Influence of supplementation on the productivity of ewes grazing improved pasture and suckling twins
by Ana Lidia Frey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Animal Science
Montana State University

Abstract:
Twenty-six mature Finn-Targhee ewes suckling twin lambs were used to determine the effects of supplementation on milk production and lamb growth. Ewes and their lambs grazed an improved summer pasture, and one-half of the ewes (n = 13) were supplemented every third day. Supplementation provided the equivalent of 25% of the daily NRC (1985) protein requirements for lactating ewes suckling twins. Ewe and lamb weights, milk volume and composition were determined at the beginning of the trial and at 21-day intervals for four periods during the summer. Forage allowance and quality were determined. Milk volume was not influenced by protein supplementation ($P > .10$). . Supplementation had no effect ($P > .10$) on milk quality (protein, fat, lactose and solid not fat content) in the four periods when calculated as a percentage, but in the fourth period a difference ($P < .10$) was observed in protein, fat and solids not fat (SNF) when calculated as total production per day ($g*d^{-1}$). Supplemented ewes produced more g of protein, fat and SNF than non-supplemented ewes during period four ($P < .10$). Weight gain for the 84-day grazing period was slightly higher for lambs suckling supplemented ewes (12.62 vs. 10.60 kg) ($P > .10$). In conclusion, there was no benefit to supplementation of lactating ewes grazing a high quality forage during the summer with the exception of increased protein, fat and SNF production during period four.

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Ana Lidia Frey

This thesis has been read by each member of the author's graduate committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style and consistency, and is ready for submission to the College of Graduate Studies.

7/29/88 — Verl M. Thomas

Date — Chairperson, Graduate Committee

Approved for the Major Department

7-29-88 — Arthur C. Linton

Date — Head, Major Department

Approved for the College of Graduate Studies

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TABLE OF CONTENTS

TABLE OF CONTENTS—Continued

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Twenty-six mature Finn-Targhee ewes suckling twin lambs were used to determine the effects of supplementation on milk production and lamb growth. Ewes and their lambs grazed an improved summer pasture, and one-half of the ewes (n = 13) were supplemented every third day. Supplementation provided the equivalent of 25% of the daily NRC (1985) protein requirements for lactating ewes suckling twins. Ewe and lamb weights, milk volume and composition were determined at the beginning of the trial and at 21-day intervals for four periods during the summer. Forage allowance and quality were determined. Milk volume was not influenced by protein supplementation ($P > .10$). Supplementation had no effect ($P > .10$) on milk quality (protein, fat, lactose and solid not fat content) in the four periods when calculated as a percentage, but in the fourth period a difference ($P < .10$) was observed in protein, fat and solids not fat (SNF) when calculated as total production per day ($g \cdot d^{-1}$). Supplemented ewes produced more g of protein, fat and SNF than non-supplemented ewes during period four ($P < .10$). Weight gain for the 84-day grazing period was slightly higher for lambs suckling supplemented ewes (12.62 vs. 10.60 kg) ($P > .10$). In conclusion, there was no benefit to supplementation of lactating ewes grazing a high quality forage during the summer with the exception of increased protein, fat and SNF production during period four.

CHAPTER 1

INTRODUCTION

Sheep constitute one of the most important species of livestock in the world. They produce a number of products: meat, wool, milk, hide, etc. World sheep population is approximately 1.2 billion head (FAO,1986). Argentina has twenty-five millon head and the United States ten millon. Montana has approximately 430,000 head, ranking sixth in sheep numbers in the United States.

Milk is essential in the first three to four weeks of the lamb's life. During this period correlation between milk intake and live weight gain is approximately 0.9 (Treacher, 1983). Although the necessity for milk declines as lactation progresses and lambs grow older, it is still a source of highly digestible energy and high quality protein utilized very efficiently by suckling lambs.

Highest nutritional requirements of the ewe occur during lactation, a time when summer pasture may not meet these requirements due to high moisture content of the forage early in the summer and reduced forage quality later in the summer.

Supplementation of nutrients may offset deficiencies of forage during mid-to-late lactation that limit milk production. Increasing the flow of amino acids to the small intestine is a potential method for stimulating milk production in ewes rearing more than one lamb (Loerch et al., 1985). However, little information is available on the efficacy of protein supplementation escaping rumen fermentation for increasing milk production in grazing sheep. Ewe milk production and milk efficiency were substantially improved in early lactation by supplementation with blood meal and dried meat and bone meal (Loerch et al., 1985).

The objective of this study was to determine the influence of feeding a by-pass protein supplement to ewes during mid-to-late lactation on milk volume, milk composition and lamb weight gains.

CHAPTER 2

LITERATURE REVIEW

This review summarizes literature concerning 1) methods of estimating milk yield, 2) lactation performance, 3) nutrition of the lactating ewe and 4) nutrition of the suckling lamb. Methods of estimating milk yield and a comparison between the methods are covered, followed by a review of milk volume and composition in different situations and non-nutritional factors affecting lactation. Third, the energy and protein requirements for lactation, the response of ewes to variation in energy and protein intake and the voluntary food or forage intake during lactation are reviewed. Last, a discussion of milk intake by lambs, the relationship between milk and solid food intake and the influence of sustained lactation on lamb growth concludes the review.

Methods of Estimating Milk Yield

A clear distinction must be made between the measurement of milk production from animals maintained for dairy purposes and the yield of milk available for consumption by suckling young. The latter estimates are of considerable importance to many aspects of studies on variation in lamb growth and on systems of ewe management (Doney et al., 1979). McCance (1959) described three main criteria which the adopted methods must satisfy before the results can be accepted as reliable estimates. First, the estimated value must be representative of the actual rate of secretion over a given test period. It is essential the udder be emptied to the same extent both at the start and end of the period over which the measurement is made. Second, the actual rate of milk secretion during the test periods must not differ significantly from that in other periods over which the estimate is to be extrapolated. Since most recorded lactations show a curvilinear pattern with increasing peak and decreasing phases, this criterion can never be absolutely satisfied. Third, methods adopted to measure milk yield must not significantly affect the rate of secretion either in the short or the long term.

Suckling and Test-Weighing Method

The test-weighing method, also called weigh-suckle-weigh, of estimating milk yield of suckled animals by measuring the amount of milk consumed after a short interval of separation or a series of such intervals has been used by many authors (Owen,1957; Doney et al., 1979). Lambs are separated from their mothers or ewes are fitted with udder covers (so that the lamb-to-mother relationship is not interrupted). During a 24 h period lambs are allowed to suckle during different, smaller periods. Prior to and after each suckling period each lamb is weighed and the sum of its weight increments in 24 hours is considered as the milk yield of its dam for the day of the test (Doney et al., 1979).

Hand or Machine-Milking Method

The oxytocin technique provides measurement of potential ewe milk production (McCance, 1959). However, it may overestimate lamb consumption by 20% (Coombe et al.,1960; Moore, 1962). This technique involves milking the ewe either by hand or machine after injection with oxytocin. Oxytocin is a hormone released by the pituitary gland that acts at the level of the mammary gland; it produces the release (let down) of milk. Doses required to elicit emptying of the udder in sheep have been investigated by several authors covering a range of 0.1 to 10 international units (IU, McCance, 1959; Semjan, 1962)). In all cases, a linear response between dose rate and the degree of emptying was found. Authors recommend that a second dose be given after response of the first has ceased (Peart, 1983). McCance (1959) working with normally suckled sheep found a second dose of 5 IU following first injection of the same amount rarely allowed more than an additional 20 milliliters (ml) of milk to be withdrawn. Therefore, the experimental error introduced by using only a single dose would rarely exceed 5% of the observed value. Ewes are milked out and separated from the lambs for a period that varies between two and six h. Ewes are then milked again, milk production for the period is recorded and daily milk production calculated. Rate of secretion is apparently faster the first 2 h, and the effect lessens as lactation declines (McCance, 1959).

