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THE WELFARE AND PRODUCTION IMPLICATIONS OF FOSTERING
METHODS IN SHEEP

Submitted for the Degree of Doctor of Philosophy
At the University of Northampton

2013

Samantha Julie Ward

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Abstract

Fostering is a method used by shepherds that allows the successful rearing of abandoned lambs onto other ewes, or the ability to provide surplus lambs a new mother in the case of triplets. Past research has focused on the success rates of the varying methods available; however, more research is needed to increase the knowledge about commonly selected fostering methods and the behaviour, welfare and production implications of the different methods used.

Questionnaires were distributed at national farming events targeting registered sheep farms around the UK to establish which foster methods were currently in use and to collate the farmers' opinions of their usage in modern day sheep farming. An experimental study was carried out to assess the welfare and production implications of the use of these methods. 84 ewes were allocated to one of the three experimental foster methods or the control group (twin lambing). They were also classified according to their lambing experience (multiparous or primiparous). Behavioural observations were conducted post-foster on the ewes and their lambs. The ewes' salivary cortisol concentration and heart rate frequency were also monitored at 0, 30, 60, 90 and 180 minutes post-foster. To assess the production implications of the different foster methods, lamb weights and body measurements were taken at 0, 7, 30, 90 and 180 days of age to assess growth rates. Lambs were weaned at 3 months of age and remained at pasture until slaughter, at approximately 6 months of age. The lambs' carcass quality was assessed by means of weights, zoometric measurements and conformation scores and some meat quality parameters (ultimate pH, water holding capacity and colour) were also investigated.

93% of farmers used fostering, preferring to foster rather than artificially rear lambs. Almost two-thirds favoured birth fluids (64%) and 19% of farmers used restraint crates. The most popular combination of foster methods was cervical stimulation plus birth fluids (CSBF). Exploratory factor analysis showed two main components helping farmers to decide which foster method to use; “the ewes’ health and welfare” and the “farmers’ previous knowledge and success” of a foster method. Birth fluids, restraint and CSBF were methods selected for behavioural data, showing that negative behaviours were significantly higher for restrained ewes compared to other treatments. Restrained ewes also showed significantly higher heart rates and salivary cortisol concentrations. Production data showed that ewe reared lambs gained significantly more weight than artificially reared lambs up to 90 days of age. However, there was no difference from that time until slaughter. Conformation and chest roundness scores were significantly better for ewe reared lambs compared to artificially reared ones. Foster methods did not have any significant effect on the growth rates, carcass or meat quality measurements for the lambs studied.

The majority of farmers selected to use birth fluids, seen as a welfare friendly and less-invasive method of fostering. However, some farmers selected the restraint method based on the urgency of the lambs to receive milk and to avoid artificial rearing. The restraint crates caused significant changes to the ewe’s behaviour and increased their heart rates and cortisol concentrations, indicating a higher level of distress that could be compromising the ewes’ welfare. Lamb growth rates, carcass and meat quality were not affected by the different foster methods, proved that successfully established foster methods of any kind have no differential implications for the farm’s productivity (under UK commercial practices). Artificially reared lambs did show worse carcass conformation, suggesting that ewe rearing, and therefore fostering, offers advantages for the productivity of sheep farmers.

Publications and Conferences

Publications:

Ward, S.J., Liste, G., and Tinarwo, A. (2011) Attitudes of UK sheep farmers towards fostering methods: A national survey. *Small Ruminant Research* **99**, 87 – 92.

Conferences and Workshops:

Ward, S.J. (2008). Welfare and production implications of fostering methods in sheep. In: 3rd Student Animal Welfare Conference, Writtle College, UK.

Ward, S.J., Liste, G. and Meredith, J. (2009). The attitudes of UK sheep farmers towards fostering methods: a national survey. In: Proceedings of the 43rd Congress of the International Society for Applied Ethology, Cairns, Australia. pp 125.

Ward, S.J. and Liste, G. (2009). The welfare and production implications of foster methods in sheep. In: Making the most of Behavioural Data: Rules, Relations and Robotics, Royal Veterinary College, London. pp 20.

Ward, S.J., Tinarwo, A., and Liste, G. (2011). Use or lose your bottle: The effects of fostering and artificial rearing on lamb meat quality. In: Making animal welfare improvements: Economic and other incentives and constraints. UFAW International Symposium, Portsmouth, UK.

Ward, S.J., McCormick, W., Liste, G., Coleman, R. and Smith, T. (2012). When sheep behave baaaa'd: The behaviour and welfare concerns associated with restraint fostering in the UK sheep farming industry. In: ISAE Regional Meeting, Harper Adams University College, UK.

Ward, S.J., McCormick, W. and Liste, G. (2012). Fatter lambs from fostered mums: the benefits of fostering lambs on daily weight gain. In: Healthy Food from Healthy Animals; BSAS Annual Conference, Nottingham, UK.

Table of Contents

Table of Contents		i
List of Figures		iv
List of Tables		vi
Abbreviations		vii

Chapter I	Literature Review	1
	1.1 Introduction	2
	1.1.1 Research Rational.....	5
	1.1.2 Project Aim.....	6
	1.1.3 Objectives of study.....	6
	1.2 Welfare Implications	8
	1.2.1 Measuring Welfare.....	12
	1.2.1.1 <i>Behavioural Indicators</i>	13
	1.2.1.2 <i>Physiological Indicators</i>	15
	1.2.1.3 <i>Behavioural and Physiological Indicators Combined</i>	20
	1.2.2 Summary.....	22
	1.3 Maternal Behaviour	25
	1.3.1 Genetic Differences.....	29
	1.3.2 Parity.....	31
	1.3.3 Summary.....	33
	1.4 Fostering	34
	1.4.1 Fostering Methods.....	35
	1.4.1.1 <i>Odour Manipulation</i>	35
	1.4.1.2 <i>Restraint</i>	38
	1.4.1.3 <i>Cervical Stimulation</i>	42
	1.4.2 Summary.....	43
	1.5 Artificial Rearing	44
	1.5.1 Welfare Issues.....	45
	1.5.2 Summary.....	47
	1.6 Production and Meat Quality Implications	49
	1.6.1 Carcass quality measures.....	50
	1.6.1.1 <i>Live Body Measurements</i>	50
	1.6.1.2 <i>Conformation and Fatness</i>	52
	1.6.1.3 <i>Carcass Measurements</i>	55
	1.6.2 Meat Quality Measures.....	55
	1.6.2.1 <i>Ultimate pH</i>	55
	1.6.2.2 <i>Water Holding Capacity</i>	57
	1.6.2.3 <i>Colour</i>	58
	1.6.2.4 <i>The Combined Effect</i>	60
	1.6.2.5 <i>Post Cooking Measures</i>	61
	1.6.3 Meat Quality and Animal Welfare.....	62
	1.6.4 Summary.....	63
	1.7 Conclusion	65

Chapter II	Attitudes of UK sheep farmers towards fostering methods: a national survey.	66
	2.1 Introduction	67
	2.1.1 Foster Methods.....	68
	2.1.2 Farmer Attitudes.....	72
	2.2 Materials and Methods	75

2.2.1	Questionnaire Design.....	75
2.2.2	Questionnaire Distribution.....	76
2.2.3	Statistical Analysis.....	77
2.3	Results.....	79
2.3.1	Fostering Methods and Welfare.....	79
2.3.2	Exploratory Factor Analysis.....	85
2.4	Discussion.....	88
2.5	Conclusion.....	93

Chapter III	The Behaviour and Welfare of Ewes Undergoing Different Foster Methods	94
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3.1	Introduction.....	95
3.1.1	Ewe-Lamb Recognition.....	95
3.1.2	Fostering.....	99
3.2	Materials and Methods.....	103
3.2.1	Subjects, Housing and Husbandry.....	103
3.2.2	Lambing and Fostering Procedure.....	104
3.2.2.1	<i>Birth Fluids (BF).....</i>	<i>107</i>
3.2.2.2	<i>Cervical Stimulation and Birth Fluids (CSBF).....</i>	<i>107</i>
3.2.2.3	<i>Restraint (R).....</i>	<i>107</i>
3.2.3	Data Collection.....	108
3.2.3.1	<i>Behavioural Data.....</i>	<i>108</i>
3.2.3.2	<i>Physiological Data.....</i>	<i>112</i>
3.2.3.3	<i>Cortisol Enzyme Immunoassay (EIA).....</i>	<i>114</i>
3.2.4	Statistical Analysis.....	115
3.2.4.1	<i>Behavioural Analysis.....</i>	<i>115</i>
3.2.4.2	<i>Physiological Analysis.....</i>	<i>116</i>
3.3	Results.....	117
3.3.1	Behaviour.....	117
3.3.1.1	<i>Fostering Effect.....</i>	<i>117</i>
3.3.1.2	<i>Parity Effect.....</i>	<i>121</i>
3.3.1.3	<i>Time Spent with Lamb.....</i>	<i>121</i>
3.3.1.4	<i>Auditory Communication.....</i>	<i>123</i>
3.3.2	Physiology.....	123
3.3.2.1	<i>Cortisol.....</i>	<i>123</i>
3.3.2.2	<i>Heart Rate.....</i>	<i>127</i>
3.4	Discussion.....	130
3.4.1	Behaviour.....	130
3.4.1.1	<i>Foster Effects.....</i>	<i>130</i>
3.4.1.2	<i>Parity Effects.....</i>	<i>132</i>
3.4.1.3	<i>Time Spent with Lamb.....</i>	<i>134</i>
3.4.1.4	<i>Auditory Communication.....</i>	<i>136</i>
3.4.2	Physiology.....	137
3.4.2.1	<i>Cortisol.....</i>	<i>137</i>
3.4.2.2	<i>Heart Rate.....</i>	<i>138</i>
3.4.2.3	<i>Combined Physiological Measures.....</i>	<i>139</i>
3.4.2.4	<i>Parity Effects.....</i>	<i>139</i>
3.5	Conclusion.....	141

Chapter IV	The Effects of Fostering Methods and Artificial Rearing on the Production, Carcass and Meat Quality of North Country Mule Lambs	143
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4.1	Introduction.....	144
4.1.1	Weaning Effects.....	144
4.1.2	Nutritional Effects.....	146

4.1.3	Distress.....	149
4.2	Materials and Methods.....	155
4.2.1	Subjects, Housing and Husbandry.....	155
4.2.2	Data Collection.....	156
4.2.2.1	<i>Pre-Slaughter Data.....</i>	<i>156</i>
4.2.2.2	<i>Post-Slaughter Data.....</i>	<i>161</i>
4.2.3	Statistical Analysis.....	165
4.3	Results.....	169
4.3.1	Pre-Slaughter Data.....	169
4.3.2	Post-Slaughter Data.....	174
4.4	Discussion.....	177
4.4.1	Pre-Slaughter Data.....	177
4.4.2	Post-Slaughter Data.....	181
4.5	Conclusion.....	185
<hr/>		
Chapter V	Conclusions and Recommendations	187
5.1	Conclusions.....	188
5.1.1	Foster Methods Survey.....	188
5.1.2	Behaviour and Welfare.....	189
5.1.3	Carcass and Meat Quality.....	189
5.1.4	Overall Conclusions.....	190
5.2	Implications for Commercial Farming.....	192
5.3	Limitations.....	194
5.4	Further Research.....	196
<hr/>		
	References.....	197
<hr/>		
Appendix I	Survey of lamb fostering methods used in UK farming practices.....	218
<hr/>		

Total Word Count: 38,649

List of Figures

No.	Title	Page
1.1	Mean lamb meat supply to the UK from 1992 to 2009.....	3
1.2	Mean (\pm SE) salivary cortisol values under basal conditions, together with fitted cosine curves (shaded lines), in growing pigs (n=6) at 24 weeks of age.....	19
1.3a	Row of ewes being held in commercial restraint crates at Moulton College Farm, Moulton.....	40
1.3b	Ewe in restraint crate showing the location of the lambs, separated behind the ewe's head to ensure rejection of the lambs is not possible....	40
1.4	Photographic chart showing the main classes for EUROP conformation and fatness scores.....	54
1.5	CIE L*a*b* uniform colour scale cube.....	59
2.1	Geospatial location of participating respondents.....	80
2.2	The procedure preferences made by farmers faced with a lamb without a mother or a triplet.....	82
2.3	Variation of fostering methods selected by farmers in the UK depending on breed type.....	83
3.1	Lambing shed layout at Moulton College, Moulton. Showing areas for ewe groups, fostering and the individual pens which ewes and lambs are moved to approximately 4 hours after birth.....	106
3.2	Fostering area 1, showing a pen with the ewe and lambs and the camera being set up for behavioural observations at Moulton College Farm, Moulton.....	111
3.3	Ewe held in a restraint crate highlighting the method of saliva extraction. The ewe's head is gently restrained and tweezers with cotton wool were inserted into the side of the ewe's mouth and slowly moved around inside of her mouth for 30 seconds.....	113
3.4	Percentage time budgets for multiparous (MP) and primiparous (PP) ewes according to foster methods.....	119
3.5	The mean (\pm S.E) high pitched and low pitched bleat frequencies that primiparous (PP) and multiparous (MP) ewes.....	120
3.6	Percentage time MP BF ewes spent performing maternal behaviours (sniffing, grooming and facilitating suckling) with the alien and natal lamb at the foster (0 mins), time post foster plus one hour (60 mins) and time post foster plus three hours (180 mins).....	122
3.7	Mean (\pm S.E) concentration of salivary cortisol of primiparous (PP) ewes undergoing different fostering procedures.....	125
3.8	Mean (\pm S.E) concentration of salivary cortisol of multiparous (MP) ewes undergoing different fostering procedures.....	126

3.9	Mean (\pm S.E) heart rates measured by primiparous ewes undergoing different fostering procedures.....	128
3.10	Mean (\pm S.E) heart rates measured by multiparous ewes undergoing different fostering procedures.....	129
4.1	7 day old lamb being weighed with the digital scale.....	159
4.2	Live body measurements taken on days 0, 7, 30, 90 and 180.....	160
4.3	Zoometric carcass measurements taken on day of slaughter.....	164
4.4a	MINOLTA colorimeter being used to assess the colour of experimental meat samples at the Moulton College laboratory.....	165
4.4b	Water holding capacity stand with mashed meat samples held between glass petri-dishes under a 2250g weight.....	165
4.5	Daily weight gain between ewe-reared and artificially-reared lambs over time.....	171
4.6	Daily weight gain across the different foster method treatments over time (n=84).....	173
4.7	Differences in live slaughter weight and cold carcass weights between primiparous (first time) and multiparous (experienced) ewe reared lambs.....	176

List of Tables

No	Title	Page
1.1	Behavioural and physiological responses of sheep to different stressors including isolation, restraint and transportation.....	24
1.2	The maternal behaviour score and description of behaviours shown by ewes whilst lambs are being tagged.....	28
1.3	Summary of odour manipulation techniques studied with latency to accept alien lambs and the percentage success rates associated with each technique.....	37
2.1	Descriptions of the different types of foster methods that can be selected by farmers and used within the questionnaire.....	71
2.2	Classification of upland, lowland, hill and mixed breed types in accordance to sheep breeds and their recorded prolificacy.....	81
2.3	Summary of the exploratory factor analysis results showing the Pattern Matrix with principle axis factoring extraction method and an oblimin rotation with Kaiser Normalisation.....	87
3.1	Definitions of positive, negative and maintenance behaviours performed by the ewe soon after parturition.....	110
4.1	Conformation (EUROP) and fatness (1-5) conversion scores used for carcass quality parameters.....	168
4.2	Mean (\pm SE) live body measurement indices measured on days 0, 7, 30, 90 and 180.....	172
4.3	Mean (\pm SE) carcass and meat quality measures for lambs slaughtered at 180 days according to their rearing methods (ewe-reared and artificially reared).....	175

Abbreviations List

a*	Redness	LIS	Litter Survival
AR	Artificial rearing	LP	Low-pitched
b*	Yellowness	LPI	Longitudinal Pelvic Index
BF	Birth Fluids	MBS	Maternal Behaviour Score
BI	Body Index	MP	Multiparous
BL	Body Length	PEI	Pelvic Index
C	Chest Circumference	PP	Primiparous
CCW	Cold Carcass Weight	PRI	Proportionality Index
CD	Chest Depth (live measure)	R	Restraint
CI	Compactness Index	RL	Rump Length
CSBF	Cervical Stimulation and Birth Fluids	RSI	Relative Shortness Index
DG	Daily Weight Gain	RTD	Relative Torso Depth
EBLEX	English Beef and Lamb Executive	RW	Rump Width
EFA	Exploratory Factor Analysis	RWI	Relative Weight Index
EIA	Enzyme immunoassay	Th	Chest Depth (carcass)
EW	Ewe reared	TL	Torso Length
F	Leg length	ToF	Time of Foster
G	buttock length	T _p	Ear-pinna temperature
HP	High-pitched	TPI	Transversal Pelvic Index
HS	Height at shoulder	VOcs	Volatile Organic Compounds
L	Internal carcass length	WHC	Water Holding Capacity
L*	Lightness	Wr	Chest Width

CHAPTER I

Literature Review

1.1 Introduction

The demand for lamb meat has rapidly increased in recent years in both developed and developing countries, within the UK alone the most recent statistics suggested that 5,210,369 tonnes of lamb meat were supplied to the UK (Figure 1.1; FAOSTAT, 2012). During this period, consumer focus within industrialised countries has moved increasingly towards access to “animal welfare friendly” and “organic” produce, with high regard being paid to the animals’ quality of life prior to and during slaughter (Mench, 2008). This has directed more attention to legal frameworks and the development of legislation to safeguard farm animal welfare (Fraser, 2008).

Lambing is the most important time during the sheep farmer’s year, yet the UK still loses around 15% of lambs annually with the majority of these deaths caused by lack of planning, preparation and organised lambing routines and facilities (Defra, 2004). This figure highlights the significant welfare challenge and financial loss to the industry and highlights the importance of good stockmanship at this crucial stage in the production cycle (Defra, 2004).

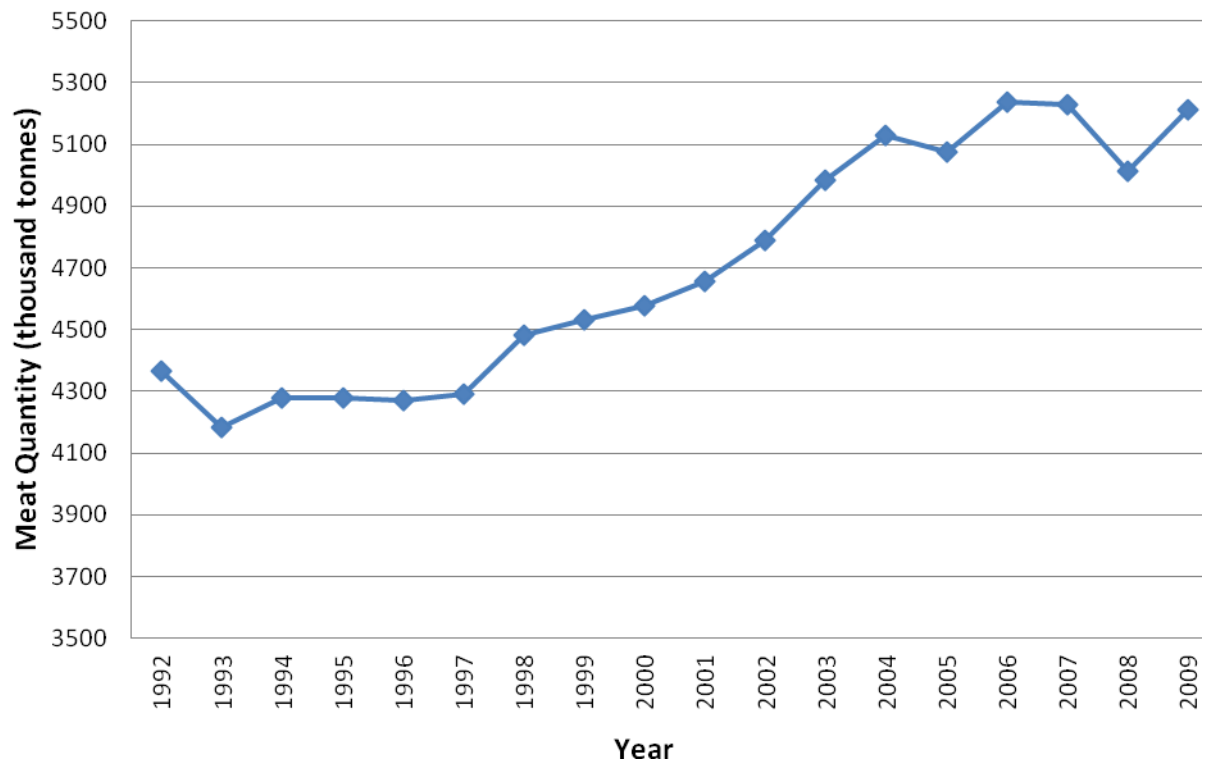


Figure 1.1: Mean lamb meat supply to the UK from 1992 to 2009 (FAOSTAT, 2012).

Research has focused on the link between animal welfare and meat quality with the idea that as the animal's welfare is improved, the quality of the meat also increases (Gregory, 1998). This can potentially add another dimension to consumer power, again, increasing the demand for welfare friendly meat and encouraging farmers to rear them in this manner (Gregory, 2007).

The English Beef and Lamb Executive (EBLEX) have previously researched methods into increasing the average return to livestock producers, known as the Better Returns Programme. Manuals, leaflets, fact sheets and DVDs published by EBLEX from 2003 to 2005 are still currently in press to benefit sheep producers in five key areas of sheep production, with three being dedicated to aspects of lambing (EBLEX, 2009). The continued production of these sources of information emphasizes the importance of good stockmanship and informed good practice and husbandry techniques during lambing time. Goddard *et al.* (2006) stated that the average age of UK shepherds is around 60 years old. As sheep farming progresses, it is crucial that this expertise and skilled labour is not lost. Strategies need to be created to ensure that their expert knowledge is passed on to generations of farmers which will help to protect from increases production losses due to a lack of appropriate stockmanship.

One way to reduce lamb losses would be to foster an abandoned or surplus lamb onto another ewe and for her to successfully rear it

(Alexander *et al.*, 1987c). This process is made difficult by the ewe's ability to discriminate between their own and an unknown/alien lambs' specific odour (Price *et al.*, 1984b).

There are numerous foster methods available for selection, and decisions are made by the shepherd, who needs the ability and knowledge to ensure the correct method is selected to enable the lambs to survive (Defra, 2003). However, little thought has been paid to the implications that the foster method may have on the ewes' welfare. With the ever increasing need for high standards of farm animal welfare (Fraser, 2008), along with the increased consumer demand for 'welfare friendly' meat (Mench, 2008), animal welfare is becoming increasingly important within every aspect of the farm animals' life cycle.

Another method of managing an abandoned or surplus lamb would be to artificially rear it. This involves a great deal of time, effort and increased costs to provide the lamb with approximately 50ml of artificially produced milk, per kilogram of body weight every 4-6 by means of bottle feeding or an automatic drinker (Eales *et al.*, 2004).

1.1.1 Research rationale

Traditionally, fostering methods have included using the skins of dead lambs (Winter and Hill, 1998), fostering restraint pens (Alexander and

Bradley, 1985) and applying the ewe's birth fluids to the fostered lamb (Basiouni and Gonyou, 1988). In addition, novel methods such as the use of odorants to mask differences between the natal and alien lambs (Price *et al.*, 2003), or stockinette jackets to transfer the odour onto alien lambs (Alexander *et al.*, 1987a) have been used; see section 1.4.

Research conducted on fostering techniques was carried out in the early 1980's and investigated success rates in terms of the latency of the ewe to accept the alien lamb (Price *et al.*, 2003). Previous research fails to distinguish between foster methods with regards to the welfare implications they may have on the animal, or the potential production implications that may be effected by the method selected or when comparing to artificially reared lambs.

1.1.2 Project Aim

To assess the welfare and production implications of commonly used foster methods in the UK sheep farming industry.

1.1.3 Objectives of study

This project set out to distinguish which methods are presently and most commonly used in the UK sheep industry, and collate the opinions of the success of these methods and their impact on the ewe's and lamb's

welfare (Objective one). This was achieved by distributing questionnaires to sheep producers around the UK using various methods. EBLEX circulated 500 via email; approximately 100 were distributed at national farming events such as “The Royal Show” and the “NSA sheep event”. Others were posted to sheep farms registered with breed societies or online.

The second objective was to examine the behaviour and welfare implications of the most prevalent fostering methods established in objective one. Objective two was achieved by evaluating the range of fostering methods received from the completed questionnaires through a fostering trial. Successful fosters were used to assess the occurrence of positive behaviours such as grooming, and facilitating suckling between the different foster methods. The welfare implications towards the ewe, of each method were appraised by an assessment of ewe behaviour along with physiological measures of stress including saliva cortisol and heart rate frequency.

Objective three was to compare production parameters of the fostered individuals to the natal and artificially reared individuals. This was achieved using average daily gain and live body measurements from day 0 until slaughter. For carcass and meat quality measures post slaughter, carcass measurements, confirmation and fatness scores, water holding capacity (WHC), pH₂₄ (meat pH 24 hours after slaughter) and the colour were then performed.

1.2 Welfare Implications

Previous research regarding fostering has focused on the success of fostering methods in terms of threshold times to acceptance (Price *et al.*, 2003), or overall rearing success (Mellor *et al.*, 1993). However, little is known about the welfare implications of these methods on the ewe and the lamb, or the comparative stress experienced by multiparous (multiple parturitions) and primiparous (primary parturition) ewes under different foster regimes.

Moberg (2000, pp 9) explained how animals have evolved to cope with short-term stressors as the cost to their biological function would be lower than the event it is trying to avoid such as predation. In dealing with a short-term stressor, the costs would be met by biological resources to ensure that there would be no impact on the biological functioning of the animal. However, it is when these short-term stressors become elongated and the reserves are moved away from biological functioning that stress becomes 'distress' where the animal may no longer be able to cope within the particular situation. The physiological response to a distressing factor such as handling or restraint consists of three events. The first being the 'fight or flight' response (Cannon, 1914), which enables the animal to meet the physical demands necessary, however increases regulatory mechanisms such as metabolic rate, cardiac output, blood pressure and respiration. In the behavioural form, this would involve the animal performing a defensive, avoidance or aggressive response such as

preparation to fight, freezing or running away. Koolhaas (2008) explained how an animals' coping style could either be 'active' which was characteristic of territoriality or aggression; or 'conservation-withdrawal', where animals showed low levels of aggression or immobility. The second is the 'acute stress response' which is a component of Seyle's general adaptation syndrome (Seyle, 1946). This provides the energy required for the increased metabolic performance in coping with the stressor. If the stressor continues, the third stage is reached known as the chronic stress response. The chronic stress response is where the glucocorticoid levels increase and has been linked to detrimental effects towards growth, health and reproduction (Hemsworth *et al.*, 1996).

In addition to the effects distress has on general animal productivity and health including lower ewe milk yield (Hernandez *et al.*, 2012), decreased growth and reproduction rates (Coleman *et al.*, 1996), decreased milk yield, protein and fats (Breuer, *et al.*, 2000, Hemsworth *et al.*, 2003), the concept also has implications for the animals' welfare. The term 'welfare' is now used commonly amongst researchers and farmers alike, with various definitions depending on the beliefs of the author. The problem relates to the common use of the word and the fact that it can mean different things to different people.

Duncan and Dawkins (1983) summarise that the majority of definitions focus around physical and mental health, feelings, harmony with the environment and adaptation without suffering. One concept concentrates

on threats to biological functioning, such as risks to survival or reproduction, as measuring animal consciousness was deemed either impossible or too difficult (Barnett and Hemsworth, 1990). In addition, Broom (1991) described welfare as the state of an individual in relation to its environment and ability to cope with changes to this. This then raises the question 'what do animals need?' with a 'need' being *"a requirement, which is part of the basic biology of an animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus"* (Broom, 2008).

The needs of animals can be monitored using motivation studies and by assessing good welfare when needs are satisfied and by poor welfare in individuals whose needs are not met (Broom and Fraser, 2007, Dawkins, 1990, Fraser and Matthews, 1997). It was then Gregory (2004) who included reference to the term "animal suffering", which begins to open new dimensions to the techniques involved with assessing animal welfare. In fact, Mason and Mendle (1993) described how the differences in the definitions can therefore make animal welfare difficult to measure and record, and that these need to be established prior to research taking place. Within this thesis, the term welfare will follow Broom's definition linked to the animals' ability to cope with changes to its environment regarding what the animal needs.

It is understood that farm animal welfare has been increasingly important since the introduction of the five freedoms (freedom from hunger, and

thirst, freedom from discomfort, freedom from pain, injury and disease, freedom from fear and distress and the freedom to express natural behaviours) by the Farm Animal Welfare Council (1979). The need for the animals to lead healthy lives, exhibit natural behaviours and a stockpersons' compassion towards the animal's awareness and cognition is now highly important (Von Borrell and Veissier, 2007). Fitzpatrick *et al.* (2006) state that the lack of good standards of animal welfare is a large contributor to prevalent inflammatory diseases seen in sheep worldwide, which in turn can cause serious consequences for the animals involved such as allodynia and hyperalgesia. In fact, several studies have linked poor welfare to increased prevalence of disease and loss in productivity (Dwyer *et al.*, 2001).

Sheep farmers are becoming increasingly aware of the potential problems caused by the lack of consideration of their animals' welfare (Morgan-Davies *et al.*, 2006). These processes, however, can become costly in terms of time and finances and some upland sheep farms are beginning to employ 'easy-care systems'. These systems are where sheep are selected according to their breed traits, enabling them to support themselves and their young without the interference of shepherds (Goddard *et al.*, 2006). This management system could then eliminate the welfare problems encountered by inadequate transport, space provisions or husbandry which are commonly quoted to have an effect on sheep welfare (Fitzpatrick *et al.*, 2006). Fitzpatrick *et al.* (2006) however did not discuss the possibilities of problems faced by the animals in the field, and

especially during lambing seasons which could be critical on their survival rate without appropriate supervision.

1.2.1 Measuring Welfare

The welfare of animals is now a respected scientific discipline with increasing numbers of researchers and scientists', working to ensure it is at a high standard for all animals involved. Some methods of assessment can be viewed as subjective and involve the assessment of an animal's state of mind, which has proven difficult to quantify without the use of scientific methodologies and standardisation (Fraser, 2009). The topic is further complicated by the distinction between physiological stress, which an animal is able to cope with and adapt to accordingly, and pathological stress (distress), when biological functions such as reproduction, growth or maintaining immune competence are compromised (Moberg, 2000). Research has focused on the methods of measuring welfare including health (e.g. body, skin and wool condition, and mortality; Caroprese, *et al.*, 2009), production implications (Gregory, 1998), changes in physiology including plasma cortisol (Thornton and Waterman-Pearson, 1999) and heart rate variability and the analysis of positive and negative behavioural performance and cognition (Cockram, 2004, Von Borrell and Veissier, 2007). Dwyer *et al.* (2001) found that all have been reported as indicators of stress in sheep.

1.2.1.1 Behavioural Indicators

It has been suggested that a distressed sheep may demonstrate an increase in vocalisations when undergoing treatments such as isolation or restraint (Lynch *et al.*, 1992, Moberg *et al.*, 1980). However, studies such as those carried out by Baldock and Sibly (1990), Syme and Elphick (1982) and Torres-Hernandez and Hohenboken (1979) were not able to discover any significant increase in the number of vocalisations when sheep were isolated compared to being housed in a social group. These findings were not repeated following investigations performed by Boivin *et al.* (1997), Cockram *et al.* (1994) and Poindron *et al.* (1997). They all found that when sheep were isolated, they did vocalise significantly more than when they were in a group. Orgeur *et al.* (1998) also found a significant increase in the number of vocalisations due to separation of a ewe from her lamb. They also reported that high-pitched bleating was an indication of a stress response to separation and a low-pitched bleat was indicative as a recognition signal and therefore a positive maternal behaviour (Nowak *et al.*, 1997). Separation may, therefore, have significant welfare implications as a result of certain fostering techniques such as being held within the restraint crates.

Another method that was suggested as an indicator of distress was change in feeding behaviour, in particular, the reduced intake of food and water. Ruckerbusch and Malbert (1986) investigated the effect of an intracerebroventricular injection of corticotrophin releasing hormone (CRF, a hormone associated with the stress response of animals) on the intake

of hay and water. Results showed that the increase of CRF within the body decreased the amount of hay eaten and also reduced the water intake of the individuals. This supported their hypothesis that food intake was a reliable measure of distress in sheep (Gougoulis *et al.*, 2010). Although, post parturition, ewes will express maternal behaviours such as licking the lamb and therefore for the initial period may not be focused on eating or drinking.

Cockram *et al.* (1993, 1994) carried out studies investigating other potential behavioural indicators of distress in sheep due to the repeated removal of their lambs and social isolation, respectively. The results showed that for both stressors there was a significant decrease in the time the sheep spent sleeping or rested and ruminating was also significantly decreased. There was also a significant increase in vocalising with both stressors and was also an increase in the number of times the ewes stood with their heads alert. The study in 1994 testing social isolation also found that there was a significant increase in the number of foot stamps by the ewe (Cockram *et al.*, 1994). This suggests that behavioural indicators of distress in sheep could include increases in vocalisations, panting and increased levels of locomotory activity.

It is important to note that all of these behavioural signs have the possibility of being context-specific and are likely to occur in many situations which may not be aversive or distressing to sheep (Cockram, 2004). As described, certain foster methods, such as restraint crates, may

replicate experiences studied within the reported articles. This highlights the potential welfare challenges that may occur using these types of foster techniques. Rushen (2000) stated that although there was plenty of literature relating to the use of behavioural responses to measure animal distress, it is highly complex and therefore research should not use them as indicators of stress without another form of assessment alongside.

1.2.1.2 Physiological Indicators

Physiological indicators are usually seen as more of an invasive method of assessing welfare (Cook *et al.*, 2000). Blood plasma has been the most widely used parameter in the mammalian species tested with most assays measuring either total corticosteroid levels or free cortisol (Moberg, 2000). Total corticosteroid shows the amount of cortisol bound to other proteins within the blood stream; however, free cortisol is biologically active and not bound to any proteins (Pretorius *et al.*, 2011). Authors have argued as to which measure is more beneficial to represent changes to an animal's stress response, with no firm conclusions. Initial research carried out in 1985 showed an increase of 20 – 30% in free cortisol during stressful situations and also highlighted that free cortisol can be measured directly rather than it having to be separated from the protein bound cortisol (Fell *et al.*, 1985). Cortisol measurements have been used to determine physiological distress in sheep, with the majority of studies showing that an increase in the normal levels measured are indicative of distress (Mormede *et al.*, 2007).

