been an excellent help during the study, I would like to especially thank Carrie Gauld, for the effort she made in ensuring the project ran smoothly. The other students utilising sheep on the trial Rosa Malseed, Ed Robinson, James McManus, Faye Griffiths and Louise Hosegood have also been a great help during data collection and it has been a pleasure to work with them. It has also been both fulfilling and interesting being involved in their respective studies.

Finally, I would like to thank my family for their support during my time at Harper Adams University.
CHAPTER ONE: INTRODUCTION

The UK red meat industry is worth £1.67 billion to the UK economy (EBLEX, 2012) and industry employs over 95,000 people of which, almost 34,000 can be directly assigned to sheep enterprises (Marsh et al., 2012). In total the UK has over 15 million breeding ewes (DEFRA, 2012) and with almost 65% of the UKs farmland only suitable for ruminant grazing (EBLEX, 2012), they are a very important part of the industry. Therefore, due to the current economic climate and the global demand for food set to increase, the productivity of the sheep industry needs to be optimised and increased for the foreseeable future to meet demands. An increase in production will result in increased pressure on feed supplies both in the UK and globally. Therefore, these improvements in production need to be carried out whilst remaining sustainable and economically viable.

Managing ewe nutrition throughout the production cycle is an integral part of sheep management and therefore, nutritional adequacy is vital in ensuring optimal productivity within a flock. The majority of farmers use body condition score, weighing and visual assessment as methods of estimating body composition and therefore, the nutrient requirements of ewes. These techniques are easy to carry out and relatively inexpensive to operate, however they are all of a subjective nature. Ultrasound scanning is an alternative measurement which is objective, therefore providing the potential to use a numerical value in estimates of body composition. This study aims to investigate the relationship between body condition score, live weight and ultrasound estimates of body composition in ewes during late gestation and early lactation.
CHAPTER TWO: LITERATURE REVIEW

2. 1 Ewe nutrition management

2.1.1 Mating

Nutrition during mating is used to maximise ovulation rate and conception. Ewes must be in adequate body condition (BCS) before mating. Vipond et al. (2009) stated that ewes mated at BCS 3 will scan at 20-40% higher than ewes mated at BCS 2.5. However Gunn et al. (1984) stated that the optimal BCS for Scottish Blackface ewes at mating is 2.5 and Vatankhah et al. (2012), found that reproductive level of ewes increases up to BCS 3.5. Therefore, due to previous investigations it is clear that breeds perform differently at different BCS (Russel et al., 1969; Gunn et al., 1984; Sanson et al., 1993; Sormunen-Cristian and Jauhiainen, 2002; Vatankhah et al., 2012). The area in which breeds originate from in terms on stratification e.g. hill or lowland will have a major effect on the appropriate BCS during the production cycle (Vipond et al., 2009). Hill breeds such as Scottish Blackface are hardy and therefore, will reach a level of optimum production at a lower BCS than a lowland e.g. Texel or Suffolk.

Several studies have described the importance of flushing ewes before mating (Gunn et al., 1979; Rhind et al., 1984; Sormunen-Cristian and Jauhiainen, 2002; West et al., 2006). West et al. (2006) said that flushing will result in an increased litter size, 10 Kg higher body weights and an increase in BCS of 1.1 at the point of lambing. If flushing is not initiated ewes will not come into oestrus as early, by up to 2 weeks and will also ovulate at a lower rate (Gunn et al., 1979; Sormunen-Cristian and Jauhiainen, 2002). Another effect can be a decrease in the number of embryos that attach properly therefore, resulting in higher embryo mortality (Rhind et al., 1984). The effect of flushing can be explained by examining the opposite effect of under-nutrition during the same period. The lack of nutrition, inhibits the release of gonadotrophin-releasing hormone, therefore resulting in decreased luteinizing hormone being secreted, and therefore less chance of fertilisation (Wade and Jones, 2004; Sejian et al., 2010). These views were supported by Orskov (1982), who wrote that inadequate feed supply results in decreased cyclic activity and reduced onset of oestrus, along with a reduction in lifetime reproductive performance.

Fthenakis et al. (2012) stated that there was a change in the effect of flushing of ewes at different BCS. Those at BCS 2.5 or higher will ovulate at higher rates and therefore, produce more lambs. However, Heasman et al. (1998) examined the effects of flushing on ewes in low BCS and concluded that even though it did not increase ovulation it did bring the ewes into oestrus at an earlier date. Abdel-Mageed and Abo El-Maaty (2012) carried out a similar study but used ultrasound estimates of body composition as opposed to BCS. However, they found similar results increased backfat levels resulting in increased ovulation in ewes and also a significant increase in lambs weaned per ewe.

2.1.2 Pregnancy

Adequate nutrient intake of the mother is imperative for the survival of the foetus and the long term productivity of the ewe (Redmer et al., 2004). If inadequate nutrients are provided then foetal growth will be affected (Mellor, 1983; Vincent et al., 1985) however, the effects will be related directly to the period of gestation in which restrictions are applied and for how long. If a ewe has adequate body reserves the foetus may not be affected by feed restrictions (Redmer et al., 2004). Russel (1984) investigated the adequacy of nutrients provided to ewes in lamb and concluded that a ewe can lose 1 BCS throughout gestation without experiencing adverse effects to the foetus.
Early – Pregnancy

During the first month of pregnancy nutrient intake should be adequate to optimise embryo implantation. Parr et al. (1982) found that by maintaining BCS in early pregnancy the chance of embryo mortality is decreased, this allows the embryo to establish due to the fact that the ewe is not experiencing the stress of weight loss. Russel (1984) argued that a ewe can lose up to 0.25 BCS in the first month of pregnancy whilst remaining on a maintenance diet. Munoz et al. (2008) provided ewes with either 60%, 100% or 200% of their nutrient requirements at early pregnancy. They found that ewes fed 200% experienced increased dystocia at parturition however, produced more milk during lactation. Ewes on the 100% treatment had more vigorous lambs that grew at the highest rates. Finally, the lambs born from ewes fed the lowest treatment saw a decreased growth rate and also less passive immunity to disease.

Mid – Pregnancy

Between months one to three the aim is to optimise placental growth. Kleemann et al. (1993) examined the effect of restricted feed intake during mid-pregnancy (up to 90 days/13 weeks) and found that there is no significant change in lamb survival rate or subsequent birth weights. This agreed with the work of both Fthenakis et al. (2012) and Russel (1984) who stated that a ewe could lose up to 0.5 BCS during this period without adverse effects to productivity. This is due to the fact that the foetus grows slowly during this period (Economides, 1981) (See Figure 1). The placenta reaches almost full size by mid pregnancy (Schneider, 1996). Overfeeding at this time in the production cycle will decrease the placenta size and also resulting lamb birth weights (McDonald et al., 2011). It is believed that this is because the extra nutrients will be reassigned to the foetuses during a period where placental growth is more important. Once the final stage of pregnancy commences and foetal growth is a priority, the foetus will be affected because the placenta will not be at a size in which it can support the foetal demands (McDonald et al., 2011).

Late – Pregnancy

During late pregnancy nutrient requirements increase, this is due to the fact that 70% of foetal growth occurs in the last two months of gestation (Russel, 1984; Fthenakis et al., 2012) (See Figure 1). However, Kenyon et al. (2012) stated that ewe nutrition can be limited until day 136 of gestation.

Due to increasing size of the foetus, there is less room available for the rumen therefore, feeds with high energy, deriving from concentrates which are easily digestible should be fed during late gestation (Cannas et al., 2004). Sub optimal nutrition will result in adverse effects for both the lamb and the ewe. Lambs will experience lower birth weights and subsequent growth rates, along with increased chances of disease (Fthenakis et al., 2012).