It is recommended that oxytocin injection be done intravenously for a faster response. However, Geenty (1980) found no difference in milk yield when dosing sheep intramuscularly compared to intrajugular injection.

Body-Water Dilution Technique

Tritiated water dilution measures body water turnover of lambs in the field during a given time period (Macfarlane et al., 1969). Most milk is greater than 80% water and the burning of hydrogen in the milk solids yields a volume of water near that of solids themselves. Therefore, measurement of water turnover in the young provides a close estimate of milk intake (Macfarlane et al., 1969). A disadvantage of this estimate is that it cannot account for non-milk sources of water intake which can lead to considerable overestimation when milk ceases to be the sole source of water (Wright and Wolff, 1976). Wright and Wolff (1976) created the double isotope method to eliminate this overestimation. They concluded it is possible to estimate not only individual milk intake but also changes in relative body composition, water turnover and, in some circumstances, pasture intake of water with this method.

Comparison of the Methods

Comparison of the weighing method with the oxytocin method suggests the latter method gives higher estimates (Treacher, 1983). Doney et al. (1979) found the oxytocin method gave higher estimates of yield in the first week of lactation, especially in ewes suckling single lambs. However, by the third week there were no significant differences between estimates made by the two methods. Estimates were not affected by level of milk production, number of lambs suckled or genotype of the ewe. From a practical point of view, the oxytocin method is more convenient, less tedious and less time-consuming than the lamb-suckling technique. Weight increases due to suckling are too small to be measured accurately at 10 wk after birth and this is another disadvantage of the weighing method (Coombe et al., 1960). Geenty et al. (1985) concluded the oxytocin method overestimates milk consumed by lambs during the initial two to three wk of lactation, particularly in breeds such as the Dorset with high milk production. Estimates of lamb water turnover gave better predictions of feed intake and hence lamb growth. Geenty and Sykes (1986) found the machine milking technique following oxytocin administration gave estimates which were, on average, 2.4, 8.9 and 18.8% higher for groups of ewes on low, medium and high forage allowances, respectively, compared to the suckling technique.

Peart (1983) stated

> Whilst a knowledge of factors responsible for variation in milk production by ewes and milk intake by lambs is essential for the interpretation and development of management systems for sheep, it must be recognized that all techniques for estimating these characters are subject to some systematic bias or to variable errors introduced by the experimental management. Nevertheless valid estimates for most applied purposes may be obtained by any of the three methods; the choice being dependent on the experimental objectives and the available resources.(1)

(1) Peart, J. N. (1982) Lactation of suckling ewes and does. In: I Coop (Ed.) Sheep and Goat Production. World Animal Science, v. C1. Elsevier, Amsterdam. pp. 121-122.

Lactation Performance

Milk Yield

Many estimates have been made to quantify the milk production of different breeds of sheep using different measurement techniques. These estimates vary according to breed, location, level of nutrition, number of lambs born or reared, breed of ewe, age of dam, body weight, moment of the lactating period when the estimate is measured and the technique used in the measurement. These differences must be taken into account when comparisons are made between sources of information (Peart, 1982). A summary of selected milk yield studies is presented in Table 1.

Table 1. Selected milk yield studies reported in the literature.

Author/Year	Breed (Birthtype)	Lactation Test Period (wk/wks)	Milk Yield ($kg \cdot d^{-1}$)
Wallace (1948a)	Suffolk	1–7	1.59
		1–12	1.39
	Border Leicester x Cheviot	1–7	2.09
		1–12	1.81
Review of authors listed by Wallace (1948a):			
a. Fuller & Kleinheinz	Oxford, Southdown, Dorset, Merion, Montana, Shropshire	1–7	1.27
b. Neidig & Iddings	Hampshire, Southdown	1–7	1.24
c. Pierce	Merino	3	1.21
		9	.65

Table 1--continued

Author/Year	Breed (Birthtype)	Lactation Test Period (wk/wks)	Milk Yield ($kg \cdot d^{-1}$)
	Suffolk	3	1.76
		9	1.07
	Border Leicester	3	2.49
		9	1.37
d. Barnicoat	Southdown Cross	2-5	1.50
		14	.65
e. Bonsma	Merino	1-12	.75
	Merino Cross	1-12	1.13
Barnicoat et al. (1949a,b)	a. Romney (twin)	1-12	1.84
	(single)		1.36
	b. Romney (single)	2-10	1.36
	c. Romney (single)	2-10	1.45
	d. Romney (single)	1-12	1.30
	e. Romney (single)	1-12	1.50
	f. Romney (twin)	1-12	1.70
	(single)		1.28
Thomson & Thomson (1953)	Sutherlandshire Cheviot	1-13	.55-.98
Burris & Baugus (1955)	Hampshire (twin)	1-12	.94
	(single)		.89
Barnicoate et al. (1956)	Romney (twin)	1-3	1.56-2.18
		1-12	.99-1.53
	(single)	1-3	1.19-1.45
		1-12	.82-1.16
Gardner & Hogue (1964)	Ramboillet x Columbia (twin)	1-13	2.08-2.33
	(single)		1.61-1.88
(1966)	Hampshire (twin)	1-12	2.47
	(single)		2.16
	Correidale (twin)	1-12	2.15
	(single)		1.44

Table 1--continued

Author/Year	Breed (Birthtype)	Lactation Test Period (wk/wks)	Milk Yield (kg·d^{-1})
Folman et al. (1966a)	Awassi medium producing dairy flock	1-8	2.52
	Awassi high producing dairy flock	1-8	3.36
(1966b)	Awassi mutton flock	1-8	1.55
Treacher (1970)	a. Dorset Horn	1-9	1.32
	b. Dorset Horn	1-9	1.43
	c. Scottish half-bred	1-6	.99
	d. Dorset Horn	1-6	1.38
	e. Dorset Horn	1-6	1.21
	f. Dorset Horn	1-9	1.45
Wilson et al. (1971)	Dorset x Merino	1	1.47
		3	1.85
		10	1.08
Peart (1967)	Blackface (twin)	1-10	1.79-2.01
	(single)		1.44
(1968a)	Blackface	3	2.00
		12	.84
(1968b)	Blackface (twin)	1	1.87-2.34
	(single)		1.23-1.38
Peart et al. (1975a)	Texel x Blackface	1-12	1.88
	Blackface	1-12	1.52
(1975b)	Finnish Lancrace x Blackface (twin)	1-12	2.10
	(single)		1.49
(1979)	Scottish Blackface (twin)	1-14	2.12
	(single)		1.47
	East Friesland x Scottish Blackface (twin)	1-14	2.63
	(single)		1.85
Torres-Hernandez & Hohenboken (1979)	Dorset Cross	1-15	1.16
	Cheviot Cross	1-15	1.20
	Finnsheep Cross	1-15	.94
	Romney Cross	1-15	1.06