Due to the fact that taking blood samples could be potentially stressful in itself, less invasive techniques have been devised including the collection of saliva (Buchanan and Goldsmith, 2004). Yates *et al.* (2009) found that the salivary cortisol concentration closely matched that of serum concentrations in sheep undergoing short term distress. They suggested that salivary cortisol is therefore a suitable and non-invasive measure for cortisol in sheep. The debate of “free” or total (free plus bound) cortisol is eliminated with saliva collection as cortisol only exists in the “free” form and is not able to bind with protein in this location (Cooper *et al.*, 1989). Pérez *et al.* (2004) stated that saliva cortisol is therefore a better indicator of the potential stressors animals undergo, however, it has also been mentioned that the validation of the technique that is used is extremely important to ensure that they are species and substance specific (Fuentes *et al.*, 2011, Heintz *et al.*, 2011, Smith and French, 1997).

There are an abundance of studies which suggest that measuring cortisol is a beneficial method of assessing distress and therefore welfare in sheep. Changes to cortisol concentration are caused by the increased functioning of the hypothalamus-pituitary-axis (HPA) in response to emotional and physical experiences. The secretion of cortisol increases the blood glucose concentration which enhances the amount of energy available; this enables the animal to behave in an appropriate manner to deal with the threatening situation (Moberg, 2000, pp 7). The range of situations effected and the similar response by the HPA axis adds

reliability to the use of cortisol as an indicator of distress (Mellor *et al.*, 2000, pp 176).

It has also been suggested that the dominant event for inducing a change in cortisol is novelty (Hall *et al.*, 1998b). However, researchers have to be aware of the potential problems and/or misleading results that are possible with using only this form of measurement. Research has shown that sheep and other diurnal species such as pigs are subjected to circadian/diurnal cycles of hormones and that these can interfere with the basal levels. It has been shown that there are peaks observed in cortisol during the morning after waking and then troughs in the evening before rest (Figure 1.2). These can vary the cortisol readings from 50-75% (Hellhammer *et al.*, 2009, Mormede *et al.*, 2007, Ruis *et al.*, 1997).

Smith and Dobson (2002) also highlight the importance of correct interpretation of cortisol results as the amount of distress is not necessarily a measurable trait and therefore may not be linear to the amount of cortisol analysed. A reduction in cortisol measurements may not be indicative of 'better welfare', it may suggest that the animal's body is adapting and coping with the distress being caused to prevent prolonged increases of cortisol. This follows the passive coping strategy which is the opposite of the active coping strategy, where the body would continue to produce higher levels of cortisol, or the animal would try to remove itself from the situation (Wechsler, 1995). Smith and Dobson (2002) recommend a cautious approach and the use of various indicators alongside cortisol,

such as changes in behaviour, which would account for these coping strategies. They also recommend increasing data sampling over a longer period of time to obtain a more balanced view of an animal's welfare.

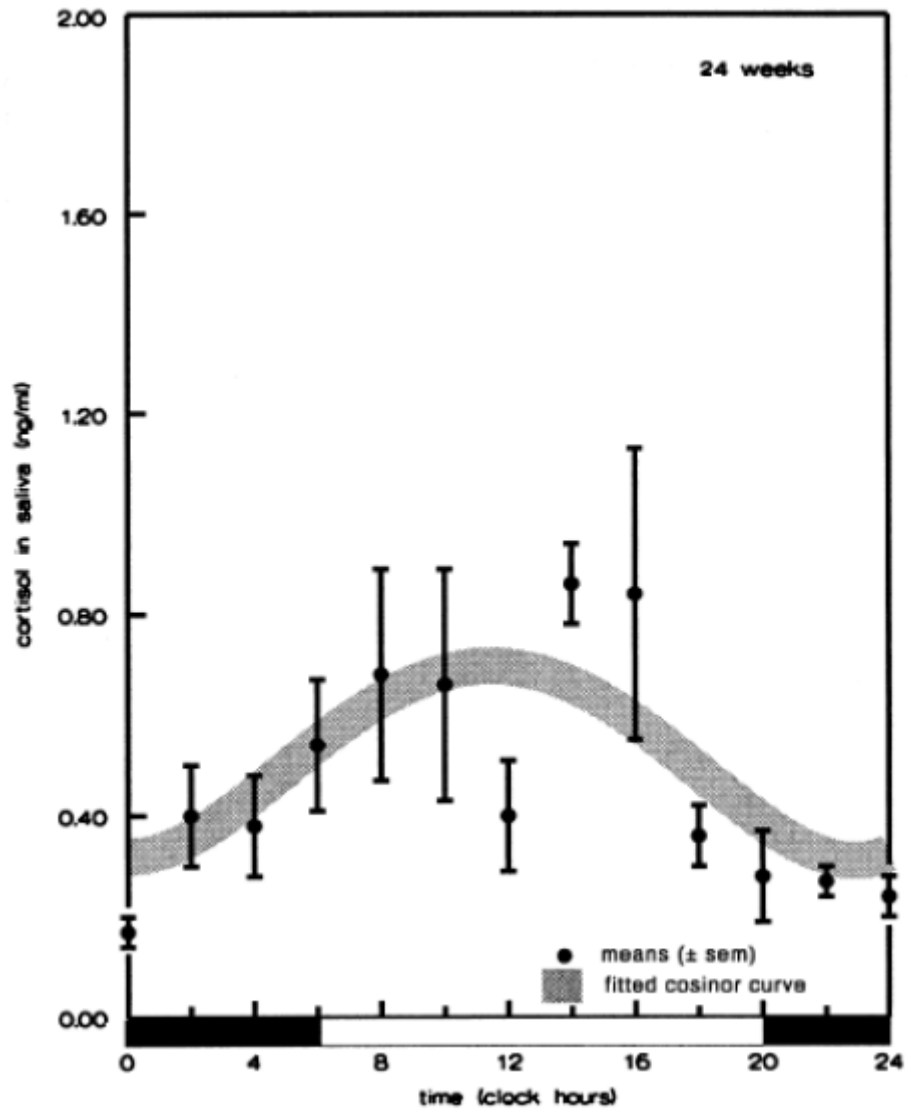


Figure 1.2: Mean (\pm SE) salivary cortisol values under basal conditions, together with fitted cosine curves (shaded lines), in growing pigs ($n=6$) at 24 weeks of age (Ruis *et al.*, 1997).

Cortisol is not always the primary physiological measurement of distress in sheep and many studies now combine this measurement with others such as heart rate and temperature to help to interpret what is occurring. Hall *et al.* (1998a) investigated the tendency of sheep in a mixed flock to remain with others of their own breed depending upon certain test scenarios. They measured both saliva cortisol and heart rate to show that there were significant differences in both measurements between the breeds. They also found that if the animals had undergone a taming process, their cortisol levels and heart rates were almost significantly lower, suggesting that husbandry practices could play a huge role in the reduction of distress in sheep and that the heart rate and cortisol measurements are valid measures of welfare. Heart rates have been utilised as a measure of potential distress in animals because of the changes to the oxygen concentration within the blood. With increased heart rate, the amount of oxygen increases enabling more to circulate body. This gives the animal the ability to perform required behaviour to alleviate or remove itself from the stressor causing the increase (Moberg, 2000).

1.2.1.3 Behavioural and Physiological Indicators Combined

The use of combined indicators of distress in sheep has improved the ability to understand potentially misleading results from using just a single indicator (Rushen, 2000). Lyons *et al.* (1993) tested to see if eleven juvenile cross bred Targhee-type ewes and eleven alpine bred goats were affected by social isolation whilst their 'pen-mates' were still visible. They

measured the rate of vocalisations, locomotion and plasma corticosteroid and found that for both species there was a significant increase in vocalisations, locomotion and corticosteroids when they were separated.

In an earlier study, Moberg *et al.* (1980) investigated the effects of two types of emotional distress (restraint and exposure to a novel environment) on the behaviour and physiology of newborn mixed-breed lambs. Plasma cortisol was used to capture the physiological indices and a number of behavioural indicators were used including latency to first movement, duration of movement, vocalisation and defecation frequencies. It was found that the defecation frequencies were not a reliable measure and so were discarded from the study. However, other behavioural aspects and the plasma cortisol measured were found to significantly increase during distressing situations and therefore can be used in conjunction with each other to fully understand the main findings.

Syme & Elphick (1982) researched the effects of social isolation in Merino sheep. They measured the animal's heart rates and recorded their behaviour whilst the sheep were in yards. They found varying results suggesting that the heart rate of some individuals were higher during the isolation period but this depended on whether they were recorded as agitated, vocal or unresponsive individuals, from the behavioural observations. They concluded that measuring heart rate in sheep would be useful as a measure of docility in pen studies for individuals, but may

be difficult to show representations of whole populations in different test situations due to individual differences of temperament.

On the other hand, a study carried out by Hall *et al.* (1998b) investigated how a transportation time of fifteen hours affected the salivary cortisol concentration, heart rate and behaviour of Clun Forest sheep compared to baseline data. Both the heart rates and cortisol response increased significantly but the behaviours observed were not significantly affected. This emphasises the need to apply caution when interpreting different indicators of distress in sheep.

1.2.2 Summary

There has been a great amount of research focusing on behavioural and physiological measures of animal welfare, with a particular focus on domesticated farm animals such as sheep (Table 1.1 for summary and additional studies). Although their use within the farm setting may vary, Rushen (2000) points out that the correlations between an animal's physiological and behavioural response are more controlled than just either response alone. Johnson *et al.* (1992) also contribute to the idea that there are links between physiological, psychological and behavioural changes that occur during a stress response with the idea originating from the study performed by Ruckerbusch and Malbert (1986).

Rushen (2000) emphasises that behavioural responses to stress are performed as a coping mechanism and that the types of responses performed will depend upon the individual and the particular type of stressor involved. Recommendations suggest that the use of both behavioural and physiological measures of animal welfare should be integrated to enable a more informed explanation of the animal's distress (Dwyer *et al.*, 2001).

Table 1.1: Behavioural and physiological responses of sheep to different stressors including isolation, restraint and transportation (where ↑ = significant increase, ↓ = significant decrease, 0 = no significant change).

Behavioural										Physiological			Reference
Stand	Locomotion	Sleep	Eat	Drink	Ruminate	Vocalise	Foot Stamp	Rearing	Vigilance	Cortisol	Heart Rate	Temperature	
	↓					0	↓						Torres-Hernandez & Hohenboken (1979)
↑	↑					↑				↑			Moberg <i>et al.</i> (1980)
						0					↑		Syme & Elphick (1982)
			↓	↓									Rukerbusch & Malert (1986)
	↑					0			↑		↑		Baldock & Sibley (1990)
↑		↓	0		↓	↑	0	0	↑	0			Cockram <i>et al.</i> (1993)
	↑					↑				↑			Lyons <i>et al.</i> (1993)
↑	↑	↓	↓	0	↓	↑	↑	0	↑	↑	↑		Cockram <i>et al.</i> (1994)
	↑					↑							Boivin <i>et al.</i> (1997)
	↑					↑		↑					Poindron <i>et al.</i> (1997)
			0			↑				0			Orgeur <i>et al.</i> (1998)
										↑	↑		Hall <i>et al.</i> (1998a)
										↑	↑		Hall <i>et al.</i> (1998b)
											↑	↓ ear-pinna ↑ vaginal	Lowe <i>et al.</i> (2005)
	↓					↓					↓		Tallet <i>et al.</i> (2006)
						↓					↓	↓ eye	Stubsjøen <i>et al.</i> (2009)

1.3 Maternal Behaviour

As with most mammalian species, strong and positive maternal behaviour in sheep is essential for the survival of their precocious lambs. Ewes are initially attracted to the amniotic fluid and spontaneously care for young presented to them; however this usually subsides within a period of 12 hours and is known as maternal responsiveness (Poindron *et al.*, 2007). In fact, anosmic ewes spent less time licking their lambs; emitted fewer maternal bleats and a higher frequency of protest bleats suggesting that maternal responsiveness plays an important role in initiating bonding (Levy *et al.*, 1995). Levy and Poindron (1984) also illustrated this by studying the behaviour of ewes whose lambs had been cleaned with either soap and water or just water. The lambs were no longer coated with the amniotic fluids and this significantly reduced the frequency of licking behaviours for both primiparous and multiparous ewes. Primiparous ewes also physically prevented the lamb from suckling and the number of incidences of aggression towards the lambs increased, which is behaviour performed towards a lamb that the ewes do not believe to be their own (Levy and Poindron, 1987).

Poindron *et al.*, (2007) discuss maternal selectivity as the ability of ewes to individually recognise their own lambs and are seen to reject alien lambs attempting to suckle (Smith *et al.*, 1966). Studies have highlighted that selectivity depends primarily on olfactory recognition from the amniotic

fluid (Levy *et al.*, 1995). Olfactory signatures have been shown to be specific to each individual lamb even between dizygotic and monozygotic lambs (Romeyer *et al.*, 1993). Other sensory channels have been linked to the development of maternal selectivity including sight and sound. Keller *et al.*, (2003) tested this with a two-choice test excluding olfaction. They found that ewes were still able to discriminate between their own and an alien lamb.

These studies highlight the importance of the ewe's ability to identify its own lamb for survival. The physical and auditory stimulation help to encourage the lamb to stand and move towards the udder to feed. Alien lambs may not be as motivated to approach the ewe's udder for milk if they were not receiving the ewes' encouragement (Dwyer and Lawrence, 1999, Levy and Poindron, 1987).

Ewes perform a variety of behaviours during the initial stages of parturition which have been used as indicators of positive and negative maternal behaviour (Table 3.1, pp 113). The frequency and duration of these behaviours can determine the success of a lamb-ewe bond and can help the shepherd to decide whether the maternal care is sufficient for the lamb to survive or that intervention is required. O'Conner *et al.* (1985) devised a means of assessing ewe maternal behaviour and termed it their maternal behaviour score (MBS). The MBS is a five point scale based on the distance the ewe moves away from her lamb when they are subjected to ear tagging, which is a procedure that is needed for every lamb as early on

as possible (Table 1.2). The MBS was seen to be useful for farmers as it was used to aid ewe breeding selection for the following year and culling programmes (O'Connor *et al.*, 1985). However, Rech *et al.* (2008) showed that when maternal care was measured using the MBS, there were no significant genetic differences between breeds and other research suggested that it was not a viable method for selecting stock in a commercial setting (Everett-Hincks *et al.*, 2005).

Table 1.2: The maternal behaviour score and description of behaviours shown by ewes whilst lambs are being tagged (Everett-Hinks *et al.*, 2005).

Description of maternal behaviour score (MBS)	MBS
Ewe flees at the approach of the shepherd, shows no interest in the lambs and does not return.	1
Ewe retreats further than 10m but comes back to her lambs as the shepherd leaves them.	2
Ewe retreats to such a distance that tag identification is difficult (5-10m).	3
Ewe retreats but stays within 5m.	4
Ewe stays close to the shepherd during handling of her lambs.	5

1.3.1 Genetic Differences

Selective breeding now plays a huge role in the development of animals for the specific qualities required. Maternal behaviour is one of these traits and it has been suggested that these behaviours can significantly affect the lamb's survival rate, and that these behaviours are a result of varying levels of hormones present in the animal's body (Grandinson, 2005).

Dwyer and Lawrence (2000) looked at maternal behavioural differences between Blackface and Suffolk ewes. Results showed that Suffolk ewes performed more rejection behaviours and less affiliation behaviours towards the lamb. Blackface ewes displayed a high level of maternal care and affiliation, and were only seen to reject the lambs occasionally (Dwyer and Lawrence, 2000).

Dwyer and Smith (2008) then went on to investigate the differences between the circulating concentrations of oestradiol and progesterone and the ratio of oestradiol to progesterone within the two breeds of sheep. They collected blood samples from 50 pregnant ewes every two weeks throughout gestation until approximately one week before parturition (Dwyer and Smith, 2008). The study showed that blackface ewes had a higher concentration of oestradiol and progesterone than Suffolk ewes from mid-gestation until parturition. It was found that the maternal behaviours displayed in the ewes were positively correlated with the concentrations of these circulating hormones; as blackface ewes showed

longer bouts of grooming, made more low-pitched bleats and fewer high pitched bleats.

The fact that there could potentially be differences in maternal behaviour and care between breeds suggests that the ewe's genetics could influence their ability to foster individuals. Hill breeds have been shown to perform stronger maternal behaviours as they have been selected by man to lamb extensively without the need for assistance or protection from predators or environmental conditions (Dwyer and Lawrence, 1998). Performance of strong maternal behaviours could mean that the ewe was less likely to accept an alien lamb as she would be quick to notice that it is not her own lamb and therefore restrict its ability to feed.

Snowder and Knight (1995) investigated this with four different breeds, Rambouillet, Targhee, Columbia and Polypay. They discovered that Targhee ewes were not as successful at rearing fostered individuals as the other three mentioned and that the lambs survival rate decreased by 12% compared to the other breeds. Suggesting that this was due to their stronger maternal abilities and concluded that there was a significant breed effect associated with fostering and that decisions by the shepherds need to be well informed before choosing ewes as foster mothers.

1.3.2 Parity

Purser and Young (1983) stated that the rearing ability of ewes was a repeatable trait in which, the more lambs that were reared, the higher the success of their subsequent performance. This indicates that lambs born to MP ewes will have a higher survival rate compared to lambs born to PP ewes. A study carried out by Dwyer and Lawrence (2000) investigated this with regards to maternal behaviour. They measured the ewe's latency to groom their lambs after parturition; proportion of time spent grooming; the frequency of rejection behaviours (such as withdrawal from the lamb, nosing, butting and pushing the lamb) and the response to lamb's suckling attempts. Results showed that PP ewes took significantly longer to groom their lambs and showed higher rates of rejection behaviours than MP ewes (Dwyer and Lawrence, 2000). These results support Purser and Young's (1983) findings indicating that mothering ability could be deemed a repeatable trait that increases with experience.

It had been suggested that MP ewes produced increased levels of ovarian steroids compared to PP ewes and that this may encourage stronger maternal behaviours (Dwyer and Bornett, 2004). Dwyer and Smith (2008) however, looked into the differing concentrations of oestradiol and progesterone between MP and PP ewes and found that there were no significant differences between the amount produced, they also identified that there were no differences according to the age of the ewe. Results showed that negative behaviours such as being aggressive, withdrawing

from the lamb and high pitched vocalisations were seen in 20% of PP ewes and were absent from MP ewes. They concluded that PP ewes do not show the same maternal qualities as MP ewes despite similar levels of hormone concentrations and suggested that this may be due to primiparous ewes being less sensitive to priming effects of elevated circulating oestradiol concentrations during gestation (Dwyer and Smith, 2008). The idea that the ewe's experience of the lambing protocol and habituation to handling i.e. a learned effect, was not explored and could be an explanation for these results.

Research carried out by Lambe *et al.* (2001) looked at the MBS of Scottish Blackface ewes over four different parities. Results showed that MBS was significantly higher in MP ewes compared to primiparous ewes and also to older ewes compared to younger ewes. A similar study conducted by Everett-Hincks *et al.* (2005) looked at the MBS of ewes along with the litter survival (litter size at weaning divided by litter size at birth) and lamb survival (from birth to weaning) of Coopworth ewes over a four year period. Their findings showed that litter survival was significantly increased as the MBS increased. The results supported previous results from Lambe *et al.* (2001) also showing that dam age was a significant factor in lamb survival for single and triplet births with 86% of lambs surviving if the ewes were aged 2 or younger and 91% of lambs surviving if the ewes were older than 2 years (Everett-Hinks *et al.*, 2005). The age could have correlated with the number of births the ewe had experienced and the 'learned' effect again could have influenced the results, but was not mentioned.

1.3.3 Summary

There is no doubt that maternal behaviour has a strong influence on the ability of lambs to survive and therefore produce healthy lambs. There are also other variables such as genetics, parity, time of foster and lamb size that may play a role and therefore it is likely that these may also influence the ability of a ewe to successfully foster an alien lamb. It may be possible that MP ewes may have the ability to discriminate between its own and an alien lamb more quickly and easily as a more experienced ewe may realise that a lamb is not her own and reject it.

1.4 Fostering

Fostering is a common technique used by shepherds to allow the successful rearing of abandoned and surplus lambs onto other ewes (Alexander *et al.*, 1985). Fostering can occur for a variety of reasons but the most common is when a ewe gives birth to more than two lambs which, with only two teats, make it difficult to viably raise them all. Traditional methods of fostering involved 'skin grafting', which was the removal of the pelt of the ewe's dead lamb placing it onto the alien orphan (Winter and Hill, 1998). Research has shown that skin grafting was not always successful (Close, 1979) and that other methods are also required in order for the alien lamb to be fully accepted (Hulet *et al.*, 1979).

Other methods which have been introduced to facilitate the fostering of lambs included the transfer of the natal lamb's odour by the use of 'hessian coats' (Alexander *et al.*, 1985, Alexander and Stevens, 1985a) or 'stockinette jackets' (Martin *et al.*, 1987, Price *et al.*, 1984b). Studies have also been carried out involving the use of novel odorants, such as neatsfoot oil to establish a common artificial odour on both the natal lamb and the alien lamb (Alexander *et al.*, 1987b, Alexander and Stevens, 1985b, Price *et al.*, 1998). Restraint techniques have also been used (Alexander and Bradley, 1985, Price *et al.*, 1984b) and using birth fluids and cervical stimulation (Basiouni and Gonyou, 1988).

Snowder and Knight (1995) investigated the effects of fostering on the ewe's ability to rear lambs. They identified that when fostered, there was a decrease in lamb viability by 7.4% at weaning and 6.7% at three weeks old compared to them being reared by their natal dams. This potentially was due to the selection of smaller, lighter lambs and highlights the importance of selecting the correct lambs for fostering.

1.4.1 Fostering Methods

1.4.1.1 Odour Manipulation

Odour manipulation involves the manipulation of the alien lamb's smell and can involve the application of textile jackets and odorants, or a combination of them both (Price *et al.*, 1998). This could also include the farmer's traditional method of skinning (Alexander *et al.*, 1987c). Although the methods may differ slightly with regard to timings of when the lambs and ewes are introduced, the basic technique remains the same. With each procedure, the natal and alien lambs would be anointed in the odorant then placed back with the ewe. When using jackets, again both the alien lamb and natal lamb would wear a jacket which would be swapped over before being placed in with the ewe.

Table 1.3 highlights the varied success rates reported from almost thirty years of research focused on fostering methods following odour manipulation. However, the variation in the success rates for the same technique such as the application of neatsfoot oil can range from 50 to

100% and the use of stockinette jackets from 20 to 84% depending on the authors and the amount of time allocated for the acceptance.

The difficulties could be due to a lack of standardisation between the final acceptance criteria. Some of the authors used the presence of olfactory investigation of the lamb by the ewe, soft bleating and acceptance of the lamb at the udder (Alexander and Stevens, 1985a, Alexander and Stevens, 1985a, Alexander *et al.*, 1987b, Alexander and Stevens, 1985b) and it was noted that this could occur at any point after a five minute period. These behaviours can occasionally occur in ewes that have not accepted their lambs or are still unsure for up to 48 hours. Some authors used the lamb's ability to suckle for a bout of 20 seconds without being pushed away by the ewe (Alexander and Bradley, 1985, Martin *et al.*, 1987, Price *et al.*, 1984b, Price *et al.*, 2003) whereas Rubianes (1992) increased this to a bout of 60 seconds without the negative behaviours being exhibited. Price *et al.*, (1998) used the 20 second bout but also stated that if the lambs were not accepted after a period of 72 hours, they would be returned to their pens and another acceptance test carried out 24 hours later.

Table 1.3: Summary of odour manipulation techniques studied with average latency to accept alien lambs and the percentage success rates associated with each technique.

Odour manipulation technique	Time to acceptance	Success rate	Author
Stockinette jackets	48 hours	50%	Alexander <i>et al.</i> (1984)
Stockinette jacket	48 hours	84%	Price <i>et al.</i> (1984b)
Stockinette jackets	24 hours	20%	Martin <i>et al.</i> (1987)
	48 hours	22%	
	96 hours	56%	
Stockinette jackets	4 hours	62%	Rubianes (1992)
	48 hours	69%	
Hessian coats	5 mins	45%	Alexander <i>et al.</i> (1985)
	72 hours	89%	
Lambs washed & hessian coats	5 mins	50%	
	16 hours	97%	
Hessian coat	48 hours	78%	Alexander & Stevens (1985a)
Hessian coat	18 hours	73%	Alexander <i>et al.</i> (1987b)
Neatsfoot oil		91%	
Skinning		100%	
Neatsfoot oil	48 hours	100%	Alexander & Stevens (1985b)
Wool wax		83%	
Vegetable oil		67%	
Mercapto ethanol		50%	
Butyric acid		67%	
Propionic acid		50%	
Vanillin		50%	
Eucalyptus oil		50%	
Methyl salicylate		33%	
Crude wool wax	120 hours	20%	
Purified wool wax		40%	
Neatsfoot oil		40%	
Vegetable oil		30%	
White soft paraffin		15%	
Washed and dried lambs		30%	
Neatsfoot oil	72 hours	50%	Price <i>et al.</i> (1998)
Neatsfoot oil & stockinette jacket		80%	
Neatsfoot oil & stockinette jacket	120 hours	85%	Price <i>et al.</i> (2003)

Although the success rates are an important aspect of the foster techniques, the results shown in table 1.3 are comparing alien lambs which are still coated in their original birth fluids. Levy *et al.*, (2004) explained how this has a huge effect on the performance of the ewes' maternal behaviours and therefore the potential to accept lambs (Levy *et al.*, 2004).

Another aspect of the previous research that has not been identified is welfare. The lambs could have received negative behaviours such as butts or kicks from the ewe for periods of up to 120 hours and may not have had access to milk for this period. This could potentially influence the lamb's growth and impede its commercial production value. In addition, none of the studies commented on the health or welfare implications of the ewes potentially ingesting damaging substances such as Mercapto ethanol or soft paraffin.

1.4.1.2 Restraint

Restraining techniques usually involve placing the ewe in a restrictive pen known as "mothering", "fostering" or "twinning" crates for a period of days or weeks depending on the success of the fostering (Alexander and Bradley, 1985). Restraint occurs just behind the ewe's head which is placed between vertical bars or boards (stanchion) which allow her to lie down or stand. The ewe's vision of the lamb is blocked by the boards placed alongside the stanchion (Figure 1.3a and 1.3b). However,

investigation of the lamb may occur in some set-ups as the lamb is able to move freely and can potentially climb around the ewe's neck. The restraint technique is mainly used for fostering lambs 2 to 3 days after parturition, when other techniques previously mentioned were unsuccessful (Price *et al.*, 1984a). However, as part of the 'Freedom Foods' farm assurance and food labelling scheme, the use of restraint crates for sheep became unacceptable from the 1st September 2010 (RSPCA, 2010).

Alexander and Bradley (1985) looked at the restrained ewe's acceptance, where the lambs were able to suckle unhindered without the ewe moving, at intervals of approximately 3 days. They tested for differences between sheep breeds and found that fostering occurred more rapidly in Dorset than in Merino or Corriedale ewes and the success rate was also higher in Dorset (81%) than the other two breeds (69% in Merino's and 73% in Corriedale's). Alexander and Bradley (1985) also studied the importance of having a screen present; they found that the prevention of close olfactory contact was necessary as the acceptance rate was much quicker in these circumstances.



Figure 1.3a: Row of ewes being held in commercial restraint crates at Moulton College Farm, Moulton (Photo: Ward, 2011).

Figure 1.3b: Ewe in restraint crate showing the location of the lambs, separated behind the ewe's head to ensure rejection of the lambs is not possible (Photo: Ward, 2008).

Alexander and Bradley (1985) study also commented on the animal's well-being both within the crate (lambs) and in the stanchion (ewes). This highlighted that there were possible welfare implications which coincide with this method of fostering as when the ewes initially entered the fostering crates, they were seen to struggle. After an unmentioned period of time this behaviour decreased in frequency and this was noted as the ewes habituating to the restraint. However, this could have been the ewes responding as the conservation-withdrawal strategy (Koolhaas, 2008) rather than being unaffected by the restraint. It was also mentioned that the flanks and udders of the ewes would become soiled and moist from lying in excreta which emphasises potential health and welfare aspects associated with the lambs suckling from the udders. A number of lambs were also reported to have died after being crushed by the ewes during the study carried out by Alexander and Bradley (1985). This again highlights the potential welfare issues associated with this method of fostering.

As mentioned in section 1.2, in terms of the five freedoms (Farm Animal Welfare Council, 1979), the restraint method of fostering inhibits the ewe's ability to express normal behaviour, to be free from fear and distress and be free from discomfort. It is therefore suggested that this is a restrictive and potentially distressing method of fostering, especially as the ewes could be restrained for up to 9 days with only a 46% success rate (Alexander and Bradley, 1985). Price *et al.* (1984a) did not comment on the welfare aspect of this method with regard to the animals. They did

however comment that it was space and labour intensive and potentially difficult for the farmers involved. The lack of investigation into the welfare implications of restraint crates may be linked to the age of the studies and that only more recently has welfare become a focus point of research.

1.4.1.3 Cervical Stimulation

Cervical stimulation of the ewes has been used to initiate maternal behaviour therefore has been used as a method for fostering lambs (Basiouni and Gonyou, 1988). A clean, gloved and lubricated hand is inserted into the ewe's vagina and cervical stimulations are performed. Moderate pressure is then applied to expand the cervix to simulate contractions normally experienced during parturition (Basiouni and Gonyou, 1988). Other studies have used vibrating rods or expanding balloons but the principle is the same (Keverne *et al.*, 1983). This process has been seen to reduce the rejection rate of alien lambs and induce a state of plasticity in maternal behaviours and may make them more inclined to bond with their lamb (Keverne *et al.*, 1983).

Basiouni and Gonyou (1988) carried out a study comparing the use of birth fluid soaked textile jackets and cervical stimulation to investigate fostering success. They found that using birth fluids alone led to a higher fostering success in terms of greater suckling and reduced aggression during the test situations. Cervical stimulations failed to influence the maternal behaviour of the foster ewes in the initial acceptance period (11

days) but did improve the final acceptance of the lamb. However, Kendrick and Keverne *et al.*, (1991) investigated the effects of vagino-cervical stimulation following oestrogen treatment (OT) and non-oestrogen treatment (NOT) in multiparous ewes. Results showed that no maternal behaviours were performed following vagino-cervical stimulation without the oestrogen treatment and an increase in positive maternal behaviours compared to those who just underwent the hormonal treatment. This highlights that the onset of maternal behaviours is linked to the cervical stimulation rather than just release of hormones.

These fostering methods were recommended rather than the previously mentioned restraint techniques or odour transfer techniques, as they were much less labour intensive and were not delayed for 24 hours due to the switching of the jackets. In addition, it can be initiated up to 24 hours after parturition and did not interfere with the maternal bonds that the ewe may have made with her own natal lamb (Kendrick *et al.*, 1991).

1.4.2 Summary

The most common methods of fostering, listed above have shown varying success rates however research has not directly compared methods following the same criteria. Welfare implications and the effect that each method may have on the ability of the ewe and lamb to bond have not been well researched and would warrant investigation.

1.5 Artificial Rearing

Within the UK, artificial rearing (AR) involves the provision of artificial milk to lambs which have been abandoned, unable to be raised by their natal mother or cannot be fostered onto another ewe. It is a feeding method which can require the largest amount of care and attention in order for it to be successful (Eales *et al.*, 2004). In specialised ewe dairy production systems it is used to gain the highest milk yield possible from each ewe, as lambs are separated from their dams at as soon as possible post parturition and then fed replacement milk (Napolitano *et al.*, 2008).

The process of AR usually involves tube feeding newborn lambs or bottle feeding the stronger and/or older lambs initially with colostrum with subsequent feedings being of artificially produced milk. Each lamb requires feeding every 4 - 6 hours on approximately 50ml per kg of body weight (Eales *et al.*, 2004). At around 72 hours of age, providing the lamb is strong, suckling well and showing no sign of disease, it can be transferred to an artificial rearing pen. The artificial pens are able to support either bottle feeding or self feeders which are less labour intensive and can increase the number of lambs successfully being reared at once (Umberger, 1997).

As previously discussed (section 1.2.1) after parturition, lambs develop a strong and selective bond to their dams (Nowak, 1996). This bond ensures

the ewe and lamb stay within close contact and rarely move more than 5 meters apart for the initial month (Arnold and Grassia, 1985). AR is abrupt and lambs are usually separated from their mothers before they are nutritionally or psychologically ready, which has been seen to decrease the lamb's natural behavioural repertoire (Dwyer and Bornett, 2004).

Stephens and Baldwin (1971) investigated how this can then lead to the expression of stereotypies such as appetitive behaviours directed towards inappropriate objects. They found that the artificially reared lambs sucked the navel or scrotum of the other lambs and that this behaviour may have been attributed to the frustration caused by the deprivation of natural suckling (Napolitano *et al.*, 2002).

AR is a possible alternative to providing a lamb with a foster dam and is common practice amongst shepherds around the UK. However, with time and money constraints it could potentially work against them in their ability to achieve healthy, well produced lambs with each lamb consuming around £15 - £20 worth of milk powder and a similar value of creep feed (Long, 2009).

1.5.1 Welfare issues

Artificial rearing has been associated with a reduction in animal welfare and this may be due to the impact of the psychological or emotional

stressors caused by the early separation of the lamb and ewe (Cockram *et al.*, 1993).

Napolitano *et al.* (1995) investigated the influence of AR on the behaviour of lambs at 2, 15 and 28 days old after their removal from the mother. Results illustrated that the younger animals (2 days old) showed a significant decrease in the duration of movement around the pen and an increase in latency to the time of first movement (indicative of teat seeking behaviour), along with an increase in blood cortisol levels compared to the older lambs. The average daily weight gain was also affected by the age of removal from the dam and showed that both the 2 day and 15 day old lambs gained significantly less weight per day than the older lambs. They concluded that early separation from the dam affects the post-separation performance of behaviours and that this may be due to the reduced ability of the younger individuals to cope with emotional and nutritional stresses (Napolitano *et al.*, 1995). This was assuming that dam-lamb bonds had been formed during the initial 2 days and therefore been broken during the separation. This effect could be directly linked to the reduced amount of maternal colostrum or as a result of the emotional stress involved with breaking the most relevant social bond at such an early age.