Another important aspect of late pregnancy is mammary development. Ewes not provided with adequate nutrition during this stage in the cycle will experience insufficient udder development therefore not supplying enough colostrum to their lambs (Mellor and Murray, 1985). Ewes will also not develop the required maternal instincts therefore, not bonding with their lambs and resulting in decreased lamb growth rates (Dwyer et al., 2002). However, Nørgaard et al. (2008) found that ewes in BCS 4+ would not experience a significant reduction in milk production and mammary gland development, if provided inadequate nutrition in late gestation. The ewes utilised their high levels of body fat reserves to meet energy requirements.
During late pregnancy ewes carrying multiple foetuses are susceptible to pregnancy toxaemia, particularly during the last three weeks (Schlumbohm and Harmeyer, 2008). Sargison (2007) stated that it is also common in undernourished and stressed ewes however, if nutrition is adequate throughout pregnancy and ewes are in the correct BCS at late gestation (2-3) then the chance of pregnancy toxaemia decreases. This disease occurs due to the high foetal growth demands at this stage, the energy demands cannot be supplied by dietary carbohydrates. Therefore, the ewe utilises body fat reserves for energy supply however, if there is insufficient fat to be mobilised the body will go into a state of hypoglycaemia (Sargison, 2007; Schlumbohm and Harmeyer, 2008). It can be expensive to treat and mortality rates are high.

![Figure 1: Placental and foetal growth during gestation](source)

Source: Adapted from (Bazer et al., 2012)

2.1.3 Lactation

Following parturition the nutrient requirements of ewes will increase by 50% (EBLEX, 2009), over the first two to three weeks of lactation, until peak milk yield is reached (Kellems and Church, 2010). This was supported by McDonald et al. (2011) who say that 38% of total milk production is in the first four weeks, assuming the ewe is lactating for 16 weeks (See Figure 2). Ewes that are suckling two lambs will produce 20-40% more milk than those suckling singles (Kellems and Church, 2010). Over the lactation period BCS loss is inevitable. This is due to a negative energy balance. Dry matter intake will still be relatively low, therefore the ewe will struggle to physically consume the required amount of metabolisable energy (ME). However, the ewe will use body reserves and fat stores to provide the remaining nutrients and produce milk (Cowan et al., 1980). McDonald et al. (2011) found that a ewe in poor BCS cannot maintain milk production if provided nutrients at only the level of maintenance. This can be up to a 50% decrease within two to three days. During late lactation, when milk production has decreased substantially, a ewe can meet her nutrient requirements by grazing grass, with no need for concentrate intake (Kellems and Church, 2010).
2.1.4 Weaning

It is recommended that lambs are weaned at 12-16 weeks old (EBLEX, 2009), therefore allowing between three and four and a half months to recover before mating (Kellems and Church, 2010). Rowe and Masters (2005) stated that live weight should be at an optimum level for the particular breed at weaning, to allow body condition to be regained prior to mating in the autumn. Schillo (1992) found that decreased feed during this period will result in a longer anoestrus period. However, Kellems and Church (2010) argued that this is a period of time in which ewes can be fed poor-quality pasture therefore, being used as a grass management tool. Grass management is a vital part of sheep farming and optimising production but, this practice should not be allowed to have adverse effect of ewe performance.

2.2 Methods of monitoring body composition:

2.2.1 Body Condition Scoring

BCS is a subjective measure of body composition (Karamichou et al., 2007; Russel et al., 1969). Measuring is carried out by placing the fingers over the backbone, behind the final rib. Pressure is applied and the sharpness of the transverse processes are measured by assessing the level of fat cover present. It is a guide to the body composition of the ewe and her ability to maintain body reserves (Croston and Pollott, 1994). The level of condition is scored from 1-5, these scores are explained in appendix 1 (Russel et al., 1969). Being a subjective measure, condition scores may vary between different assessors.

MLC (1983) stated that for 0.5 BCS the live weight will change by 6-7% however, Sanson et al. (1993) found that for half a BCS the ewe will change live weight by 5 Kg. Russel et al. (1969) had similar results to Sanson et al. (1993) finding that for 1 unit change in BCS there was a change of 10.56 Kg in live weight, (Therefore, 0.5 BCS = 5.28 Kg). Russel et al. (1969), MLC (1983) and Sanson et al. (1993) have all based their results concerning change in live weight compared to BCS, on ewes that are not pregnant. Therefore, these guidelines may not fit in with ewes that are in gestation. This would be due to the ever changing weight of the conceptus (See Figure 1).
Cannas and Boe (2003) examined whether an equation could be developed to estimate live weight of the ewe based on the BCS. They concluded that if live weight at BCS 2.5 was known for that particular breed or population, then live weight could be estimated with a good level of accuracy (Cannas and Boe, 2003).

Body weight (BW) = (0.594 + 0.163 * BCS) * BW@BCS 2.5 (Cannas and Boe, 2003).

Being a subjective measurement and requiring low input costs means that BCS is easily utilised and therefore, commonly used on sheep farms as a management tool. Figure 3 shows the target BCS in the production cycle for lowland ewes (EBLEX, 2009) therefore, allowing the farmer to calculate nutrient requirements based on ewe performance.

![Figure 3: Target body condition scores throughout the production cycle](image)

Source: (Adapted from: EBLEX, 2009)

### 2.2.2 Weighing

Estimates of body condition can be carried out by weighing ewes and making decisions on nutritional adequacy in relation to the comparative weight of the ewe to the rest of the flock. However body weights can be deceiving, especially during pregnancy, this is due to the variance in placental and foetal weight between ewes (Croston and Pollott, 1994). Using both BCS and live weight is a better measurement than just live weight Russel et al. (1969) however, it is improved if live weight records can be recorded and results kept for each individual ewe. There is also the issue of breed variation with Welsh mountain ewes being on average almost half the weight of a Suffolk (Croston and Pollott, 1994). With weighing, the ewe is not necessarily handled therefore, a visual assessment is generally also used by the assessor. Again, this can be deceiving due to wool cover (ASIA, 1997), with changes in wool type, density and yields between breeds.

Research undertaken by Cannas and Boe (2003), showed that live weight target zones can be calculated for individual breeds. If an adequate sample of ewes from a breed are available, then live weight and BCS measurements can be taken and then average weights for each BCS can be estimated. Therefore, allowing differences between breeds to be eliminated.
2.2.3 Drafting

Once ewes have been classified, they tend to be drafted into the different management groups. This allows them to be provided with the correct nutrition while optimising performance and profitability.

2.3 Alternatives

2.3.1 Ultrasound

BCS is a subjective measurement, therefore ultrasound measurements have been proven to bring an objectiveness to body composition measurements and subsequently increase reliability (Abdel-Mageed and Abo El-Maaty, 2012). This was backed up by Ripoll et al. (2009) who said that BCS can vary between scorers whereas, ultrasound measurements will be more consistent and reliable. Studies have shown that ultrasound measurements have high correlations with carcass composition (Fennessy et al., 1993; Simm et al., 2002). However, Delta et al. (1995) disagreed with these statements, their investigation into whether ultrasonic estimates of body composition can be used to predict carcass composition, found that the relationship was not significant.

In the sheep industry ultrasound scanning is used mostly for recording growth rates of lambs in pedigree flocks, this data is then used in the Sire Reference Scheme (SRS) (Davis, 2010). These then feed into Estimated Breeding Values (EBVs) to select stock to breed from and improve the flock. They also provide a vital marketing tool by producing a numerical record of performance to back up claims made by breeders (Signet, Undated). There appears to be little evidence to show that commercially, ultrasound scanning is used to measure ewe body composition and therefore, manage ewes throughout the production cycle.

2.3.2 X-ray Computer Tomography (CT)

CT scanning generally takes measurements throughout the body, and then calculates the amounts of fat, bone and muscle at each section (Karamichou et al., 2007). CT scanning is currently the best technology available to predict carcass composition (Macfarlane et al., 2006) but, due to the cost implications it is rarely used as a tool for commercial farmers to utilise (Jones et al., 2004). However, there has been large scale research done using research institute flocks in the UK (Jones et al., 2004; Karamichou et al., 2007). Jones et al. (2004) carried out statistical analysis on live weight, ultrasound (from SRS), CT results and carcass measurements to examine if a correlation could be found. They found that there was a positive correlation between CT and carcass composition measurements, therefore they concluded that these methods could potentially be used effectively in a selection program for sheep. These findings were supported by Macfarlane et al. (2006). Following this Karamichou et al. (2007) used a CT index to select breeding stock from, in which CT measurements were inserted into a formula and the CT index was derived. Sheep were then selected for breeding using this index, they found that carcass quality could be improved using this method, resulting in decreased fat class and improved conformation of the lambs once they reached slaughter.