Table 1—continued

Author/Year	Breed (Birthtype)	Lactation Test Period (wk/wks)	Milk Yield (kg·d^{-1})
Robinson et al. (1979)	Finnish Landrace x Dorset Horn (twin)	2–4	3.05
Cowan et al. (1981)	Finnish Landrace x Dorset		
	Horn (twin) LP	1–6	3.32
	(twin) HP	1–6	3.50
Gonzalez et al. (1982)	Finnish Landrace x Dorset Horn (twin)		1.92
Hinch et al. (1983)	Booroola x Romney (single)	1–2	1.38
	(twin)	1–2	1.97
	(triplet)	1–2	2.23
Loerch et al. (1985)	Finn Crossbred (twin)	3	2.73
	(triplet)	3	3.06
Geenty (1979)	Romney (twin)	1–9	1.85
	(single)	1–9	1.28
	Dorset (twin)	1–9	3.50
	Dorset (single)	1–9	2.09
	Romney x Dorset (single)	1–9	1.85
	Dorset x Romney (single)	1–9	1.70
Geenty (1980)	Dorset (single)		
	Suckled	1–15	1.89
	Dary with oxytocin	5–15	1.21
	Dary without oxytocin	5–15	1.02
Geenty et al. (1985)	Dorset (single)	1–5	2.09
	Romney (single)	1–5	1.39
	Romney x Dorset (single)	1–5	1.75
	Dorset x Romney (single)	1–5	1.84
Geenty et al. (1986)	Dorset (single)		1.85

Milk Composition

The composition of ewe's milk is given in Table 2. Differences may be due to breed of ewe, suckling intensity and nutrition. Peart et al. (1972) found significant differences in energy and protein production between single and multiple suckled ewes. Production was significantly higher for twin and triplet than single suckled ewes. Geenty (1979) reported no significant differences in milk composition for two successive years for three different breeds. Significant breed differences were apparent for the non-fat components, with Dorsets being higher than Corriedales and Romneys having the lowest values. Protein and fat levels for crossbred ewes were similar to the means of their parent breeds. Robinson et al. (1979) found an increase in the N content of the milk when fish meal was included in the diet of Finnish Landrace X Dorset Horn ewes and a subsequent N reduction when fish meal was removed. The same authors reported ewes given fish meal tended to produce milk with a higher N content than those given either soybean or groundnut meals. Milk crude protein, fat and lactose percentage were not altered by protein content of the diet; however, g of crude protein in milk was higher for ewes given a high protein diet compared to a low protein diet (Cowan et al., 1981). Supplementing ewes in late lactation with soybean meal increased milk yield but decreased fat content of milk (Gonzalez et al., 1982).

Table 2. Composition of ewe's milk (2.5 weeks postpartum).[a]

Item	Amount
Dry Matter	18.2%
Fat (5-10%)	7.1 $g \cdot 100\ g^{-1}$ milk
Protein (true)	4.5 x 5.49 = 24.7% DM basis
Lactose	4.8 x 5.49 = 26.4% CM basis
Ash	0.85 $g \cdot 100\ g^{-1}$ milk
Fiber	0.00 $g \cdot 100\ g^{-1}$ milk
Caloric value (GE)	110 $kcal \cdot 100\ g^{-1}$ x 5.49 = 6.04 $Mcal \cdot kg^{-1}$ milk DM basis
Minerals ($g \cdot 100\ g^{-1}$)	
Na	0.040
K	0.150
Ca	0.200
Mg	0.016
P	0.150
Cl	0.075
Citrate	0.170
Trace minerals ($mg \cdot l^{-1}$)	
Fe	0.60-0.70
Cu	0.05-0.15
Mn	0.06
Al	1.70
Zn	2.00-3.00
Vitamins ($mg \cdot l^{-1}$, except where noted)	
A	1,450 $IU \cdot l^{-1}$
E (α-tocopherol)	15
Thiamin	1.0
Riboflavin	4.0
Niacin	5.0
B6	0.7
Pantothenic acid	4.0
Biotin	0.05-0.09
Folacin	0.05
B12	0.006-0.010
Ascorbic Acid	40-50

[a]NRC (1985)Nutrient requirement of sheep. National Academy Press, Washington, D.C. Sixth Revised Edition. p. 51.

Non-Nutritional Factors Influencing Yield

Influence of Suckling Stimulus

Under similar circumstances twin-suckled ewes produce approximately 40% more milk than single-suckled ewes (Peart, 1982). Hinch and Kyle (1983) reported ewes rearing one, two and three lambs produced 97, 138 and 156 l of milk, respectively, during a 70 d lactation. Influence of rearing rank was most pronounced in early lactation. Milk production of single and twin-reared ewes tended to peak at day 20 at approximately 2 and 2.5 $l \cdot ewe^{-1} \cdot d^{-1}$, respectively, and then declined.

Suckled yield of ewes rearing twins was 18 to 30% higher than those rearing singles (Geenty, 1980). Ewes with twin lambs normally reach peak yield in the second or third week of lactation compared to the third to fifth week in ewes with singles. However, persistency is slightly lower in ewes with twins, and by 12 wk of lactation differences in milk production between ewes with one or two lambs are negligible (Treacher, 1983). Number of lambs suckled has a greater effect on milk yield than nutrition during pregnancy or lactation. Peart et al. (1972) found differences in total yield between suckling groups were mainly due to differences during the first three to four weeks of lactation. There is evidence initial milk yield of ewes is influenced by number of lambs born or total weight of the concepta (Peart et al., 1972).

Suckling and milking are the most potent natural stimuli that cause milk ejection. Visual and auditory cues associated with milkers and milk routines may also affect milk ejection (Tucker, 1985). Ewes that are not adapted to milking (e.g., suckled sheep) may be stressed. This varies between animals. Sheep are very susceptible to any change in management or environment, and it has been observed that minor disturbances will depress measured milk production (Peart, 1982).

Hormones

Maintenance of intense lactation requires maintenance of alveolar cell numbers, synthetic activity per mammary cell and efficacy of the milk ejection reflex. A hormonal complex controls lactation, but unless milk is removed frequently from the udder, synthesis of milk will not persist despite an adequate hormonal status. Hormones required for maintenance of milk synthesis include prolactin, growth hormone, ACTH (or glucocorticoids), TSH (or thyroid hormones), insulin, and parathyroid hormone. Oxytocin is essential for milk removal. An essential component of the milk ejection reflex is the binding of oxytocin, specifically and with high affinity, to protein receptor sites on the myoepithelial cell and expulsion of milk from the mammary gland. The number of oxytocin receptors increases to maximal amounts during first lactation, then probably persists for the lifetime of the myoepithelial cell (Tucker, 1985).

The importance of the estrogen hormones produced by the placenta in the development of the udder during pregnancy in the ewe suggests a mechanism by which the number or genotype of fetuses may affect udder development and, hence, the milk yield potential (Delouis, 1981). In a commercial context, current interest centers on the ability of bovine growth hormone (GH) to stimulate consistent increases in milk is thought to be partly mediated via the nutrient-partitioning actions of GH. Stimulation of milk production by GH administration indicates an effect on the mammary gland capacity for nutrient uptake and synthesis of milk components. Whether this stimulation is exerted directly by binding of GH to receptors of alveolar cell membranes or whether it is mediated by local formation of a specific somatomedin remains to be investigated (Riis, 1983). The likelihood that rapid advances in biotechnology would eventually make large quantities of recombinant-DNA-derived GH available gave impetus to a re-examination of the galactopoietic role of GH. It also stimulated research into the biological action of the hormone in the lactating animal, mainly dairy animals (Johnsson and Hart, 1986).