Napolitano *et al.* (2002) explored the welfare implications of AR and naturally reared Comisana lambs. At 42 days old, they were subjected to an isolation test to carry out behavioural observations and also take blood samples for cortisol analyses. Results showed that the rearing did not

affect the latency to first movement, duration of movement or the number of bleats, nor did it affect the blood cortisol levels. However, the ewe-reared lambs did perform significantly more flight attempts and had higher immune responses to a percutaneous injection. This indicated that the AR lambs could have suffered from an increase in stress and that the separation from the dam is more stressful than separation from peers (other lambs), as flight attempts have been associated with individuals trying to rejoin their conspecifics (Napolitano *et al.*, 2002).

Cockram *et al.* (1993) also investigated the effects on the ewes with the continued removal of their lambs before the age of natural weaning. The results showed that the sheep found the process aversive with behaviours such as vocalisations, standing with their heads raised and ears erect being performed, thus indicating a negative behavioural response to the treatment. The dams also showed a decrease in the amount of time spent resting, sleeping and ruminating during the lambs' removal, again showing the psychological effects associated with the removal of lambs (Cockram *et al.*, 1993). This indicates that the AR technique has negative implications for the ewe as well as the lamb.

1.5.2 Summary

AR could potentially be a viable alternative to fostering lambs. However, there are implications that could steer the decision away from this option due to the increased amount of time, money and equipment involved.

Questions regarding the lamb's welfare, and potentially the meat quality need to be answered before informed decisions can be made. Research into the meat quality and growth rates of artificially reared lambs compared to fostered lambs is vital to enable the producers to weigh up the benefits and costs involved with the different options available for abandoned or orphaned lambs.

1.6 Production and Meat Quality Implications

Studies of the links between animal welfare and meat production (including growth rates) and carcass and meat quality have controversial outcomes depending on the distress experienced and the species being studied. Gregory, (1998) suggested that as the welfare of the animal decreases so does the quality of the meat.

However, Miranda-de la Lama *et al.* (2009) investigated the affects of a visit to a pre-slaughter classification centre which is an additional holding area where the lambs are assessed prior to slaughter for potentially up to a month on meat quality parameters including water holding capacity, pH and colour. Essentially the lambs were in unfamiliar surroundings for an unknown amount of time and were then transported to the slaughter house. Increased levels of plasma cortisol showed that these events were distressing to the lambs. However, results showed that over varying amounts of time at the classification centre, there were no significant differences between the WHC values and that this could have also been linked to the non significance in the ultimate pH values and colour measurements. Results suggest that even though lambs were experiencing distress, with potential relevance for the animals' welfare, this did not affect the meat quality of the end product.

Garrett *et al.* (1999) explored the effects that extensive treadmill exercise had on the carcass quality of Hampshire-Rambouillet lambs. They found that lambs which had undergone regular exercise prior to weaning produced a leaner carcass with more tender hind leg meat. It was explained that this was due to the reduction of carcass adiposity linked to the exercise; however, this was not a feasible method in a commercial situation. Although a treadmill would not be feasible, the ability of the lambs to exercise and move freely around animal pens could have the same effect. This could be an important limitation for some foster methods (e.g. restraint crates) as the lambs are confined in smaller pens that would limit their ability to exercise.

1.6.1 Carcass Quality Measures

1.6.1.1 Live Body Measurements

The use of live body weight has been widely reported as a strong measure to estimate productivity of lambs (Salako, 2006), however other live body measurements previously used for assessing breed type and function have become useful in assessing carcass quality prior to slaughter (Stanford *et al.*, 1998). Measurements such as body length (base of neck to beginning of tail), torso length (shoulder to ischium), height at shoulder (floor to shoulder), rump length (Ilium to ischium), rump width (left ilium to right ilium), chest depth (largest depth of ribs to shoulder) and chest circumference (around chest) have been used as indicators of weight in cattle (Alderson, 1999) or goats (Ribeiro *et al.*, 2004), or to investigate

growth rates according to age in sheep (Arthur and Ahunu, 1989). In a review of methods to estimate live animal and carcass composition, Hedrick (1983) explained the importance of more than one objective measurement being taken to enable a successful evaluation of an animal prior to slaughter. These additional measurements have since been utilised to calculate the potential quality and shape of a carcass to combat this bias.

Lambe *et al.* (2008) investigated the use of live animal measurements to predict the carcass quality of Texel and Scottish Blackface lambs. They used a collection of images of each lamb and software developed at the research centre to measure 15 linear dimensions per animal. Results suggested that these measurements increased the accuracy of predicting carcass quality compared to other methods previously used, including CT scans and intramuscular fat content. They did, however, conclude that this set up would not be commercially viable due to the expensive equipment and time needed to evaluate each lamb. Another limitation would be the need to shear the lambs prior to the images being taken. Within the UK the majority of lambs are finished prior to shearing therefore reducing the quality of the dimensions being measured.

Peana *et al.* (2007) investigated the effects of heat stress on ten Sarda dairy ewes' milk yield and composition. They found that during extreme conditions the milk yield was significantly decreased by 20% per animal and the somatic cell count also increased, reducing the quality of the milk.

Similar results were also found by Caroprese *et al.* (2010) when investigating the effects in Comisana dairy ewes. They found that ewe isolation, even three days prior to milk collection, significantly affected the milk yield, cortisol levels and somatic cell count. Ewes undergoing distressing conditions produced less milk and of a poorer quality which may affect the lambs' growth rates and therefore carcass quality.

1.6.1.2 Conformation and Fatness

Commercial carcass classification within the UK is based upon the EUROP system (Commission Regulations EEC, 1993) and aims to assess the carcass quality in accordance with its estimated value for further processing (Johansen *et al.*, 2006). Carcasses are allocated a score for conformation, which describes the shape in terms of concave or convex profiles and highlights the amount of meat, in relation to bone, and a fatness score that describes the amount of visible (subcutaneous) fat on the outside of the carcass (Fisher and Heal, 2001). The scores used are shown in table 1.4 where a high score for conformation class indicates a carcass with well to excellent rounded muscles, and a high fatness score is indicative of a carcass with a large amount of subcutaneous fat, and utilises the relationship between external and total fat content.

Other, less subjective methods are available to measure carcass quality including infrared reflectance, conductivity and data intensive computer tomography. However, it is due to the speed and reduced costs involved

with the visual EUROP system that makes this method the most commonly used in a commercial abattoir throughout the majority of Europe (Kongsro *et al.*, 2009).

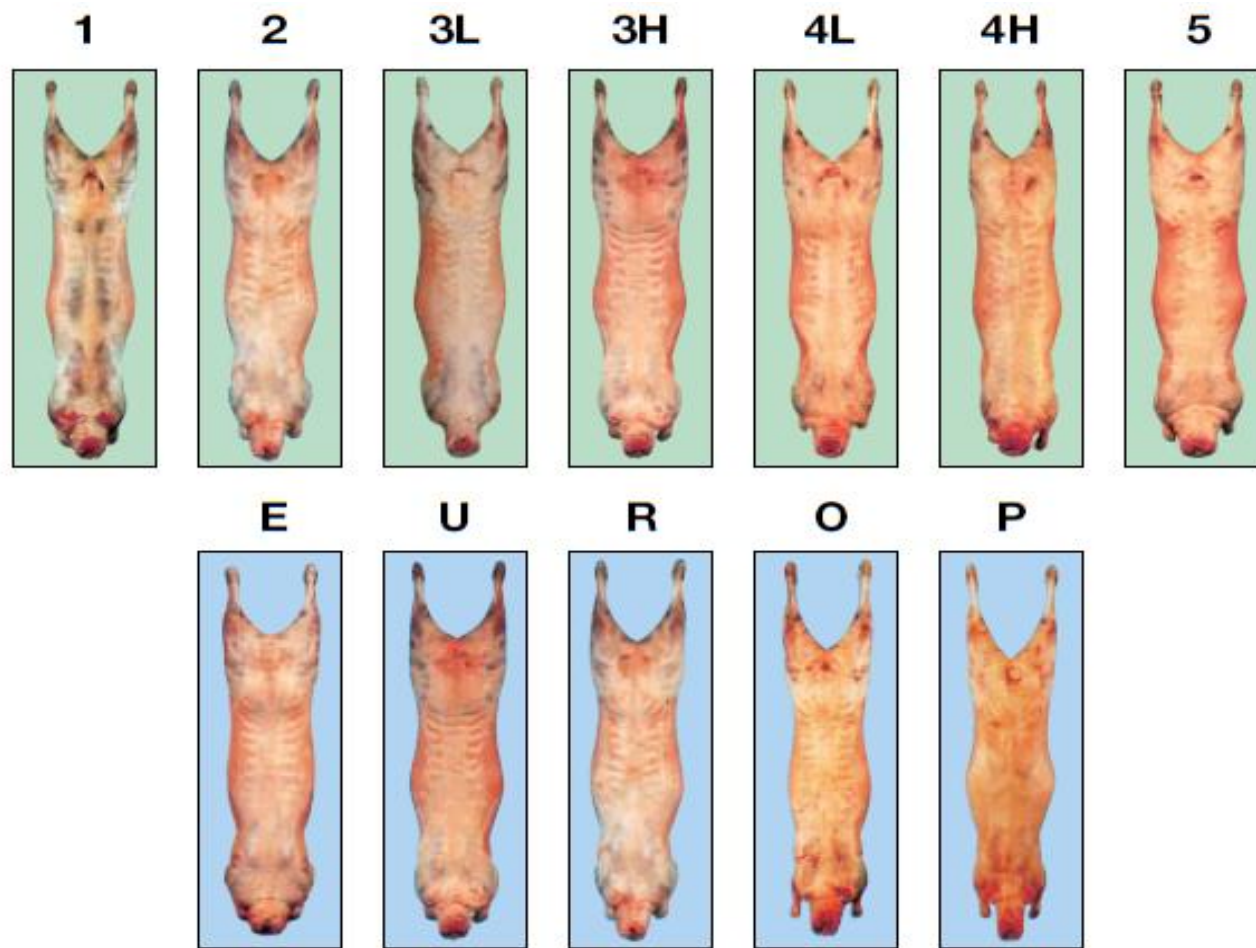


Figure 1.4: Photographic chart showing the main classes for EUROP conformation and fatness scores (MLC, 2009).

1.6.1.3 Carcass Measurements

Alongside the use of the EUROP system, additional measurements have been reported as being useful in grading the final carcass. Cañeque *et al.* (2004) studied the relationship between final carcass weight and carcass quality in light lambs (slaughtered at weights between 8 and 15kg) using carcass indices from measurements including chest width (widest carcass measurement at the ribs), chest depth (maximum distance between the sternum and back of the carcass at the sixth thoracic vertebra), buttock length (widest buttock measurement in a horizontal plane), leg length (length from perineum to distal edge of the tarsus) and internal carcass length (length from cranial edge of the symphysis pelvis to the cranial edge of the first rib). Principal components analysis showed that the indices calculated from the carcass measurements explained 74% of the variation in carcass weight compared to 50% when using meat quality parameters such as ultimate pH, colour and water holding capacity (explained below). These results highlighted the possible use of these measurements for lamb carcass evaluation rather than the reliance of cold carcass weight.

1.6.2 Meat Quality Measures

1.6.2.1 Ultimate pH

Meat quality can be assessed using several indicators. The ultimate pH, (hereon pH) is the final pH once the muscle glycogen has converted to

lactic acid and for research purposes, is usually measured after a 24 hour period (Huff-Lonergan and Lonergan, 2005). It is also the most common method of assessing meat quality in a commercial setting (Gregory, 2007). After slaughter, the muscle becomes anaerobic and the glycogen is converted to lactate. Hydrogen ions are also produced at the same time causing the pH to decline. If the glycogen concentration is limited or the hydrogen ion production is halted for various reasons, it results in a higher meat pH (Young *et al.*, 2004). The acceptable pH range for lamb should be between 5.4 – 5.8 (Huff-Lonergan and Lonergan, 2005) with measurements above these figures causing undesirable odours, changes to the flavour, difficulties to the palatability and reduced storage time compared to lamb meat with a lower pH (Pethick and Jacob, 2000).

Bond *et al.* (2004) examined the effects of exercise stress (five minutes of exercise using a dog, 30 second rest then another five minutes of exercise) on the ultimate pH of $\frac{3}{4}$ crossbred lamb meat. They found that the exercise stress caused significantly higher pH values than lamb meat not undergoing the exercise. The pH was in fact indicative of animals producing dark, firm and dry (DFD) meat with a pH reading of between 5.7 – 5.9 (see section 1.6.2.4). Bond and Warner (2007) later investigated the effects of exercise (ten minutes of continual exercise without rest) on the pH of crossbred lamb meat. They found that the pH decline was much greater in the exercised animals compared to the control group which did not undergo any exercise; however, the ultimate pH of the meat at rigor was not significantly affected. These two studies used the same lamb

breed and methods involved with collecting data, however, they differed in the type of exercise or stress that the animals underwent prior to slaughter. This suggests that the type of stress the lambs undergo prior to slaughter may have consequential effects on the ultimate pH and therefore the meat quality.

1.6.2.2 Water Holding Capacity

The structure of meat is extremely complex with the myofibrillar protein being able to perform fast and specific repetitive movements. These movements are supported by the presence of water within the muscle fibres which act as lubricants in addition to aiding the transportation of metabolites in the fibre. For efficient movements, the water content needs to remain fairly constant but must be able to move to other places in the sarcomere during contractions (Lampinen and Nojonen, 2005). The Water Holding Capacity (WHC) is described as the ability of meat to retain this water between the spaces of the thin and thick filaments of the muscle after slaughter (Bond *et al.*, 2004). It is one of the most important quality characteristics of raw meat and is linked to the juiciness of the meat in taste testing research (Huff-Lonergan and Lonergan, 2005).

In the studies mentioned in section 1.6.2.1, Bond *et al.* (2004) and Bond and Warner (2007) also found that the increased exercise significantly reduced the meats ability to retain water. They explained that this was likely due to the exercise causing changes in the ion distribution and the

proteolysis of the muscle proteins which decreased the ability of the muscle to hold water.

1.6.2.3 Colour

A high proportion of meat colour research uses the CIE L*a*b* colour scale which was intended to provide a uniform colour scale used by everyone to enable comparisons. Figure 1.3 shows the cube in which the CIE L*a*b* is organised with L* (lightness) being the vertical axis and measured on a scale of 0 (black) to 100 (white). Redness is measured using 'a*' with high numbers meaning more red in colour and b* measuring yellowness with high numbers meaning the meat was more yellow in colour.

Initially colour was measured using visual measures by trained panellists referring to standard colour charts, this has been seen to be affected by external factors such as lighting (Barbut, 2001) and the panellists' individual cognition and perception of different shades of colour (Carpenter *et al.*, 2001). Computer vision has also been used to assess colour based on the analysis of digital camera images. These images can then be processed to remove any backgrounds, fat or bone to ensure the colour reading is representative of the meat alone, and then converted into the CIE Lab values (Lu *et al.*, 2000). The other method of measuring colour is to use a colourimeter that can be calibrated to suit (Mancini and Hunt, 2005).

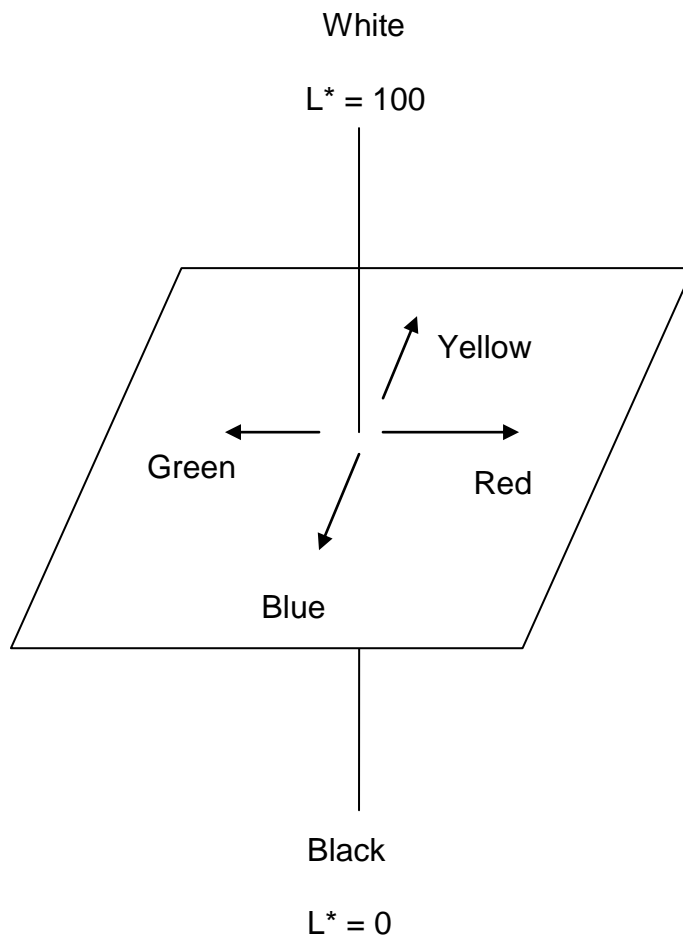


Figure 1.5: CIE L*a*b* uniform colour scale cube adapted from HunterLab (2008).

1.6.2.4 The Combined Effect

Meat pH is strongly linked to the colour and WHC of meat. Warner (2008) and Young *et al.* (2004) stated that if the meat pH was high and above 6.0, the meat would undergo several defects, mainly that it would be much darker in colour and lose a lot more water (lower WHC). This is what is known as “DFD” meat or dark, firm and dry; referring to the meats physical properties (Young *et al.*, 2004).

Meat colour is the main indicator of freshness and wholesomeness to the consumer and meat outside the desired pH range could therefore be less attractive to them, discouraging a purchase (Mancini and Hunt, 2005). Bond & Warner (2007) stated that the WHC is also influenced by the pH and that it is the *rate* of decline from the initial pH measured directly after slaughter to the ultimate pH, which affects the ability of the meat to retain the water. Huff- Lonergan and Lonergan (2005) advised that a rapid decrease can lead to a lower WHC.

For commercial purposes, studies have highlighted how different genders, breeds and slaughter weights may influence the pH, WHC and colour of meat. Studies conducted to investigate gender differences have generally found there to be none when comparing ewe and castrated ram lamb quality characteristics such as pH colour and tenderness (Arsenos *et al.*, 2002, Dransfield *et al.*, 1990, Ellis *et al.*, 1997). However Johnson *et al.* (2005) compared entire ram lambs with ewe lambs to find significant

differences in carcass size, with rams being much larger and heavier. They also found that ram lamb meat had significantly higher ultimate pH values and were significantly lighter, less red and more yellow in colour. Although the ram lambs were larger, they concluded that the quality of the meat from the ewe lambs was better than that of the entire ram lambs. Teixeira *et al.* (2005) examined the differences between male and female Bragançana and Mirandesa lambs. They found that ultimate pH was significantly affected by live weight prior to slaughter but not by breed or gender. Live weight, sex and breed also had no effect on the red index (a^*) however, lightness (L^*) was inversely related with live weight, with darker meat being present with heavier lambs. Light lambs also had a higher yellow (b^*) index than others.

1.6.2.5 Post-Cooking Measures

Other forms of measuring meat quality have included the formation of sensory panels who taste portions of the meat once cooked. The members on the panels are often formally trained to score qualities such as tenderness, juiciness, chewiness and fibrosity (Fernandez and Vieira, 2012). In addition, the Warner-Bratzler shear force can be used to again measure tenderness (Hoffman *et al.*, 2003). Although these methods are both reputable and reliable measures, the methods involved with conducting these tests are difficult to coordinate without the correct set up

and equipment and therefore were not carried out within the current research.

1.6.3 Productivity and Animal Welfare

Research has demonstrated a significant negative correlation between distress and the productivity of pigs and cattle. Hemsworth *et al.* (2000) investigated the effects of stockmanship on the productivity of dairy cows over a lactation period (approximately 44 weeks). When stockmen interacted negatively with cows, there was a significant negative correlation with milk yield, protein and fat and a significant positive correlation with milk cortisol concentrations. These results indicated that the negative interactions from the stockmen elevated stress levels which consequently decreased the productivity of the cows.

Similar results have also been seen in pigs where trained observers measured the stock-keepers' behaviour and types of interactions they had with farmed pigs. The interactions were classified as either positive (including pats and strokes), or negative (including slaps, pushes and hits with their hand). Results showed that negative interactions decreased reproduction rates and also decreased the growth rates of the pigs (Coleman *et al.*, 1998). Coleman *et al.* (2000) later found that pigs demonstrating a reduced fear of humans showed an increase in these production parameters.

The aim of measuring production rates in the context of fostering was to identify if the rearing systems (i.e. the foster method) had an effect on the product quality of the lamb. Research has shown that poor maternal bonds between the lamb and the ewe can reduce the welfare state of the lamb (Sevi *et al.*, 2003), which can in turn have detrimental effects on the lamb growth and the carcass and meat quality (Napolitano *et al.*, 2003). Diet has also been shown to influence these meat quality factors (Mancini and Hunt, 2005, Phillips *et al.*, 2009, Santos-Silva *et al.*, 2003) and, therefore, the ability of the lamb to access milk due to poor fostering or maternal bonds may have implications on the lamb growth and meat quality (section 4.1.2, pp 146).

1.6.4 Summary

Different stressors, with potential negative implications for animal welfare, have shown to influence meat quality. However, it is important to mention that not all the effects of rearing regimes can be directly related to individual measures of meat production and quality. Meat quality characteristics such as those mentioned above can influence each other, i.e. Ultimate pH affecting the water holding capacity which in turn affects the meat colour. It is therefore important to combine meat production and quality indicators to gain a full picture of the effects distress has on meat quality. The use of meat quality parameters and growth rates combined for lamb production research will enable an overall summary of the effects of

the different rearing techniques and potentially impact on the producers' decisions about which fostering/rearing methods to select.

1.7 Conclusion

There are many contributing factors that can influence the welfare of ewes and therefore the growth rate and meat quality of the lambs which they produce during the lambing period. Although research has investigated some of these factors in detail, the effects of fostering on ewe welfare and lamb production still remains to be investigated further. Fostering is a large area of interest from the shepherds' perspective and additional measures to increase lamb survival during this crucial time are critical to their rate of return.

Assessing methods of fostering with regard to welfare will determine good techniques in terms of improved ewe welfare and production outcomes. This will result in increased productivity and decreased economic losses for the producers, along with provision of the appropriate conditions for sheep required.

CHAPTER II

Attitudes of UK Sheep Farmers

Towards Fostering Methods: A

National Survey

2.1 Introduction

Within the EU, the UK is the largest producer of lamb meat with around 59,000 tonnes of meat being exported to other European countries (EBLEX and AHDB, 2011). With this in mind, lambing is an extremely important time during the sheep farmer's year. However, the UK still loses between 15 and 20% of lambs annually with the majority of these deaths caused by lack of planning, preparation and organisation of lambing routines and facilities (Defra, 2004). This figure highlights the significant welfare problem and financial loss to the industry and emphasises the importance of good stockmanship at this crucial time of year (Defra, 2004).

The English Beef and Lamb Executive (EBLEX) realised this important lack of knowledge within the sheep industry and in 2003, with help from Defra, produced numerous documents targeted at sheep farmers in order to increase their returns, such as "Target lamb management for better returns" and "Target lamb selection for better returns" booklets. Plush *et al.* (2011) highlight that a large aspect of ensuring an optimum level of production is to successfully manage the lambs from an early age.

In 2009, the national average of lambs reared per ewe mated was 1.18 which was 6% higher than in 2008 (Defra and ADAS, 2009), with the average number of singles, twins and triplets varying according to the breed. Lamb fostering is a technique that could potentially increase this average as it enables the successful rearing of abandoned lambs onto

other ewes or the ability to provide surplus lambs a new mother in the case of triplets (Alexander *et al.*, 1987a, 1987c). However, this process is made difficult by the ewe's ability to discriminate between her own and an unknown alien lambs' specific odour (Price *et al.*, 1984b). The most appropriate fostering method is selected by the flock's farmer who needs the ability and knowledge to care for the flock's welfare at all times (Defra, 2003).

2.1.1 Foster Methods

Foster methods available to farmers include skinning, birth fluids, odorants, restraint, textile jackets and cervical stimulation (Table 2.1). Some of these methods such as the cervical stimulation and restraint techniques are invasive and restrictive, therefore, conceivably distressing for the ewes involved (Dwyer, 2009). This distress could then affect the ewe-lamb bond (Dwyer *et al.*, 1999).

Dwyer (2003) also highlighted that if lambs required assistance during delivery they were significantly slower in performing neonatal behaviours than unassisted lambs, and they were also less active over the first three days of life. This research could be crucial with regard to foster method selection. Some of the foster methods involve close contact with the lambs at parturition and could jeopardise the neonatal behaviours performed by the lambs. If the lambs are fostered too early, their ability to suckle or stand

could be jeopardised, yet if the lambs are fostered too late, this could affect the ewes' acceptance of them.

Previous research on fostering focused on the success of the methods in terms of the latency to accept by the ewe, using ewe behaviour to test acceptance (Alexander *et al.*, 1987a, 1987c, Basiouni and Gonyou, 1988, Price *et al.*, 1998, Price *et al.*, 2003). Although the methods of fostering can vary, the majority of studies have highlighted similar evaluation techniques to classify a foster as a success or not with no real consideration for, or measurement of the welfare implications involved with these methods.

Alexander and Stevens (1985a), however, did measure the occurrence of soft bleating from the ewe alongside strong olfactory interest in the lamb. They deciphered loud bleating and negative behaviours, such as circling away from the lamb and threatening gestures with the head or butting the lamb as rejection of the alien lamb. This research also measured the weight changes in the lambs and noted that behavioural acceptance was associated with mean weight gain by lambs of $210 \pm 30 \text{ g day}^{-1}$. This was with eighty-five Merino ewes with single lambs being switched between other single bearing ewes, allowing for a higher quantity of milk per lamb than those bearing twins. Similar acceptance tests have involved the ewe's behaviour and also incorporated the lamb suckling successfully for a minimum of 20 seconds without being pushed or butted away (Price *et al.*, 1998). Furthermore, this assessment is still strongly linked to the ewes'

behaviour and dependent on whether the lamb wishes to feed for that length of time.

The study completed by Price *et al.* (1984a) was the only study to comment on the animal's well-being during a restraint foster technique. It highlighted that there were possible welfare implications with this method of fostering, as when the ewes initially entered the fostering crates, they were seen to struggle. After an unmentioned period of time this behaviour decreased in frequency and this was noted as the ewes habituating to the restraint. A number of lambs were also reported to have died from being crushed by the ewes during the study carried out by Alexander and Bradley (1985), which highlights the potential welfare problems to both the ewe and the lambs involved. However, neither of these studies measured welfare empirically.

Table 2.1: Descriptions of the different types of foster methods that can be selected by farmers and used within the questionnaire.

Foster Method	Description	Reference
Skinning	Removing the skin of the dead natal lamb and placing it onto the alien lamb.	(Winter and Hill, 1998).
Birth Fluid	Rubbing the birth fluids from one lamb onto another lamb prior to fostering.	(Basiouni and Gonyou, 1988, Dwyer, 2009).
Odorants	Coating the foster lamb and natal lamb in the same lotion, such as neatsfoot oil to ensure both lambs smell the same to the ewe.	(Price <i>et al.</i> , 2003, Alexander and Stevens, 1985b, Price <i>et al.</i> , 1998).
Restraint	Placing the ewe in a crate of some form to restrict her movement allowing the lambs to suckle beneath her without allowing her to discard them.	(Alexander and Bradley, 1985, Price <i>et al.</i> , 1984a).
Textile Jacket	Placing cloth jackets onto the natal and alien lamb and swapping the jackets prior to fostering.	(Alexander <i>et al.</i> , 1985, Rubianes, 1992).
Cervical Stimulation	Inserting a hand, for example, into the ewes' vagina and applying pressure to expand the cervix. This simulates contractions, so the ewe believes she is in labour.	(Basiouni and Gonyou, 1988, Keverne <i>et al.</i> , 1983).
Other	Any other fostering techniques not mentioned in the table above examples could include scaring ewe with a dog or bucket on the ewes head.	Anecdotal
Combination	A selection of two or more of the above methods used in conjunction with each other.	Anecdotal

2.1.2 Farmer Attitudes

Te Velde *et al.* (2002) investigated the perception of the treatment of farm animals in the Netherlands. They interviewed fifteen livestock-breeders to find that the farmers had an overall positive perception of the animals' welfare and they felt that within livestock breeding systems there were no real welfare concerns. Morgan-Davies *et al.* (2006) also investigated farmers' opinions on welfare, in addition to the animals' health and production practices in hill flocks in the UK. The study highlighted that the farmers did acknowledge welfare implications of certain animal management methods yet they relied on previous experience of the animals' health as an indicator rather than through an extensive knowledge of the topic. Vanhonacker *et al.* (2008) discovered that farmers did consider certain aspects of an animal's health and welfare including the provision of food, water, medication and good human-animal relationships. The authors felt that the farmers would have based their responses to the questions on expertise and knowledge rather than a perceptual perspective. The farmers in this study did not consider performance of natural behaviours as a prerequisite of animal welfare.

Hemsworth *et al.* (2000) investigated the effects of human – animal interactions and its affect on the productivity of commercial Holstein-Friesian dairy cows. Behavioural observations were conducted at 66 commercial dairy farms with a total of 129 stock-people who handled the cows during milking. They noted that negative interactions between the

farmers and the cattle significantly increased the distress experienced by the cows ($r = 0.37$, $p < 0.01$) which significantly decreased the milk yield ($r = 0.26$, $p < 0.05$). Negative interactions were also significantly reducing the cows' conception rate to first insemination ($r = 0.32$, $p < 0.05$). Dwyer (2009) suggested that the farmer's attitude and behaviour can significantly influence the welfare of sheep. She also suggested that the farmers under-estimated the negative impact that they had on the sheep, and believed that the animals were not scared of them but were respectful. The article concluded that the farmer's attitude towards sheep welfare, along with their subject knowledge, was crucial to increasing the welfare of commercially farmed sheep.

Previous research on lamb fostering has measured percentage success rates and has made recommendations as to whether the practicalities of the method are suitable for use in the lambing regime (Alexander and Bradley, 1985, Alexander *et al.*, 1984, Alexander *et al.*, 1985, Alexander *et al.*, 1987a, Martin *et al.*, 1987, Rubianes, 1992,). However, there are no current studies on the frequency of use of the different methods, nor the farmers' perception of the effects of the methods on ewe welfare or technique choice.

“fostering.....is a far from foolproof technique and very high mortality rates are often recorded in fostered lambs.....decisions to which technique to use can be risky and could have detrimental effects on the health and welfare of the lambs and ewe involved.” (Eales et al., 2004, p199).

This study aims to highlight the methods commonly used in commercially run sheep farms using a sample from around mainland UK. It also intends to gain an insight into the farmers' attitudes towards sheep, with particular reference to the ewe's behaviour and welfare.

2.2 Materials and Methods

2.2.1 Questionnaire Design

The questionnaire was designed to collate farmer's preferences for fostering methods and gather opinions on the implications of these methods for the animal's welfare. A pilot study was carried out to identify methods and potential answers for a variety of questions asked. The study would also highlight any potential areas for improvement and test the validity and feasibility of the questionnaire and distribution methods.

The questionnaire (Appendix 1) consisted of sections relating to general farm and flock information including the number of ewes and rams held, the breed and breed type (including hill, upland, lowland and mixed) and lambing dynamics. Participants were also asked about their preference, frequency of use and measures of success of the fostering methods, using the examples shown in Table 2.1. Their opinions on the fostering process and any animal welfare implications due to fostering were also investigated following a Likert scale design ranging from one to five. These 10 statements were subsequently subjected to a factor analysis:

"I believe animal welfare is important",

"It is important to keep as many lambs alive as possible",

"I have tried a variety of foster methods",

"I think increased animal health will increase returns",

"Fostering is an important way to increase my returns",

“I want to find out about other foster methods”,
“I stick to foster methods that I know about”,
“I want to know the most successful foster methods to increase returns”,
“I always have the animals’ health and wellbeing in mind when fostering”
and “Production levels are on my mind when fostering”.

2.2.2 Questionnaire Distribution

Questionnaires were available from March until September 2008. An online version of the questionnaire, hosted by Moulton College’s virtual learning environment, was made available and advertised by external interest groups, such as the EBLEX and National Rural. To improve access, paper copies were also distributed to mainland UK sheep farmers at farming events such as the Royal Show 2008. Fifty paper copies were then posted to sheep farmers from regions that were unrepresented from an initial evaluation of the responses. This was to ensure that a representative sample of farmers were contacted from different regions, farm types and sheep breeds. Following the ethical guidelines produced by the British Educational Research Association (The British Educational Research Association, 2004) response to the questionnaire was on a voluntary basis. The participants were offered a copy of the study’s results as part of a de-briefing, in accordance with best practice (The British Psychological Society, 2009).

2.2.3 Statistical Analysis

SPSS[®] version 17 (2008) was used for the analysis of all data. Due to the ordinal data, a Kruskal Wallis test was performed to interrogate relationships between the type of foster method selected and the flock type (i.e. hill, upland, lowland and mixed). A Spearman's rho correlation was performed to identify if there was a relationship between the foster method and flock size and Chi-square analysis was used to investigate associations between the frequencies of fostering methods.

Exploratory Factor Analysis (EFA) was employed to evaluate the decision making process for why farmers chose the foster methods that they performed. It was conducted on the 10 statements referring to farmers' attitudes towards fostering (Likert scale), with an oblique rotation (varimax) as the questions were linked and strongly related. This was selected to enable the latent variable, the attitudes of farmers towards the selection of foster methods, to be measured. There were three questions which were highly correlated ($R > 0.9$) and consequently removed from the analysis (Field, 2009), these were "Fostering is important to increase my profits", "I wish to find out about other foster methods" and "Production levels are on my mind when fostering". In total, the remaining seven factors were included in the analysis to create components indicative of the farmers' attitudes towards fostering based on the criterion of having an eigenvalue greater than 1.00. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy and size for the analysis with $KMO = 0.748$ which was well above the acceptable limit of 0.5 (Hutcheson and Sofroniou, 1999).

The KMO value and the Bartlett's test of sphericity ($\chi^2_{21} = 132.91$, $P < 0.001$) indicated that the correlations between items were sufficiently large enough for an EFA to be performed. A paired t-test was then used to identify any differences between the calculated component scores.

2.3 Results

2.3.1 *Fostering Methods and Welfare*

Due to the difficulty in collating the exact number of distributed questionnaires, it is difficult to provide an accurate percentage return rate for them. However, it is estimated that 15% of the questionnaires were returned. Seventy-five responses were collated in total and used in the primary analysis. Fifty-six responses were from 24 English counties, 3 from Wales and 3 from Scotland (Figure 2.1). However, 13 did not indicate their locations and were not included in subsequent analysis. A significantly large proportion of responses managed lowland flocks compared to other flock types ($H_4 = 43.89$, $P < 0.01$). A summary of the different flock types, specific breeds and their prolificacy as reported by the National Sheep Association and the breed societies is listed in Table 2.2.