2.4 Other Sectors

2.4.1 Pigs

Many studies have been carried out in the pig industry using ultrasound technology as a method of predicting body composition and carcass quality (Lawrence et al., 2002; Fabian et al., 2004; Doeschil-Wilson et al., 2005). However, in this sector of agriculture there has also been work carried out into sows reactions to different diets throughout late gestation.
and early lactation (McNamara and Pettigrew, 2002). They used ultrasound scanning to monitor body composition changes throughout this period of the production cycle which is something that has not been used very often in the sector of sheep research.

### 2.5 Protein Supply

#### 2.5.1 Calculating requirements

Metabolisable Protein (MP) is the amount of a feed source that is converted to amino acids and is therefore, made available for the animal to use. It is calculated by adding together the amount of Effective Rumen Digestible Protein (ERDP) and Digestible Undegradable Protein (DUP) (AFRC, 1993). Ewes require protein for maintenance, growth, wool growth, conceptus growth if pregnant and also lactation.

#### 2.5.2 Sources

The main source of protein currently used in UK sheep production is Soya bean meal. Soya (S) must be imported therefore, is not as sustainable as home grown products (AHDB, 2012). The options for decreasing reliance on this source are either using improved proteins that supply similar levels of DUP from lower amounts of product or other sources which can be grown in the UK such as Beans (B), Peas or Rapeseed meal.

### 2.6 Improving Protein supply

Protein is subject to microbial fermentation while passing through the rumen (Tuncer and Sacakli, 2003). High quality protein is mostly degraded at this stage, resulting in a loss of the advantages gained from increased protein supply. Therefore, if protein degradation can be decreased at this point, it will result in increased digestion in the intestine and a better balance of essential amino acids and overall digestibility of the diet (Harstad and Prestløkken, 2000; Tuncer and Sacakli, 2003).

#### 2.6.1 Xylose treatment

The xylose treatment of protein sources is carried out by mixing the enzyme with the desired feed and then heating the mixture to “brown” the substance. This decreases the degradability of the protein within the rumen, meaning that it bypasses the stomach and is digested in the intestine instead (Cleale et al., 1987). Tuncer and Sacakli (2003) found that the addition of 20 g/kg of Dry matter (DM) of xylose treatment to soya bean meal caused a 65% reduction in crude protein degraded in the rumen.

#### 2.6.2 Heat treatment

Heat treatment is a method of protecting protein to decrease degradation in the rumen and allow digestion to take place in the intestine. Soya bean meal degradation in the rumen was reduced from 87.6% to 64.2% by roasting in an oven at 90°C (Mosimanyana and Mowat, 1992). Therefore, proving an effective way of protecting protein but not as well as xylose treatment.

#### 2.6.3 Micronisation

Another method of improving protein supply from a particular source is micronisation. This is a method of reducing the particle size by the use of heat and infrared treatment (Sharma, 2009). The starch molecules crack and gelatinise this means that rumen microbes find them hard to digest and the feedstuff travels to the intestine where the digestion takes place and the protein source becomes more efficient.
2.7 Conclusion of the literature review

Whilst research has been carried out into the relationship between ultrasound scanning and carcass composition in lambs, there appears to be little research into the use of these methods on ewes. Further to this, there has been little work done on the relationship between ultrasound scanning and BCS. Therefore, this study has been designed to investigate whether ewe BCS has a positive correlation with ultrasound scanning during the period of late gestation and early parturition, when live weight can be a deceiving assessment.

In addition, due to the issues surrounding protein utilisation and sustainability, another aspect of the trial will include ewe performance in relation to protein source and level. With a view of assessing the adequacy of nutrition and whether ewes can perform at similar levels with home-grown protein sources as imported feeds such as S.

Trial objectives:

- To determine the relationship between live weight, body condition score and ultrasound estimates of body composition
- To investigate the effect of source and level of protein within a ewes diet on performance during late gestation and early lactation.
CHAPTER THREE: MATERIAL AND METHODS

All the procedures involving animals were conducted in accordance with the UK Animals (Scientific Procedures) Act 1986.

3.1 Experimental design

Forty-eight Suffolk X North Country Mule multiparous ewes of mean live weight 84.21 (s.e. 6.3) kg were utilised within the trial that took place at Harper Adams University. The Universities ewe flock were synchronised using progesterone sponges and a Pregnant Mares Serum Gonadotrophin injection and subsequently were mated to Texel rams. This resulted in a mean lambing date of Thursday 14th February. Ewes were pregnancy scanned and any that were carrying twins were selected for the trial, 48 were randomly selected, with any ewes with health issues such as lameness discounted from selection.

3.2 Ewe nutrition

Six weeks pre-parturition (3rd January) ewes were individually penned. Ewes were bedded on sawdust, to ensure optimum control of feed intake. They were also allowed ad libitum access to water.

On Tuesday 7th January ewes were allocated onto one of six experimental treatments (table 2), they were allocated by condition score, live weight and parity in a randomly blocked design. Grass silage was offered at a level of 0.5 kg DM/day each morning to all ewes. Silage was re-analysed weekly to ensure the correct dry matter was being provided. Concentrate was provided to the ewes, this was calculated to each animals individual requirements in relation to the treatment which they were on. This initial level of concentrate was split between two offerings per day. The concentrates were increased over time to meet requirements, therefore two weeks prior to parturition feed was split into three equal offerings due to the level being fed. During lactation ewes were also offered 1.0 kg DM/day, to meet nutrient requirements.

Table 2: Experimental diets

<table>
<thead>
<tr>
<th>Diet source</th>
<th>Protein level</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Soya bean meal (S)</td>
<td>Low (L)</td>
<td>(SL)</td>
</tr>
<tr>
<td>2. Soya bean meal (S)</td>
<td>High (H)</td>
<td>(SH)</td>
</tr>
<tr>
<td>3. Rape seed meal (R)</td>
<td>Low (L)</td>
<td>(RL)</td>
</tr>
<tr>
<td>4. Rape seed meal (R)</td>
<td>High (H)</td>
<td>(RH)</td>
</tr>
<tr>
<td>5. Field beans (B)</td>
<td>Low (L)</td>
<td>(BL)</td>
</tr>
<tr>
<td>6. Field beans (B)</td>
<td>High (H)</td>
<td>(BH)</td>
</tr>
</tbody>
</table>

The concentrates were formulated to supply similar levels of Metabolisable Energy (ME), Fermentable Metabolisable Energy (FME) and Effective Rumen Degradable Protein (ERDP), but different levels of Crude Protein (CP) and Digestible Undegradable Protein (DUP) (table 3).
Treatments that provided L protein supplied 180 g/kg DM CP and 28 g/kg DM DUP, respectively. The H treatments were formulated to supply 212 g/kg DM CP and 56 g/kg DM DUP. This was carried out by adding either xylose treated soya bean meal (SoyPass ©), higher levels of xylose treated rapeseed meal (RaPass ©) or an increased amount of micronised beans (table 4). The concentrates were manufactured by HJ Lea Oakes Nantwich, Cheshire.

The diets were formulated to meet the requirements of ewes producing 3.0 litres of milk/day, with each ewes individual requirements calculated. The total ration including silage and concentrate provided L ewes with 100% and 85% of ewe MP requirement during gestation and lactation, respectively. However, those on an H treatment had 125% and 100% of MP requirement during gestation and lactation, respectively (AFRC, 1993).

Ewes were fed twice daily at 08:00 and 16:00 between weeks six and two weeks pre-partum and three times daily (also at 12:00) from two weeks pre-partum onwards. Bedding was carried out when necessary to ensure the pens were clean and hygienic for the ewes.