Peel et al. (1981) first examined effects of pituitary bovine GH during early, but not peak, lactation in high-yielding cows typical of the United States dairy industry. They reported a 10 to 15% increase in milk yield in two studies. In general, the effect of GH on milk composition appeared to be small in relation to the marked changes in total output of milk fat, protein and lactose. However, several studies have reported significant increases in the concentration of milk fat and a tendency for protein concentration to decrease in GH treated cows (Peel et al., 1982). These changes appear to be primarily associated with early lactation (Johnsson and Hart, 1986). Since endogenous GH secretion and food intake appear to be linked in ruminants, the possibility of a feedback inhibition of appetite by GH treatment at a time of decreasing metabolic demand in late lactation may have implications for the repletion of body fat reserves in preparation for the following lactation (Johnsson and Hart, 1986). As stated by Riis (1983), GH is apparently more important than other lactogenic hormones for adaptation of mammary gland metabolism after lactation is initiated in cows.

Lactating animals have lower glucose and insulin concentrations than non-lactating ones. Low glucose concentration in lactating animals is a result of the rapid uptake and utilization of this nutrient in the mammary gland. Decline of the plasma insulin level after parturition may be a result of lower glucose concentration (Riis, 1983). Low insulin concentration in lactating cows inhibits glucose uptake and utilization in adipose, muscle and most other body tissues. Like nervous tissue, the mammary gland is insensitive to insulin (Hove, cited by Riis, 1983).

Secretion of pituitary prolactin and placental lactogens during mammary gland development determines the production capacity of the gland at the start of lactation. Pituitary prolactin is presumably very important for the initiation of lactation. Placental lactogen is secreted from the fetal placenta, and its secretion, therefore, ceases at parturition.

The role of pituitary prolactin after initiation of lactation is not clear (Riis, 1983). Inhibition of prolactin affects milk production in ewes but not in cows and goats (Hooley et al., 1987). Growth hormone is apparently more important than prolactin, or it may replace prolactin as a stimulating factor for maintenance of milk production in cows and goats (Riis, 1983).

Other Factors Influencing Milk Production

Owen (1957) reported estimates for heritability of milk production of suckling ewes of 0.50 and 0.61. In a genetic selection experiment, Pattie and Trimmer (Cited by Peart, 1982) recorded a 10% increase in milk production in a line of Merino ewes which were selected on the basis of lamb weaning weight.

Differences in milk production among breeds of sheep have been reported. Coop et al. (1963) found that Border Leicester X Romney ewes produced 20% more milk than Romneys. Geenty (1979) showed up to 88% greater milk production by Dorsets compared with Romneys.

Lactation yields in successive lactations are influenced by both parity and age at first lambing. Yields increase from the first to third lactations by 5 to 40% (in ewes lambing for the first time at two years of age), then remain relatively constant until the sixth lactation, after which a decline occurs except under very good management and feeding (Mason et al., cited by Treacher, 1983). Yield in the first lactation is lower, partly as a result of a shorter lactation, than in ewes that lamb for the first time at two years of age, but the subsequent lactation yields are similar (Treacher, 1983).

Nutrition of the Lactating Ewe

Plane of Nutrition

The most important factor influencing milk yield of the ewe is the plane of nutrition during lactation (Jagusch et al., 1972). They found that restricted nutrition for one week following parturition delayed peak lactation yields by several days, while restriction for four weeks created a depression.

Barnicoat et al. (1949) suggested that a high plane of nutrition during late pregnancy was necessary to sustain milk yields by ewes in late lactation (also a conclusion of Wallace, 1948). However, they concluded that nutrition during lactation was the primary factor influencing both initial and total milk yield.

Peart (1967) evaluated milk production of Blackface ewes fed three different levels of nutrition during late pregnancy and then fed *ad libitum* during lactation. He found Blackface ewes attained maximum daily milk yields three to four weeks after parturition. At this point twin suckled ewes yielded about 50% more milk than single suckled ewes. Thereafter, milk yields declined but at different rates; from about the eighth week of lactation milk production from twin and single suckled ewes were similar. He suggested that 1) nutrition is not limiting during lactation; 2) a principle effect of malnutrition during pregnancy may be to inhibit the growth potential of the lamb; and 3) the effect on actual milk production is a result of an inability of the small lamb to exploit the milking potential of the ewe.

Energy and Protein Requirements

Energy and protein requirements for ewes during lactation have been published by the National Research Council (NRC 1985). Wide variations exist in the estimations of energy requirements for maintenance and for efficiency of conversion of metabolizable energy to milk energy.

Lactation is the period of highest nutrient requirement in the ewe's annual production cycle. Although a minor restriction of nutrient intake in some instances may not greatly reduce milk production, it will result in loss of liveweight and body condition of the ewe (Peart, 1983). Therefore, evaluation of energy requirements for lactation is very difficult (Treacher, 1983). Energy requirement for milk production is defined as the part of the total energy requirement that is strictly proportional to the amount of milk produced; the rest is attributed to maintenance and is generally considered proportional to metabolic body weight (Moe and Tyrrell, 1975).

Requirements the last six to eight wk of lactation are based on the assumption that milk production during that period is approximately 30 to 40% of the production during the first eight wk. Thus, nutrient intake the last six to eight wk of lactation may be reduced (NRC, 1985).

Energetic efficiency of milk production in the ewe was investigated by Gardner and Hogue (1964). They estimated that 65 to 83% of metabolizable energy (ME) intake is converted to milk energy during the first 12 weeks of lactation. Higher values were obtained for ewes suckling twins than ewes with single lambs (NRC, 1985). Graham (1964) reported heat production for lactating ewes was greater than for non-lactating, non-pregnant ewes, which pointed to an elevated basal metabolic rate during lactation.

Geenty and Sykes (1986) reported maintenance energy requirements during lactation of 0.057 Mcal $ME \cdot kg^{-1} \cdot d^{-1}$ and efficiency of use (K_1)

(K_1) of total energy available above maintenance for milk synthesis decreased from 0.84 to 0.51 with increasing rate of tissue energy mobilization. There was a positive relationship between K_1 and the proportion of mobilized energy derived from body protein. They reported overall energy requirement of lactating ewes well-fed during pregnancy was similar to previous estimates but that of sheep undernourished during pregnancy was 10 to 20% greater.

Calderon Cortes et al. (1977) found diets containing 7 to 10% crude protein had to be fed before protein content of ewe's milk was reduced. There is increasing evidence that in early lactation, when the ewe's energy requirements are high and are in negative energy balance, protein intake influences partitioning of nutrients between milk production and liveweight loss. In the ruminant, as in the monogastric animal, the utilization of protein is affected by energy intake (Peart, 1983).

Responses in milk yield to increased inclusion of dietary protein have been observed in a number of experiments in which ewes received insufficient dietary energy to enable them to fully express their genetic potential for milk production (Robinson et al., 1979). Magnitude of these responses is directly related to quantity of amino nitrogen available for absorption in the small intestine. A highly significant negative correlation has been observed between milk yield of ewes and rumen degradability of protein sources (Gonzalez et al., 1984).

A comparison of respective amino acid compositions of tissue and milk with that of rumen microbes and feed ingredients indicates methionine, histidine, tryptophan and, possibly, leucine may be limiting milk production, while methionine limits wool production (Van Soest, 1983).

Growth rate, milk and wool production all react to inadequate protein intake. Extreme deficiency results in severe digestive disturbances, loss of weight, anemia, edema and reduced resistance to disease. Excess protein becomes an expensive and inefficient source of energy, but rather large excesses can be fed without producing acute toxicity (NRC, 1985).