Ninety-three percent of farmers questioned used some form of fostering within their flock, mainly as a means of managing triplets. Results also showed that 61% of respondents preferred to foster lambs than to artificially rear them or to not interfere with them at all ($\chi^2 = 29.10$, $df = 2$, $p < 0.01$; Figure 2.2). The foster method selected by the farmer was dependant on the flock type being farmed, with lowland and mixed breed sheep farmers using the majority of methods compared to hill and upland sheep ($H_4 = 14.94$, $P < 0.05$, Figure 2.3). However, there was no relationship found between the size of the flock and the type of foster method selected ($\rho = -0.062$, $n = 59$, $P > 0.05$).

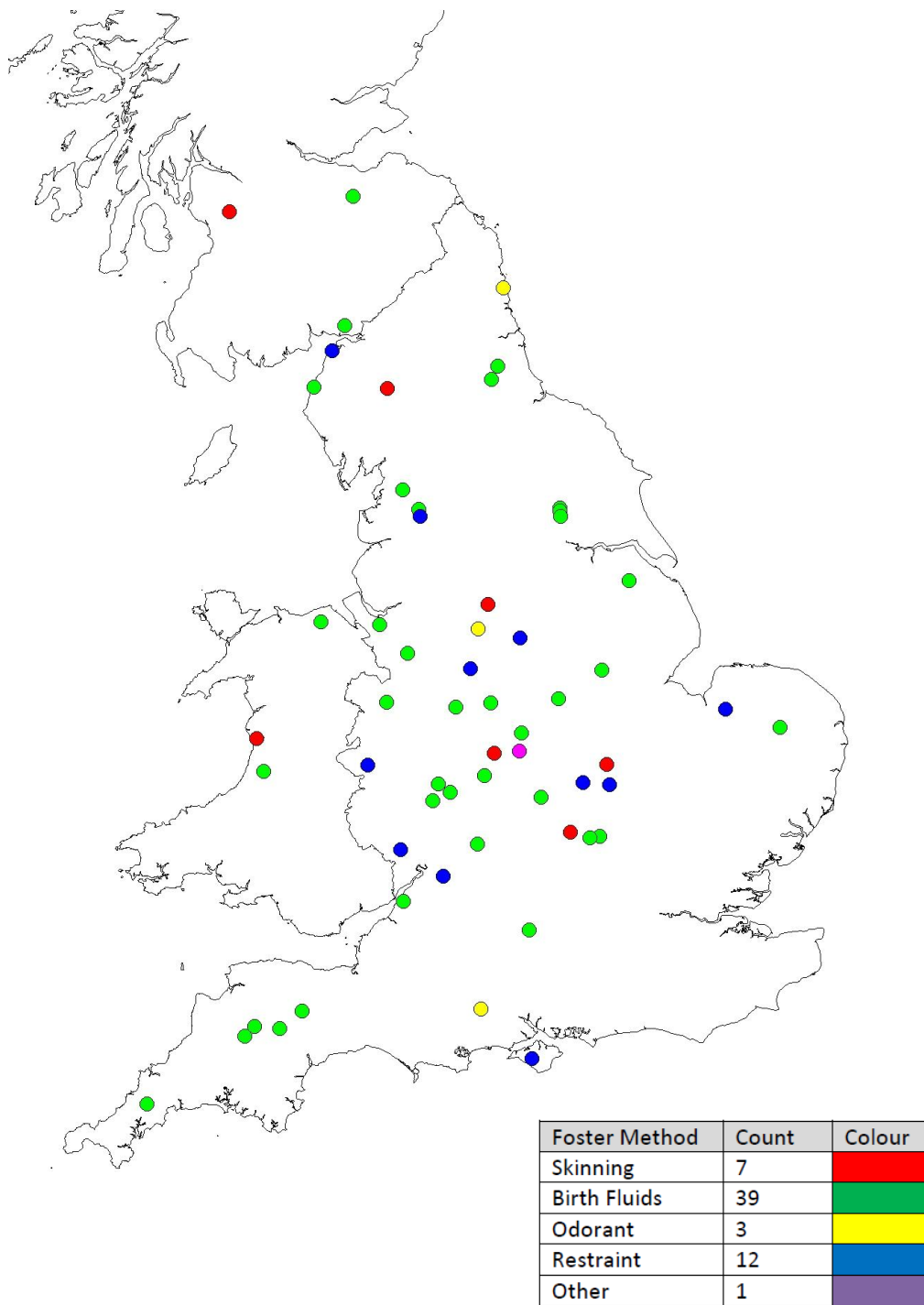


Figure 2.1: Geospatial location of participating respondents.

Table 2.2: Classification of upland, lowland, hill and mixed breed types in accordance to sheep breeds included in the questionnaires. Recorded prolificacy according to the National Sheep Association (1998) and the individual breed associations (personal communication) also reported.

Breed Type	Breeds	Prolificacy as reported by NSA	Prolificacy as reported by breed societies
Hill	Blackface	80 – 125%	100 - 150%
	Swaledale	N/A	100 – 140%
	Welsh Mountain	95 - 130%	150 – 170%
Upland	Blue Faced Leicester	140 - 220%	180 – 190%
	Cotswold	150 – 175%	N/A
	Hampshire Down	110 – 150%	N/A
	Southdown	155 – 200%	150%
	Wiltshire Horn	130 – 150%	150%
Lowland	Beltex	170%	130%
	Charollais	180 – 220%	N/A
	Leicester Longwool	N/A	N/A
	Ryeland	150 – 160%	180%
	Suffolk	158 – 171%	160 – 170%
	Texel	130 – 180%	N/A
Mixed	Vendeen	180 – 200%	180 – 200%
	Mules	N/A	N/A
	Variety of the above on one holding	N/A	N/A

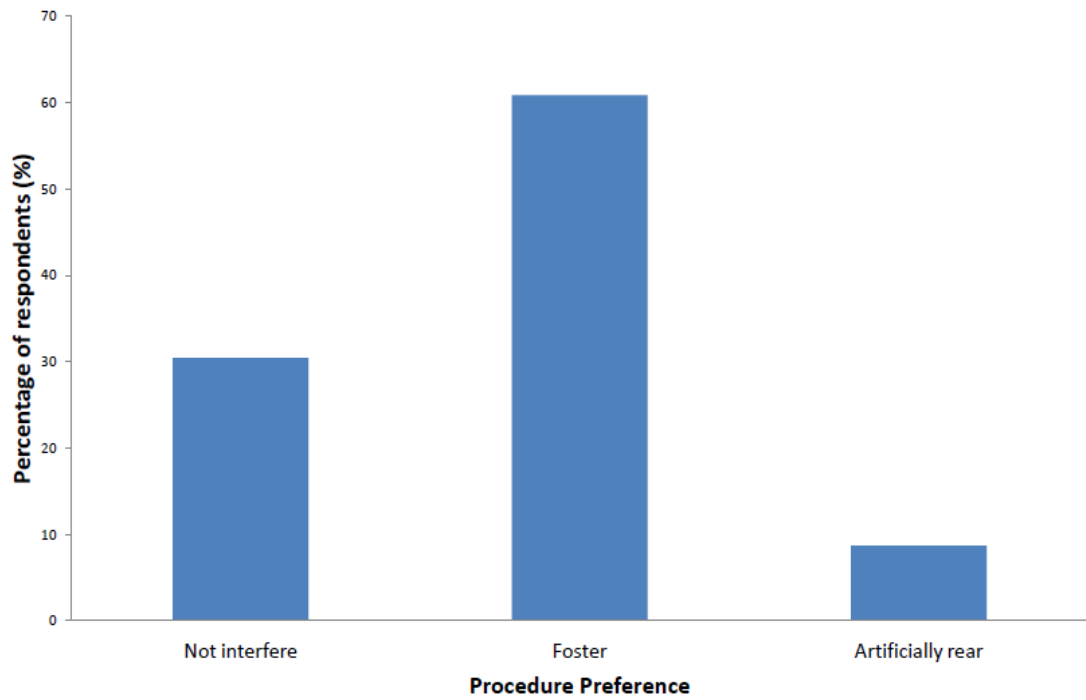


Figure 2.2: The procedure preferences made by farmers faced with a lamb without a mother or a triplet.

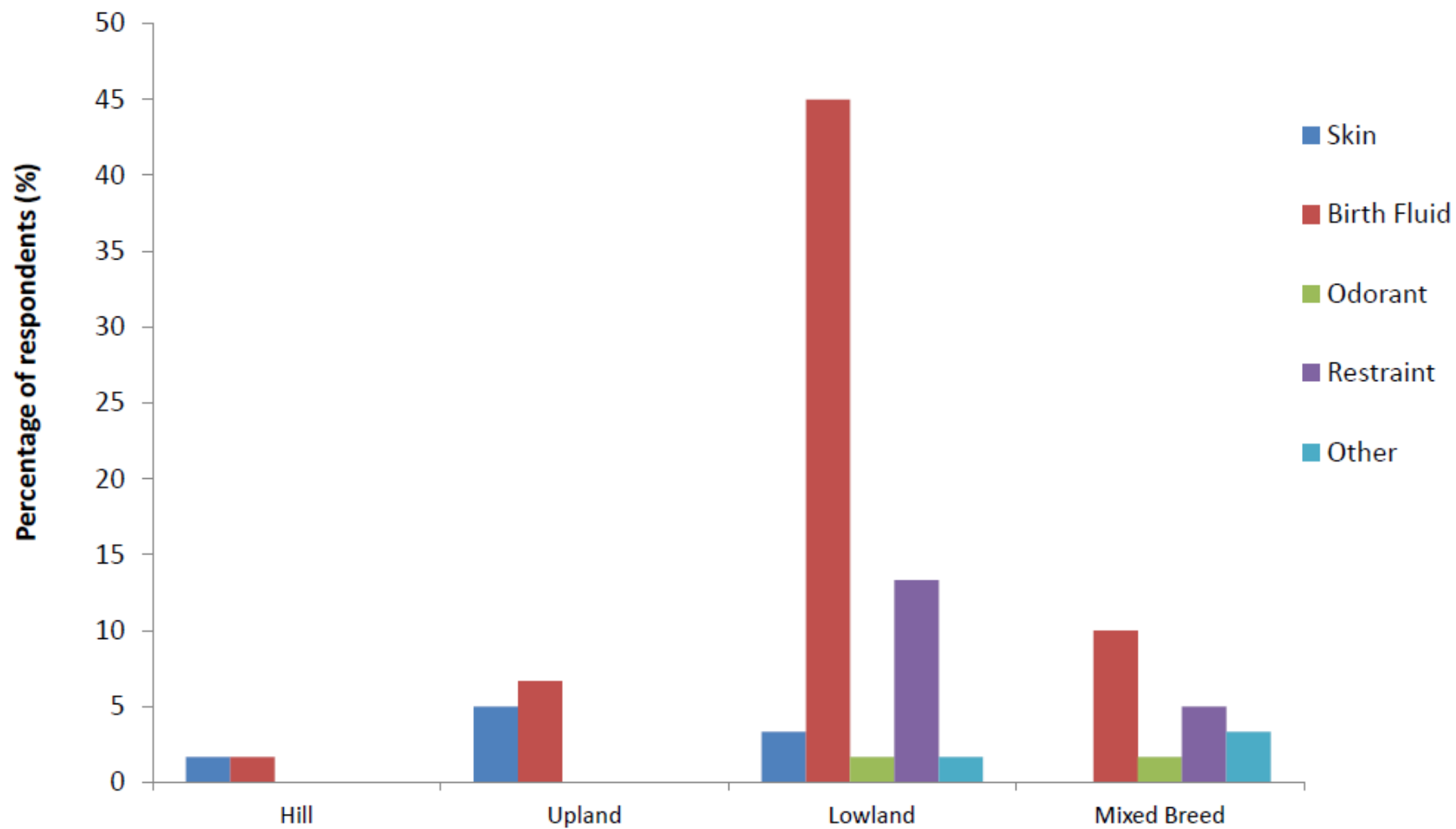


Figure 2.3: Variation of fostering methods selected by farmers in the UK depending on breed type.

The majority of the farmers (62%) stated that if they were to use a single method on its own, they preferred to use birth fluids, 19% of participants preferred to use restraint, 11% used skinning, 5% used odorants and 3% selecting another technique not listed in the questionnaire. Seventy-three percent of the farmers also indicated that they thought that the use of birth fluids was the easiest and thought that the ewe herself would prefer to experience the birth fluid technique compared to others. Textile jackets and cervical stimulation alone were not selected by any of the participants.

52% of the farmers had used a combination of foster methods. Further investigation revealed that cervical stimulation and birth fluids (CSBF) were the most commonly selected combination of methods ($\chi^2 = 36.419$, $P < 0.001$) with 39% of the respondents who combine methods using this combination. Other combinations included birth fluids and restraint (19% of respondents) and skinning and restraint (13% of respondents).

When farmers were asked which lambs they would select to foster onto another ewe, 46% said they would have selected the strongest lamb, 38% would have chosen a lamb of average size and weight, 13% would have selected the smallest of the lambs and the remaining 3% would try to match the fostering lamb to the ewes own lamb.

The questionnaire also investigated techniques which the farmers used to identify a successful foster. Thirty-one percent indicated that they used the behaviour of the ewe alone as a measure, whereas 39% specified that

ewe behaviour and the growth and weight of the lamb are important factors for identifying a successful foster. Other combinations of measures to examine successful fosters were reported but only in small proportions totalling the remaining 30%.

When investigating the farmers' opinions on the welfare implications of the fostering methods, including freedom to perform natural behaviours, mortality and morbidity, 73% of participants indicated that there were implications due to the selection of the appropriate method ($\chi^2 = 47.63$, $P < 0.01$). These were classified as none, slight, medium or high welfare implications, with 59% of farmers indicating that there was a slight welfare issue and that this influenced their overall productivity and therefore returns from the lambing process.

2.3.2 Exploratory Factor Analysis

Two main components contributed towards the farmer deciding which foster method to select and these explained 65.06% of the total variance (Table 2.3). The components were the ewes' health and welfare (including the application of the five freedoms such as their ability to perform natural behaviours, access to food and water, avoidance from pain and discomfort) and farmers' previous knowledge and success of a foster method when selecting one to be used. Table 2.3 includes the pattern matrix used for the production of these two components. When the scores were investigated further, they showed that the farmers used the ewes

health and welfare significantly more than their previous success and knowledge of a foster method when selecting it to be used ($t_{56} = 5.153$, $P < 0.001$).

Table 2.3: Summary of the exploratory factor analysis results showing the Pattern Matrix with principle axis factoring extraction method and an oblimin rotation with Kaiser Normalisation. The Eigenvalue, percentage of variance and Cronbach's alpha score are also provided for the two components.

Questions	Rotated Factor Loadings	
	Health and Welfare	Knowledge and Success
I always have the animals' health and wellbeing in mind when fostering.	0.890	
I think that increased animal health will increase returns	0.835	
It is important to keep as many lambs alive as possible	0.696	
I believe Welfare is important	0.349	
I stick to the foster method that I know about		0.727
I have tried a variety of foster methods		0.695
In want to know the most successful foster method to increase returns		0.518
Eigenvalue	3.22	1.34
% of variance	45.94	19.12
α	0.88	0.70

2.4 Discussion

Although generally an even spread of participants over a variety of locations, there were significantly more lowland flock farmers than any others. This is likely to be due to a small number of respondents from Scotland and Wales where upland and hill farming is prevalent (The National Assembly for Wales, 2010, The Scottish Government, 2010), and the majority of respondents being from 24 English counties where lowland farming is more feasible (Defra, 2010). There was a significant relationship between the breed type and the chosen foster method; which suggests that methods might be selected according to the provisions available soon after parturition and be dependent upon the location of the births. Use of equipment such as adopter crates or odorants might not be feasible if the sheep are left to lamb outside, which is more likely with hill and upland sheep. On the other hand, farmers of lowland and mixed breed flocks make use of the majority of methods including skinning, birth fluids, odorants, restraint and 'other', since lambing in these breeds is carried out in more controlled conditions. However, this could also be because of the lower number of upland and hill farms responding to the questionnaires. Future research focused on these types of farms could investigate this further.

The majority of farmers chose to foster lambs without mothers over the other options available. This could be because farmers want to ensure that all the lambs born are cared for in the most natural way possible. Fostering

makes use of milk which is already being produced by the ewe rather than having to pay for additional milk powder. Farmers may choose to foster in order that the lambs are able to form maternal bonds, which are important for the survival of young lambs (Nowak, 1996), and to save themselves the substantial amount of time and money needed to artificially rear lambs (Eales *et al.*, 2004). This highlights the importance of research into foster method usage on UK farms as it is a technique that is commonly selected by farmers.

A significant proportion (93%) of the farmers used some form of fostering within their flocks, mainly as a result of triplets being born. It is likely that the use of artificial sexual inductors in flocks necessitates the use of fostering to cater for the resulting triplets (Horta *et al.*, 2010).

The highest proportion of farmers (62%) chose to use birth fluids as their chosen foster method. The majority of these farmers (73%) stated that it was the easiest method and was preferred by the ewe due to it being less invasive and restrictive. The second most common method selected was the restraint (19%). This method has been argued to conflict with the ewe's welfare as the pen will become contaminated with faeces and the ewe may be unable to turn around or lie comfortably (Dwyer, 2009). The two most common methods have potentially conflicting consequences on the ewe's welfare. Birth fluid was highlighted by the participants of the survey as a more natural method of fostering, whilst the restraint method was considered artificial and less welfare friendly. The apparent

contradiction demonstrates the complexity of the decision making process that warrants further investigation.

Foster methods involving textile jackets and cervical stimulation alone were not selected by any of the farmers questioned. Success rates for cervical stimulation alone have been reported as 60% which is low compared to other methods (Basiouni and Gonyou, 1988). The additional financial costs involved with purchasing textile jackets could explain the reasons why these methods were not selected by the farmers questioned.

However, when asked if the participants combined more than one method, over half said “yes”, with 39% of these farmers using CSBF. Basiouni and Gonyou, (1988) found that when fostering lambs, CSBF was 80% successful and that the lambs had similar growth rates to weaning the ewes natal lamb compared to other combinations of methods. Keverne *et al.* (1983) also found that success rates were much higher following this method of fostering alien lambs. Both studies concluded that fostering is facilitated by CSBF, thus success could be a reason why the majority of farmers select this combination of methods over all others.

The decision for which lambs to select for fostering onto another ewe were varied with the most common answer being, to foster the strongest lamb and then the lamb of average size and weight. These differences are likely due to the farmers’ personal opinions and based on their previous experience, as there are no guidelines or recommendations for farmers

relating to this topic. Further research in this area would aid farmers in making the correct choice when it comes to selecting a lamb to be fostered.

The novel use of EFA analysis identified two main components which informed the selection of foster methods and these were 'the health and welfare of the ewe' and 'the previous knowledge and success of the foster methods'. These highlight the two main influencing factors that the farmers consider when choosing an appropriate foster method. Results showed that the farmers were more concerned with the animals' health and welfare before they used their personal knowledge and known success rates of that method. This follows similar findings from Morgan-Davies *et al.* (2006), Te Velde *et al.* (2002) and Vanhonacker *et al.* (2008) and highlights farmers' increasing concern for welfare over farming traditions.

Previous research into foster methods classified a successful foster in accordance with the behaviour and time taken to accept the lamb (Price *et al.*, 2003). In contrast, this study found that 39% of the farmers tended to use the ewes' behaviour and lamb weight and growth as indicators to measure fostering success. This demonstrates that the farmers use more than just the health of the animals as an indicator of welfare but also follow behavioural cues performed by the ewes in their assessment.

A high proportion of farmers (73%) commented that foster methods can influence the animal's welfare and acknowledged the impact of this on

their overall returns. This suggests that farmers are aware of the potential problems relating to the animals undergoing negative experiences and how this may influence the animals' productivity (Dwyer, 2009, Hemsworth, 2003). The idea also links to findings from Vanhonacker *et al.* (2008) who found that the farmers' perspective of animal welfare was linked to animal growth and satisfactory productivity.

The farmers included in the study were animal welfare conscious, measuring foster success in terms of the ewe's expression of positive and negative behaviours and the progression of the lamb's growth and weight rather than just the animal's health. They also considered the selection of foster methods based on the ewes' health and welfare during the process and their own previous success rates and knowledge of the foster method; the former of these two considerations being more influential than the latter.

2.5 Conclusion

Fostering is an important part of the lambing process and the method selected by UK farmers was believed to influence the returns from their flock due to the welfare constraints associated with certain methods. With the increase in production, the use of foster methods could help to ease the pressure.

In the conditions of the study most respondents were farming in England which explains why the majority of farms were classified as lowland. There were a large proportion of farmers that used foster methods routinely in this flock type. The ewes' health and welfare was the predominant factor in how the farmers selected foster methods to use on their flock. This indicates that farmers were concerned about animal welfare as determined by behavioural indicators and that they considered welfare on a regular basis when assessing the fostering success.

The welfare and production implications associated with the most commonly used fostering methods in current sheep farming practice need to be investigated further. This will provide commercial farmers with up to date information that can help them to increase their returns from the lambing period. The second stage of this research will investigate the welfare implications associated with the most commonly selected foster methods in terms of behavioural and physiological effects on the animals.

CHAPTER III

The Behaviour and Welfare of Ewes Undergoing Different Fostering Methods

3.1 Introduction

The growth and development of any ewe-reared lamb is largely dependent upon the maternal care provided by the ewe (Burfening and Kress, 1993) and strongly linked with the bonds which are formed within the first few hours after birth (Levy, 2002, Shayit *et al.*, 2003). These bonds are aided by the suckling of the lamb and postnatal vocal communication including specific low-pitched bleats emitted by the ewe (Alexander, 1988, Nowak *et al.*, 1997, Shillito and Hoyland, 1971). It has been suggested that the low pitched bleats orient that lamb towards the ewes' body and also provide cues for later recognition of the dam (Nowak *et al.*, 2000). Olfactory cues are important for the ewe to recognise her lamb, however, it was suggested that they are not as important as visual or vocal cues in order for the lamb to initially recognise the ewe (Vince and Ward, 1984).

3.1.1. Ewe-Lamb Recognition

Dwyer *et al.* (1998) described the two characteristic vocalisations, the low pitched bleat being more of a "rumble" sound that is emitted from the ewe with her mouth closed and the high pitched bleat being more of a distress call made with the ewe's mouth open. Dwyer and Lawrence (1998) studied the rate of low-pitched and high-pitched vocalisations between MP and PP Scottish Blackface and Suffolk ewes. They found that PP ewes performed more low pitched bleats than MP and that Suffolk ewes were more likely to abandon and be aggressive towards their lambs. Blackface ewes were

more attentive and performed significantly more positive maternal behaviours than Suffolk ewes. They also found that when the litter size was increased or lambs of a different breed were being reared, there was no effect on the low pitched bleat rate; this may be beneficial for fostering. High pitched bleats were also found to be emitted more frequently in PP ewes compared to MP ewes. They explained that PP ewes may perform more high pitched bleats due to their inexperience which could lead to slower bond formation between the ewe and lamb.

Sèbe *et al.* (2008) also investigated the role of acoustic communication on the maternal behaviours performed by Il-de-France ewes. They found that mother-young vocal communication is biologically relevant at the time of nursing, ensuring that the appropriate care is directed towards the ewe's own lamb. They suggested that vocal communication and nursing are strongly associated and are to develop stronger maternal bonds between the ewe and lamb. Sèbe *et al.* (2010) further suggested that low-pitched vocalisations are crucial for the onset of maternal care from the ewe and for filial preference before cues such as high pitched bleats can be used for recognition. Nowak *et al.* (1997) believed that the maternal bonds were emphasised by the positive reinforcement that both the lamb and ewe experience from suckling.

Olfactory cues have also been considered vital for the bonding process, which begins when the ewe grooms the new-born lamb and smells the amniotic fluid (Nowak *et al.*, 2000). Levy *et al.* (1983) investigated the

ewes' behaviour towards amniotic fluid throughout the oestrous cycle, gestation and parturition and found that only after parturition were they attracted to amniotic fluid. The strength of this attraction was demonstrated by Levy and Poindron (1984) who indicated that the use of any ewes' amniotic fluid would induce maternal acceptance compared to the absence of it or if the lambs were coated in just water. They concluded that the origin of the amniotic fluid, whether from the focal ewe or from an alien dam, had no reliable effect on maternal acceptance and that the function of the amniotic fluid was a means to stimulate maternal behaviours rather than to aid recognition.

Otal *et al.* (2009) and Poindron *et al.* (2010) prevented MP and PP ewes from physical contact (olfactory and auditory contact was still present) with their own and alien lambs for a period of four hours immediately after parturition and discovered that this impaired the establishment of maternal selectivity. MP ewes performed significantly more acceptance behaviours, including low-pitched bleats, and acceptance of the lamb under the udder when reunited with their own and alien lambs than ewes not undergoing separation. PP ewes on the other hand were more likely to reject their own and alien lambs after being reunited due to their inexperience. These studies suggest that the presence of amniotic fluid is initially important to encourage inexperienced ewes to groom and nurse their lambs but also that the fluid must be linked to the recognition and, therefore, maternal selectivity of ewes.

Wyatt (2010) suggested that each ewe may possess an “odour signature” which coats the lamb and this provides a final assurance that the ewe was enabling its own lamb to suckle. Alternatively, other authors suggest that it could be the lamb’s wool and skin supporting its own odour through different volatile organic compounds (Brennan and Kendrick, 2006). Burger *et al.* (2011) identified 133 volatile organic compounds in Dohne Merino lambs which were then tested for ewe recognition. The results were relatively inconclusive suggesting that there was likely to be other cues that were linked to ewe recognition when confronted with a decision to accept or reject a lamb. Difficulties in isolating the lamb volatile organic compounds from visual or vocal cues may have hampered the experimental design impacting the results also suggesting that it may be a combination of factors that enable recognition.

Nowak *et al.* (2011) suggested that lamb recognition is initially linked to the olfactory and this gradually declines in importance as the lamb reaches one week old, with other methods of recognition taking over. Kendrick *et al.* (1996) investigated the ability of fifteen MP Clun Forest ewes to discriminate between their own and alien lambs using black and white photographs in a Y-maze. This method ensured ewes were only able to use visual cues but took six months to train them on how to use the system. Only one ewe was able to reach the 80% choice criterion after a period of two weeks, which increased to 10 individuals after three weeks of training. The results were surprising considering ewes could discriminate between adult ewe images in a matter of days. A breed effect was

suggested to be affecting the experiment as the lambs' heads were predominately black and approximately 30% smaller than the size of an adult head. This point was confirmed by the fact that ewes struggled to distinguish between adult ewe images when the photographs were reduced by 25% of their normal size (Kendrick *et al.*, 1996).

Keller *et al.* (2003) investigated the ewes' use of olfactory cues, and then visual and auditory cues combined, to enable discrimination between familiar and unfamiliar lambs. Results showed that both MP and PP ewes were able to identify their own lambs due to olfaction as early as 30 minutes postpartum, highlighting no difference due to maternal experience. There was, however, a difference due to experience when using the visual and auditory cues. MP ewes were able to select and make preference for their own lamb six hours postpartum whereas PP ewes took up to 24 hours. It was concluded that both types of recognition (olfaction and visual/auditory) were vital for the discrimination between natal and alien lambs. However, these may be used at different stages during the maternal bonding. The ewes' maternal experience may also have differential effects on the dynamics of their learning process.

3.1.2. Fostering

Fostering techniques have been used to increase the number of lambs suckling on ewes producing singlet's (Alexander *et al.*, 1987a). Some of these methods involve minimal interference (e.g. birth fluids) but still could

pose a possible threat to the ewe-lamb bond, due to the intervention from the shepherd which could impact on olfactory cues or general disturbance. Fisher and Mellor (2002) suggested that the movement of ewe and lambs away from the birth site or the presence of moving objects, including a vigilant shepherd at parturition could cause disturbances to the bonding process and therefore potential problems.

Restraint fostering (R) involves the placement of the ewes' head behind a stanchion restricting her movement and ability to lick or smell the lambs (Alexander and Bradley, 1985, Price *et al.*, 1984a; Figure 1.3a and 1.3b, pp 40). This type of fostering would reduce the ewe's ability to recognise an alien lamb using olfactory and visual cues and could cause detrimental effects to the vital bond formation.

Otal *et al.* (2009) investigated whether deprivation of maternal behaviours initially after parturition had an effect on the ewes' ability to recognise their own and alien lambs. 56 MP and 44 PP Ile de France ewes were either able to interact freely with their lamb (control) or unable to physically contact their lamb for a period of 4 hours postpartum. Results showed no significant differences between the treatment groups of MP ewes accepting their own lambs (100% in each treatment). MP ewes rejected a high proportion of alien lambs overall but accepted significantly more when physical contact was restricted. Results for PP ewes did show different acceptance rates for their own lambs according to the different treatment groups with the higher proportion of acceptances coming from the control

group. There was no difference in the number of alien or natal lambs accepted when the PP ewes were unable to contact them. Both MP and PP ewes behaved differently towards the alien lamb than their own lamb, with fewer low pitched bleats and lower udder acceptance durations seen, more aggressive behaviours and more high pitched bleats observed. Otal *et al.* (2009) concluded that the inability of the ewes to physically contact their lambs could aid the fostering of alien lambs for both MP and PP ewes but it is unlikely to be practical on a large commercial scale due to the shepherd's time constraints and the space needed for the separations to take place. This research demonstrated that slowing down the bonding process initially after parturition could impair maternal selectivity. However, this was after a separation period of just 4 hours, and afterwards ewes and lambs are able to behave and interact as normal. In a commercial setting the ewes remain within the restraint crates for a period of 4 to 9 days which could potentially be detrimental to the ewes and lambs' health, welfare and maternal bonding (Alexander and Bradley, 1985).

Previous results (Chapter 2) have shown that the most commonly selected foster methods by UK shepherds were birth fluids (BF) and restraint (R). The most commonly selected combination of methods was cervical stimulation plus birth fluids (CSBF, see chapter 2, Table 2.1, pp 71). The differences between the ewes' ability to perform maternal and maintenance behaviours between BF and R justify the importance of investigating the welfare and behaviour of the ewes and lambs experiencing them. CSBF is a combination of methods that requires some

interference by the shepherd but not as intensive as the restraint method and may provide a middle ground as an effective, yet minimally invasive method of fostering.

The aim of this study was to evaluate the behaviour and welfare issues associated with BF, CSBF and R methods. Measures of ewe welfare are extremely diverse and it is now more common to involve the use of both behavioural and physiological measures to increase accuracy of the data interpretation for researchers and farmers alike (Table 1.1, pp 24). Therefore, alongside behavioural data, heart rate and saliva cortisol will be analysed to enhance the understanding of any effects.

As discussed in section 1.2.1.2 (pp 15), the use of saliva as a measure of cortisol response has been used in a range of different species (Perez *et al.*, 2004, Ruis *et al.*, 1997). Results supported that once a species and substance were validated it can be an appropriate measure to use for assessing welfare and that saliva cortisol levels closely matched plasma cortisol in sheep (Mormède *et al.*, 2007, Yates *et al.*, 2009).

3.2. Materials and Methods

3.2.1 Subjects, Housing and Husbandry

One thousand North Country mule ewes were split into two flocks (for winter and spring lambing). Ewes were mated and grazed outside until approximately 4 weeks prior to the estimated parturition dates when they were housed together in large covered pens according to their pregnancy scan results creating three groups; singlets, twins or triplets (Ewe area 1, 2 or 3, as shown in Figure 3.1). They were given a food mixture consisting of home grown maize silage and concentrate on an *ad lib* basis in accordance to recommendations provided by the farm management.

84 ewes were monitored during two lambing seasons (Spring 2009 and 2010) for the period of the current experiment. Ewes were classified as either MP (n = 48) or PP (n = 36) and were balanced over the two years of data collection.

3.2.2 Lambing and Fostering Procedure

At lambing, ewes were left to complete parturition on their own unless they experienced difficulties in which case an experienced shepherd aided the delivery.

Each ewe and its' lambs were relocated to an individual pen within four hours of parturition where interference from other ewes was avoided and maternal bonds between the ewe and lambs could be better established. After approximately 210 minutes post birth, the lambs were routinely checked, had their navels coated with iodine to prevent infection, treated with Spectram Scour Halt (CEVA Animal Health; France) for watery mouth and their ears tagged with information recorded onto the farm's records. This followed the farm's standard procedure and lambing protocols.

Lambs being born in lambing areas two or three (Figure 3.1) were prime candidates for the fostering experiment. When a ewe mothered a single lamb, they were carefully moved into a smaller pen within Fostering Area 1 (figure 3.1). If a triplet or orphan lamb was available, it was also moved into the pen and a fostering method was applied. Foster methods were chosen at random with a maximum of 30 minutes post parturition that they were carried out. Each individual pen within any of the Fostering Areas was identical in size (1520mm x 1140mm) and BF and BFCS (detailed technique explained below) treatments were applied on them. For the R

treatment, special restraint crates (figure 1.3a and 1.3b, pp 40) were used, which measured 1200mm x 1100mm.

Both natural and alien lambs were sprayed on the back of their necks and at the base of their tails with different coloured sheep marking sprays. Fosters were monitored every 15 minutes to identify any lambs being rejected. The foster was classified as a success if the lamb was able to suckle from the dam for a minimum period of 8 seconds without being repeatedly moved away (via butting or ewe withdrawal; Table 3.1).

A maximum of 4 hours after the 'time of foster', the ewe and lambs were moved to the individual post-lambing pens which were the same size as the fostering area pens (Figure 3.1). This allowed space within foster areas to be free for new individuals. Fostering pens were then disinfected and re-bedded with fresh straw before the allocation of another ewe and its lamb's occurred. This cleaning protocol was in place to ensure appropriate levels of hygiene during lambing, but also to eliminate any olfactory cue from previous ewes or lambs.

A random sample of 24 ewes (12 primiparous and 12 multiparous) were selected from the group of ewes scanned as twins and used as controls. They were directly moved to the individual post-lambing pens, and all protocols were followed as for the fostered groups.