On Friday 14th March (four weeks post-partum) ewes were group housed within their treatments until Friday 11th April (eight weeks post-partum). During this period they were fed ad-libitum silage and the diets were formulated to provide adequate nutrition for ewes rearing twin lambs and producing 2.0 litres of milk daily. The lambs were weaned after the final data collection took place, eight weeks post-partum.
Table 3: Chemical composition of experimental diets

<table>
<thead>
<tr>
<th></th>
<th>Soya Low</th>
<th>Soya High</th>
<th>Rape Low</th>
<th>Rape High</th>
<th>Beans Low</th>
<th>Beans High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (g/kg)</td>
<td>870</td>
<td>873</td>
<td>868</td>
<td>866</td>
<td>868</td>
<td>869</td>
</tr>
<tr>
<td>Crude protein</td>
<td>178</td>
<td>212</td>
<td>179</td>
<td>213</td>
<td>174</td>
<td>212</td>
</tr>
<tr>
<td>ERDP (0.05)</td>
<td>128</td>
<td>132</td>
<td>127</td>
<td>129</td>
<td>127</td>
<td>139</td>
</tr>
<tr>
<td>DUP (0.05)</td>
<td>28</td>
<td>57</td>
<td>28</td>
<td>56</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>Ether extract</td>
<td>50</td>
<td>52</td>
<td>53</td>
<td>57</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>Ash</td>
<td>76</td>
<td>76</td>
<td>79</td>
<td>78</td>
<td>73</td>
<td>71</td>
</tr>
<tr>
<td>NDF</td>
<td>206</td>
<td>212</td>
<td>208</td>
<td>213</td>
<td>211</td>
<td>189</td>
</tr>
<tr>
<td>Starch</td>
<td>348</td>
<td>351</td>
<td>352</td>
<td>358</td>
<td>389</td>
<td>414</td>
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<tr>
<td>ERDP/FME</td>
<td>11.24</td>
<td>11.59</td>
<td>10.95</td>
<td>11.16</td>
<td>11.12</td>
<td>12.03</td>
</tr>
</tbody>
</table>

Table 4: Raw composition of experimental diets

<table>
<thead>
<tr>
<th>Composition (g/kg)</th>
<th>Soya Low</th>
<th>Soya High</th>
<th>Rape Low</th>
<th>Rape High</th>
<th>Beans Low</th>
<th>Beans High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>265</td>
<td>265</td>
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<tr>
<td>Wheat</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>265</td>
<td>265</td>
</tr>
<tr>
<td>Sugar beet pulp</td>
<td>142</td>
<td>65</td>
<td>120</td>
<td>23</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Soya hulls</td>
<td>78</td>
<td>65</td>
<td></td>
<td></td>
<td>85</td>
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<td>Soya bean meal</td>
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<tr>
<td>Rape seed meal</td>
<td></td>
<td></td>
<td>145</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RaPass</td>
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<td>240</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Beans</td>
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<td>30</td>
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<tr>
<td>Micronised beans</td>
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<td></td>
<td></td>
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<td>120</td>
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<tr>
<td>Megalac</td>
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<td>40</td>
<td>40</td>
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<td>40</td>
</tr>
<tr>
<td>Urea</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Molasses</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Min/Vits</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>
3.3 Body condition scoring and Weighing

Live weight and body condition score was determined in weeks 6, 4 and 2 prior to lambing, at lambing and then in weeks 2, 4, 6 and 8 during lactation. All body condition score recordings were taken according to the standard procedure set out by Russel et al. (1969) and were carried out by the same technician at each point. Scores were taken on a scale of 1-5 with 1 being thin and scores were measured at an accuracy of ¼ scores. The same set of Shearwell ID3000 weighing scales were used at each weighing point. Each time they were used, a standard 10 kg weight was used to calibrate the machine. These measurements were made at the same time of day (14:00Hrs) at each measuring point to ensure that there was no changes due to time of day or length of time since feeding.

3.4 Ultrasound scanning for backfat and muscle depth determination

Ewes were ultrasound scanned during weeks 6 and 2 prior to and weeks 2, 4 and 8 after lambing. The scanning was taken out on the left hand side of the ewe if facing the animal, each time and carried out by the same person. This procedure was carried out while ewes were in the weighing scales for live weight measurements. The ultrasound scanning machine used was a BCF Digiprince DP-6900Vet with a BCF ultrasonic transducer 75L50EAV scanning probe attached.

The wool was parted at the 3rd lumbar vertebra at 90 degrees to the spine (Davis, 2010). Then a lubricating gel was applied to allow the probe to gain a good contact with the skin and provide a clear scan. Once a clear picture was secured, the scanner was able to use a cursor and marker system to measure lengths within the scan picture. A single muscle depth measurement was taken at the deepest muscle point, then three fat depth measurements were taken with the first at the same distance from the spine as the deepest muscle point and the next two were taken at 1cm intervals, moving away from the spine (See Plates 1 and 2.).
3.5 Statistical analysis of data

Regression analysis between the traits using Pearson’s Correlation Coefficient (R) was undertaken to measure correlation along with line equations. Coefficients of determination ($R^2$) were calculated to determine the effect of variance in one variable has on the other. These measurements were carried out using excel.

Using Genstat (16th edition), a randomly blocked two way anova design analysis was undertaken on live weight, BCS and both muscle and fat depth. Repeated measures were also carried out, this enabled the effect of time on the variables to be taken into account and calculated. Error bars were presented using the standard error of the difference of the means (SED). $P<0.05$ was used to show significance and when $P \leq 0.1$ this was represented as a trend.

3.6 Laboratory analysis

A sample of each concentrate feed was taken three weeks post-partum. Analysis was then carried out on each feed to determine Dry Matter (DM), Crude Protein (CP) was analysed using a LECO machine which complies with Association of Official Analytical Chemists (AOAC) method 990.03 (LECO, 2013). Ether Extract (EE) was analysed using AOAC (2000) methods. Ash content (ASH), Acid Insoluble Ash (AIA), Neutral Detergent Fibre (NDF) were all analysed using methods set out by Galyean (2010). Gross Energy (GE) was derived using a bomb calibration Galyean (2010).
CHAPTER FOUR: RESEARCH RESULTS

4.1 Animal health

All ewes were scanned as carrying twins however, the ewes in pens two, 14 and 42 each produced single lambs. Therefore, all of their data throughout the trial was removed due to the fact that the ewes had been overfed as their requirements were calculated assuming they were carrying twins.

In addition to the three ewes that had single lambs there was also five ewes that only reared one lamb. All of these ewes had their data removed following parturition. The ewe in pen 47 reared both lambs until 8th March when one lamb was removed however, the lambs gained just 0.29 and 2.37 Kg of weight between lambing and this data collection. The ewe had been treated for mastitis on the 21st February. Therefore, her data was removed from the time of parturition.

On 1st April ewe 6 was euthanized due to chronic mastitis therefore, there is no data for this ewe at eight weeks post-partum. Also ewes 32 and 36 had lambs die on the 3rd and 5th April respectively. This was due to coccidiosis, therefore data has been removed for these ewes at eight weeks post-partum. A summary of ewes removed from trial is shown in table 5.

Table 5: Summary of reasons for removing ewes from trial

<table>
<thead>
<tr>
<th>Pen Number</th>
<th>Reason for removal</th>
<th>Treatment</th>
<th>Point of data removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Had single lamb</td>
<td>BH</td>
<td>Start of trial</td>
</tr>
<tr>
<td>6</td>
<td>Ewe euthanized</td>
<td>BL</td>
<td>8 weeks post-partum</td>
</tr>
<tr>
<td>9</td>
<td>Lamb died – suffocation 17/2/14</td>
<td>BH</td>
<td>Parturition</td>
</tr>
<tr>
<td>14</td>
<td>Had single lamb</td>
<td>SL</td>
<td>Start of trial</td>
</tr>
<tr>
<td>18</td>
<td>Lamb born dead</td>
<td>BL</td>
<td>Parturition</td>
</tr>
<tr>
<td>32</td>
<td>Lamb died coccidiosis 3/4/14</td>
<td>RH</td>
<td>8 weeks post-partum</td>
</tr>
<tr>
<td>36</td>
<td>Lamb died coccidiosis 5/4/14</td>
<td>SH</td>
<td>8 weeks post-partum</td>
</tr>
<tr>
<td>42</td>
<td>Had single lamb</td>
<td>SH</td>
<td>Start of trial</td>
</tr>
<tr>
<td>43</td>
<td>Lamb born dead</td>
<td>BH</td>
<td>Parturition</td>
</tr>
<tr>
<td>44</td>
<td>Lamb died 14/2/14 reason unknown</td>
<td>RH</td>
<td>Parturition</td>
</tr>
<tr>
<td>47</td>
<td>Lamb removed 8/3/14</td>
<td>RL</td>
<td>Parturition</td>
</tr>
</tbody>
</table>
4.2 Analysis of feed