Response of the Ewe to Variation in Energy and Protein Intake

Treacher (1983) discussed a model proposed by Robinson (Figure 1) which demonstrated three important principles of the lactating ewe's response to variation in intake of both metabolizable energy and protein.

1. At a particular level of energy intake there is a minimum protein intake and reduction in protein intake below this level will cause a reduction in milk yield.
2. The minimum ratio of crude protein (CP) to ME increases with increasing level of milk yield.
3. An increase in dietary CP concentration without a change in ME intake will increase milk production if the ewe has not reached her potential yield.

Change in liveweight of ewes complicates the interpretation of responses to energy intake in lactation. In the first 4 to 6 weeks

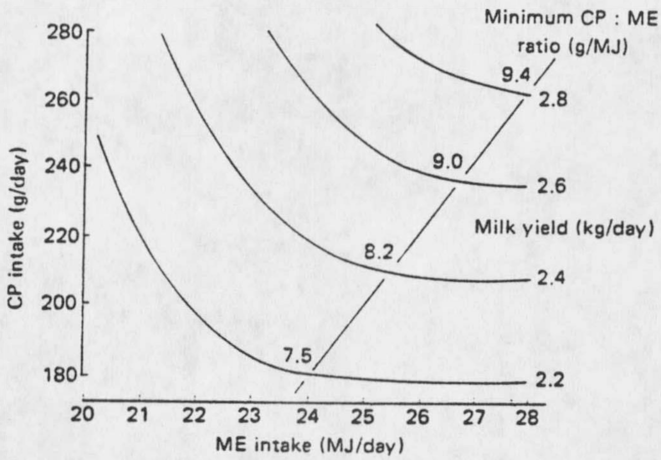

Figure 1. Response of milk yield to change in intake of metabolizable energy (ME) and crude protein (CP). Adapted from Treacher (1983).

lactation reductions in liveweight usually occur and these losses may be large. Maintenance or liveweight gain in early lactation are usually associated with low milk yields or with high quality food. Energy contributed by catabolism of body reserves may not reflect the change in tissue weight and composition (Peart, 1982).

As little protein is available from the ewe's body to supply amino acids for milk secretion, the efficiency of utilization of body tissue for milk production appears to be closely linked to intake of dietary protein (Cowan et al., 1980). Cowan et al. (1979; 1980) found protein losses were negligible in ewes losing four to eight kilograms liveweight in the first six weeks of lactation. In a later report, Cowan et al. (1981) suggested labile body protein can contribute to maintaining milk production in the first weeks of lactation. Ewes in this experiment lost an average of 4.3 kg of liveweight and 800 g of protein between days 6 and 42 of lactation. This was approximately 10% of total body protein and sufficient for the production of about 10 kg of milk over the period.

Loerch et al. (1985) reported that when blood meal was fed to twin-rearing ewes at 3.3% of their diet (25% of total dietary protein), milk production was greater (3,176 vs. 2,506 $g \cdot d^{-1}$) and efficiency of milk production improved (1.05 vs. 0.79 g milk$\cdot g^{-1}$ feed) compared to ewes fed supplemental soybean meal. This suggests blood meal was increasing the supply of limiting amino acids to the small intestine.

Feeding ewes nursing twins rations containing 11.5 or 15.0% CP and either soybean meal, blood meal or fish meal resulted in lamb average daily gain as follows: low soybean--0.266 kg; high soybean--0.293 kg; low blood meal--0.282 kg; high blood meal--0.309 kg; low fish meal 0.330 kg; and high fish meal--0.311 kg (Thomas et al., 1984). These data suggest increasing the protein level from 11.5 to 15% in rations of ewes in early lactation fed ad libitum may result in increased lamb gains when soybean meal is the protein source.

Voluntary Food or Forage Intake

The relationship between diet quality and voluntary food intake in ruminants is biphasic, with a positive correlation between the content of available energy and the weight of food eaten with poor and medium roughage feeds (Forbes, 1977). A negative correlation exists between high quality roughage and cereal-based diets. When poor-to-medium quality roughages are fed, the physical limitations of gut capacity are thought to set an upper limit to food intake. When energy requirements are below the physical limit, food intake is related to nutrient demand, and changes in demand by, for example, exposure to a cold environment or a change in milk energy output will be followed by compensatory changes in food intake (Forbes, 1977). Voluntary food intake is 50 to 100% higher in lactating ewes than in dry or pregnant ewes. Intake usually increases immediately after lambing, rapidly in the first two to three weeks of lactation, then continuing to rise more slowly to reach a maximum two or three weeks after the maximum daily milk yield is reached. Intake then steadily declines. Intake is lower initially on diets of low digestibility and may continue to rise slowly until as late as the 12th week of lactation (Peart, 1982). Foot and Russel (1979) reported ewes with twin lambs ate more than those with single lambs, and ewes fed hay diets during pregnancy consumed more than those grazing dried grass. They concluded that up to 64% of the variation in intake during lactation was related to factors prevailing before and at lambing (pregnancy diet, ewe weight and fat content) and during lactation (lamb gain and ewe weight change).

In grazing animals the patterns of intake are modified by the complex process of food gathering. Grazing ewes will select a diet much higher in digestibility and nutrient concentration than the mean sward composition unless the quantity of herbage available is very low. Herbage availability also affects DM intake, but the grazing animal compensates to some extent by increasing grazing time. The lactating ewe has a higher grazing time than dry or pregnant ewes, particularly at high allowances of herbage (Peart, 1982). Organic matter intake declines with increasing stocking rate and decreasing herbage availability (Langlands and Bennett, 1973). Intake (sheep) was more closely correlated with herbage availability than with stocking rate. Intake is not determined by stocking rate per se but is reduced at high stocking rates because there is limited forage available.

When high herbage allowance of 100 to 116 g organic matter (OM)$\cdot$kg^{-1} liveweight$\cdot$d^{-1} were provided from the start of lactation, intakes were high initially and did not increase after the second or third week of lactation (Gibb et al., 1981). Huston and Engdahl (1983) reported that lactating ewes consumed 45% more forage during spring than non-lactating ewes. Increasing levels of supplemental feed decreased forage intake but increased total digestible dry matter. Lactating ewes rearing twin lambs grazing a highly digestible sward were offered three different amounts of supplement (0, 480 and 960 g OM$\cdot$ewe$^{-1}\cdot$d^{-1}), the mean decline in herbage intake was 0.93 g OM per g OM supplement consumed (Milne et al., 1981).

Addition of readily available carbohydrates to a roughage diet decreases voluntary intake. Conversely, addition of protein supplements to low-quality roughage diets increases voluntary intake and digestibility (Peart, 1982). There is evidence that intake responses to protein supplementation occur only when forages contain less than 8 to 10% crude protein (Allison, 1985).

Nutrition of Suckling Lambs

Geenty (1979) reported single lambs were 80 to 110 g heavier at six weeks of age for each kg of milk produced by its dam and at the same age twins were 20 to 40 g heavier. He also indicated that between 34 and 58% (depending on the year) of the variation in six-wk live weight of single lambs was associated with variation in total milk production. These values decreased to 28 to 49% for nine-wk live weights. Corresponding values for twin lambs were 18 to 8% at six weeks and 26 to 3% at nine wk. Correlation coefficients between milk components and lamb live weights indicated lactose and protein had a higher relationship with lamb live-weight gains than did the fat component. Levels of significance suggested quantitative milk production was a better indicator of early lamb growth than were any of the individual components.