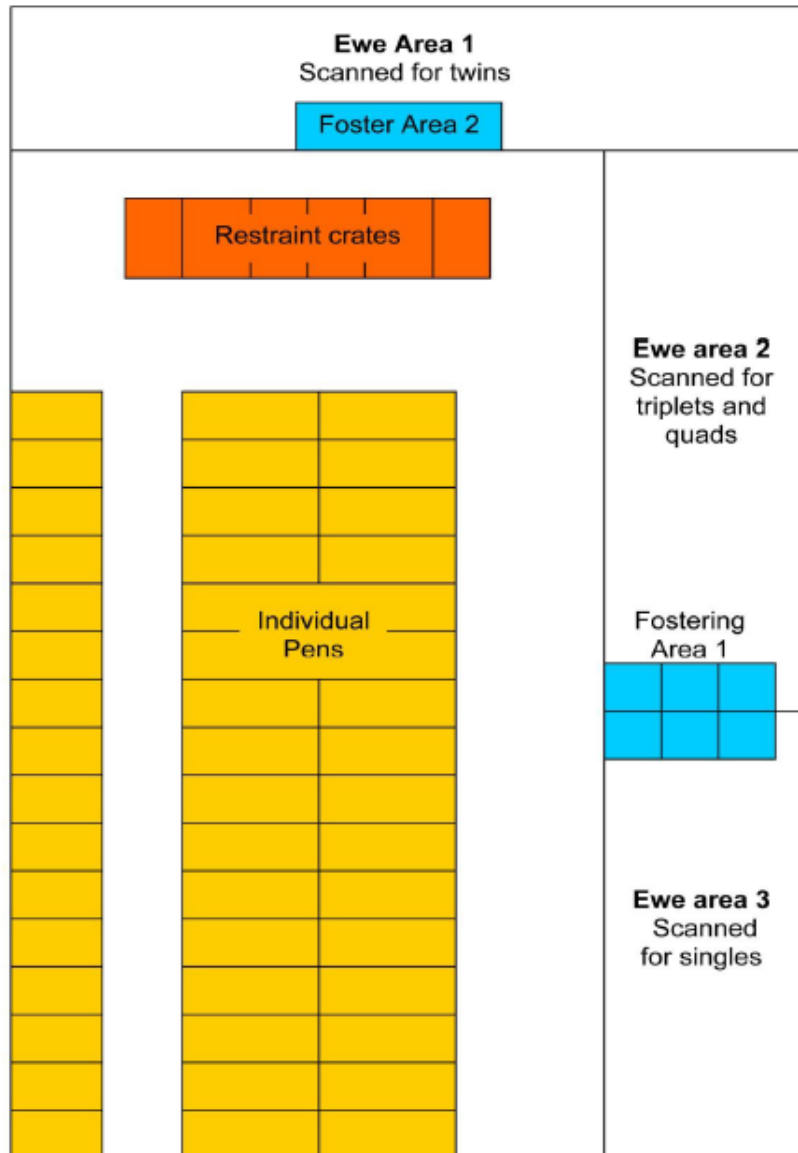


Figure 3.1: Lambing shed layout at Moulton College, Moulton. Showing the distribution of different working areas: ewe pre-lambing areas (according to pregnancy scan results), fostering areas and individual post-lambing pens (where ewes and lambs were moved approximately 4 hours after birth).

3.2.2.1 Birth Fluids (BF)

Once at the fostering pen, the birth fluids emitted from the fostering ewe were used to coat the alien lamb (a triplet, quad or orphan lamb). This process was carried out at the rear of the ewe with both lambs present and rubbed together to ensure both of them smelt as similar as possible. Lambs were then brought around to the front of the ewe and the group was left alone to avoid distressful interferences.

3.2.2.2 Birth Fluids and Cervical Stimulation (CSBF)

Once the fostering group has been moved to the fostering pen, the shepherd gently pushed his hand into the cervix of the fostering ewe and simulated contractions by opening and closing the hand at ten seconds intervals. After three minutes, the shepherd coated both lambs with the ewes' birth fluids (as explained above) and then brought them around to the front of the ewe before leaving the fostering pen. Due to ethical implications, CSBF was not performed on PP ewes as per the farm's lambing protocol.

3.2.2.3 Restraint (R)

The ewes were moved into the restraint pens and their heads were restrained by the neck (Figure 1.3a and 1.3b, pp 40). The lambs were then placed inside the crate, behind the ewe's head restraints. The restraint crates allowed the ewes to lie down, to stand and have access to food and

water. However, they inhibited the ewes' ability to see and smell the lamb in order to hide the lambs' identity. The ewes were left in the crates for a maximum of 5 days depending on their level of acceptance of the lamb and the lamb's ability to successfully feed. Acceptance was monitored by watching for a lack of negative behaviours performed by the ewe such as kicking or attempting to move teats away from the lamb and the lambs' ability to successfully suckle for a minimum period of 8 seconds once the animals were removed from the crate. The ewe and lambs were then relocated to the individual pens as per other foster methods. The use of restraint crates is common practice during lambing time and on this basis, were approved by the ethics committee to study.

3.2.3 Data Collection

Successful fosters were only included in the study if they took place between the hours of 07.00 and 13.00. This was to ensure that, differences in physiological patterns, circadian rhythms and daily activity budgets were kept to a minimum.

3.2.3.1 Behavioural Data

Three DVD cameras (Sony Hybrid Handycam, Model: DCR-DVD110E) were positioned over each individual fostering pen and the restraint crates (Figure 3.2). Continuous focal recordings were taken at three different time periods (twenty minutes each) to record behaviours performed by both the ewe and lambs (Table 3.1). The recordings took place at the time of foster

(0mins), 60mins and 180mins post foster. These time frames were chosen to allow a good spread over the initial period of the foster before the ewe and lambs were to be moved to the individual pens and to allow for medical care to be performed. This also reduced the amount of disruption ensuring that the ewe and lambs were able to bond and behave normally. The objective was to assess the initial fostering period where negative behaviours such as those mentioned in Table 3.1 were most likely to occur.

Table 3.1: Ethogram used to establish the positive, negative and maintenance behaviours performed by ewes soon after parturition. Adapted from Dwyer & Lawrence (1998). Where +ve = a positive effect and –ve = a negative effect.

Behaviour	Effect	Description
Grooming alien lamb	+ve	Licking and nibbling movements on the alien lamb's body.
Sniff alien lamb	+ve	Ewe places nose against or on alien lamb, no evidence of grooming
Facilitates sucking (alien lamb)	+ve	Ewe crouches, turns one hind leg out to aid alien lamb sucking.
Pawing alien lamb	+ve	Movement of front leg towards or on the alien lamb to encourage it to move or stand.
Maintenance of non-alien lamb	+ve	Licking, nibbling, sniffing, pawing and/or facilitating suckling of the non-alien lamb.
Low pitched vocalisation	+ve	Ewe makes bleating noise in a low pitch or 'rumble' sound with mouth closed; approx 110-140Hz (Sèbe <i>et al.</i> , 2010).
High pitched vocalisation	-ve	Ewe makes bleating noise in a high pitch with mouth open; approx 141-170Hz (Sèbe <i>et al.</i> , 2010).
Prevents suckle (alien lamb)	-ve	Ewe repositions itself as alien lamb attempts to suckle, three possibilities: <ol style="list-style-type: none"> 1. Circling: ewe moves hind quarters away from the alien lamb 2. Backing: ewe moves backwards away from alien lamb 3. Forwards: ewe steps forwards over the top of the alien lamb
Foot stamp	-ve	Front leg used to strike the ground in a quick and aggressive manner (Houpt, 1998) not to move hay around before resting.
Butt towards alien lamb	-ve	Ewe pushes alien lamb down or away with a downwards, sideways or forwards movement of its head.
Urinate	-ve	Ewe passes water
Escape	-ve	Ewe attempts to or is successful in removing its head and/or body from the enclosed pen or restraint stanchion.
Rest	N/A	Lying down either sleeping or chewing cud
Locomotion	N/A	Slow, leisurely movement around the holding pen. Or movement of legs and body from side to side within restraint crate, no force applied or attempt to remove head from the stanchion.
Stationary	N/A	On all four feet while not eating, drinking, exhibiting other motor behaviours or being vigilant.
Scratch	N/A	Movement of body part leaning against surrounding fencing
Drink	N/A	Consumption of water
Feed or forage	N/A	Consumption of hay or pellets
Vigilance	N/A	Head position focused toward surrounding area, ears pricked up, can be lying or standing
Shake	N/A	Ewe moves vigorously from side to side without movement of its feet to remove straw or debris from its fleece.



Figure 3.2: Fostering area 1, showing an experimental pen being set up for behavioural observations at Moulton College Farm, Moulton (Photo: Mawson, 2011).

3.2.3.2 *Physiological Data*

Heart rate monitors (Polar Electro Oy, Model: C0357) were attached around the ewe (immediately behind the ewe's fore-limbs) at the time of foster and left in place until the ewe and lambs were relocated to the individual pens. Ultrasound gel was applied to the sensors of the monitor and held in place using an elastic band supplied with the monitor. Each ewe's heart rate was recorded for a period of three minutes per session. Measurements were then averaged to provide a mean heart rate at that particular session. Sessions were 0, 30, 60, 90 and 180 minutes post foster. These intervals were coincident with the time just before and after the behavioural observations.

Approximately 5ml of saliva was collected once the heart rates had been recorded at every time point for cortisol analysis. A cotton swab was pinched between a pair of tweezers, the ewe's head carefully restrained (Figure 3.3) and the tweezers inserted into the side of its mouth. The swabs were gently moved around the inside of the ewe's mouth for thirty seconds and removed. The swab was then transferred into a clean centrifuge tube containing a pipette tip which helped to separate the saliva from the swab during centrifugation. Samples were stored at 3 - 4°C before being spun at 1500 rpm for 20 minutes. The swab was then removed and the remaining sample pipetted into an eppendorf safe-lock tube, labelled and stored at -20°C until further testing.



Figure 3.3: Sample collection for the salivary cortisol analysis. Ewe held in a restraint crate with head gently restrained and swab inserted into the side of the mouth and slowly rubbed for 30 seconds (Photo: Mawson, 2011).

3.2.3.3 Cortisol Enzyme Immunoassay (EIA)

Cortisol concentrations were measured in all viable saliva samples using the EIA technique at Chester University, developed and validated for use in *Ovis aries*' saliva, modified from a cortisol EIA previously described by Smith and French (1997) and Setchell *et al.* (2008). Validation tests consisted of specificity, accuracy, precision and biological validations. The specificity of the technique was estimated by comparing a dilution series of the pooled sample against the standard curve (a dilution series of pure cortisol). To evaluate the accuracy, the percentage recovery of cortisol concentrations added to saliva samples without cortisol was calculated. The precision of the technique was assessed using intra-assay coefficients of variation.

For the cortisol concentration readings, the antibody R4866 and the steroid, horseradish peroxidase, were diluted in EIA phosphate buffer solution 1:12,000 and 1:22,000 respectively. Each cortisol measurement required 150µL of saliva per repetition (n = 3). The Dynatech MR5000 microplate reader was used to read the cortisol concentrations at 405nm. Results from the specificity, accuracy, precision and biological validations are to be published by Coleman *et al.*

3.2.4 Statistical Analysis

3.2.4.1 Behavioural Analysis

SPSS[®] version 17 (SPSS Inc, 2008) was used for the statistical analysis of all data. Only fosters that were classified as successful were included and followed in the experiment. This was in accordance with the ethical procedures assessed prior to data collection. The behaviours 'grooming', 'facilitating suckling' and 'sniffing' were pooled together and classified as time spent with the lamb. Behaviours including 'butt', 'escape attempts', 'stamp foot' and 'prevent suckle' were pooled together and classed as negative behaviours. Other behaviours were treated individually. Data for MP and PP ewes were treated separately rather than pooled together and percentage time budgets were calculated for analysis and graphical representation.

All behavioural data were checked for normality and homogeneous of variance using Shapiro-Wilk test and Bartlett's test respectively. Only the time spent with the alien and natal lamb data proved to be normally distributed and was treated accordingly (see below). All other behavioural data was established as not normally distributed. Logarithm, square-root and reciprocal transformations were attempted, however the data still violated normality assumptions and therefore non-parametric tests were performed. Kruskal Wallis tests were performed to investigate any differences in the performance of behaviours due to the different foster methods. Mann Whitney U tests were used to evaluate positive and

negative behavioural differences between MP and PP ewes. Relationships between the high pitched and low pitched bleats and the time spent with alien and natal lambs were explored using Spearman Rho correlations.

When investigating the time spent with the alien or natal lamb according to foster method and ewe experience, a repeated-measures ANOVA was used, with time as the repeated variable (0, 60 and 180 minutes post-foster) and the lamb (alien or natal) as the between-subject factor.

Due to the inability to attend to their lambs, the restrained ewe data was analysed separately, grouping all positive behaviours together. Data was analysed following the same model as previously mentioned for the foster methods and ewe experience.

3.2.4.2 Physiological Analysis

MP and PP data were analysed separately. Cortisol and heart rate data for both MP and PP ewes were deemed to be parametric. Therefore, ANOVA's were performed to identify differences within each time frame between the foster methods for cortisol and heart rate data to identify differences within each session rather than across the entire range of data collected.

3.3. Results

3.3.1 Behaviour

3.3.1.1 Fostering Effect

The foster method did not significantly affect the percentage time which PP ewes spent drinking ($H_2=1.748$, $p>0.05$), feeding ($H_2=1.408$, $p>0.05$) or moving around ($H_2=1.515$, $p>0.05$). Results suggested that the PP restrained ewes spent significantly more time performing negative behaviours ($H_2 = 21.794$, $P<0.001$), urinating ($H_2 = 9.099$, $P<0.05$), being vigilant ($H_2 = 18.680$, $P<0.001$) and standing still ($H_2 = 9.420$, $p<0.01$) than the other foster method treatments. The PP control ewes spent significantly more time resting when compared to the R and BF ewes ($H_2 = 9.023$, $p<0.05$; Figure 3.4).

Figure 3.4 shows that foster method did not significantly affect the percentage of time that MP ewes spent resting ($H_3 = 4.376$, $p>0.05$), feeding ($H_3 = 0.938$, $p>0.05$), drinking ($H_3 = 4.204$, $p>0.05$), stationary ($H_3 = 5.955$, $p>0.05$) or moving around ($H_3 = 4.523$, $p>0.05$). However, the MP restrained ewes performed significantly more negative behaviours (including butting, escape attempts, stamping; $H_3 = 31.504$, $p<0.001$) and spent significantly longer urinating ($H_3 = 27.066$, $p<0.001$) and being vigilant ($H_3 = 14.313$, $p<0.01$; figure 3.4) than the rest of the foster methods. The MP control ewes spent significantly more time resting when compared to the R and BF ewes ($H_2 = 9.023$, $p<0.05$; Figure 3.4).

Figure 3.5 shows how the emission low and high pitched bleats were significantly affected by the foster treatment. MP and PP ewes undergoing the restraint technique emitted significantly less low pitched bleats ($H_3 = 21.276$, $p < 0.001$; $H_2 = 15.999$, $P < 0.001$ respectively) and significantly more high pitched bleats ($H_3 = 25.654$, $p < 0.001$; $H_2 = 13.414$, $P < 0.01$ respectively) than control and BF in the case of PP ewes and also including CSBF ewes when comparing MP ewes.

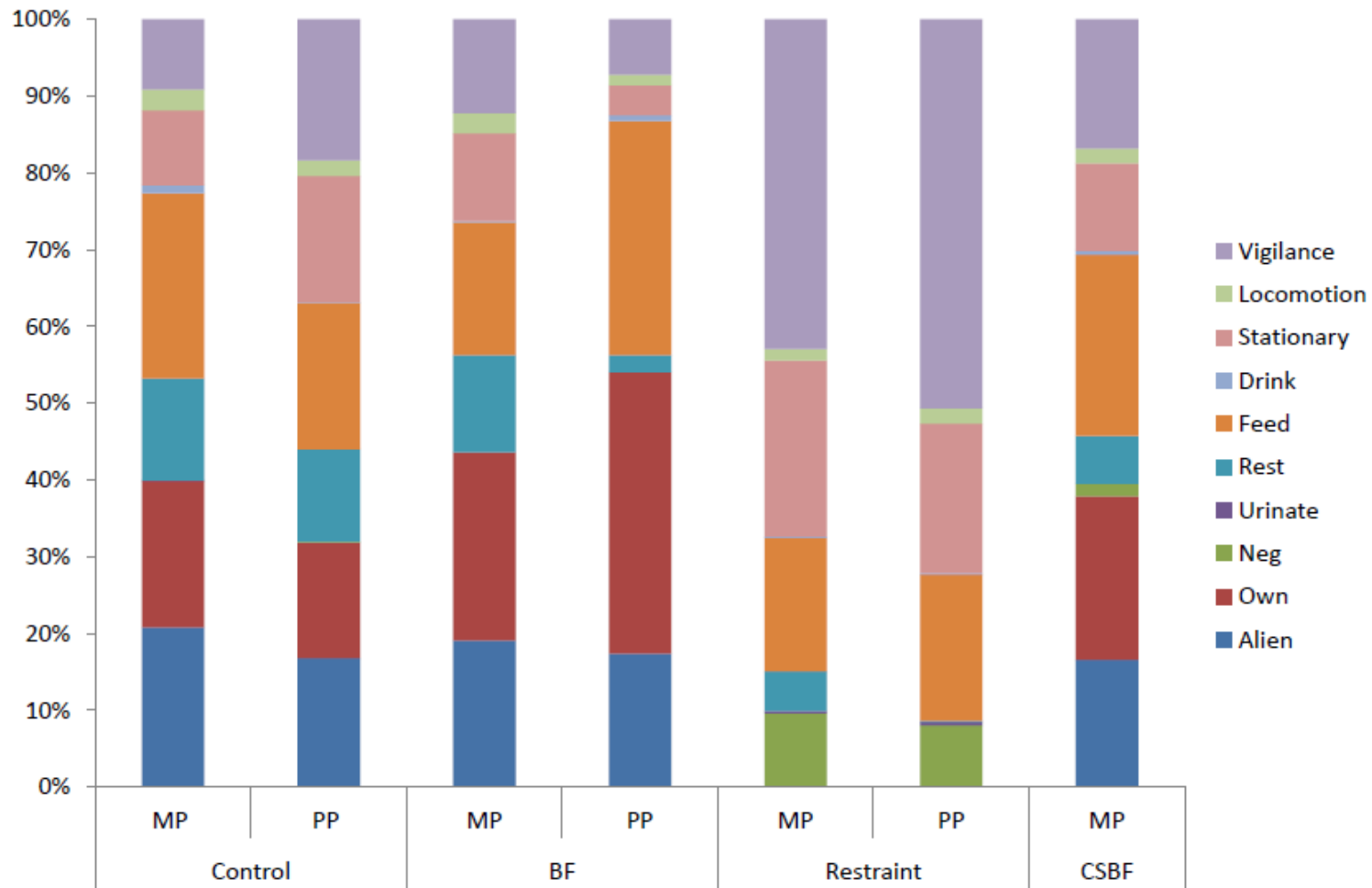


Figure 3.4: Percentage time budgets for multiparous (MP) and primiparous (PP) ewes according to foster methods. BF = Birth Fluids, CSBF = Cervical stimulation and birth fluids.

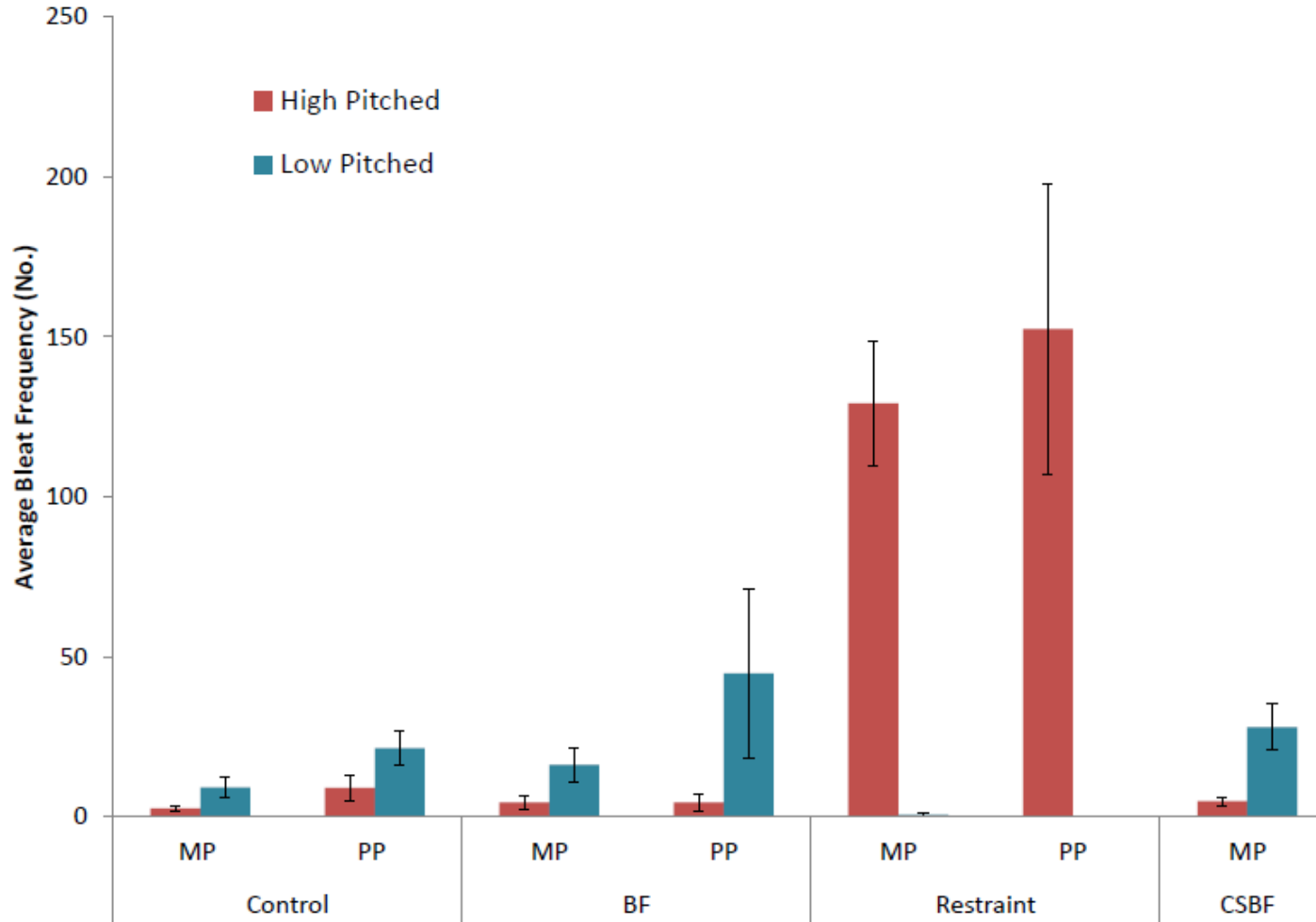


Figure 3.5: The mean (\pm S.E) high pitched and low pitched bleat frequencies that primiparous (PP) and multiparous (MP) ewes. BF = Birth Fluids, CSBF = Cervical stimulation and birth fluids.

3.3.1.2 Parity Effects

When comparing parity effects within a foster method, there were found to be no significant differences between the amount of time the PP and MP ewes spent performing all maternal and most maintenance behaviours (Figure 3.4). The PP control ewes however spent significantly longer being vigilant compared to MP ewes ($Z=2.339$, $p<0.05$).

3.3.1.3 Time Spent with Lamb

The control group of ewes within both the PP and MP groups showed that they distributed their time evenly between the both lambs ($F_{1,24} = 0.429$; $F_{1,24} = 0.404$ respectively). All MP CSBF ewes and the PP BF ewes also showed no significant differences between the time dedicated to the natal or the alien lamb ($F_{1,24} = 1.029$; $F_{1,24} = 1.513$ respectively).

Results however for the MP BF ewes indicated that overall, the percentage of time that was spent with its' natal lamb was significantly higher than the alien lamb ($F_{1,24} = 11.585$, $p<0.01$; Figure 3.6). There was a significant effect of the post foster time on the percentage of time spent with the natal or alien lamb ($F_{2,40} = 17.904$, $p<0.001$) indicating that as time progressed, ewes spent significantly less time tending to its' lambs. Results revealed that the ewe spent significantly more time tending to her lambs at the point of foster (0mins) and 60mins after a foster ($F_{1,20} = 47.261$, $p<0.01$) than three hours later ($F_{1,20} = 8.189$, $p<0.05$; Figure 3.6).

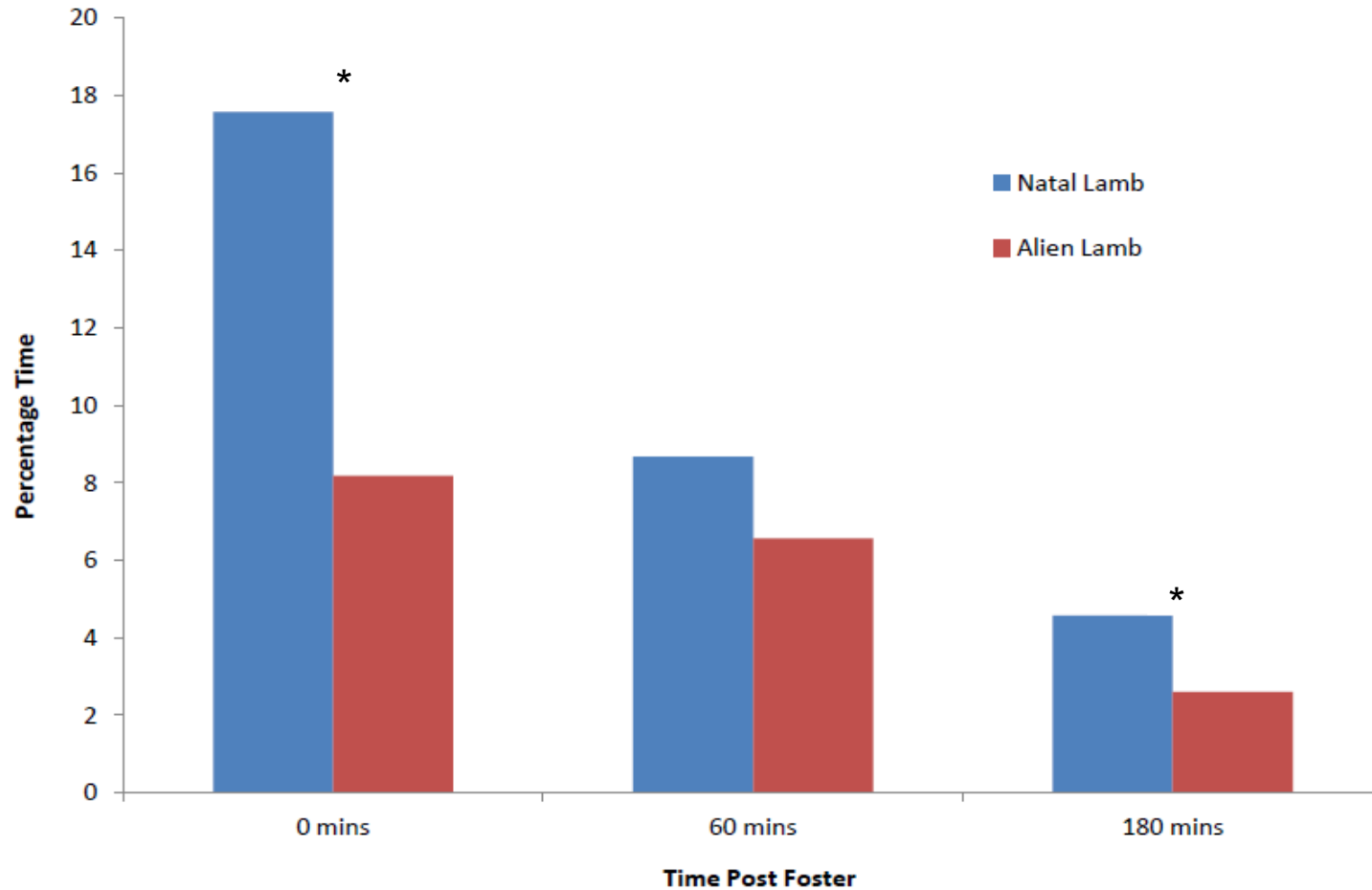


Figure 3.6: Percentage time MP BF ewes spent performing maternal behaviours (sniffing, grooming and facilitating suckling) with the alien and natal lamb at the foster (0 mins), time post foster plus one hour (60 mins) and time post foster plus three hours (180 mins). * Indicates a significantly higher percentage of time spent with natal lamb.

3.3.1.4 Auditory Communication

Non-parametric correlations were performed to investigate the relationship between the ewes LP and HP bleats and the percentage of time spent with the natal or the alien lamb. MP ewes showed significant positive correlations between the number of LP bleats and time spent with the natal ($\rho = 0.579$, $p < 0.01$); and the alien lambs ($\rho = 0.396$, $p < 0.01$). The same effect was observed for the PP ewes for both the natal ($\rho = 0.835$, $p < 0.01$) and alien lambs ($\rho = 0.859$, $p < 0.01$). Correlations for MP ewes were significantly negative for the number of HP bleats emitted ($\rho = -0.366$, $p < 0.05$) and the amount of time spent with the natal and the alien lamb ($\rho = -0.642$, $p < 0.001$). This was also the case for PP ewes for the number of HP bleats ($\rho = -0.614$, $p < 0.01$) and the time spent with the natal and alien lamb ($\rho = -0.573$, $df = 27$, $p < 0.01$).

3.3.2 Physiology

3.3.2.1 Cortisol

Figure 3.7 shows that primiparous restrained ewes produced significantly higher concentrations of salivary cortisol than PP BF and control ewes at 0mins ($F_2 = 6.821$, $p < 0.05$), 30mins ($F_2 = 10.635$, $p < 0.01$), 90mins ($F_2 = 8.441$, $p < 0.05$) and 180mins ($F_2 = 9.330$, $p < 0.01$) post foster. There was no significant difference between the salivary cortisol levels for 60mins ($F_2 = 4.388$, $p > 0.05$) between the foster methods.

The MP restrained ewes showed significantly higher cortisol levels at all time scales post foster (0mins: $F_3 = 8.650$, $p < 0.05$; 30mins: $F_3 = 8.096$, $p < 0.05$; 60mins: $F_3 = 9.894$, $p < 0.05$; 90mins: $F_3 = 10.269$, $p < 0.05$ and 180mins: $F_3 = 11.199$, $p < 0.01$) compared to MP BF, CSBF and control ewes (figure 3.8).

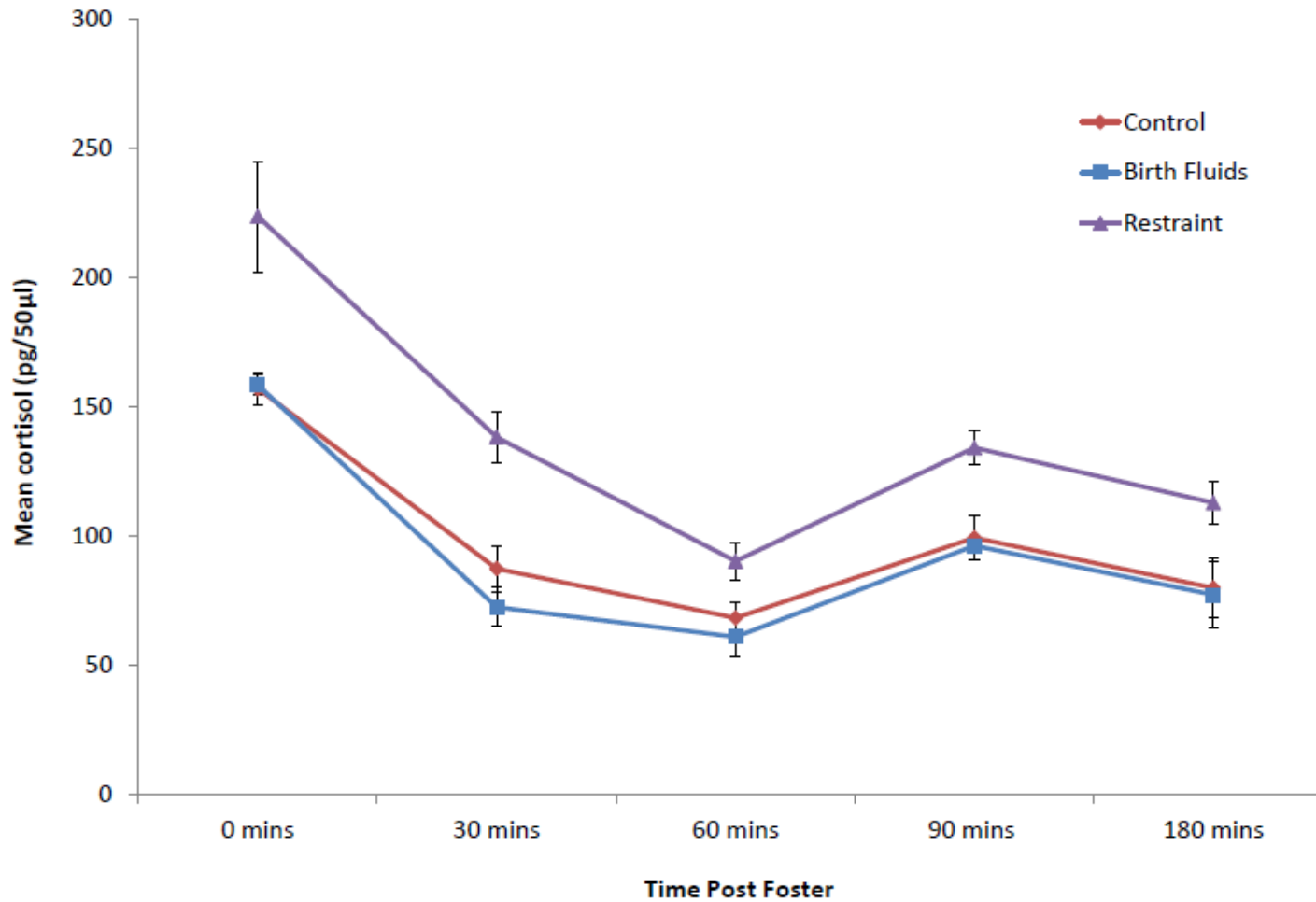


Figure 3.7: Mean (\pm S.E) concentration of salivary cortisol of primiparous (PP) ewes undergoing different fostering procedures.