Analysis of concentrate feeds (table 6) showed that DM was similar to the chemical composition expected. Ash content also showed similar values to that expected however BH was low at 59.25 g/Kg DM compared to 71 g/Kg DM. Both CP and ME were consistently lower than expected values being on average 21.7 g/Kg DM and 2.27 MJ/Kg DM lower respectively. EE was also lower than expected in all feeds apart from BH which was similar. NDF was the most variable part of the chemical composition of the feeds. Both SL and RH were 42 and 30 g/Kg DM higher than expected respectively. BL and RL had similar values of NDF to what was expected. However, BH and SH were considerably lower with a difference of 17.2 and 42.8 g/Kg DM respectively.

Table 6: Chemical analysis of diets (Week+3)

<table>
<thead>
<tr>
<th>g/kg DM</th>
<th>Soya Low</th>
<th>Soya High</th>
<th>Rape Low</th>
<th>Rape High</th>
<th>Beans Low</th>
<th>Beans High</th>
<th>Silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>859.70</td>
<td>859.70</td>
<td>860.30</td>
<td>863.30</td>
<td>859.90</td>
<td>858.80</td>
<td>517.30</td>
</tr>
<tr>
<td>CP</td>
<td>144.95</td>
<td>184.39</td>
<td>160.00</td>
<td>195.38</td>
<td>152.54</td>
<td>200.55</td>
<td>161.71</td>
</tr>
<tr>
<td>EE</td>
<td>37.71</td>
<td>37.37</td>
<td>44.57</td>
<td>51.08</td>
<td>41.98</td>
<td>52.29</td>
<td>20.08</td>
</tr>
<tr>
<td>ASH</td>
<td>74.84</td>
<td>76.16</td>
<td>78.86</td>
<td>75.77</td>
<td>69.17</td>
<td>59.25</td>
<td>90.99</td>
</tr>
<tr>
<td>AIA</td>
<td>13.45</td>
<td>9.18</td>
<td>8.92</td>
<td>5.62</td>
<td>8.86</td>
<td>4.13</td>
<td>11.70</td>
</tr>
<tr>
<td>NDF</td>
<td>248.28</td>
<td>194.79</td>
<td>215.72</td>
<td>243.23</td>
<td>202.58</td>
<td>146.21</td>
<td>603.86</td>
</tr>
<tr>
<td>MJ/Kg DM</td>
<td>17.84</td>
<td>18.01</td>
<td>18.23</td>
<td>17.93</td>
<td>17.99</td>
<td>18.53</td>
<td>18.39</td>
</tr>
<tr>
<td>GE</td>
<td>11.40</td>
<td>11.45</td>
<td>10.91</td>
<td>11.17</td>
<td>11.55</td>
<td>11.40</td>
<td></td>
</tr>
</tbody>
</table>

4.3 Ewe live weight pre and post-partum

Table 7 shows that during pre-partum there was no significant effect of treatments on live weight.

Post-partum weight change showed no significant difference. However, at week two after lambing ewes that were being fed a diet which used B as a protein source also had a significantly (P=0.020) lower live weight than both S and R with on average a difference of 3.86 kg and 3.75 kg, respectively (See Figure 4). There was also a significant (P=0.049) effect of the interaction on ewes being fed the BH treatment having a significantly lower live weight than ewes on SL, SH and RH as shown in figure 5.

Figures 6 and 7 show no significant effect of protein source an level on pre and post-partum weight change, respectively.

All ewes gained weight during pre-partum and lost weight post-partum and there was a significant effect over time (P<0.001) (See Figure 8).
Table 7: Live weights of twin bearing ewes fed one of six experimental diets pre and post-partum

<table>
<thead>
<tr>
<th>Weeks from lambing</th>
<th>Treatment</th>
<th>Significances†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SL</td>
<td>SH</td>
</tr>
<tr>
<td>Week – 6 (Kg)</td>
<td>83.8</td>
<td>84.5</td>
</tr>
<tr>
<td>Week – 2 (Kg)</td>
<td>94.8</td>
<td>96.0</td>
</tr>
<tr>
<td>Pre Partum Weight Change</td>
<td>11.0</td>
<td>11.5</td>
</tr>
<tr>
<td>Week - 0 (Kg)</td>
<td>83.3</td>
<td>83.2</td>
</tr>
</tbody>
</table>

| Week + 2 (Kg)     | 83.5<sup>b</sup> | 85.7<sup>b</sup> | 82.7<sup>b</sup> | 86.2<sup>b</sup> | 82.5<sup>b</sup> | 78.9<sup>c</sup> | 2.06<sup>*</sup> | * | NS | * |
| Week + 8 (Kg)     | 74.0 | 75.4 | 69.8 | 71.6 | 73.0 | 70.3 | 2.72 | NS | NS | NS |
| Post-Partum Weight Change | -9.4 | -7.4 | -12.5 | -11.7 | -9.5 | -7.4 | 2.78 | NS | NS | NS |

†P values: P = main effect of protein source, L = Level of protein, Int = Interaction between protein source and level
Means with different superscripts within columns indicates significant differences (P<0.05)

Figure 4: Effect of protein source two weeks post-partum on live weight. Error bars represent SED
Figure 5: Effect of protein source and level on live weight two weeks post-partum. Error bars represent SED.

Figure 6: Effect of protein source and level on pre-partum live weight gain. Error bars represent SED.

Figure 7: Effect of protein source and level on post-partum live weight loss. Error bars represent SED.
4.4 Ewe condition score pre and post-partum

Table 8 shows there was no significant effect of treatment on BCS pre-partum.

Eight weeks post-partum there was a significant (P= 0.016) effect of protein source in with both ewes on B and R based diets having a lower BCS than those on S based diets. There was also a weak trend (P=0.086) between differing levels of protein with ewes on low protein diets having 0.264 higher BCS than ewes on high protein.

Overall BCS change over the whole trial period was significantly (P=0.018) affected by source of protein (See Figure 9). With ewes on S based diets losing on average 0.217 which was significantly lower than ewes on R based diets which lost 0.885 BCS, while ewes with B based diets lost 0.614 BCS which was statistically the same as both R and S.

Post-partum BCS change showed a trend (P=0.079) relating to source of protein with ewes on S diets losing less BC than ewes on R and B with an average of 0.403 and 0.411 more loss in condition, respectively (See Figure 10).

Over the whole period all treatments lost BCS however, pre-partum all treatments had an increase in BCS apart from RL. There was a significant (P<0.001) effect of time on BCS as shown in figure 11.
Table 8: Body condition scores of ewes fed one of six experimental diets pre and post-partum

<table>
<thead>
<tr>
<th>Weeks from lambing</th>
<th>SL</th>
<th>SH</th>
<th>RL</th>
<th>RH</th>
<th>BL</th>
<th>BH</th>
<th>s.e.d</th>
<th>P</th>
<th>L</th>
<th>Int</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCS Week - 6</td>
<td>3.37</td>
<td>3.18</td>
<td>3.31</td>
<td>3.34</td>
<td>3.19</td>
<td>3.18</td>
<td>0.249</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>BCS Week - 2</td>
<td>3.67</td>
<td>3.33</td>
<td>3.13</td>
<td>3.44</td>
<td>3.31</td>
<td>3.23</td>
<td>0.228</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Pre Partum</td>
<td>0.30</td>
<td>0.15</td>
<td>-0.19</td>
<td>0.09</td>
<td>0.13</td>
<td>0.05</td>
<td>0.222</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>BCS Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCS Week 0</td>
<td>3.50</td>
<td>3.16</td>
<td>3.25</td>
<td>3.16</td>
<td>3.22</td>
<td>3.13</td>
<td>0.204</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

| BCS Week + 2       | 3.33| 3.00| 3.07| 3.28| 3.14| 3.11| 0.207 | NS    | NS    | NS    |
| BCS Week + 8       | 3.16| 2.82| 2.46| 2.45| 2.76| 2.34| 0.256 | *     | T     | NS    |
| Post-Partum BCS Change | -0.34| -0.23| -0.74| -0.64| -0.52| -0.87| 0.280 | T     | NS    | NS    |

Overall BCS Change: -0.21, -0.23, -0.96, -0.82, -0.35, -0.88, 0.381, *NS NS NS

\(^1\)P values: P = main effect of protein source, L = Level of protein, Int = Interaction between protein source and level

Figure 9: Effect of protein source and level on body condition score loss throughout the whole trial period. Error bars represent SED.
Figure 10: Effect of protein source on body condition score loss post-partum

Figure 11: Effect of protein source and level on body condition score change throughout the trial period. Error bars represent SED.
4.5 Fat depth pre and post-partum

Table 9 shows there was no significant effect of treatment pre partum on fat depth.