Langlands (1977) reported that organic matter intake as milk ($g \cdot d^{-1}$) declined at all stocking rates investigated, but the rate of decline differed significantly between stocking rates. The greatest decline occurred at 9.4 and 14.1 sheep per ha. Consumption of organic matter as grass ($g \cdot d^{-1}$) was evident from three wk of age on and increased an average of 8.2 $g \cdot d^{-1}$ and declined by 3.0 $g \cdot unit^{-1}$ increase in stocking rate. Rate of increase in grass consumption was greater than rate of decline in milk consumption, and total organic matter intake increased with time. These results are in agreement with later findings by Doney et al. (1985) who concluded milk intake within genotype is negatively related to herbage intake and that a higher herbage intake does not compensate fully for a lower milk intake.

Ewes grazing a lucerne pasture had similar dry matter intake and lamb growth rates but lower ewe milk production and weight gain than those grazing a ryegrass pasture (Rattray et al., 1982). This suggests lambs on lucerne were consuming more herbage than those on ryegrass pasture. High quality lucerne has been shown to be an ideal feed for young, early-weaned lambs with limited rumen capacity. Van Keren (1985) in a review of the role of forages in lamb production reported a range in daily gains from 130 to 390 $g \cdot d^{-1}$ and he suggested the following for the variation: forage species, forage management, age and sex of the lambs, breeds, sheep management practices (e.g., use of suckling vs. weaned lambs), age at weaning, use of creep-feeding or forward grazing, degree internal parasitism and weather conditions. Daily gains also vary widely throughout the pasture season, generally declining as season progresses, reflecting such factors as increasing age of lambs, decline in forage nutrient content, digestibility and yield, parasite buildup and onset of summer heat and drought conditions.

Gibb and Treacher (1982) found large differences in milk consumption between single and twin lambs resulted in only a small difference in absolute herbage intake in the second month of lactation. Efficiency of conversion of ME to gain in lambs was on the order of 0.33 for herbage and 0.71 for milk; therefore herbage intake must increase by 4.7 g for each 1 g reduction in milk intake to maintain the same total net energy intake for gain (Treacher, 1983).

This demonstrates how important a prolonged lactation may be in a grazing situation.

CHAPTER 3

MATERIAL AND METHODS

The experiment was conducted during the spring and summer of 1987 at Fort Ellis Experimental Station near Bozeman, Montana. A permanent pasture composed of orchardgrass (Dactylis gomerata), regar brome (Bromus biebersteinii), birdsfoot treefoil (Lotus corniculatus) and vetch (Vicia spp.) was fertilized (Table 3) on April 15, 1987 and used in the experiment.

Table 3. Pasture fertilization.

Type of Fertilizer	Application $Kg \cdot ha^{-1}$	Fertilizer Composition (%)		
		N	P	K
1	186	21	0	0
2	56	0	0	60
3	73	18	46	0
4	94	46	0	0

Twenty-six Finn X Targhee ewes were randomly allocated on May 18, 1987, into two groups with the only condition being that there were the same number of ewes of the same age in each group (Table 4). One group was used as a control (no supplement) while the other was fed a by-pass protein supplement (Table 5). All sheep had ad libitum access to a salt mixture composed of two parts trace mineralized salt and one part dicalcium phosphate. All ewes suckled twins when the experiment started, although some had given birth to triplets.

Table 4. Number of ewes by age.

Age (Years)	Supplementation	
	Non-supplemented	Supplemented
5	3	3
3	5	5
2	5	5
TOTAL	13	13

Table 5. Ingredient composition of supplement (DM basis).

Item	%
Ingredients	
Beet pulp, dehydrated	22.5
Blood meal	20.0
Corn gluten meal	50.0
Dehydrated molasses	5.0
Fat, tallow	1.5
TM salt	1.0
Flavoring agent	
Nutrient composition	
Dry matter	92.0
Crude protein	53.5

Stocking rate was 5.2 ewes plus their twin lambs per ha. Ewes were individually supplemented every third day in individual pens ($0.10\ kg \cdot hd^{-1} \cdot d^{-1}$). This is equivalent to 25% of the daily NRC (1985) protein requirements for ewes rearing twins in late lactation. Ewes and their lambs were weighed at the beginning, at 21-day intervals and at the end of the experimental period on August 8, 1987.

Early in the morning of each weigh day, ewes and lambs were separated and milk volume determined (McCance, 1959). The ewe's udder was emptied of milk by hand milking after the ewe was given 10 IU of oxytocin intravenously. Three hours later a second oxytocin injection was given, ewes were milked as previously described and the three-hour milk volume was recorded and adjusted to a 24-hour basis. Milk subsamples were collected for milk composition determination (protein, fat, lactose and solids not fat) by electronic infrared procedures.

Estimates of forage mass were made by cutting herbage within quadrates (0.25 m^2) to 2 cm level with hand clippers (Milner and Hughes, 1968). Three transects were designed along the paddock. In each transect an exclosure cage was placed and moved at weekly intervals along the transect. At the beginning of the trial and at weekly intervals, forage production was measured inside and outside the cages in each transect. One measurement was made inside each cage and three measurements were made outside of the cages. Forage samples were weighed and dried at 60 C. The proportion of grasses, legumes and dead matter was determined in the forage samples by hand separation. Samples were ground through a 2 mm Wiley mill and organic matter content was estimated by ashing at 500 C for 12 h. Laboratory analyses included nitrogen (N; AOAC, 1980) and neutral detergent fiber (NDF, Goering and Van Soest, 1975). Crude protein (CP) was calculated as 6.25 X %N.

Extrusa samples by total rumen evacuation technique (Lepesperance et al., 1960) were taken between milking days to establish diet quality. Samples were dried at 60 C for 48 h. Samples were then processed and analyzed by a method similar to that previously described for forage samples.

Three in situ trials were conducted using four western whiteface ewes. Two trials were conducted to determine the rate of disappearance of extrusa samples obtained at the beginning of July (first trial) and August (second trial). Ewes were given alfalfa pellets twice a day. Two ewes were supplemented with the same regime as the experimental ewes. A third trial was conducted to determine the rate of disappearance of the protein supplement; under this condition, all ewes were supplemented. Nylon bags (10 x 7.5 cm, pore size 44 μ) containing approximately 1.2 g of sample were suspended in the rumen at 0 h, and duplicate samples were taken at 3, 6, 12, 18, 24, 48, 72 and 96 h by post introduction. Blanks were taken from two ewes alternatively. Upon removal from the rumen, the bags were washed and dried at 60 C for 48 h. Loss of weight was used for calculating dry matter disappearance. Nitrogen content of the bags was determined and N disappearance calculated.

Rate and potentially degradable DM or N were determined using the equation $y = ae^{-kt} + u$, where y = predicted amount remaining at time t, a = the potentially degradable portion, e = 2.718, k = the relative rate of potentially degradable portion, t = time in hours and u = the predicted non-digestible fraction (Mertens, 1977). In each trial, data were analyzed using analysis of variance by the GLM procedure of SAS (1985). No differences ($P > .10$) were detected between treatment groups and, therefore, data were pooled and means reported by period.

Data were analyzed using analyses of variance by the GLM of SAS (1985). All analyses were performed within period. Milk volume and composition and ewe weight change were dependent variables for ewe data, while independent variables were treatment, age of the ewe, type of birth and their two-way interactions. Initial volume or milk composition and birth date were used as covariates in their respective analyses. Dependent variables for lamb data were lamb weight change and average daily gain, while independent variables were age of the ewe, sex of the lamb, birth date and their two-way interactions. Initial weight was used as a covariate. Least significant differences were used to separate means. A multivariate analysis of variance was also conducted to test the influence of period on the dependent variables measured. Period had no effect ($P > .05$) on the dependent variables investigated.