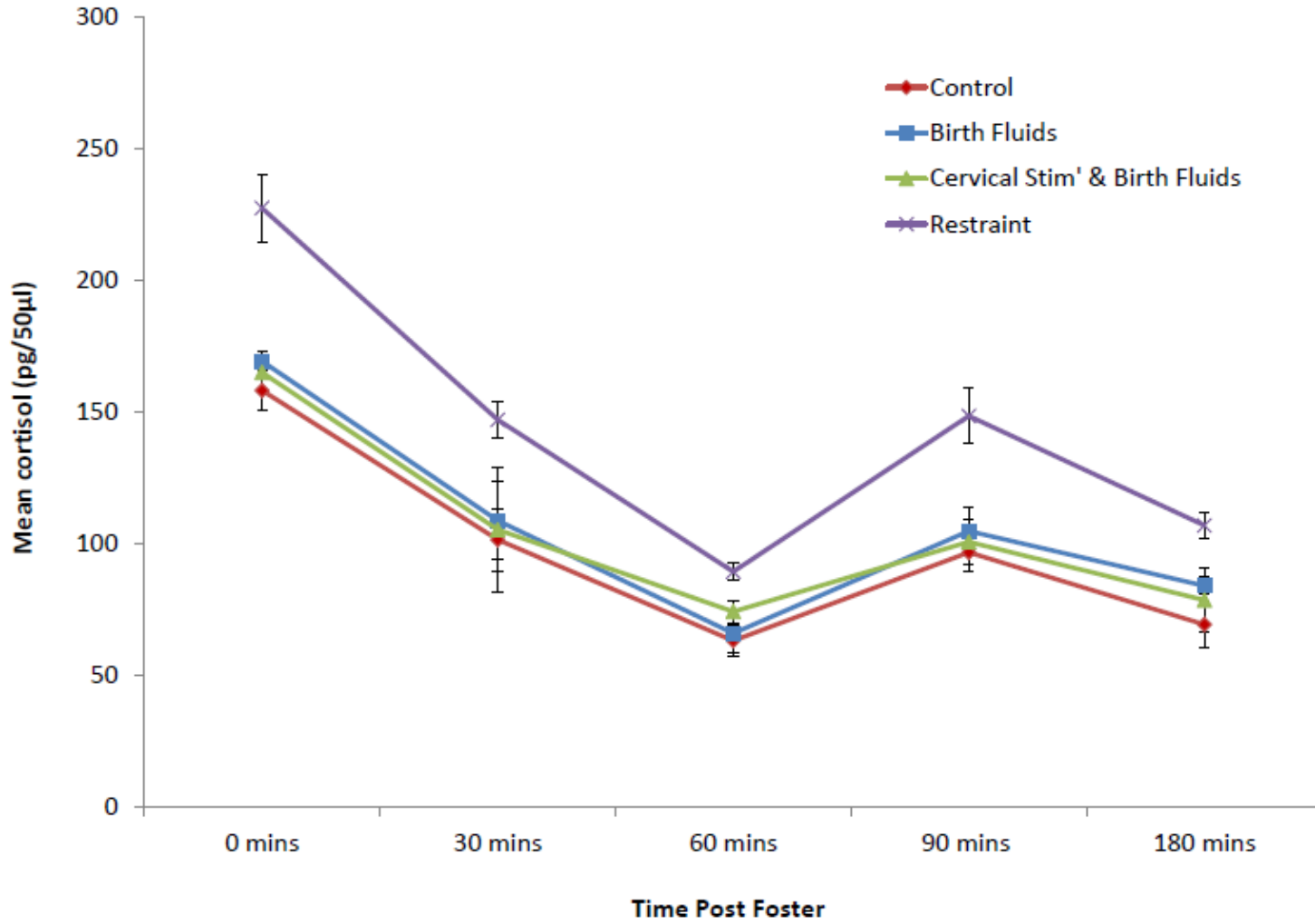


Figure 3.8: Mean (\pm S.E) concentration of salivary cortisol of multiparous (MP) ewes undergoing different fostering procedures.

3.3.2.2 Heart Rate

The heart rates for the PP ewes did not show any significant differences between the foster methods at 0mins ($F_2 = 2.202$, $p > 0.05$), 30mins ($F_2 = 2.027$, $p > 0.05$) or 180mins ($F_2 = 1.382$, $p > 0.05$) post foster. Results did however show significantly higher heart rates for the R ewes at 60mins ($F_2 = 4.146$, $p < 0.05$) and 90mins ($F_2 = 3.537$, $p < 0.05$) post foster as shown in Figure 3.9.

Multiparous ewe heart rates did not show significant differences among foster method at 30 ($F_3 = 1.480$, $p > 0.05$), 60 ($F_3 = 0.748$, $p > 0.05$), 90 ($F_3 = 2.367$, $p > 0.05$) and 180 ($F_3 = 0.760$, $p > 0.05$) minutes post foster. However, the restrained MP ewes' initial heart rate was found to be significantly higher ($F_3 = 4.158$, $p < 0.05$) than that of the other foster methods as shown in Figure 3.10.

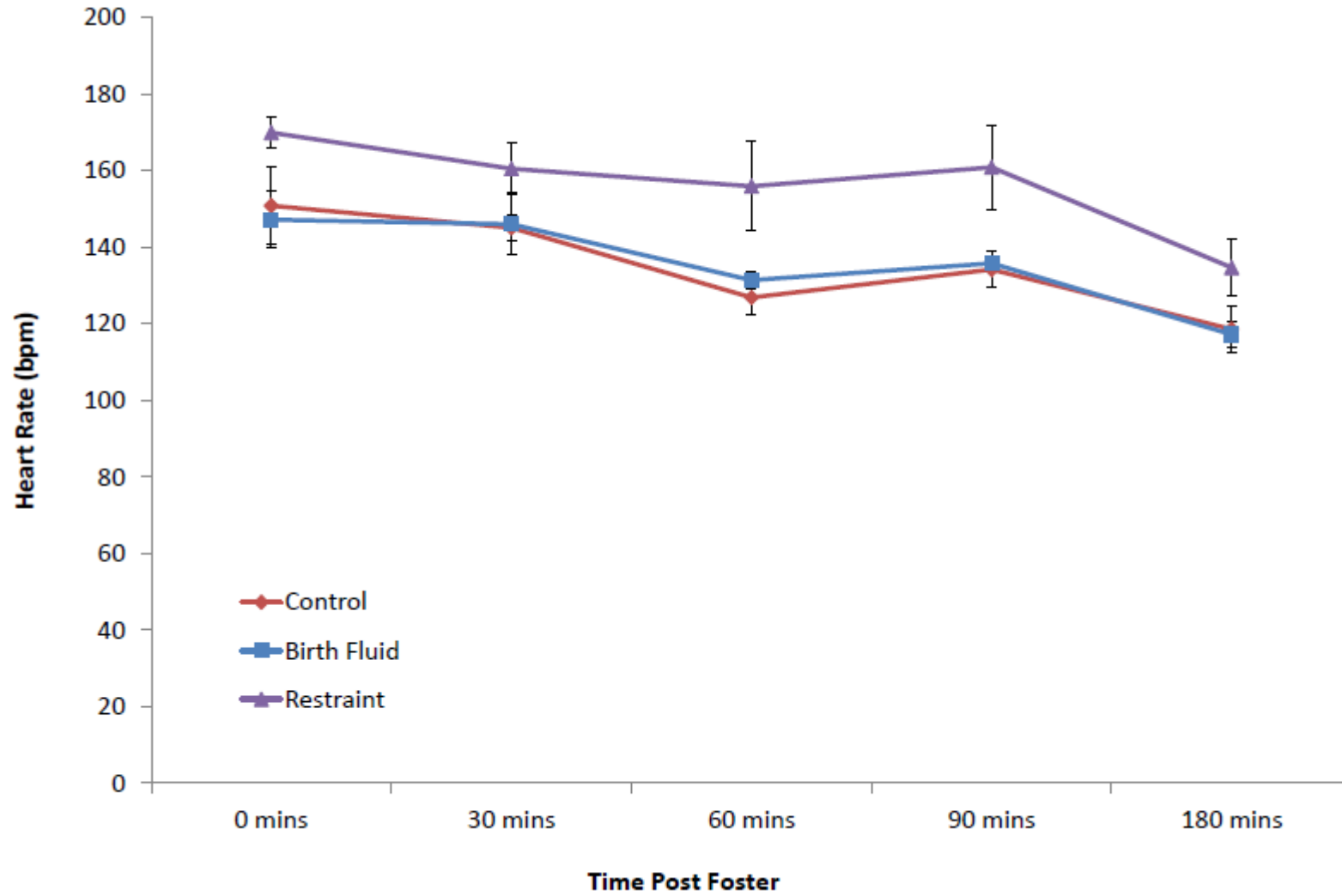


Figure 3.9: Mean (\pm S.E) heart rates measured by primiparous ewes undergoing different fostering procedures.

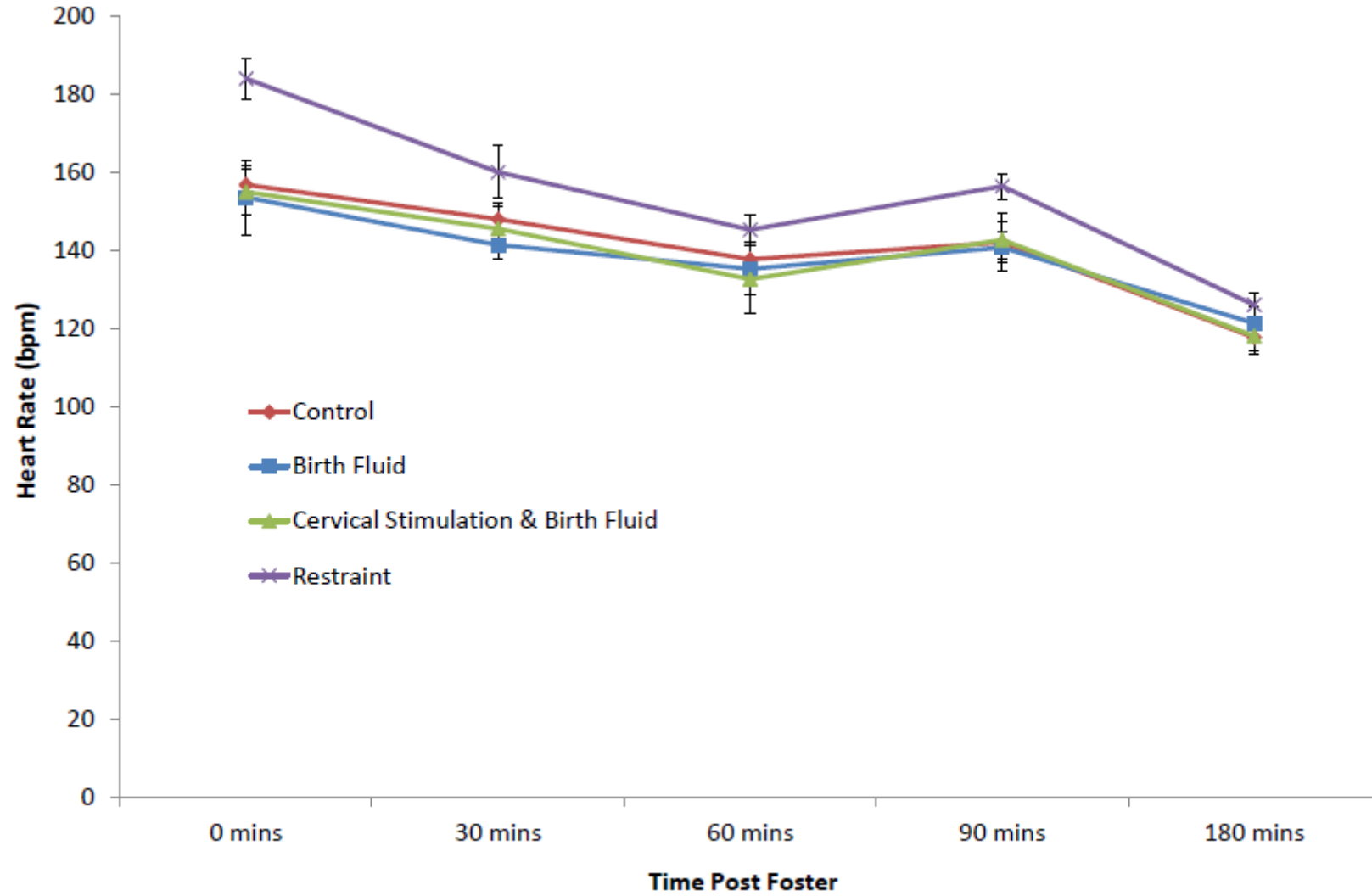


Figure 3.10: Mean (\pm S.E) heart rates measured by multiparous ewes undergoing different fostering procedures.

3.4. Discussion

3.4.1 Behaviour

3.4.1.1 Fostering Effect

The average percentage of time spent resting, feeding, drinking and in locomotion for MP and PP ewes were not affected by the foster treatment within the first 3½ hours post foster. Restrained ewes were classified as moving around if their legs and body moved from side to side within the restraint crate, with no attempt to remove their head from the stanchion. This result was expected as all ewes were able to perform these behaviours freely, irrespective of the foster method.

Restrained MP and PP ewes emitted significantly more HP bleats and significantly less LP bleats than ewes belonging to any other foster method treatment. Dwyer *et al.* (1998) suggested that HP bleats were linked to the distress of ewe-lamb separation and that LP bleats were emitted almost exclusively in the presence of the lamb (most likely function to be specific about lamb bonding and care-giving to the neonate). Restrained ewes were unable to make visual or olfactory contact with their lambs and this could be explaining why they emitted more HP and less LP bleats compared to the other treatments. Sèbe *et al.* (2010) explained how high pitched bleats were not recognisable by the lambs and that the performance of these could induce problems linked to the maternal care

and therefore the bonding process. It would be possible for this process to be delayed due to a low frequency of LP bleats.

Restrained MP and PP ewes spent significantly more time performing negative behaviours (such as 'escape', 'butt', 'foot stamp' and 'prevent suckle'), urinating and being vigilant than ewes within any of the other treatments. Because these ewes were in restraint crates, they were unable to move freely around the pen. This restriction was therefore likely to have caused the performance of more fearful/nervous and negative behaviours such as urinating and attempted escapes (Forkman *et al.*, 2007, Torres-Hernandez and Hohenboken, 1979, Vandenheede and Bouissou, 1994).

After parturition, ewes use visual, touch, auditory and olfactory cues to enable identification of their lambs (Dwyer *et al.*, 1998, Keller *et al.*, 2003, Nowak *et al.*, 2011, Poindron *et al.*, 2010, Sèbe *et al.*, 2010). The restraint method of fostering inhibits the ewes' ability to explore these cues for identification. The ewes were unable to touch, smell and see their lambs while suckling therefore possibly causing great distress to the ewe. The restraint method does enable the ewe to hear the lambs, but due to the fact that other aspects of communication were limited, the ewes might react performing significantly less LP bleats which are initially required for the lamb to identify their dam (Sèbe *et al.*, 2010). This could result in a slower bond formation between the ewe and the lamb which becomes extremely important with time as the lambs grow and the rearing

conditions evolve (such as the need to recognise their dam from a distance once on the pastures).

The time that primiparous ewes spent resting was also found to be effected by the foster treatment. The control ewes spent significantly more time resting compared to restrained or BF ewes. It is possible that the extra human intervention needed to perform the foster could have had an impact on the resting behaviour of primiparous ewes. Previous research has found that disturbance at birth or soon after parturition can cause alterations to maternal and maintenance behaviours (Fisher and Mellor, 2002) especially with primiparous ewes that have had no previous experience of birth and the management practices associated previously (Viérin and Bouissou, 2002).

3.4.1.2 Parity Effects

Previous research has shown that MP ewes have stronger maternal instincts and that they have higher lamb survival rates than PP ewes (Purser and Young, 1983). Dwyer and Lawrence (2000) also suggested that in general, PP ewes took longer to groom their lambs and showed higher rates of rejection than MP ewes. When investigating the influence of maternal experience on the time budgets of the ewes for the first 3½ hours post foster, results suggested that both PP and MP ewes behaved in a similar manner.

The current study shows that both PP and MP ewes spent a similar amount of time performing maternal and maintenance behaviours. These results show that over the initial hour post foster all control ewes tended to their lambs for a similar amount of time. Dwyer and Lawrence (2000) found that there were no significant differences between the ewe parities on the time spent grooming. They suggested that grooming soon after parturition was strongly linked with the consummatory aspects of maternal behaviour. Poindron *et al.* (2010) suggested that the birth fluid played a vital role in encouraging inexperienced ewes to perform these behaviours and therefore initiate a bonding process.

Results showed that PP control ewes spent more time being vigilant than MP control ewes ($17.75\% \pm 3.33\%$ compared to $11.82\% \pm 1.89\%$). This was likely to be because of the novelty of the lambing procedure and the management practices associated. If the lambing yard was not managed in an appropriate manner, this could be problematic and influence the survival of the ewes' lambs.

The current experiment was not designed to compare PP and MP rejection rates as only successful rearing or fostering occurrences were recorded, this was in keeping with the ethical guidelines set out prior to the data collection. However, it was anecdotally noted that both MP and PP control ewes were highly successful at accepting their natal lambs without any permanent rejections. This was mostly due to good management practices (experience and knowledge of the shepherd) but could also be

caused by a possible learning process occurring among ewes due to the fact that both primiparous and multiparous ewes were housed together (Nicol, 1995).

3.4.1.3 Time Spent With Lamb

A successful foster occurs when a ewe accepts an alien lamb, allows it to suckle and provides the lamb with maternal care including grooming (Alexander and Stevens, 1985). Therefore it was expected that for the successful fosters included in the current study, all dams would show a similar percentage of time spent attending to both their lambs (alien and natal), independently of the type of foster method used. However, when data investigating percentage of time spent with each type of lamb were analysed it was revealed that multiparous BF ewes spent a higher percentage of the time with their natal lamb compared to the alien lamb. This difference was not observed for any of the other treatment groups for both multiparous and primiparous ewes. Results suggest that multiparous BF ewes were somehow able to discriminate to a certain extent between their natal and the alien lamb, yet still accepted the alien lamb as their own.

However, the importance of fostering success and lamb acceptance may not solely be based on the ewe's ability to discriminate between lambs but could be also linked to the lamb's behaviour. Nowak (1994, 1997) investigated the mother-seeking behaviour of newborn lambs. Results

suggested that lambs spent more time near their mothers than near alien ewes. However, Dwyer and Lawrence (1999) discussed that offspring behaviour had no effect on maternal and bonding behaviours. Val-Laillet and Nowak (2006) investigated maternal preference in lambs but considered the effects of the ewes' social interactions on the decisions made by the lambs. They discovered that the more social interactions a ewe had with other flock members, the clearer the preference of its lambs for their natal mother.

Another possibility to consider could be the ability of a lamb to discriminate its natal siblings. Porter *et al.* (1997) investigated 24 pairs of twin Prealpes-du-Sud lambs which had been kept indoors with their mothers in large enclosures, 10-12 ewe-offspring family units. Results not only suggested that the lambs were able to identify their own twin but also spent more time with their own twin compared to non-twins. Porter *et al.* (1997) found that lamb-lamb recognition was mainly due to visual and olfactory cues and was not linked to behavioural or vocal communication. All these findings could partially explain the tendency found in the current study for BF multiparous ewes to spend significantly more time with their natal lamb (or vice versa). However, further investigations would be needed to ascertain the reasoning behind this particular result.

Current results showed that as time post foster increased the amount of time the ewes spent tending to their lambs decreased. This was in accordance to other studies showing that initial interactions with newborn

lambs are vital for the development of bonds and recognition (Nowak *et al.*, 2000, Otal *et al.*, 2009, Poindron *et al.*, 2010). Therefore, it seems that ewes initially invest a lot of time into recognition and bond formation and, as the bond becomes stronger and visual, auditory and olfactory recognition gets established, ewes no longer needed to be as attentive to their lambs and can focus on other maintenance behaviours (such as resting or food/water intake) for their own survival.

3.4.1.4 Auditory Communication

Dwyer *et al.* (1998) showed that both PP and MP ewes emitted LP bleats as a means to communicate and form maternal bonds with their lambs. The results for the current study showed that for both PP and MP ewes, there was a positive correlation between the percentage of time spent with both lambs and the number of LP bleats emitted. This could suggest that the performance of LP bleats, with positive connotations, reinforced the maternal bond or acted as a means to facilitate the lambs approach for grooming or other maternal behaviours to occur.

The current results also suggest that the reverse applies: if ewes emitted more HP bleats, with negative connotations, less time was spent with the lambs. Dwyer *et al.* (1998) proposed that the function of HP bleats was linked to the separation between the ewe and lamb, which would support the current findings. However, it is difficult to establish the causality process between both facts (auditory cue and behaviour); in other words, it

is difficult to assess if the increase in HP bleats acts negatively to reinforce the time the ewe and lamb spent together (HP as general distress signal, e.g. restraint) or if the lack of time spent together encourages ewes to emit HP bleats (HP as specific distress signal for lamb separation).

3.4.2 Physiology

3.4.2.1 Cortisol

Plasma cortisol is commonly used as indicator of stress in welfare research, however a shift from invasive (blood samples) to non-invasive procedures (e.g. saliva and faecal) has become more common to reduce the potential negative impacts of data collection (Fell *et al.*, 1985, Buchanan and Goldsmith, 2004). Different methods for the analysis of cortisol in salivary samples have evolved, such as RIA (Radioimmunoassay), ELISA (Enzyme Linked Immunosorbent Assay) and EIA (Enzyme Immunoassay; Raff *et al.*, 2002, Reimers and Lamb, 1991). One common, relevant aspect, is the importance of validation of the method used for the species being analysed and the type of sample collected (Buchanan and Goldsmith, 2004). Samples collected within the current study were validated for sheep saliva showing that they were specific, accurate, precise and biologically relevant for the species and the medium (saliva). EIA procedures to analyse the amount of free cortisol within the current samples followed previously published methods (Setchell *et al.*, 2008, Smith and French, 1997).

Current results showed that for the most of the samples collected (4 out of 5 sampling times) restrained PP ewes had significantly higher cortisol levels compared to the ewes from the other foster methods and control. Similarly, restrained multiparous ewes showed significantly higher cortisol levels than any other group throughout all sampling times. As previously explained with the behavioural data, this is possibly due to the fact the ewes subjected to the restraint treatment were unable to move around freely or tend to their lambs appropriately. These restrictions could therefore cause distress and increase their stress response. Previous studies have found similar results when sheep experience distress due to a range of different stressors (Cockram *et al.*, 1994, Hall *et al.*, 1998b, Hall *et al.*, 1998a, Lyons *et al.*, 1993). Moberg *et al.* (1980) investigated the effects of restraint on the plasma cortisol levels of lambs at 1, 4, 7, 14, 21 and 28 days of age and adult ewes. They found that for every age group, restraint significantly increased the concentration of cortisol in plasma and that behaviour (such as struggling and HP vocalisations) confirmed restraint as a distressing event.

3.4.2.2 Heart Rate

The measurement of cardiac activity has become a valuable tool to use alongside behaviour in the understanding of animal welfare studies (Tallet *et al.*, 2006). When behaviour is used alone it can be easily misinterpreted (Boissy, 1998). Results within the current study showed that restrained multiparous and primiparous ewes presented overall higher heart rates

than any other treatment groups. However, only the initial heart rate for the multiparous and heart rates at 30 and 60 minutes post-foster were found to be significantly higher at the statistical level. This is likely to be due to the large standard deviations from the data. An increased sample size per treatment group could be more likely to show significant differences for all times.

3.4.2.3 Combined Physiological Measures

Figure 3.7 to 3.10 showed a peak of increased cortisol and heart rate at 90mins post foster for the ewes studied. There were no adverse changes in the ewes' behaviour at this point so it is not possible to link these increases to performance of specific behaviours. However, it could be linked to generalised fluctuations in physiological functioning around this point in time after birth. This would need to be investigated further as it could have implications on future studies examining ewe physiology post parturition.

3.4.2.4 Parity Effects

The current study did not find significant differences in the cortisol levels or heart rate frequencies between multiparous and primiparous ewes. Fukasawa *et al.* (2008) investigated the effects of parity on milk cortisol in dairy cows; they also found no significant differences between the concentrations measured. Dwyer and Smith (2008) studied parity effects on oestradiol concentrations in Scottish Blackface and Suffolk post-

parturient ewes. They found that both primiparous and multiparous ewes presented similar concentrations. It is suggested that although primiparous ewes could potentially suffer higher distress due to the novelty of parturition, handling and restraint, they are able to cope with the situation and present a similar physiological profile than more experienced, and potentially calmer, multiparous ewes.

3.5. Conclusion

As previously discussed, the combination of behavioural, physiological (and production) data help to paint a clearer picture of what level of distress individuals are experiencing. In this specific case, the main issue is to ascertain if restraint crates used for fostering do cause unnecessary distress. The current behavioural results seem to be supported by the physiological data, showing that restrained ewes experience a higher level of distress (exhibit increased heart rates and salivary cortisol concentrations).

Unfortunately, it was not possible to establish if the restrained multiparous ewes had prior experience to the crates from previous lambing seasons, although this is highly unlikely. Current results showed that initial heart rates and cortisol concentrations were similar for multiparous and primiparous ewes.

Erhard *et al.* (2006) suggested that over time, it is possible for ewes to habituate to certain aversive stimuli and highlighted the importance of the correct time duration that an animal should undergo certain conditions. Dodd *et al.* (2012) described how ewes undergoing restraint could show two types of coping patterns. The first was named “threat to control”, which would be an active fight-flight response where the ewe displays aggressive behaviours. This would lead to either regained control or a struggle to fight

for control. The second coping pattern was named “loss of control”, where the ewe behaves passively and non-aggressively showing a defeat reaction which could lower maternal drive. Ultimately, this coping pattern would lead to the loss of control which can increase corticosteroid release. From the current combined behavioural and physiological results, it is possible to suggest that initially, the restrained ewes were showing signs of “loss of control” and therefore fighting to regain control. At some point between 60 and 90 minutes post-foster, it seems possible that the coping pattern might have switched to “loss of control” leading to an increase in cortisol levels and heart rate frequency with the subsequent decrease in performance of negative behaviours.

Overall, the results from the current study have shown that, non-restrictive methods of fostering such as CSBF and BF seem to be more beneficial to the welfare of the ewes compared to the restraint method. The restraint crates caused significant behavioural restrictions and also increased heart rate frequencies and salivary cortisol concentrations. Although the restraint crate can be a successful foster method, the effects on the ewe’s maternal behaviours and physiological responses can be seen as an indicator of poor welfare.

CHAPTER IV

The Effects of Fostering

Methods and Artificial Rearing on the Production, Carcass and Meat Quality of North Country Mule Lambs

4.1 Introduction

The English lamb industry is estimated to be worth £343 million for home and export consumption, yet, it is also estimated that only 54% of lambs reach acceptable market requirements for weight or conformation (EBLEX, 2007). The UK produces approximately 20% of the European supply of lamb with 14,035,400 lambs being slaughtered in 2010, producing 282,111 tonnes of meat (FAOSTAT, 2012). If this amount was just over half of the potential lambs sent to slaughter, it suggests that almost 13 million lambs did not reach acceptable market requirements. These figures highlight the importance of production issues and husbandry techniques that can be used to improve the turnover. An important aspect to ensure that lambs reach an acceptable sale standard is the husbandry and care (Diaz *et al.*, 2002) which is influenced by the husbandry system and protocols in place (Chestnutt, 1994).

4.1.1 Weaning Effects

A study by Ekiz *et al.* (2012) set out to investigate the effects of different weaning lengths on the carcass and meat quality of Kivircik lambs in Turkey. The lambs were in one of three treatment groups where they were either weaned at 45, 75 or 120 days old. All lambs were slaughtered at 120 days of age, denoting that the third weaning group were with their dam for the entire experimental period. After the 45 and 75 day weaning groups were separated from their dams, their average daily weight gain

decreased significantly. This was attributed direct to the distress caused by weaning.

A reason behind this decline in daily weight gain has been linked to two factors. Cañeque *et al.* (2000) concluded that it was linked to the nutrient intake and the physiological changes needed to switch from a liquid to a solid food source. However, Gaulty *et al.* (2004) suggested that it was due to the distress that the lambs undergo during the weaning process. Ekiz *et al.* (2012) found that plasma cortisol levels were, in fact, elevated up to 24 hours after weaning in each of the treatment groups, and were significantly higher on the day of slaughter for the 120 day old lambs. The authors felt this was explained to be due to the stress caused by separation from their dams, together with the transport process. Conformation and fatness scores were also significantly higher the longer the weaning length, coinciding with the higher growth rates of the 120 day old weaned lambs. Ultimate pH levels were not found to be significantly affected by the weaning length, and ranged between 5.62 and 5.68 which were within the acceptable quality range of lamb meat pH. The WHC was also found to be not significantly affected and it was probably due to the lack of differences in the ultimate pH. The study concluded that daily weight gain and carcass quality were improved if the lambs were kept with their dams until slaughter yet there were no improvements to meat quality.

4.1.2 Nutritional Effects

Studies have shown that different feeding or finishing systems can have different effects on lamb carcass and meat quality. Priolo *et al.* (2002) investigated the effect of grass or concentrate fed Ile-de-France lambs. Thirty-two male lambs were separated into a field or an indoor group at 37 days of age. Both groups were weaned at day 70, where the lambs were left to feed naturally on grass or concentrate depending on the treatment they belonged to. Lambs were slaughtered when they reached around 35kg and results showed that concentrate fed lambs were heavier than the pasture-reared (15.8kg compared to 14.7kg respectively). Pasture-reared lambs also had lower conformation and fatness scores than the concentrate-reared lambs. The meat samples showed a significantly darker meat with a lower lightness (L^*) for the pasture-reared lambs. However, meat redness (a^*) and yellowness (b^*) and ultimate pH were unaffected by the feeding system. It was suggested that the lower scores in the conformation and fatness could be linked to the pasture-reared lambs' ability to exercise as there were no space restrictions within the field compared to the indoor, concentrate-reared lambs. They also suggested that the changes in the meat L^* could be a result of the slight, but non-significant difference in ultimate pH. In summary, the authors suggest that carcass quality but not meat quality was affected by the feeding treatment. Furthermore, it may be that exercise limitations had a greater effect than diet in this setting.

Carcass and meat quality studies have focused on the effects that artificial rearing has on young lambs which were removed from their dams at around 40-50 days. Napolitano *et al.* (2006) investigated the effects of ewe-reared and artificially-reared lambs receiving a milk replacer on growth rates and carcass quality. Results showed that ewe-reared lambs had a higher daily weight gain during the initial 14 days post weaning. However, this period of increased daily gain evened out after 15-30 days where the artificially reared lambs underwent a period of compensatory growth; this was associated with an adaptation to the artificial rearing conditions (Napolitano *et al.*, 2006). The ewe-reared lambs also produced a significantly higher percentage of warm and cold carcass yields compared to artificially reared lambs. Similar results have been replicated in other comparative studies suggesting that initially there may be differences between ewe-reared and artificially reared lambs with no lasting effect on the carcass characteristics (Norouzian and Valizadeh, 2011).

A similar study (Diaz *et al.*, 2002) also investigated concentrate versus grass fed Talaverana lambs in Spain. This method on the other hand, balanced the possible issue of space allowance and the lambs' exercise ability by housing the lambs in the same sized groups and areas. It was found that conformation and fatness scores were no different in the two rearing systems on the subjective 'EUROP' conformation and fatness 1-5 scores. Results did show some differences when looking at more objective measures such as dorsal fat thickness and kidney knob and channel

fat/right-half carcass weight percentage, with the concentrate-reared lambs having significantly higher scores for both measurements. The ultimate pH and the WHC were not found to be affected but the pasture-reared lamb meat was significantly darker with a lower L* score, which replicated results previously found by Priolo *et al.* (2002). Diaz *et al.* (2002) also proposed that the difference in the L* of the meat could be linked to the different physical activity undertaken by the animals at pasture, even though stocking density corresponded in both situations. Vestergaard *et al.* (2000) suggested that differences in meat colour were due to the skeletal muscle characteristics and that outdoor reared animals had better vascularisation and enhanced oxidative metabolism which made them more resistant to muscle fatigue compared to indoor reared animals, therefore redder muscle fibres. Lamb-rearing procedures, such as restraint fostering, may increase distress and reduce the lambs' outside access so could therefore potentially jeopardise carcass and meat quality.

Lanza *et al.* (2006) found that ewe milk enabled Barbaresca lambs to grow significantly faster and produced heavier carcass weights. The lamb meat was also significantly lighter from lambs fed on ewe milk compared to artificial milk. Vicenti *et al.* (2004) also found that ewe-milk showed improvements on meat quality. They investigated the effects of ewe milk compared with a milk replacer on the meat quality of 10 male Gentile di Puglia lambs slaughtered at 45 days of age. They found that artificially reared lamb meat had a significantly higher fat content than those reared by ewe milk.

Conversely, Napolitano *et al.* (2002) discovered that the artificially reared lambs produced better quality meat than lambs receiving ewe milk. They reared 10 male Comisana lambs on ewe milk and 10 on a milk replacer. Lambs were slaughtered at 45 days old and results showed that there was a significantly higher carcass yield percentage; second grade cut percentage and less leg fat percentage. This study, however, also investigated the immune response and plasma cortisol in both treatments. They found that both artificially reared and ewe reared lambs reacted the same to separation from their dam/peers. However, ewe reared lambs had a much stronger cellular immune response compared to artificially reared lambs. Napolitano *et al.* (2002) suggested that although carcass and meat quality may be improved with artificial rearing, careful consideration needs to be made regarding the lambs' welfare and immune response. This may be even more crucial for the lambs' morbidity as they live beyond 50 days of age.

4.1.3 Distress

Bond *et al.* (2004) investigated the effects of exercise stress on the muscle pH and WHC of 40 crossbred lambs. Exercise stress consisted of five minutes of exercise using a dog, 30 seconds rest, and five minutes of exercise again. Results showed that animals experiencing exercise stress produced significantly higher ultimate pH values (5.92) than animals not experiencing exercise stress (5.54) again, indicative of dark-firm-dry meat (DFD, as explained in 1.6.2.4, pp 60). They reported that when comparing

lambs in the exercise treatment group, the pH values were significantly higher and the WHC was significantly lower than the lambs without the exercise stress. The exercise stress was also seen to increase water loss within the meat with lower water holding capacity (WHC) scores. They described that pH had a dramatic effect on the WHC of lamb meat and that the different ionic conditions established before and during *rigor mortis* are reducing the ability of the muscle protein to hold water. These studies highlight the negative effects that conditions such as these prior to slaughter can have on the pH and WHC of lamb meat, potentially affecting meat quality.