Figure 12 shows that week eight post-partum there was a significant (P=0.005) effect of protein source on fat depth with ewes on S based diets having on average 0.08 cm and 0.07 cm more backfat than those on B and R based diets, respectively. At week 8 post-partum there was also a trend (P=0.079) from the effect of protein level with ewes on low protein diets having more backfat than those on high protein diets.

Figure 13 shows no significant effect of protein source and level on backfat depth loss throughout the whole trial period.

Ewes on all treatments lost backfat depth at pre and post-partum and therefore, overall. There was a significant effect of time (P<0.001) on backfat depth change as shown in figure 14.

Table 9: Fat depths of ewes offered one of six experimental diets pre and post-partum

<table>
<thead>
<tr>
<th>Weeks from lambing</th>
<th>Treatment</th>
<th>s.e.d</th>
<th>P</th>
<th>L</th>
<th>Int</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat Depth Week – 6 (Cm)</td>
<td>SL</td>
<td>1.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SH</td>
<td>0.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RL</td>
<td>0.89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RH</td>
<td>1.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BL</td>
<td>0.97</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BH</td>
<td>0.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre Partum Fat Depth Change</td>
<td>-0.13</td>
<td>-0.14</td>
<td>-0.11</td>
<td>-0.16</td>
<td>-0.13</td>
</tr>
</tbody>
</table>

| Fat Depth Week + 2 (Cm)     | SL        | 0.77  |    |    |     |
|                             | SH        | 0.65  |    |    |     |
|                             | RL        | 0.66  |    |    |     |
|                             | RH        | 0.69  |    |    |     |
|                             | BL        | 0.65  |    |    |     |
|                             | BH        | 0.62  |    |    |     |
| Fat Depth Week + 8 (Cm)     | SL        | 0.43  |    |    |     |
|                             | SH        | 0.38  |    |    |     |
|                             | RL        | 0.34  |    |    |     |
|                             | RH        | 0.34  |    |    |     |
|                             | BL        | 0.36  |    |    |     |
|                             | BH        | 0.30  |    |    |     |
| Post-Partum Fat Depth Change| -0.34     | -0.26 | -0.32 | -0.32 | -0.26 |
| Overall Fat Depth Change    | -0.66     | -0.55 | -0.57 | -0.62 | -0.64 | -0.65 |

1P values: P = main effect of protein source, L = Level of protein, Int = Interaction between protein source and level, ** = P<0.01

Figure 12: Effect of protein source on backfat depth eight weeks post-partum. Error bars represent SED.
Figure 13: Effect of protein source and level on backfat depth loss throughout the trial period. Error bars represent SED.

Figure 14: Effect of protein source and level on backfat depth throughout the whole trial period. Error bars represent SED.
4.6 Muscle depth pre and post-partum

Table 10 shows that there was no significant effect of treatment on Muscle depth however, there was a trend (P=0.096) between level of protein and muscle depth change pre-partum. Ewes that were fed a high level of protein lost more muscle depth than those on low levels of protein.

In week two post-partum there was a very weak trend (P=0.100) between level of protein and muscle depth with ewes on high protein level diets having more muscle depth than ewes on low protein. Source of protein also showed a trend (P=0.076) with ewes on R based diets having more muscle depth than S and B.

Figure 15 shows that throughout the whole trial period there was no significant effect of protein source and level on muscle depth loss.

Figure 16 shows that eight weeks post-partum there was a significant (P=0.036) effect of protein source on muscle depth. Ewes on B based diets had significantly lower levels than R and S with 0.153 cm and 0.17 cm less, respectively. Over the whole trial period there was a trend (P=0.077) relating source of protein to overall muscle depth change. Ewes on S based diets lost less muscle depth than both R and B sourced diets.

Ewes on all treatments lost muscle depth during pre and post-partum and subsequently over the whole trial period. Figure 17 shows there was a significant (P<0.001) effect of time on muscle depth.

Table 10: Muscle depths of ewes offered one of six experimental diets pre and post-partum

<table>
<thead>
<tr>
<th>Weeks from lambing</th>
<th>SL</th>
<th>SH</th>
<th>RL</th>
<th>RH</th>
<th>BL</th>
<th>BH</th>
<th>s.e.d</th>
<th>Significances¹</th>
<th>P</th>
<th>L</th>
<th>Int</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle Depth Week – 6 (Cm)</td>
<td>2.57</td>
<td>2.65</td>
<td>2.65</td>
<td>2.83</td>
<td>2.69</td>
<td>2.73</td>
<td>0.146</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Muscle Depth Week – 2 (Cm)</td>
<td>2.41</td>
<td>2.41</td>
<td>2.45</td>
<td>2.49</td>
<td>2.48</td>
<td>2.43</td>
<td>0.128</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Pre Partum Muscle Depth Change</td>
<td>-0.16</td>
<td>-0.23</td>
<td>-0.21</td>
<td>-0.34</td>
<td>-0.21</td>
<td>-0.30</td>
<td>0.102</td>
<td>NS</td>
<td>T</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Muscle Depth Week + 2 (Cm)</td>
<td>2.22</td>
<td>2.32</td>
<td>2.29</td>
<td>2.43</td>
<td>2.21</td>
<td>2.22</td>
<td>0.086</td>
<td>T</td>
<td>T</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Muscle Depth Week + 8 (Cm)</td>
<td>2.20</td>
<td>2.29</td>
<td>2.23</td>
<td>2.22</td>
<td>2.08</td>
<td>2.06</td>
<td>0.096</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Post-Partum Muscle Depth Change</td>
<td>-0.03</td>
<td>-0.06</td>
<td>-0.06</td>
<td>-0.23</td>
<td>-0.18</td>
<td>-0.17</td>
<td>0.107</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Overall Muscle Depth Change</td>
<td>-0.38</td>
<td>-0.35</td>
<td>-0.43</td>
<td>-0.63</td>
<td>-0.58</td>
<td>-0.62</td>
<td>0.143</td>
<td>T</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

¹P values: P = main effect of protein source, L = Level of protein, Int = Interaction between protein source and level
Figure 15: Effect of protein source and level on muscle depth loss throughout the whole trial period. Error bars represent SED.

Figure 16: Effect of protein source on muscle depth eight weeks post-partum. Error bars represent SED.
Figure 17: Effect of protein source and level on muscle depth throughout the whole trial period. Error bars represent SED.

4.7 Correlation between traits

4.7.1 Body condition score and Fat depth

BCS and fat depth measurements had a weak to moderate positive correlation between the two variables, over the whole data set (See Figure 18). Correlations at each time point ranged from 0.1844 six weeks pre-parturition to 0.439 post-partum. BH had the highest positive correlation of 0.52 and SH had the lowest of 0.26

Figure 18: Relationship between body condition score and fat depth over the whole trial period.
4.7.2 Body condition score and Muscle depth

Figure 19 shows that BCS and muscle depth showed a very weak positive correlation, over the whole time period. Correlations at each time point ranged from 0.034 four weeks post-partum to 0.238 two weeks pre-partum. RL had the highest positive correlation of 0.41 and SH had the lowest of 0.09.