CHAPTER FOUR

RESULTS AND DISCUSSION

Forage and Supplement Characteristics

Green forage available at the beginning of the experiment on May 17 was 1,000 kg DM$\cdot$ha^{-1}, increasing to 4,000 kg DM$\cdot$ha^{-1} on June 26 and declining to 1,500 kg DM$\cdot$ha^{-1} on August 8 at the end of the experiment (Figure 2).

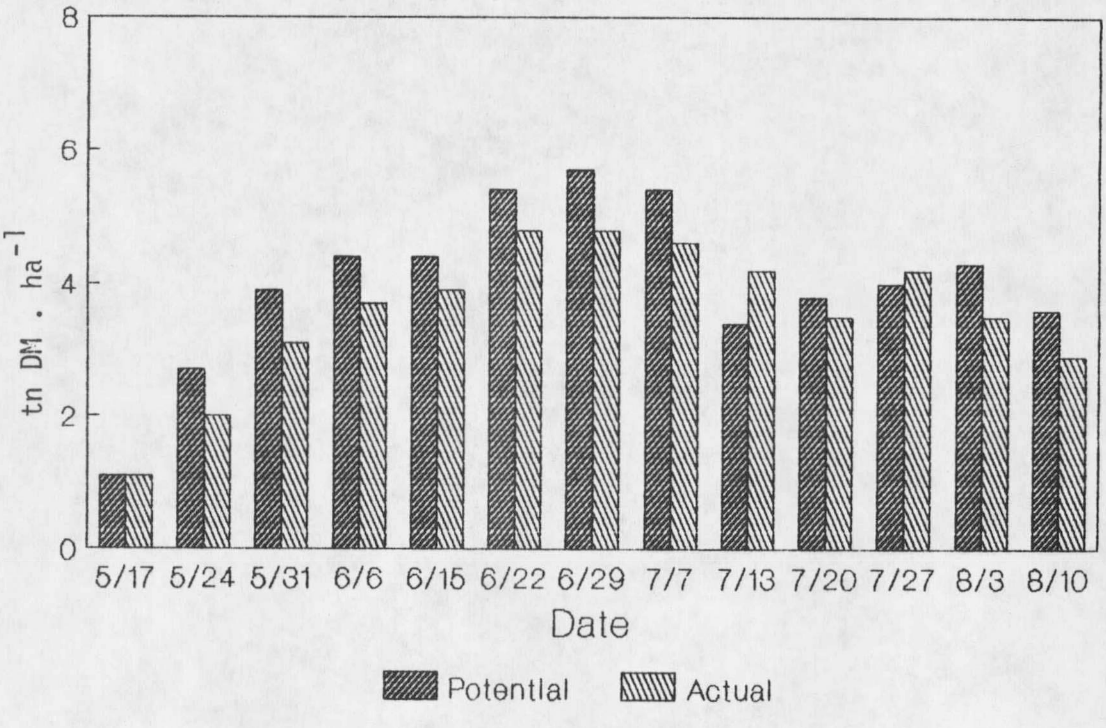

Figure 2. Forage dry matter availability.

Rainfall was sufficient and well-distributed during the experiment (Figure 3). Dead material increased during the

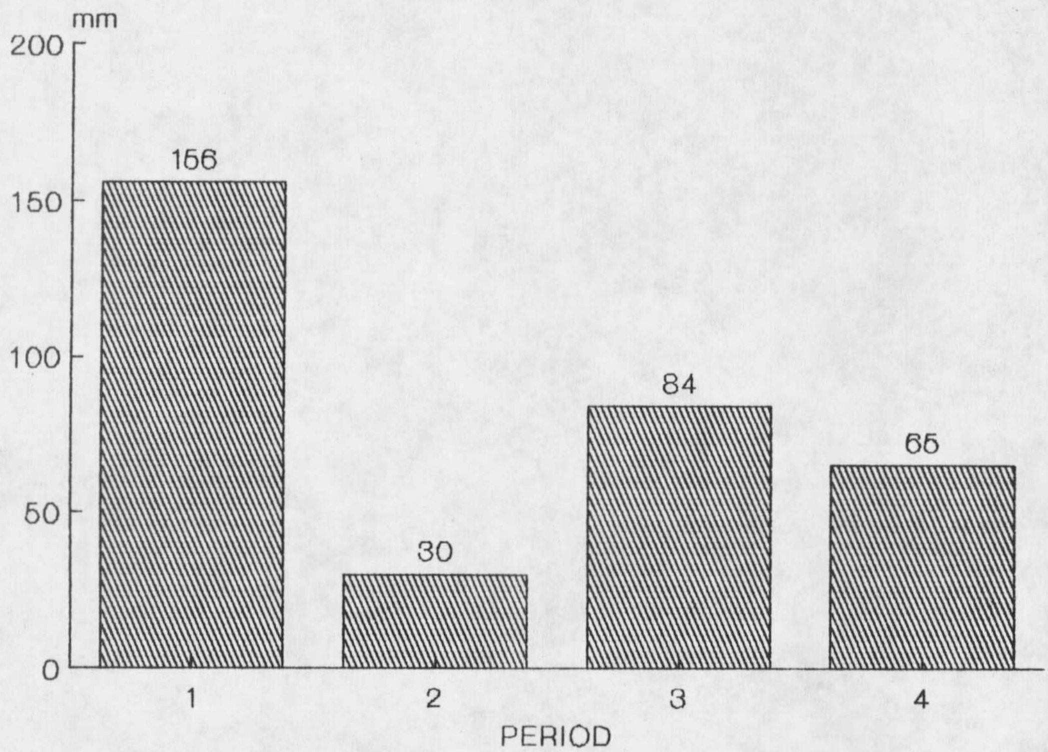

Figure 3. Precipitation by period of the experiment (mm).

experimental period from 100 kg DM$\cdot$ha^{-1} on May 17 to 1,400 kg DM$\cdot$ha^{-1} on August 8. The proportion of grasses, legumes and dead material are presented in Figure 4. Grasses provided approximately 90% of the forage available for the ewes' consumption, with legumes and dead material providing the remainder. The total amount of forage available during the 84-day experiment was estimated to be approximately 150 g OM$\cdot$kg^{-1} ewe body weight$\cdot$day^{-1}. Due to the quantity of available forage, intake was probably not limited during the experiment. Penning et al., (1986) studying the effect of forage allowance on intake and performance of ewes suckling twin lambs suggested that at allowances of 160 g OM$\cdot$kg^{-1} ewe body weight$\cdot$day^{-1}, intake was not limited.