Bond and Warner (2007) also investigated a similar effect with twelve crossbred lamb carcasses where prior to slaughter the exercise treatment group were subjected to 10 minutes of continual exercise with a stock handler and their dog. Results showed that the lambs undergoing exercise stress did have significantly lower WHC than lambs that had not, although the ultimate pH did not differ. In this case, the pH was not affected by the exercise conditions experienced prior to slaughter but the WHC, an important aspect of meat quality, was.

Other aspects of rearing during lambing practices have been seen to affect the carcass and meat quality, such as restraint and social isolation. Apple *et al.* (1995) set out to investigate the effects of these two stressors on the ultimate pH levels and colour measurements (L^* , a^* and b^* , as described in section 1.6.2.3, pp 58) of 30 crossbred lambs. Isolation and restraint

stress included the removal of lambs from their home stanchion to another room. They were isolated from visual and tactile contact of other lambs, and restrained by being placed in a right lateral recumbency position with all four limbs bound together with tape for 6 hours. Results showed that isolation and restraint significantly increased the muscle pH in excess of 6.0 which is classified as higher than the normal quality range for lamb meat (Muela *et al.*, 2012). Isolation and restraint also significantly lowered the L*, a* and b* measurements suggesting that the meat was darker, with a less attractive colour for potential consumers than the control meat (Sanudo *et al.*, 1998). These results suggest that distress of this nature can have detrimental effects on the meat quality of lamb and induce DFD, a meat defect with severe economic implications (Apple *et al.*, 1995). However, this form of restraint would not naturally be used within a commercial farm setting and so is difficult to ratify the implications of such type of restraint.

As previously discussed, some methods used to foster lambs onto ewes can invoke a lack of maternal care and inhibit a lambs' free access to milk from the teat. Napolitano *et al.* (2003) assessed the effects of maternal separation and prevention of suckling on the growth rates of 30 Comisana lambs. 10 lambs were subjected to either ewe milk from a bucket without their dam being present (EM) or ewe milk from a bucket with their dam being present but with the dams' udders being covered (EM+D), both classified as potentially distressing treatments. The control lambs were reared by their dam with milk available *ad-lib* from the dams' teats. It was

found that control lambs had significantly higher weight gain than EM and EM+D groups for the first 14 days; however, the test lambs recovered their daily weight gains and all groups were similar from day 15 up to day 42. The study also reported indicators of distress (plasma cortisol) and found that the EM+D and EM lambs had significantly higher cortisol levels than the control lambs. This could suggest that increased distress may have had an impact on the initial growth rates of the lambs as seen and explained by Sevi *et al.* (1999, 2001). Unfortunately, this study does not specify the final weights of the lambs within each treatment as this would have been useful to discuss the overall implications of early distress on the final target weights of the lambs. This type of early distress could have been similar to the implications of fostering and could be useful to compare if this data was present.

One way to potentially reduce distress that may be experienced by the lambs would be to increase the positive human-animal bonds. Napolitano *et al.* (2006) investigated the effects of gentling (positive handling) on the meat quality characteristics of Comisana lambs. Lambs were either ewe-reared or artificially reared and were subjected to a five minute handling session with trained stock-people per day or left to minimal human contact. Data on daily weight gain was collected and after 49 days the lambs were taken to slaughter for meat quality measurements. Results showed that handled lambs gained significantly more weight between 31 and 49 days of age and their warm and cold carcass weights were heavier. However, there were no significant differences in the ultimate pH or the colour of the

meat between the treatments. They concluded that although the meat quality was not affected by gentling, growth rates and carcass quality was improved. These results suggest that positive human contact can potentially reduce fear of humans and therefore have a positive impact on meat production (Hemsworth, 2003).

Section 1.6 (pp 49) explains how different focal points could be considered when measuring production in lambs. Meat quality refers to the instrumental quality (measures such as WHC, pH or colour) or sensorial quality (trained tasters or consumers' opinions) of the finished product, and can be affected by external factors as discussed above (section 1.6.2, pp 56). Carcass quality, on the other hand, refers to the carcass measurements (such as zoometric measures or conformation and fatness scores) that are routinely used to assess the type and composition of sheep carcasses. Live production measures and indices (such as growth rates or live body measurements) are an extra tool to assess how the rearing process develops. These measures, especially the live body measurements, are not commonly used to compare experimentally different rearing conditions. The current study explores its use within this context with the main intention of adding information about the way a product's quality develops during rearing, and also to support more subjective measures (such as the EUROP classification system) when assessing carcass quality.

Fostering and artificial rearing are common techniques used within the UK lamb industry. Studies have not investigated the impact that commercial farming practices and rearing techniques may have on the lamb meat production system where typically the lambs would be slaughtered around 140-180 days old. The current study investigates how the carcass and meat quality of artificially reared and fostered lambs compares to the standard ewe-twin set up of commercially farmed meat lambs at this later slaughter age.

4.2 Materials and Methods

4.2.1 Subjects, Housing and Husbandry

The same lambs studied from the previous behaviour and welfare study (pp 106) were used for the research presented in this chapter. A total of 90 North Country mule lambs classified as natal (raised by their own mother; n = 30), alien (fostered; n = 30), and artificially reared (AR, bottle fed; n = 30) were included in this study, located at Moulton College Farm Sheep Farm Unit, UK. Each group had equal numbers of male and female lambs. As explained in section 3.2.3 (pp 111), the fostered and the included AR lambs were selected at random from ewes giving birth to triplets. Fostered lambs were allocated a foster dam and housed in an individual pen (1520mm x 1140mm).

Lambs for AR were placed in an AR pen of the same size and were initially force fed natural cow colostrum sourced from the Moulton College dairy unit using a stomach tube. Subsequent feedings were every 4-6 hours with artificial milk powder (*Lamb Force ewe milk* replacer, Downland®; Carlisle) mixed at 20g of milk powder for 250ml of warm water. Each lamb was fed from an individual bottle at a rate of 50ml per kg of body weight. The lambs were housed in a group pen (1520mm x 1140mm) and provided with a heat lamp in groups of up to six individuals.

After three days, any male lambs were castrated using elastic rings, were numbered with spray markers corresponding to their dams and relocated into 'mothering pens' of approximately 400m². These pens were larger, sheltered areas within the lambing sheds which housed up to 10 ewes and their lambs on a bed of straw. When the lambs reached seven days old, the ewes and lambs were taken to the surrounding fields where they remained in outdoor grass pastures with supplementary feeding of lamb creep pellets to suit normal maintenance and growth requirements of the lambs. This was assessed by the experienced shepherd following standard commercial practice protocols. At around three months of age, the lambs were weaned, and then kept grazing in the same fields without their dams until slaughter (approximately six months of age).

The AR lambs remained in the AR pens and after approximately one month were fed the same lamb creep feed in addition to the milk provided. At around 3 months old, when they were moved out to pasture within the same field as the weaned lambs until slaughter.

4.2.2 Data Collection

4.2.2.1 Pre-Slaughter Data

Alien, natal and AR lambs were weighed and live body measurements taken on their date of birth (day 0) and then on days 7, 30, 90 and 180. These days were chosen as coincident with relevant farm procedures. Day 0 represented the lambs' weight and measures at birth. Day 7 referred to

the weight/measures before the lambs were put out to pasture. Day 30 coincided with the routine medication for the lambs (fly-strike and prophylactic treatment for fly-strike and endoparasites). Day 90 represented weight/measures at weaning. Finally, day 180 corresponded to weight/measures of the finished lambs, on the day prior to slaughter. Weights were taken using a digital spring balance (Portable Electronic Scale, OCS-1, UK) with the lambs placed in a bucket (Figure 4.1) until they reached 20kg (up to day 30). Salter Brecknell® LS300 (West Midlands) weighting scales were used for 90 and 180 day measurements. Average daily gain was calculated for the first week of life (DG1), between day 8 and 30 (DG2), between day 31 and 90 (DG3) and between day 91 to 180 days, when lambs were slaughtered (DG4).

Figure 4.2 outlines the additional live body measurements taken including body length (BL; base of neck to beginning of tail), torso length (TL; shoulder to ischium), height at shoulder (HS; floor to shoulder), rump length (RL; Ilium to ischium), rump width (RW; left ilium to right ilium), chest depth (CD; largest depth of ribs at shoulder) and chest circumference (C; around chest). BL, TL, HS, RL and C were measured using a measuring tape and a calliper (max 60cm) was used for RW and CD. Several live body indices were calculated from the measures taken: relative torso depth ($RTD = (CD/HS) \times 100$), pelvic index ($PEI = (RW/RL) \times 100$), transversal pelvic index ($TPI = (RW/HS) \times 100$), longitudinal pelvic index ($LPI = (RL/HS) \times 100$), body index ($BI = (TL/C) \times 100$), relative shortness index ($RSI = (TL/HS) \times 100$), compactness index ($CI =$

(weight/HS) x 100), relative weight index (RWI = (weight/HS) x 100) and proportionality index (PRI =(TL/HS) x 10). Each index was calculated for each measuring day (day 0, 7, 30, 90 and 180).



Figure 4.1: 7 day old lamb being weighed with the digital scale at Moulton College Farm, Moulton (Photo: Wood, 2011).

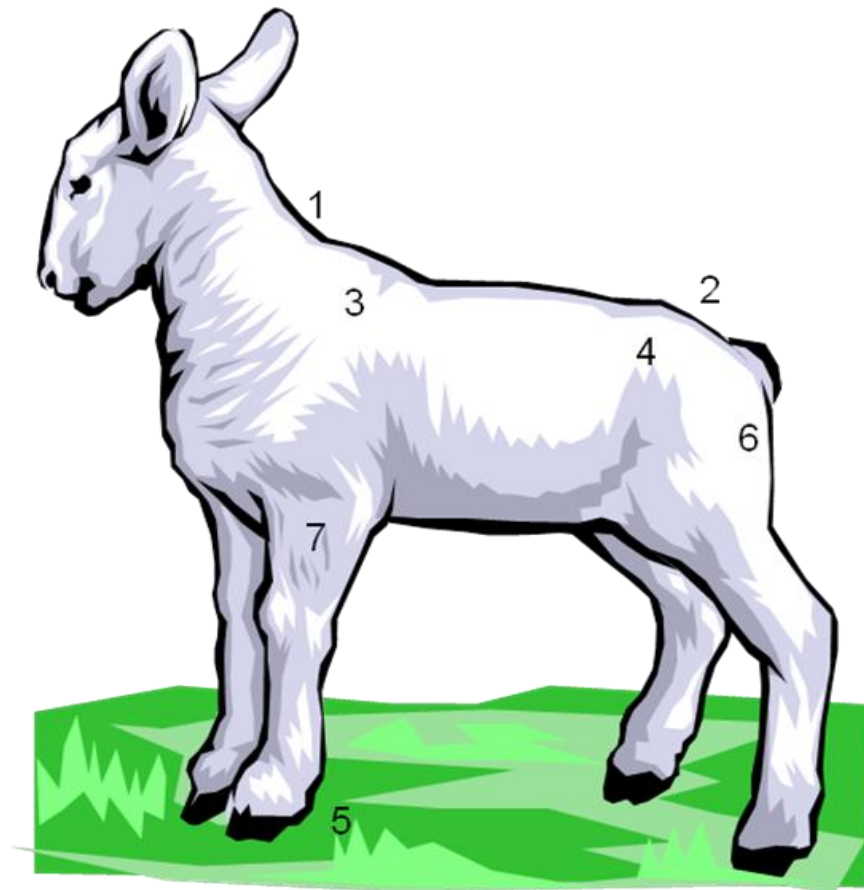


Figure 4.2: Live body measurements taken on days 0, 7, 30, 90 and 180. With body length being from points 1→2; torso length 3→4; height at shoulder 3→5; rump length 4→6; rump width 4→4 (left to right); chest depth 3→7 and chest circumference being around the entire chest at point 3 (Picture: Clipart, 2011).

4.2.2.2 Post-Slaughter Data

Slaughter was carried out in-keeping with UK commercial standards which meant that before they were taken to the abattoir, lambs were approximately six months of age, weighed a minimum of 40kg and were fit in accordance with the shepherd's finishing/selection criteria (EBLEX, 2007). Joseph Morris abattoir and butchery (EU approved; South Kilworth, Leicestershire) was selected to minimise travelling distance (20 miles from Moulton College farm). The average journey length was 35 minutes for all experimental lambs.

In each transportation (n=10), between 7 and 10 lambs were loaded at 05.00 am on the morning of the slaughter into an Ifor Williams® DP120 (model: 10'x6' H/R) livestock trailer. On arrival at the abattoir, the animals were unloaded into the lairage area which consisted of concrete flooring with solid metal separation gates between pens of approximately 8.6m². Animals were housed in their arrival groups and remained in this area for 30 minutes. The animals were slaughtered using electronarcosis stunning then bled out immediately. Experimental lambs were followed through the processing line and labels were attached to the carcass to ensure individual identification. Carcasses were kept in the abattoir's cold storage room at 2 – 4°C for 24h after processing.

On the day of slaughter, conformation and fatness scores were recorded using the EUROP system on the experimental carcasses at the end of the

processing line. Conformation was graded as E, U, R, O or P, where E was classified as excellent and P classified as poor (Carrasco *et al.*, 2009, Russo *et al.*, 2003) by trained staff employed at the abattoir. Fatness was graded as 1, 2, 3, 4 or 5 where a grade 1 was very fat and grade 5 was very lean (Russo *et al.*, 2003; Figure 1.4).

Figure 4.3 outlines an additional set of carcass measurements used to assess carcass quality, including chest width (Wr; widest carcass measurement at the ribs), chest depth (Th; maximum distance between the sternum and back of the carcass at the sixth thoracic vertebra), buttock length (G; widest buttock measurement in a horizontal plane), leg length (F; length from perineum to distal edge of the tarsus) and internal carcass length (L; length from cranial edge of the symphysis pelvis to the cranial edge of the first rib). Th, Wr and G were measured using calliper (max 60cm) and a tape measure used for L and F. These measurements were used to calculate carcass conformation indices including chest roundness index ($Wr/Th \times 100$) and buttock/leg index (G/F).

Meat pH was taken 24h *post-mortem* in the lumbar region (*M. Longissimus dorsi lumborum*) using a Crison® (Barcelona, Spain) model: 507 spear tip penetration probe electrode with portable pH meter. Cold carcass weight was also recorded at this point and carcass compactness ($CCW/L \times 100$) and commercial dressing indices ($CCW/slaughter\ weight \times 100$) were calculated (Cañeque *et al.*, 2004).

The lambs were then butchered and the left loin (*Longissimus dorsi*) was removed and taken to the laboratory at Moulton College without breaking the cold chain with the loins being placed inside Styrofoam boxes and covered with ice packs. Meat samples were stored for a further 24 hours at a constant temperature of 4°C at the laboratory. 36h post-mortem) the colour and WHC were assessed. A section of the loin, approximately 3cm wide, was separated for the colour measures while a second piece, of a minimum of 30g, was also separated for the WHC measurement. Both pieces were placed into polystyrene boxes on the day of arrival at the lab, covered with O₂ permeable film and stored in the fridge at 4°C for a further 24 hours for the colour and WHC measurements. This was to ensure oxygenation of the samples prior to tests being completed.

Colour readings were measured at 36 hours *post-mortem* (24 hours at abattoir, 12 hours at the lab) with a portable MINOLTA® colorimeter (model: CR-200b) to measure lightness (L*), redness (a*) and yellowness (b*) of the meat samples following CIE L*a*b* system (Figure 4.4a). Each sample was measured three times and an average score of L*, a* and b* was calculated. WHC was also measured 36 hours *post-mortem* and was expressed as percentage (%) of expelled juice after compression, using the Grau and Hamm method as outlined by Beriain *et al.* (2000) and Boakye and Mittal (2004) as shown in Figure 4.4b.

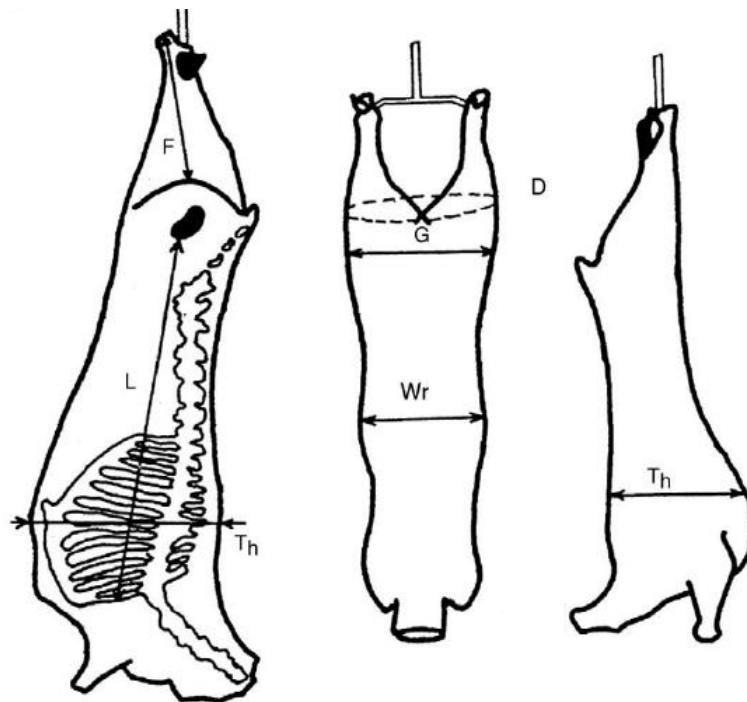


Figure 4.3: Zoometric carcass measurements taken on day of slaughter, adapted from Carrasco *et al.* (2009). Measurements included chest width (Wr), chest depth (Th), buttock length (G), leg length (F) and internal length (L).



Figure 4.4a: MINOLTA CR-200b colorimeter being used to assess the colour of experimental meat samples at the Moulton College laboratory (Photo: Mawson, 2011).

Figure 4.4b: Water holding capacity stand with mashed meat samples held between glass petri-dishes under a 2250g weight, method from Beriain *et al.* (2000) and Boakye and Mittal (2004). Taken at the Moulton College laboratory (Photo: Mawson, 2011).

4.2.3 Statistical Analysis

SPSS[®] version 17 (SPSS Inc, 2008) was used for the statistical analysis of all data. All data proved to be normally distributed. Average daily gain for the ewe reared lambs was analysed using general linear models with lamb origin (natal/alien), foster method and ewe experience (primiparous or multiparous) as independent variables.

The effect of rearing type (ewe or artificially reared) was analysed using Kruskal Wallis tests due to the unequal group sizes of between the AR (n = 30) and pooled ewe-reared data (fostered and natal lambs n = 60). Lamb breed and gender were included in the model as factors due to their possible but uncontrollable effects on the growth rates.

Weights over the 0, 7, 30, 90 and 180 days and live body indices were analysed using general linear models with lamb origin (natal/alien), foster method and ewe experience (primiparous or multiparous) as independent variables. Age was not considered in the analysis as comparisons were always planned between data from the same age lambs.

Conformation and fatness were converted into numerical data for statistical analysis as shown in Table 4.1. Carcass and meat quality measurements including CCW, conformation, fatness, commercial dressing, chest roundness index, buttock/leg index, carcass compactness

index, ultimate pH, WHC and colour (L^* , a^* , b^*), were also analysed using a general linear model with gender and breed as factors and the foster method, ewes' experience and lamb origin (natal/alien) as the independent variables. Rearing type was again analysed using a Kruskal Wallis test with the inclusion of data for artificially reared lambs.

Table 4.1: Conformation (EUROP) and fatness (1-5) conversion scores used for carcass quality parameters.

Conformation:	P-	P	P+	O-	O	O+	R-	R	R+	U-	U	U+	E-	E	E+
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Fat:	1-	1	1+	2-	2	2+	3-	3	3+	4-	4	4+	5-	5	5+
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

4.3 Results

4.3.1 Pre-Slaughter Data

There was a significant rearing effect on DG1 (0-7 days), DG2 (8-30 days) and DG3 (31-90 days) with the lambs reared by ewes gaining significantly more weight than artificially reared lambs ($K = 21.30$, $p < 0.001$; $K = 16.935$, $p < 0.001$ and $K = 4.428$, $p < 0.05$ respectively). However, DG4 (91-180 days) did not show any significant differences between ewe and artificially reared lambs ($K = 1.134$, $p > 0.05$; Figure 4.5). Table 4.2 shows the Kruskal Wallis values and significant differences for the live body indices when comparing ewe reared (foster method and control) and artificially reared lambs. No significant differences were found in any of the indices measured at 180 days. However, significant differences were found in all indices at some stage within the growth periods with the ewe reared lambs having significantly better indices (Table 4.2).

When considering the effect of fostering, there were no differences in daily weight gain between the different foster methods for DG1 ($F_{3,87} = 1.887$, $p > 0.05$), DG2 ($F_{3,84} = 0.943$, $p > 0.05$), DG3 ($F_{3,82} = 2.073$, $p > 0.05$) or DG4 ($F_{3,72} = 1.433$, $p > 0.05$) as shown in Figure 4.6. No significant differences could be found between the foster methods for any of the live body indices at any age.

Weights at day 0 and day 7 showed that natal lambs were significantly heavier than alien lambs ($F_{1,64} = 5.702$, $p < 0.05$; $F_{1,64} = 4.574$, $p < 0.05$

respectively), however, at days 30, 90 and 180 there were no significant differences between the weights of the lambs ($F_{1,64} = 0.003$, $p > 0.05$, $F_{1,64} = 0.774$, $p < 0.05$ and $F_{1,64} = 0.118$, $p < 0.05$ respectively). There were no significant differences found between the average daily gain of the natal compared to the alien lambs for any of the time periods analysed.

Results suggested that ewe experience significantly affects weight gain, with lambs reared by multiparous ewes, gaining significantly more weight during DG1 ($F_{1,89} = 8.782$, $p < 0.01$), DG3 ($F_{1,84} = 7.156$, $p < 0.01$) and DG4 ($F_{1,74} = 20.390$, $p < 0.001$).

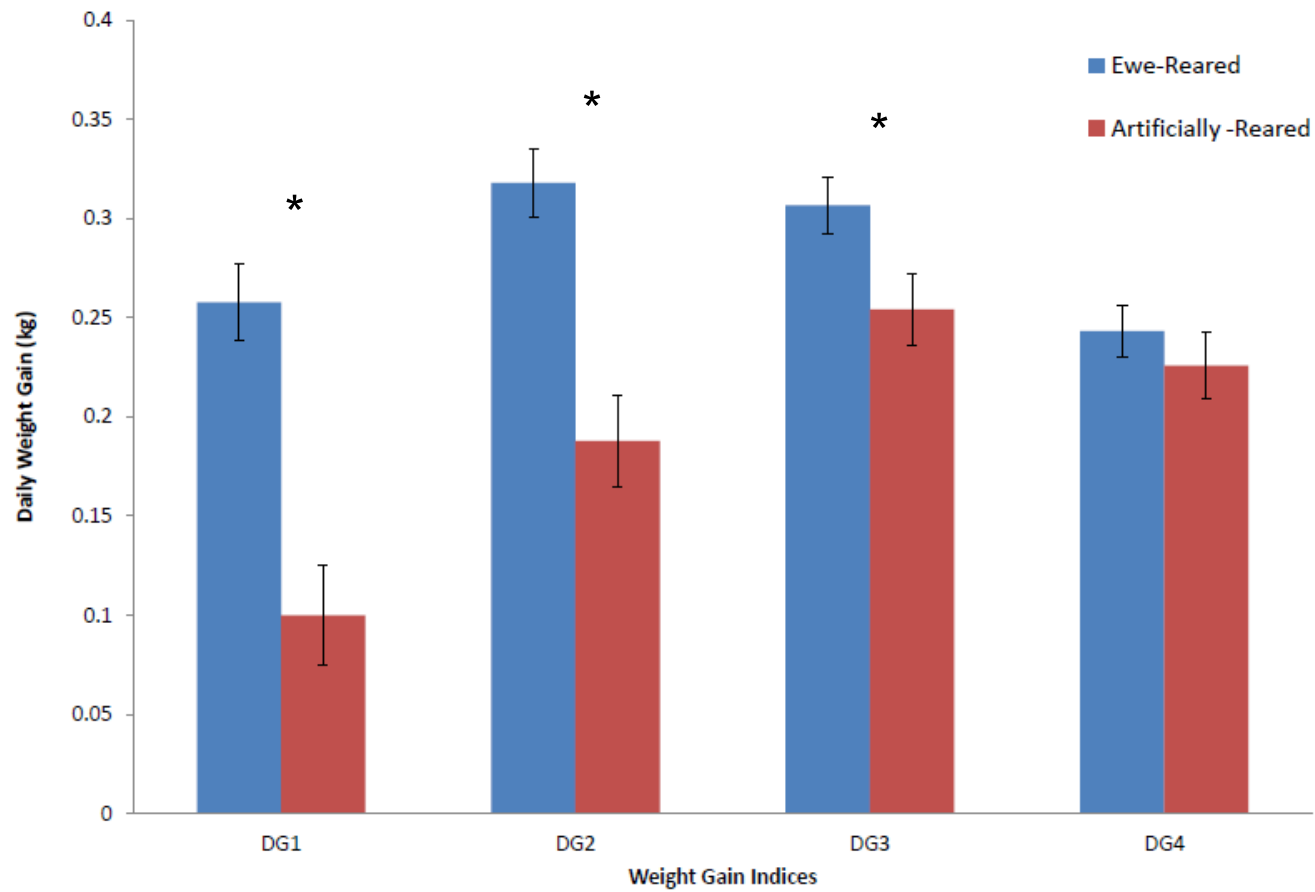


Figure 4.5: Daily weight gain between ewe-reared and artificially-reared lambs over time. Where DG1 = average daily gain from day 0 - 7, DG2 = average daily gain from 8 - 30, DG3 = average daily gain from 31 – 90 and DG4 = average daily gain from 91 - 180. * indicates significant higher average daily gain.

Table 4.2: Mean (\pm SE) live body measurement indices measured on days 0, 7, 30, 90 and 180 with subsequent significance between ewe and artificially reared lambs.

Live Body Measurements	Ewe-Reared		Artificially Reared	K Value
	Natal	Alien		
Relative Torso Depth 0	42.02 \pm 1.43 ^a	41.61 \pm 1.22 ^a	38.09 \pm 1.21 ^b	5.631
Relative Torso Depth 7	44.86 \pm 0.94 ^a	43.49 \pm 1.02 ^a	39.15 \pm 1.38 ^b	2.355
Relative Torso Depth 30	46.24 \pm 1.27 ^c	45.00 \pm 0.94 ^c	41.62 \pm 1.71 ^d	9.929
Relative Torso Depth 90	54.83 \pm 1.22 ^a	53.57 \pm 1.13 ^a	48.80 \pm 1.40 ^b	2.063
Relative Torso Depth 180	58.11 \pm 0.97	58.80 \pm 0.97	54.94 \pm 1.58	1.520
Pelvic Index 0	41.89 \pm 1.51	49.37 \pm 4.18	52.80 \pm 2.30	1.460
Pelvic Index 7	59.24 \pm 1.52 ^c	58.65 \pm 2.95 ^c	47.63 \pm 1.59 ^d	3.687
Pelvic Index 30	61.87 \pm 1.82 ^a	63.90 \pm 2.07 ^a	58.69 \pm 1.38 ^b	2.347
Pelvic Index 90	69.55 \pm 1.95 ^a	71.18 \pm 2.23 ^a	65.71 \pm 1.72 ^b	2.756
Pelvic Index 180	69.30 \pm 1.46	72.48 \pm 3.35	74.01 \pm 1.92	1.756
Transversal Pelvic Index 0	15.71 \pm 0.51 ^a	16.81 \pm 1.07 ^a	13.24 \pm 0.70 ^b	6.170
Transversal Pelvic Index 7	17.84 \pm 0.62 ^a	17.99 \pm 1.02 ^a	16.15 \pm 0.49 ^b	4.927
Transversal Pelvic Index 30	24.32 \pm 0.83 ^a	23.89 \pm 0.85 ^a	21.85 \pm 0.68 ^b	2.841
Transversal Pelvic Index 90	26.14 \pm 0.75 ^a	27.04 \pm 0.74 ^a	24.11 \pm 0.80 ^b	2.852
Transversal Pelvic Index 180	28.07 \pm 0.59	29.68 \pm 1.08	29.27 \pm 1.14	1.795
Longitudinal Pelvic Index 0	33.79 \pm 0.48 ^a	33.40 \pm 0.90 ^a	31.79 \pm 0.63 ^b	2.489
Longitudinal Pelvic Index 7	35.22 \pm 0.61 ^a	35.34 \pm 0.59 ^a	32.98 \pm 0.73 ^b	6.679
Longitudinal Pelvic Index 30	39.42 \pm 0.87 ^a	37.77 \pm 0.69 ^a	35.76 \pm 0.91 ^b	2.087
Longitudinal Pelvic Index 90	38.90 \pm 0.75	38.13 \pm 0.77	40.05 \pm 0.65	1.805
Longitudinal Pelvic Index 180	40.58 \pm 0.51	41.38 \pm 1.01	39.48 \pm 0.84	1.412
Body Index 0	86.09 \pm 1.45 ^a	87.32 \pm 2.60 ^a	82.54 \pm 1.22 ^b	2.125
Body Index 7	88.00 \pm 1.48 ^a	89.02 \pm 1.29 ^a	82.64 \pm 1.28 ^b	2.151
Body Index 30	88.23 \pm 1.22 ^a	86.77 \pm 1.47 ^a	84.70 \pm 1.96 ^b	2.027
Body Index 90	81.78 \pm 1.28	79.59 \pm 1.42	83.99 \pm 1.42	1.195
Body Index 180	75.12 \pm 0.93	75.30 \pm 1.21	77.39 \pm 1.53	1.529
Relative Shortness Index 0	115.2 \pm 1.93	114.4 \pm 2.16	113.9 \pm 2.10	1.507
Relative Shortness Index 7	105.3 \pm 2.15 ^a	105.1 \pm 2.05 ^a	101.6 \pm 1.54 ^b	2.405
Relative Shortness Index 30	98.08 \pm 1.84	98.55 \pm 2.84	98.01 \pm 2.46	1.698
Relative Shortness Index 90	96.67 \pm 1.94	95.41 \pm 2.21	91.90 \pm 2.02	1.695
Relative Shortness Index 180	92.58 \pm 1.31	90.82 \pm 1.76	93.45 \pm 1.23	1.507
Compactness Index 0	15.45 \pm 0.46 ^a	17.15 \pm 0.74 ^a	12.93 \pm 0.78 ^b	2.592
Compactness Index 7	18.09 \pm 0.43 ^c	19.85 \pm 0.65 ^c	13.97 \pm 0.75 ^d	5.553
Compactness Index 30	28.49 \pm 0.65 ^c	31.13 \pm 1.45 ^c	21.44 \pm 1.17 ^d	7.397
Compactness Index 90	143.9 \pm 3.76	145.97 \pm 3.42	144.4 \pm 1.96	1.012
Compactness Index 180	68.32 \pm 2.54	72.30 \pm 2.28	68.01 \pm 1.75	2.001
Relative Weight Index 0	15.48 \pm 0.43	15.23 \pm 0.76	13.84 \pm 0.68 ^b	2.296
Relative Weight Index 7	17.34 \pm 0.57 ^c	18.96 \pm 0.66 ^c	14.63 \pm 0.88 ^d	4.072
Relative Weight Index 30	30.58 \pm 0.96 ^c	32.14 \pm 1.22 ^c	28.91 \pm 1.31 ^d	6.843
Relative Weight Index 90	154.6 \pm 2.71 ^a	154.3 \pm 2.79 ^a	150.6 \pm 2.87 ^b	2.742
Relative Weight Index 180	78.79 \pm 2.50	80.39 \pm 2.44	81.95 \pm 2.29	1.192
Proportionality Index 0	87.36 \pm 1.50 ^c	88.08 \pm 1.76 ^c	81.73 \pm 1.78 ^d	6.198
Proportionality Index 7	95.86 \pm 1.96 ^a	97.10 \pm 1.80 ^a	90.27 \pm 1.28 ^b	2.372
Proportionality Index 30	105.2 \pm 2.17 ^a	104.7 \pm 2.84 ^a	100.6 \pm 2.49 ^b	3.198
Proportionality Index 90	105.6 \pm 2.52	104.4 \pm 2.36	103.3 \pm 2.32	1.652
Proportionality Index 180	109.5 \pm 1.57	112.4 \pm 2.26	109.2 \pm 1.49	1.547

Different superscripts in the same row are significantly different. a and b, $p < 0.05$; c and d, $p < 0.01$.

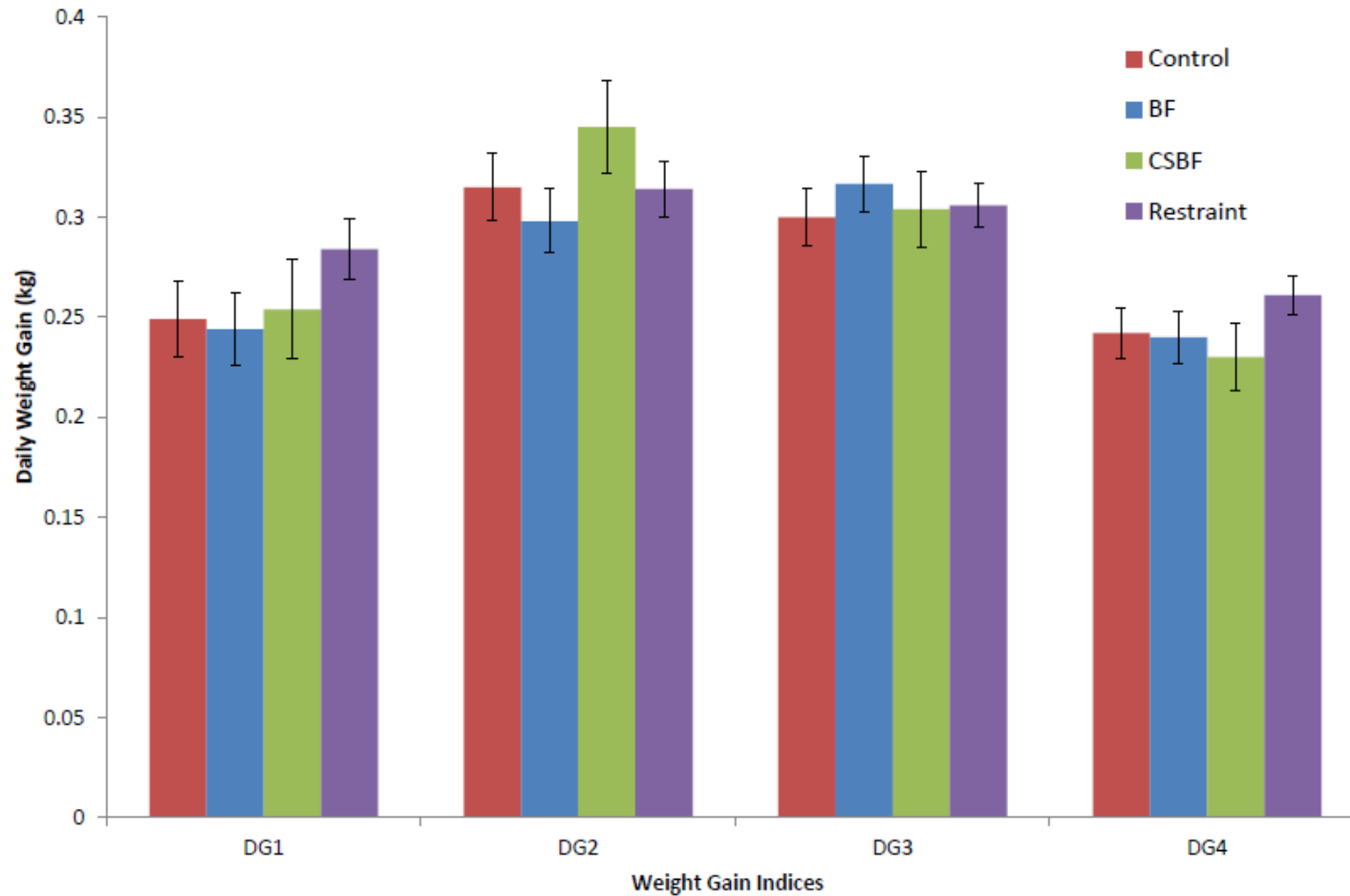


Figure 4.6: Daily weight gain across the different foster method treatments over time. Where BF = birth fluids, CSBF = cervical stimulation & birth fluids, DG1 = average daily gain from day 0 - 7, DG2 = average daily gain from 8 - 30, DG3 = average daily gain from 31 – 90 and DG4 = average daily gain from 91 - 180.