![Figure 19: Relationship between body condition score and muscle depth over the whole trial period.](image)

4.7.3 Live weight and Body Condition Score

LW and BCS showed a very weak positive correlation over the whole time period (See Figure 20). Correlations at each time point ranged from 0.003 two weeks pre-partum to 0.2252 eight weeks post-partum. SL had the highest positive correlation of 0.38 and BH had the lowest of 0.04.

![Figure 20: Relationship between body condition score and live weight over the whole trial period.](image)
4.7.4 Fat depth and Muscle depth

Figure 21 shows that fat and muscle depth showed a weak to moderate positive correlation over the whole time period. Correlations at each time point ranged from 0.0301 two weeks post-partum to 0.1508 six weeks pre-partum. The overall correlation was higher than these values due to having a more complete data set over the whole time period. BH had the highest positive correlation of 0.73 and SH had the lowest of 0.22.

![Figure 21: Relationship between fat depth and muscle depth over the whole trial period.](image)

\[ y = 0.5068x - 0.4713 \]

\[ R^2 = 0.3172 \]
CHAPTER FIVE: DISCUSSION AND INTERPERATION

5.1 Effect of level and source of protein on ewe performance pre-partum

Neither the increase in DUP supply in feeds or differing sources of protein resulted in significant differences in ewe-performance during the six weeks leading up to parturition. Dawson et al. (1999) had similar findings. Ewes on six treatments with increasing levels of undegradable dietary protein (UDP), ERDP and DUP during the last six weeks of gestation showed no significant difference in ewe live weight and condition score. However, this particular study did not extend to the use of ultrasound scanning to measure backfat and muscle depth. Another study written by Houdijk et al. (2005) again found no effect between ewes offered either high (130%) or low (80%) levels of MP. In addition, this research used ultrasound estimates of muscle and fat depth and again found no significant difference between treatments.

Ewes on L protein diets increased slightly in BCS during pre-partum, while ewes on H treatments decreased by a miniscule amount. However, Fthenakis et al. (2012) stated that ewes could lose between 0.5-1 BCS and Russel (1984) had similar findings with ewes losing 1-1.5 BCS during late pregnancy. This could suggest that the ewes on this trial have been fed a higher level of protein than recommended. The DUP and ERDP of the feeds used in this present study have not been analysed. There have been differences between the chemical composition the feed supplier stated and those analysed in the laboratory. Therefore, it is likely that both DUP and ERDP values are different and this could have resulted in the lack of BCS loss during late pregnancy.

Alternatively, findings of a study carried out by Kidane et al. (2010) found that ewes fed on a H protein diet (130% of MP requirements) had a significant effect on live weight change (P=0.015) compared to ewes on L protein (80% of MP requirements). Kidane et al. (2010) also found there was a tendency for ewes on L protein to have lower BCS during late pregnancy compared to H protein (2.35 vs 2.46 14 days pre-partum). The ewes started the trial with a mean BCS of 2.43, whereas the ewes on this trial had a mean BCS of 3.26 6 weeks pre-partum. This could be a major reason for the significant loss of BCS score, due to the fact the ewes were in a worse condition at the start of the trial. Therefore, those on low MP supply were not fed enough protein and lost BCS. The ewes on this current trial started with a higher BCS and could cope with a lower level of feed while still growing their lambs. There is also the possibility of human error in BCS due to the subjective nature of the measurement which could have resulted in skewed or inaccurate results.

The experimental diets with a H level of protected proteins (BH, SH, RH) should have improved DUP supply and therefore, increase the digestion on undegradable protein. The xylose treated R and S along with the micronised B should have a higher quality of protein compared to the BL, SL and RL treatments (Tuncer and Sacakli, 2003). However, this does not seem to have been the case during pre-partum with ewes on both H and L level diets performing at the same level. However, without the actual chemical analysis of the DUP of the feeds, the composition of the diets cannot be confirmed.

5.2 Effect of level and source of protein on ewe performance post-partum

Post-partum ewe performance showed some differences in relation to the treatments. Two weeks post-partum ewes on diets sourced from B had significantly (P=0.02) lower live weight than those on either R or S. There was also a significant interaction (P=0.49) with ewes on the SH, SL and RH diets being significantly higher than ewes on the BH diet. This agreed with Mcdonald et al. (2011) and the fact that S is a better supply of protein. There was no difference in ewe performance between the levels of protein post-partum. This is different to that which was shown pre-partum as MP supply is now just 80% of
requirements for L ewes and 100% for H ewes. These results were similar to those found by Houdijk et al. (2005) who found no significance. However, Kidane et al. (2010) found that H ewes were significantly (P=0.025) heavier than L ewes by 1.6 kg. Again these ewes are a lot lighter than those used in this current study. There is a possibility that feed requirements of ewes are outdated and do not accommodate ewes at higher live weights, which could be a reason for the differences between results.

In terms of BCS post-partum the results showed that ewes on S based diets lost less condition. At week eight post-partum S ewes averaged a BCS of 2.989 which was significantly (P=0.016) higher than those on B and R by 0.439 and 0.534, respectively. This was a major factor contributing to the overall BCS loss throughout the whole trial period being significantly (P=0.018) less in S based diets (0.217) than R (0.885). There has been little published research on the effects of protein source on ewe performance. However, there has been some published data on the effect of protein level. This current study showed no significance from the effect of protein level on BCS which is the same as that found by Houdijk et al. (2005). Again Kidane et al. (2010) found that ewes on an L diet tended (P=0.09) to have a lower BCS than those on H (2.35 vs 2.46).

The ultrasound measurements showed some effects of protein source in week eight post-partum. Fat depth was significantly (P=0.005) deeper for ewes on S diets compared to that on B and R by 0.08 cm and 0.07 cm, respectively. While muscle depth was significantly (P=0.036) deeper in both R and S than B. There was no effect of treatment on fat depth change over time. Once again there was no significance found between protein level and either fat or muscle depth. However, this agrees with Houdijk et al. (2005) who found no significant difference in fat or muscle depth in ewes offered either 0.8 or 1.3 times MP requirements.

The post-partum results tend to show that ewes on B sourced diets have lower LW, less BCS and also shallower fat and muscle depth. Whereas, the ewes on S based diets seem to have performed better maintaining more body condition and live weight. However, looking at total litter weights at birth there was significantly (P=0.024) lighter litters from ewes on S based diets compared to those on R. There was also a significant interaction (P=0.026) between protein source and level with ewes on SL treatment having a significantly lower litter weight than RL, RH, BL and BH, while RL was significantly higher than all treatments apart from BL and BH. In addition to lower litter weights, lambs with mothers on S diets had a 15.84 kg increase in live weight in the first eight weeks of their life compared to lambs with mothers on R diets that had a 16.57 kg increase. This is consistent with milk production three weeks post-partum where ewes on R based diets produced on average 379ml more milk daily than those on S and significantly (P=0.006) 701ml more than those on B. The overall average milk yield at three weeks post-partum was 3.41 L which is 13.8% higher than the diets have been formulated for this suggests that ewes should have been fed more than they were.

The fact that there was no difference between protein level provided agrees with results the produced by Dawson et al. (1999) who found no significant difference in lamb performance to weaning within ewes offered 6 different diets with ranging levels of protein supply.

### 5.3 Relationships between traits

#### 5.3.1 Body condition score and Fat depth

Body condition score and ultrasound measurements of backfat depth showed a moderate positive correlation (R²=0.367). This value was low compared to findings by Sanson et al. (1993) who found a strong positive correlation (R²=0.69). However, the ultrasound measurements in this study were taken from carcasses, they also commented that
throughout the study all of the correlation values produced had been high. Sanson et al. (1993) found that for each one unit increase in BCS there would be a .02 cm increase in fat depth but, this was on a 1-9 scale so converted to a 1-5 scale would result in a 0.036 cm increase. However, the findings of this research project show that an increase in BCS will result in a 0.033 cm increase in fat depth which is similar.