4.3.2 Post-slaughter data

When comparing the carcass quality of lambs subjected to different rearing conditions, results showed that ewe reared lambs had significantly higher conformation scores and chest roundness indices than artificially reared lambs ($K = 7.215$, $p < 0.01$; $K = 4.073$ $p < 0.05$ respectively; Table 4.3). Other parameters were not found to be affected by rearing condition including slaughter weight. There were no significant differences for any of the carcass and meat quality measures between foster methods. This was also the case for the comparison between alien and natal lambs as no significant differences were found between them for any of the carcass or meat quality measures.

Figure 4.7 shows how the ewes' experience had a significant impact on the live slaughter weight ($F_{1,59} = 5.075$, $p < 0.05$) and cold carcass weight ($F_{1,59} = 4.346$, $p < 0.05$) with the multiparous ewes rearing significantly heavier lambs compared to the primiparous ewes. The ultimate pH was also significantly affected by the ewes' experience with the multiparous ewe lambs having significantly lower pH values ($F_{1,59} = 4.512$, $p < 0.05$). The remaining carcass and meat quality parameters showed no significant differences between the multiparous and primiparous ewes.

Table 4.3: Mean (\pm SE) carcass and meat quality measures and median (\pm SE) conformation and fat scale scores (according to converted grades from Table 4.1) for lambs slaughtered at 180 days according to their rearing methods (ewe-reared and artificially reared).

Quality measures	Ewe Reared		Artificially Reared
	Control	Fostered	
Live Slaughter Weight	46.66 \pm 2.10	48.45 \pm 1.97	43.46 \pm 1.20
Cold Carcass Weight	23.04 \pm 1.39	23.65 \pm 1.37	20.51 \pm 0.85
Conformation	10.05 \pm 0.39 ^a	10.66 \pm 0.45 ^a	8.90 \pm 0.56 ^b
Conformation Scale Grade	U-	U-	R
Fatness	7.68 \pm 0.19	8.22 \pm 0.28	8.00 \pm 0.30
Fatness Scale Grade	3	3	3
Ultimate pH	5.80 \pm 0.02	5.80 \pm 0.02	5.81 \pm 0.02
Water Holding Capacity	19.36 \pm 0.47	19.35 \pm 0.32	19.37 \pm 0.31
L* (Lightness)	35.52 \pm 0.79	34.50 \pm 0.86	35.67 \pm 0.32
a* (Redness)	7.04 \pm 0.04	7.01 \pm 0.93	6.99 \pm 0.08
b* (Yellowness)	3.31 \pm 0.05	3.32 \pm 0.08	3.25 \pm 0.13
Commercial Dressing Index	48.97 \pm 5.20	47.27 \pm 4.37	47.38 \pm 2.19
Chest Roundness Index	91.55 \pm 2.56 ^a	89.72 \pm 2.57 ^a	81.85 \pm 3.44 ^b
Buttock/Leg Index	69.54 \pm 2.01	73.04 \pm 2.46	76.01 \pm 1.06
Carcass Compactness	35.12 \pm 3.08	35.76 \pm 2.99	35.29 \pm 1.25

Different superscripts in the same row are significantly different.
a and b, $p < 0.05$.

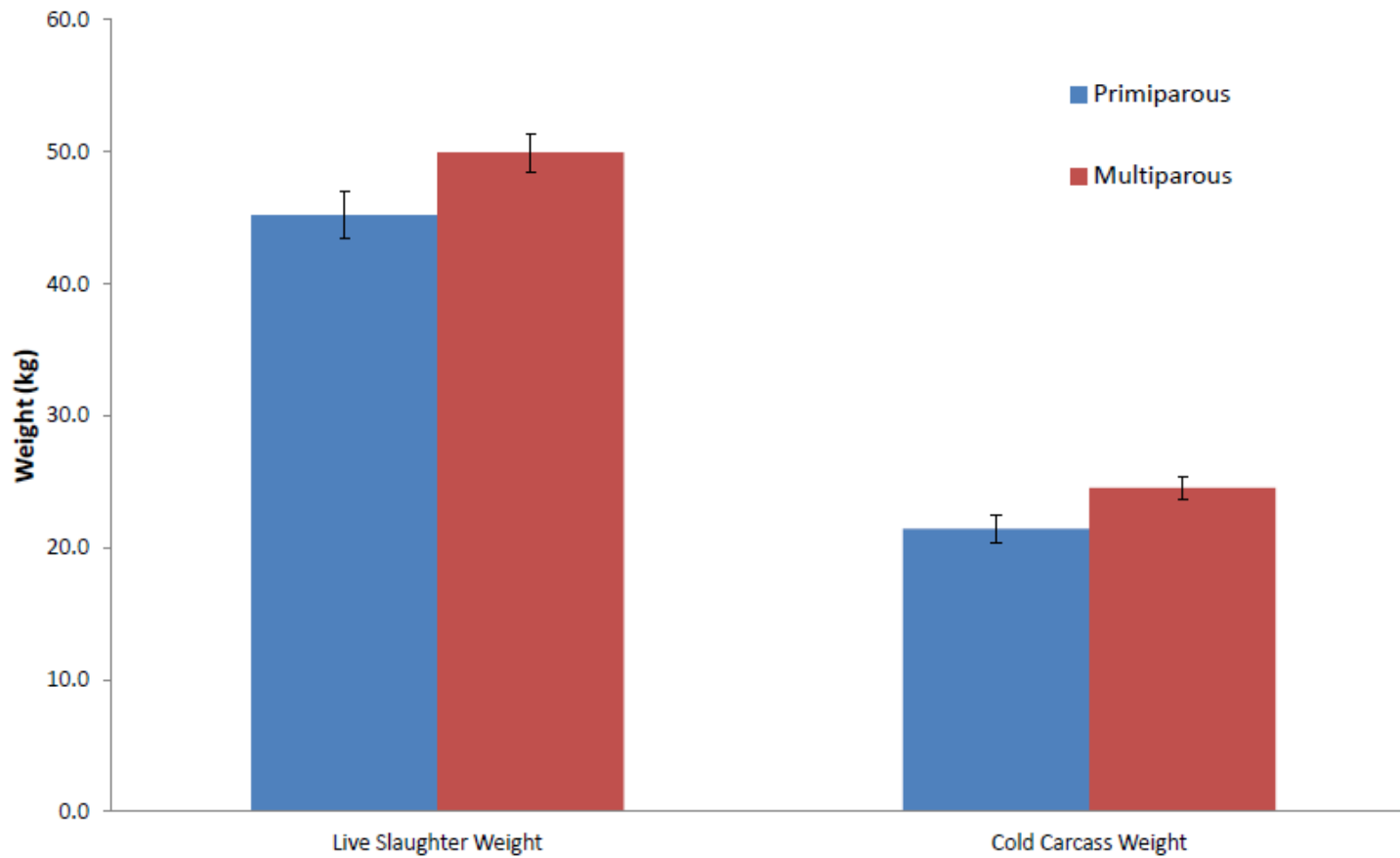


Figure 4.7: Differences in live slaughter weight and cold carcass weights between primiparous (first time) and multiparous (experienced) ewe reared lambs.

4.4 Discussion

4.4.1. Pre-slaughter data

Results showed that for at least the initial three months of life, the artificial rearing of lambs significantly reduced the lambs' daily weight gain. The use of any of the fostering methods was beneficial when compared to artificial rearing, and these animals followed a similar growth rate to the control lambs. These results compare favourably to work by Oztabak & Ozpinar (2006) and Napolitano *et al.* (2006) who showed average daily weight gain for the ewe reared lambs was significantly higher than for the AR lambs from birth up until 21 days. However, Napolitano *et al.* (2002) and Sevi *et al.* (2003) found no differences between the artificially and ewe reared average lamb growth rates. The opposing results may be linked to the *ad lib* feeding available for the ewe reared lambs therefore having access to milk at all times. Due to the setting of this study, this feeding apparatus was not available and the AR lambs had feeding sessions every three hours which was similar to the set up of Oztabak and Ozpinar (2006). In a commercial setting it is difficult to maintain constant milk availability due to the intensity of the lambing period and the time constraints that the shepherd undergoes (Napolitano *et al.*, 2002).

Live body measurement indices at varying points between 0 and 90 days were found to be significantly more advanced for the ewe-reared lambs compared to the artificially reared lambs. This suggests that the AR lambs were not growing at the same rate as the ewe-reared lambs were.

Previous studies have found that there are strong correlations between body weight and live body measurements (Alderson, 1999, Arthur and Ahunu, 1989, Ribeiro *et al.*, 2004) with different body features being more prominent at different ages in growing lambs. Arthur and Ahunu (1989) suggested this was a reflection of the different growth rates in different locations of the body and that areas grew at different rates, current results follow this idea in that if the animals are showing a significant difference in the daily weight gain, they also show differences with some of the live body measurement indices.

The daily weight gain and the live body measurement indices showed no differences between the rearing treatments between 91 and 180 days (DG4). This was linked to the fact that lambs were weaned at 90 days and then fed on grass with access to the same pastures so the AR lambs were able to compensate their weight gain during this period of equal resource availability. Norouzian and Valizadeh (2011) also found that after weaning, the growth rates were not affected by the rearing treatment.

Neither the average daily gain nor the live body indices varied among the three foster methods studied, for any of the time periods analysed. These daily gains and live body indices did not differ from those of control twins either. It is possible that because the lambs that were studied came from successful fosterers, the daily gain and growth rates were not affected. Bickell *et al.* (2009b) suggested that calm ewes produced better quality milk than nervous ewes and that this was dependant on the hormones

prolactin and insulin which were significantly lower in nervous ewes due to the diversion of biological resources to cope with fight/flight reactions. Distress also stimulates the fight/flight response and therefore could suggest that the milk quality of restrained ewes could be lower than that of an un-distressed ewe. The results of this study imply that restraint, even though shown to be initially distressing, may either not be influencing the ewes' ability to produce high quality milk or effect her capacity to raise lambs at the same rate as non-distressed ewes during the first week of life. Previous research has shown that in some breeds of sheep (Columbia and Polypay) fostered lambs can have significantly lower weights at weaning compared to dam-reared lambs (Snowder and Knight, 1995). This research did not investigate average daily weight gain and it was also highlighted that the initial birth weights of the fostered lambs were significantly lower which disadvantaged these animals.

Alien lambs were found to be significantly lighter than the natal lambs on days 0 and 7. This is mainly due to the fact that alien lambs were being born mostly as triplets and the natal lambs as singletons. These weight differences have been observed in previous studies (Hernandez *et al.*, 2009). Although the lamb weights were different for this time period, there were no significant differences in the average daily gain between them. These results suggest that both types of lambs were able to eat as much as necessary and implied that the ewe did not restrict or favour any particular individual with regards to milk provision. However, animals which are lighter or potentially behind their normal growth curve show increased

appetite and feeding behaviours to recover the weight. Weights and average daily gain of the alien and natal lambs at 30, 90 and 180 days continued to show no significant differences between them. The lack of differences between the average daily gain between the natal and alien lamb indicates that successful fosters, even if including a lighter or possibly weaker lamb, can produce similar results to lambs being reared by their own dam.

It was found that multiparous ewes raised heavier lambs than primiparous ewes during DG1, DG3 and DG4 as the weight gain during these periods were significantly higher for multiparous ewes. No previous research has compared the rearing ability of North Country mules with respect to growth rates. However, these results are possibly due to the more experienced ewes' ability to stimulate the lambs to suckle and encourage them to feed (Dwyer and Lawrence, 2000). This is also due to the fact that primiparous ewes generally produce lighter offspring, as shown in the current study, which has been linked to their lower bodyweight and age at lambing (Dwyer, 2003). These results suggest that when selecting ewes for fostering, an experienced ewe would be more beneficial to ensure a high daily weight gain for each lamb compared to a primiparous ewe. Behavioural and cortisol results from section 3.3.1 (pp 117) and 3.3.2 (pp 123) respectively also showed that primiparous ewes spent less time tending to their lambs and more time feeding and drinking and had significantly higher cortisol responses compared to multiparous ewes. This suggests that not only do the primiparous ewes produce lighter offspring

but also perform behaviours different than seen in experienced dams and also they are more influenced by parturition and fostering physiologically.

4.4.2 Post-slaughter data

Rearing was found to have a significant effect on the conformation score and chest roundness index with the lambs being ewe-reared achieving higher scores suggesting that ewe-reared lambs had better scores. It is possible that this result is also linked to the availability of milk and once the lambs had been weaned the AR lambs had the opportunity to match the other components of the ewe-reared lambs as previously suggested. Arthur and Ahunu (1989) showed that different areas of the body developed at different stages of the lamb's life and it could also be suggested that factors involved with future carcass composition develop in the initial stages when growth in ewe-reared lambs is larger than AR lambs. Further research in this area would be needed to investigate possible explanations as this aspect of carcass quality is vital for some farmers in commercial settings, as they are paid in accordance to the carcass conformation rather than weight.

Although carcass conformation is frequently used within the abattoir for carcass quality assessment it is a subjective measure and caution is needed if using this measure alone. It is likely that the majority of carcass quality measures were not found to be different between the rearing types due to the slaughter age and the time after weaning spent grazing in the

same conditions. All ewe and artificially reared lambs were out at pasture for 90 days prior to slaughter, time enough for any potential differences in carcass quality from the nursing period to even out.

Comparison of this data with other papers is difficult because traditionally these types of production studies have been conducted in southern European countries. Here, lambs are slaughtered at a much earlier age due to the increased demand for ewe milk and fed on lamb pellets rather than grass due to their drier climate and difficulties in growing pasture (Resconi *et al.*, 2010). This is an area that could be further studied as lambs within the UK are slaughtered at much heavier weights than lambs in current literature.

Carcass and meat quality measures were similar when comparing foster methods and according to whether the lamb was the alien or natal. There were no significant differences found between them, again suggesting that if a foster was classified as a success (i.e. the dam accepted the lamb and did not attempt to move away or withhold milk from it), then the growth and carcass quality would not be affected. It had been suggested that fostering and artificial rearing cause's ewe-lamb bonds to be broken which can be distressing (Levy, 2002, Shayit *et al.*, 2003). Distress during the initial stages of life could have detrimental effects on the lambs' behaviour, immune and endocrine responses (Napolitano *et al.*, 2003) which ultimately could influence the carcass quality (Gregory, 1998). However, these results imply that this was not the case or in fact, that any distress

caused by fostering or artificial rearing did not have implications on the carcass or meat quality at a slaughter age of 180 days.

Multiparous ewes were able to rear lambs with significantly higher live slaughter weight and cold carcass weights than primiparous ewes. Again, this could be linked to the increased experience of the ewes and their ability to produce more milk or to better support lambs. The ultimate pH was also significantly higher in lambs reared by primiparous compared to multiparous ewes, which was a surprising finding. Generally, the recognised pH for lamb meat ranges from 5.4 – 5.8 (Huff-Lonergan and Lonergan, 2005). The pH of the lambs reared by MP ewes did fall within this range, however, the lambs reared by primiparous ewes showed an average ultimate pH of 5.82, which was slightly over the normal range. As discussed in section 1.6.2.4 (pp 60) a high ultimate pH can cause undesirable odours, and flavours, affect palatability and reduce storage time compared to meat with a lower pH (Pethick and Jacob, 2000). High pH levels have been linked to many forms of distress including heat, transportation, dehydration, hunger, injury and fear (Ferguson and Warner, 2008). Bickell *et al.* (2009a) showed that temperaments of calm or nervous ewes were passed down genetically to their lambs and with fear being linked to a nervous temperament (Bickell *et al.*, 2011) it is possible that the lambs of primiparous ewes, which display more behaviours indicative of nervousness/fear, could perform more of these behaviours causing the increase in meat ultimate pH. More research within this area to identify

specific temperament traits of the ewes and lambs would be needed to aid clarity to this discussion.

4.5 Conclusions

This research has identified growth rates, carcass and meat quality measures for lambs within a commercial farming system in the UK. Differences were noted between the artificially reared and ewe reared lamb's average daily gain as seen with other studies with younger lambs. However, due to the extended post-weaning period where all lambs were grazing together for a period of approximately 90 days, any differences were compensated and AR lambs produced similar meat quality results as ewe reared lambs. AR lambs, however, did show significantly lower quality conformation and chest roundness scores. This suggested that ewe-rearing and therefore fostering offers proven advantages in carcass conformation. This can potentially increase farmers' income compared to artificial rearing systems similar to the one in this set up.

Different foster methods and alien or natal lambs showed no differences between the growth rates, carcass and meat quality characteristics. This suggests that once a foster of any type was successfully established, the alien lamb was able to feed similarly to the natal lamb. The average daily gain weight was also increased at the same rate as the natal lamb thus not affecting the carcass and meat quality characteristics post-slaughter.

Multiparous ewes were capable of rearing heavier lambs and were able to support a higher average daily gain than primiparous ewes therefore

suggesting that they would be better suited for fostering in comparison to primiparous ewes.

CHAPTER V

Conclusions and Recommendations

5.1 Conclusions

5.1.1 Foster Methods Survey

The first objective of the current study was to investigate which foster methods were most commonly used in the UK sheep industry and to collate the farmers' opinions about these methods mainly regarding their impact on the ewe's and lamb's welfare. Results showed that a high proportion of respondents selected the use of foster methods to deal with orphans, rather than other possibilities, such as artificial rearing.

The ewes' health and welfare was the principal component farmers took in account to select a particular foster method. They monitored this mainly by observing the ewes' behaviour.

The most popular foster method was birth fluids, followed by restraint crates. Farmers explained that using birth fluids was the easiest method to perform and, in their opinion, the most preferred by the ewe as it was less invasive and restrictive. The fact that restraint crates represented the second choice may be linked to the urgency for the lamb to feed quickly and to avoid artificial rearing. Cervical stimulation and birth fluids, were selected as the most common combination of methods and were described by farmers as an intermediate step between less invasive (birth fluids) and more invasive (restraint crate) fostering methods.

5.1.2 Behaviour and Welfare

The second objective was to examine the behaviour and welfare implications of the most prevalent fostering methods established in objective one; which were birth fluids, restraint crates and the combination of birth fluids plus cervical stimulation. The results showed that restraint crates caused significant negative changes to the ewe's behaviour and also increased their heart rates and salivary cortisol concentrations. The behavioural and physiological changes together could be considered indicative of distress.

There were no differences found in the behaviours, heart rate variability and cortisol levels between the multiparous and primiparous ewes. This suggests that experience may not affect ewes' ability to foster an alien lamb successfully or perform satisfactory behaviours to enable it to survive.

5.1.3 Carcass and Meat Quality

The third objective of the current study investigated production parameters of fostered individuals comparing different foster methods, differences between natal and alien lambs and differences between ewe and artificially reared individuals.

The different foster methods had no effect on the carcass or meat quality and no differences were found between natal and alien lambs either. This

suggests that successfully fostered lambs all presented a similar product quality. Differences were noticed, between artificially and ewe reared lambs with the initial average daily gain being significantly lower in artificial compared to ewe reared lambs. However, these differences disappeared after weaning, due to the compensatory growth of the artificially reared lambs while grazing *ad libitum* on the pastures. Ewe reared lambs also presented better carcass conformation, which suggests that ewe rearing, and therefore fostering, offers proven advantages over artificially rearing when considering production outcomes.

Multiparous ewes were capable of rearing heavier lambs and were able to support a higher average daily gain than primiparous ewes, suggesting that they would be better suited for fostering in comparison to primiparous ewes.

5.1.4 Overall Conclusions

From the behaviour and physiological point of view, some foster methods can be seen as restrictive and distressing for the ewe. However, the outcome of the production enterprise (lamb weights and quality) was not affected by the type of foster method being used. Therefore, production parameters such as meat and carcass quality do not seem to be necessary to assess the suitability of a foster method. Conversely, on welfare grounds, it seems beneficial to select a foster method that causes the lower level of distress to the ewe.

Distressing foster methods, such as restraint crates, should be avoided because they increase the performance of negative behaviours, heart rate variability and salivary cortisol concentrations. If shepherds were to foster using less invasive methods such as birth fluids, ewes would benefit from an improved welfare status, plus lambs would be of a better conformation at sale than those artificially reared.

5.2 Implications for Commercial Farming

The current research has shown that fostering has a wide range of benefits over artificial rearing within UK commercial practices. Not only does it reduce the time and financial burden on the shepherds during lambing time, but it also helps to improve the carcass conformation of the lambs at the point of sale. This is an important aspect of increasing a farm's monetary return as carcass conformation can lead to increases in payment for the lambs produced.

Less invasive methods of fostering, such as birth fluids, are more beneficial than the use of restraint crates, because they do not negatively affect maintenance and maternal ewe behaviours. If farmers chose to eradicate the use of restraint crates, they could avoid unnecessary distress to their stock with the additional benefit of being eligible for welfare schemes such as the RSPCA's Freedom Foods.

When selecting ewes to become a foster dam, farmers would benefit to opt for more experienced multiparous ewes. Although maternal and acceptance behaviours, cortisol and heart rate variability between multiparous and primiparous ewes were similar, data showed that multiparous ewes were able to rear heavier lambs.

According to the results found in the current study, once lambs had been accepted and a successful foster has taken place, there were no differences in the average daily gain or the carcass and meat quality among foster methods or between alien and natal lambs. As mentioned above, this highlights that production outcomes are not necessary to choose which foster method would be more beneficial for a farming enterprise.

5.3 Limitations

Throughout the course of the current investigation, certain potential bias has proved difficult to minimise. The objective of the current research was to investigate fostering in a commercial setting and to ensure the practical application of the results. This made it unfeasible to study the behavioural and physiological implications of primiparous ewes undergoing the cervical stimulation and birth fluid method.

There were no previous records at Moulton College farm about the exact age and maternal experience of each multiparous ewe monitored in the current study. It was therefore impossible to identify if the number of times the ewe had lambed played a role in their behavioural and/or physiological response. In addition, no records existed about previous foster dams, which made impossible to ascertain previous fostering experience in the ewes used for the trials. Especially important was the fact that foster dams used during the current investigations, even if highly unlikely, might have had previous experience with restraint crates, which may have affected their behavioural and physiological response to them.

Due to the type of facilities and equipment available, it was not possible to analyse individual ewe-lamb communication. Ewe sounds were easily heard and seen on the videos analysed during the current study, but often the lambs' communicative response was too subtle to hear or visualise.

Therefore, lamb responses to high and low pitched ewe bleats could not be collated and had to be omitted from the analysis.

The original intention also set out to evaluate the salivary cortisol response of the lambs during fostering. However, during the first stages of data collection, the difficulties in getting enough saliva per sample for the EIA analysis to take place were soon patent as the lambs did not produce enough saliva within the time frame of the study.

5.4 Further Research

Results in the current study (Foster Methods Survey) suggest that the choice of lamb to foster is a controversial one. Some shepherds chose the strongest triplet, some routinely selected a lamb of average size and weight and a small proportion of shepherds always selected the smallest lamb. With such a variety of responses it is clear that scientific knowledge in this area is lacking, and further studies into which lamb could have a better chance of acceptance by the foster dam would aid the decision that shepherds need to make.

Bickell *et al.*, (2011) found that ewe-lamb recognition was not influenced by sheep temperaments. Research into whether calm or nervous ewes would be more likely to accept or reject an alien lamb in a commercial setting could help shepherds to decide which ewes should be selected as foster dams.

The key welfare focus within the context of the current research was on the ewes undergoing the foster method. It would be valuable to explore the behaviour and welfare implications towards the lambs and to investigate if they were affected behaviourally or physiologically due to the fostering procedures. Further studies would be needed to investigate the lambs' motivation to be accepted and also to see if the new lamb-lamb bond affected the alien lambs' ability to suckle.

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Lamb Fostering Methods Questionnaire

Survey of lamb fostering methods used in UK farming practices

The following survey has been planned to assess how often fostering lambs onto other ewes occurs in UK sheep farms, how it is achieved and which methods are most successful. These results can then be used to compare popular and successful methods in terms of production and animal welfare. The results of the survey will be analysed and made available for interested parties.

Please complete all questions as fully as possible. All comments will be treated anonymously. Please find enclosed a pre-paid envelope for your reply.

The table below list and defines some of the fostering methods which are mentioned in this study.

Method	Description
Skinning	Removing the skin of the dead natal lamb and placing it onto the alien lamb
Textile Jacket	Placing cloth jackets onto the natal and alien lamb and swapping the jackets prior to fostering
Birth Fluid	Rubbing the birth fluids from one lamb onto another lamb prior to fostering
Odorants	Coating the foster lamb and natal lamb in the same lotion, such as neatsfoot oil to ensure both lambs smell the same to the ewe
Restraint	Placing the ewe in a crate of some form to restrict her movement allowing the lambs to suckle beneath her without allowing her to discard them
Cervix stimulation	Inserting your hand, for example, into the ewes' vagina and applying pressure to expand the cervix. This simulates contractions, so the ewe believes she is in labour
Induced lactation	Injecting or sponging areas of the ewe with hormones to provoke the production of (more) milk

Location					
Please give the beginning of your postcode so that area comparisons can be made	<table border="1"> <tr> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> </tr> </table>				

Lamb Fostering Methods Questionnaire

Section 1. Your Flock				
Do you have any of the following?	Number of ewes		Number of rams	
<input type="checkbox"/> Hill (above 500m)	N ^o	Breed:	N ^o	Breed:
	N ^o	Breed:	N ^o	Breed:
<input type="checkbox"/> Upland (300-500m)	N ^o	Breed:	N ^o	Breed:
	N ^o	Breed:	N ^o	Breed:
<input type="checkbox"/> Lowland (below 300m)	N ^o	Breed:	N ^o	Breed:
	N ^o	Breed:	N ^o	Breed:
<input type="checkbox"/> Mixed breed	N ^o	Breed:	N ^o	Breed:
		Breed:		Breed:
	N ^o	Breed:	N ^o	Breed:
		Breed:		Breed:

Section 2. Lambs (Most recent season)	
How many lambs were born alive?	
How many lambs were weaned?	

Age at sale of finishing lambs?		7 - 9 wks	10 - 12 wks	13 - 15 wks	16 - 18 wks
<i>(Tick 1 per birth type)</i>	Single				
	Twin				
	Triplet				

Lamb Fostering Methods Questionnaire

Section 3. Fostering Methods	
<p>1. Do you ever foster lambs onto other ewes? (Tick one)</p>	<p><input type="checkbox"/> Never <input type="checkbox"/> Sometimes (once or twice per season) <input type="checkbox"/> Frequently (5+ every season) <input type="checkbox"/> Always (every season when needed)</p>
<p>2. Why do you decide to foster? (Tick as many as apply)</p>	<p><input type="checkbox"/> Ewe dies <input type="checkbox"/> Triplets are born <input type="checkbox"/> Ewe too weak <input type="checkbox"/> Ewe not producing enough milk <input type="checkbox"/> Other (Please state) </p>
<p>3. Which lamb would you normally choose for fostering onto a ewe?</p>	<p><input type="checkbox"/> The strongest <input type="checkbox"/> The smallest <input type="checkbox"/> Average size/weight <input type="checkbox"/> Other</p>
<p>4. Do you ever use any other forms of fostering?</p>	<p><input type="checkbox"/> No <input type="checkbox"/> Yes (please specify) </p>
<p>5. Do you ever combine two or more methods at the same time?</p>	<p><input type="checkbox"/> No <input type="checkbox"/> Yes (please specify) </p>
<p>6. From the statements aside, If you had to choose one method which would you prefer?</p>	<p><input type="checkbox"/> Bottle/tube feed lamb <input type="checkbox"/> Foster the lamb <input type="checkbox"/> Not interfere with the lamb</p>
<p>7. Which of the methods described above do you feel is the easiest method of fostering? (Tick one only)</p>	<p><input type="checkbox"/> Skinning a dead lamb <input type="checkbox"/> Textile jacket <input type="checkbox"/> Birth fluid <input type="checkbox"/> Odorant <input type="checkbox"/> Restraint <input type="checkbox"/> Cervical stimulation <input type="checkbox"/> Other (Please specify below) </p>

Lamb Fostering Methods Questionnaire

Fostering Methods	
<p>8. Which of the methods described above do you feel is the best and most successful fostering method for yourself?</p> <p>(Tick one only)</p>	<p><input type="checkbox"/> Skinning a dead lamb</p> <p><input type="checkbox"/> Textile jacket</p> <p><input type="checkbox"/> Birth fluid</p> <p><input type="checkbox"/> Odorant</p> <p><input type="checkbox"/> Restraint</p> <p><input type="checkbox"/> Cervical stimulation</p> <p><input type="checkbox"/> Other (Please specify below)</p> <p>.....</p>
<p>9. Which of the methods described above do you feel is the best and most successful fostering method for the animals?</p> <p>(Tick one only)</p>	<p><input type="checkbox"/> Skinning a dead lamb</p> <p><input type="checkbox"/> Textile jacket</p> <p><input type="checkbox"/> Birth fluid</p> <p><input type="checkbox"/> Odorant</p> <p><input type="checkbox"/> Restraint</p> <p><input type="checkbox"/> Cervical stimulation</p> <p><input type="checkbox"/> Other (Please specify below)</p> <p>.....</p>
<p>10. Place in order of preference your top 4 fostering methods</p> <p>(Indicate by numbering 1 – 4 in order, where 1 is the most preferred)</p>	<p><input type="checkbox"/> Skinning a dead lamb</p> <p><input type="checkbox"/> Textile jacket</p> <p><input type="checkbox"/> Birth fluid</p> <p><input type="checkbox"/> Odorant</p> <p><input type="checkbox"/> Restraint</p> <p><input type="checkbox"/> Cervical stimulation</p> <p><input type="checkbox"/> Other (Please specify below)</p> <p>.....</p>
<p>11. Do you think that fostering methods used have any impact on the lambs'/ewes' welfare?</p>	<p><input type="checkbox"/> No welfare implications</p> <p><input type="checkbox"/> Slight welfare implications</p> <p><input type="checkbox"/> Medium welfare implications</p> <p><input type="checkbox"/> Severe welfare implications</p>

Lamb Fostering Methods Questionnaire

Fostering Methods	
12. How do you decide if the fostering method is successful or not? (Tick as many as apply)	<input type="checkbox"/> Behaviour of ewe <input type="checkbox"/> Weight of lamb <input type="checkbox"/> Growth of lamb <input type="checkbox"/> Amount of time showing success <input type="checkbox"/> Other (Please specify below) <input type="checkbox"/> All of the above <input type="checkbox"/> Combination of.....

Definitions for the following questions can be found on the front page. For the following questions please select one of the following:

- Never,
- Sometimes (once or twice per season),
- Frequently (5+ every season) or
- Always (every season when needed)

	Never	Sometimes	Frequently	Always
13. How often do you bottle feed the lamb(s)?				
14. How often do you use the skinning method?				
15. How often do you use the textile jacket method?				
16. How often do you use the birth fluid method?				
17. How often do you use the odorants method?				
18. How often do you use the restraint method?				
19. How often do you stimulate the ewes' cervix as a method of fostering?				

Section 4

The next part of the survey will look at your thought and opinions towards fostering lambs.

Using a five point scale:

- 1 Strongly disagree,
- 2 Disagree,
- 3 Neither agree or disagree,
- 4 Agree,
- 5 Strongly agree,
- N/A Not applicable,

Please circle the answer that most closely matches your personal opinion:

Strongly disagree → Strongly agree

20. I believe ewe welfare is important	1	2	3	4	5	N/A
21. It is important to keep as many live lambs as possible	1	2	3	4	5	N/A
22. I have tried a variety of fostering methods	1	2	3	4	5	N/A
23. I think that increased animal health will increase my returns	1	2	3	4	5	N/A
24. I think that fostering is an important way of increasing my returns	1	2	3	4	5	N/A
25. I want to find out about other foster methods	1	2	3	4	5	N/A
26. I tend to stick to the foster methods I know Have worked before	1	2	3	4	5	N/A
27. I would like to know the most successful fostering method to increase my returns	1	2	3	4	5	N/A
28. I always have the animals' health and wellbeing in mind when fostering lambs	1	2	3	4	5	N/A
29. I always have the production levels in mind when fostering lambs	1	2	3	4	5	N/A

Please use the space below to add any additional comments you think may be beneficial to this study.

.....

Finally.....

Would you be willing to be contacted again if needed?

- Yes
- No

Would you be interested in receiving a summary of the results of this questionnaire?

Appendix I.

Lamb Fostering Methods Questionnaire

Yes

No

If you answered yes to either of the above questions, please could you leave your contact details below?

Email:.....
.....

Telephone:.....
.....

Address:
.....
.....
.....
.....
.....

Please return in the SAE provided or to the following address:

Sam Ward,
Moulton College,
Moulton,
Northampton,
NN3 7RR

You can also contact me on:

Tel: 01604 491131 ext: 607

Email: Sam.Ward@moulton.ac.uk