The positive correlation between BCS and fat depth is to be expected. However, being an objective measurement, ultrasound scanning is a more accurate analysis of fat depth and therefore, body composition. This could suggest that fat depth measurements could more accurately assess body changes over time and be used to formulate diets which match the requirements of the ewes. Pre-partum all treatments experienced a loss in fat depth whereas, all treatments apart from RL had a miniscule increase in BCS. Again this demonstrates the subjective nature of BCS, ultrasound scanning is a more accurate, objective measure which can identify acute changes in body composition more efficiently. This could suggest that the time period between ultrasound scanning measurements could be shorter than that of BCS, due to the fact that ultrasound can pick up smaller differences. Therefore, allowing a farmer to react in a practical situation quicker than if BCS was used.

Ewes on the BH treatment showed a stronger positive correlation between these traits ($R^2=0.52$). This suggests that the condition loss in these sheep was more obvious and therefore, more easily assessed by the technician.

Findings published by Delfa et al. (1995) found that ultrasound scanning of fat depth can only estimate actual fat cover at a level of 34%. They scanned lambs and then once they had been slaughtered measured the fat cover and found that there was only a weak positive correlation between the measurements ($R^2=0.34$). However, these lambs were just 21.37 kg on average at slaughter and 9.97 kg dead. This in comparison to the ewes in the present study is approximately a quarter of the live weight. A criticism of the work by Delfa et al. (1995) would be that the lambs had not been able to reach a finished weight and therefore, due to the level of immaturity, the measurements did not show an accurate assessment of body composition.

Delfa et al. (1995) measured ultrasonic fat depth through the lumbar region, similar to this study which used the 3rd lumbar vertebra. However, Teixiera et al. (2006) found that measuring between the 12th and 13th rib was a more accurate representation of body composition, saying that 85% of the variation in fat cover can be correlated to this fat measurement.

5.3.2 Fat depth and Muscle depth

Ultrasound measurements of muscle and fat depth showed a weak positive correlation ($R^2=0.317$). This suggests that muscle depth will decrease at the same time as fat depth however, at a slower rate or only when fat depth loss becomes extreme. Therefore, when the ewe cannot mobilise body fat at a rate that matches energy requirements, muscle reserves will be utilised instead (Joseph and Foot, 1990). Muscle depth reduced at a quicker rate during late pregnancy than at any other point. This is the time at which the nutritional imbalance would be at its highest, meaning that the ewe must mobilise body reserves. During lactation, concentrate volume was increased from the level fed during gestation and ewes were also fed 1 Kg DM/day of silage compared to 0.5 Kg DM/day pre-partum. These factors would have contributed to the ewe being provided with more nutrients and resulting in a slower rate of muscle reserves being utilised.

Ewes on the BH treatment had a strong positive correlation between these traits ($R^2=0.73$). This suggests that these ewes lost more muscle depth over this time period and therefore, had to mobilise more muscle reserves to counter any nutrient imbalances.
5.3.3 Live weight and Body condition score

There is a wide range of published values for the correlation between live weight and BCS. Using all of the data collected in this study a very weak positive correlation was found ($R^2=0.17$). Sanson et al. (1993) found a strong positive correlation ($R^2 = 0.78$) however, the sheep in this study were all of the western-range breed in the USA also, they were not pregnant, which would have had a large effect on BCS and live weight in this present study. Russel (1984) says that ewes carrying twin lambs will have an 18% increase in live weight during the last eight weeks of pregnancy. Another factor is that in this study the ewes were crossbred ewes with, Suffolk x North Country mules have genetics which derive from three (Suffolk, Bluefaced Leicester and Swaledale) therefore, the possible genetic variation in live weight is quite high. Vatankhah et al. (2012) states that due to the low correlation between these variables (they found $R^2=0.08$) that live weight cannot be used to accurately estimate body condition and therefore body fat or muscle depth, stating that variations in the bone structure of each individual sheep is a main factor in the lack of correlation.

5.4 Utilisation of body reserves

The ewes in this study showed no extreme levels of BCS, with a score of 4.25 only observed on five separate occasions, of which all were during the first four weeks of the trial. In addition a low score of 1.75 was only observed once eight weeks post-partum. EBLEX (2009) states target BCS at 3.5 during mid-pregnancy, decreasing to 3 at the end of gestation and 2.5 during lactation, this shows that overall the ewes on the present study were all at acceptable BCS for the stage of the production cycle. It could be suggested that the majority of ewes on this trial were carrying too much body condition. It has meant that no ewes have experienced a BCS drop that would be considered unhealthy. These findings are similar to those of Caldiera et al. (2007), who found that ewes between BCS 2 and 3.5 can control body reserves without a detrimental effect on ewe performance. Kenyon et al. (2012) stated that ewe nutrition can be limited up to two weeks prior to parturition. This suggests that ewes should be allowed to utilise body reserves with no supplementation therefore, resulting in a rapid decrease in fat and maybe even muscle depth. However, one criticism of the work carried out by Kenyon et al. (2012) is that it was research on Romney ewes in New Zealand. This breed is familiar with the low availability of nutrients during the winter in this country and are rarely given supplementary feeding. Therefore, they are more likely to be able to withstand the lack of nutrition in this period of the production cycle.

5.5 Limitations and further research

The fact that by 8 weeks post-partum there was 11 ewes removed from the trial, means that the number of replicates has been reduced, especially on the BH treatment which lost three ewes worth of data. Three ewes having just single lambs is due to human error whilst pregnancy scanning the ewes. This could have been improved by scanning the ewes twice to double check scanning results. Two ewes data was removed late in the trial because their lambs died due to coccidiosis, if the lambs had been drenched earlier then this could have been avoided.

Rations were formulated using predicted values provided by the feed company. On analysing feed in the laboratory it was found that proximate analysis differed from that stated by HJ Lea Oakes. This could account for some variation in animal performance. If the DUP of the feeds had been analysed then that would also provide an extra part of chemical composition to which the results could be justified.
BCS is a subjective measure however, this was measured by just one trained individual. Two scorers, with an average score used could prove a more accurate measure or even the use of an independent assessor.

A considerable amount of the literature shows that ewes utilised on similar trials to this one were of a lower mean weight. At the start of this trial the ewes averaged 84.21 kg, Sanson et al. (1993) used ewes which weighed 72.8 kg (± 4.5), Kidane et al. (2010) used two breeds Bluefaced Leicester - 57.6 kg and Mule - 69.1 kg, Dawson et al. (1999) used ewes with a mean weight six weeks pre-partum of 76 kg and Houdijk et al. (2005) had ewes which averaged 74.2 kg (± 1.9). The mean weight at the start of this trial is similar to that of the modern lowland breeds. Which poses the question, “are feed requirement recommendations for ewes outdated?”. AFRC (1993) is an ageing piece of literature and is likely to underestimate the requirements of ewes given the current thinking in relation to partitioning of nutrients. The adequacy of feed could have changed over time as breeds have been developed. Therefore, this is an area which could be further researched in the future, to take into account changes in MP and ME requirements in ewes during this stage of the production cycle and indeed the whole life cycle.
CHAPTER SIX: CONCLUSION

In this study the main finding has been the effect of protein source on live weight, body condition score and ultrasound measurements. Ewes supplemented with soya bean meal out performed those on both rapeseed meal and field beans. However, the offspring of ewes on rapeseed based diets had higher growth rates and the ewes produced more milk, suggesting that this protein supplement may be a suitable replacement for soya bean meal during late pregnancy and early lactation. Also, as a home-grown protein source, it is more sustainable environmentally. There was no effect of changing protein level, suggesting that feed requirements of ewes during this stage of the production cycle may need to be re-evaluated.

The most important relationship between traits measured in this study was the moderate, positive correlation between body condition score and fat depth. It would appear that although these measurements are related, ultrasound scans are a more accurate assessment of body composition than body condition scoring. Therefore, if the practice of ultrasound scanning is viable and practical then it could be recommended that this method is used to assess body composition in a commercial farming environment. This practice could then be used to assess the nutritional adequacy of diets offered to ewes in late pregnancy and early lactation more accurately than body condition score estimates.
CHAPTER SEVEN: REFERENCES