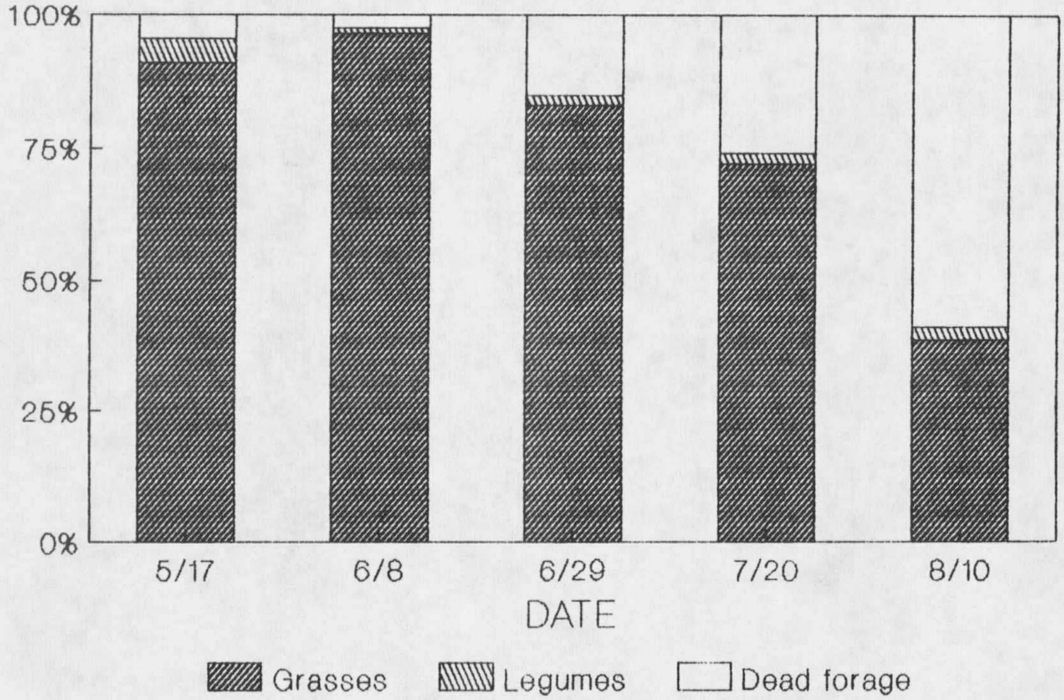

Figure 4. Proportion of grasses, legumes and dead forage (considered as a percent of the total forage in each period).

Forage protein content was initially 18%, decreasing to eight % by the end of the experiment (Table 6). Average crude protein content during the summer averaged 12%. Rumen extrusa samples tended to be 30% higher in crude protein than clipped forage samples (Table 6). This suggests ewes were probably selecting legumes over grasses during the trial. Neutral detergent fiber was lower for clipped forage than extrusa samples. Neutral detergent fiber content varied from 48% for period one to 61% for the last period and extrusa samples were approximately 10% higher (Table 6). Lesperance et al. (1974) reported higher acid detergent fiber values for extrusa than clipped forage. Higher values for extrusa may be related to the drying method used and because the forage was highly digestible and some carbohydrates may have been digested and removed (Lesperance et al, 1974).

Table 6. Crude protein (CP) and neutral detergent fiber (NDF) content of clipped forage and rumen extrusa samples (% DM).

Period	Clipped Sample	Extrusa Sample
	CP	
1	18	22
2	11	17
3	10	12
4	8	11
Mean	12	16
	NDF	
1	48	58
2	55	64
3	57	66
4	61	67
Mean	55	64

Correlation coefficients between extrusa and forage protein concentration tended to be higher during each experimental period than NDF correlations (Table 7); however, they were not significant ($P > .10$). This was probably due to the small number of samples involved in the calculation.

Table 7. Correlation coefficients between extrusa and forage samples for crude protein (CP) and neutral detergent fiber (NDF).

Period	CP	NDF
1	0.73	0.08
2	− 0.61	−0.17
3	− 0.95	0.88
4	− 0.86	0.31

Results of the in situ digestion studies for the forage DM disappearance are reported in Table 8 and illustrated in Figure 5.

Table 8. Means of predicted extrusa DM disappearance (%).

Hour	July	August
3	16	13
6	28	24
12	46	41
18	56	52
24	63	60
48	73	73
72	74	76
96	74	77

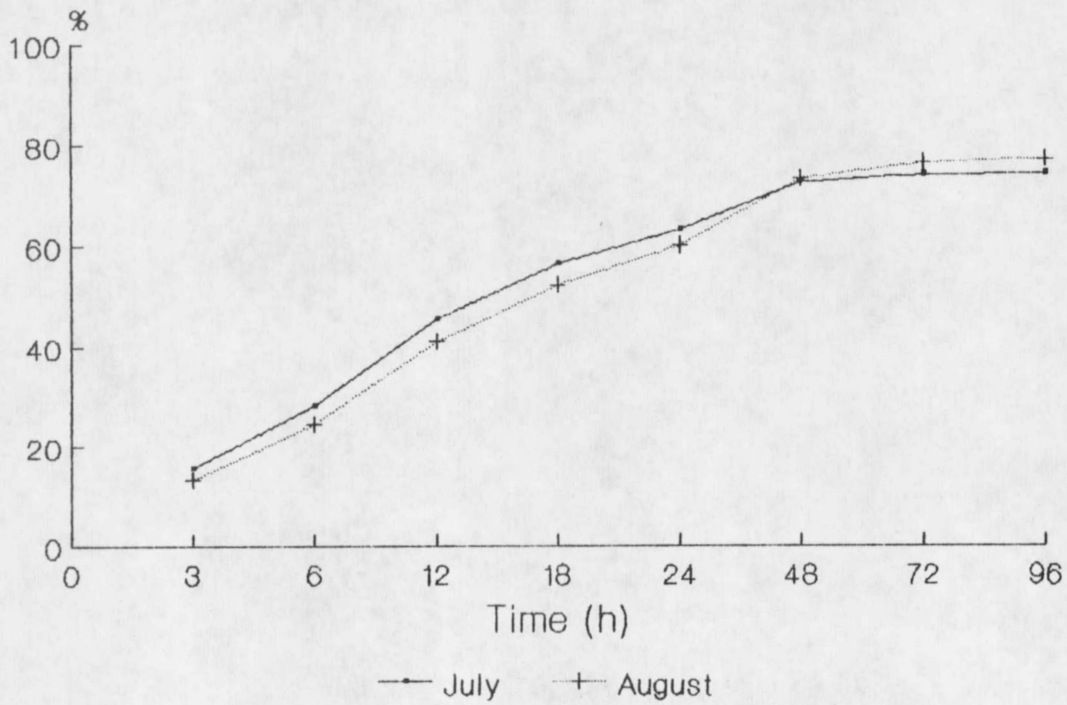

Figure 5. Pasture in situ DM disappearance for two periods of the study.

Rate of disappearance for July and August for each 96-hour trial was $7.92\%\cdot h^{-1}$ and $6.3\%\cdot h^{-1}$, respectively. By 48 hours, more than 70% of the DM had disappeared. In both periods, forage was highly digestible, demonstrating that DM digestibility of diet did not decline from July to August.

Results for N disappearance are presented in Table 9 and illustrated in Figure 6. Forage selected by ewes in July was higher in N content (Table 6) and degraded at a faster rate—$7.82\%\cdot h^{-1}$ vs. $4.65\%\cdot h^{-1}$) compared to August. The content of lignin in August was probably higher and, consequently, more N was bound to it which would result in less N being available for ruminal breakdown.

Table 9. Means of predicted extrusa N disappearance (%).

Hour	July	August
3	17.5	10.5
6	31.5	20.0
12	51.0	35.0
18	63.5	46.5
24	71.0	55.0
48	82.0	73.5
72	84.0	80.0
96	84.0	82.5

Approximately 49% and 26.5% of the supplements DM and N, respectively, disappeared within 24 hours (Table 10). Nitrogen disappearance data confirm the supplement had high N bypass characteristics. The rate of disappearance was $5.6\%\cdot h^{-1}$ and $1.44\%\cdot h^{-1}$ for DM and N, respectively.

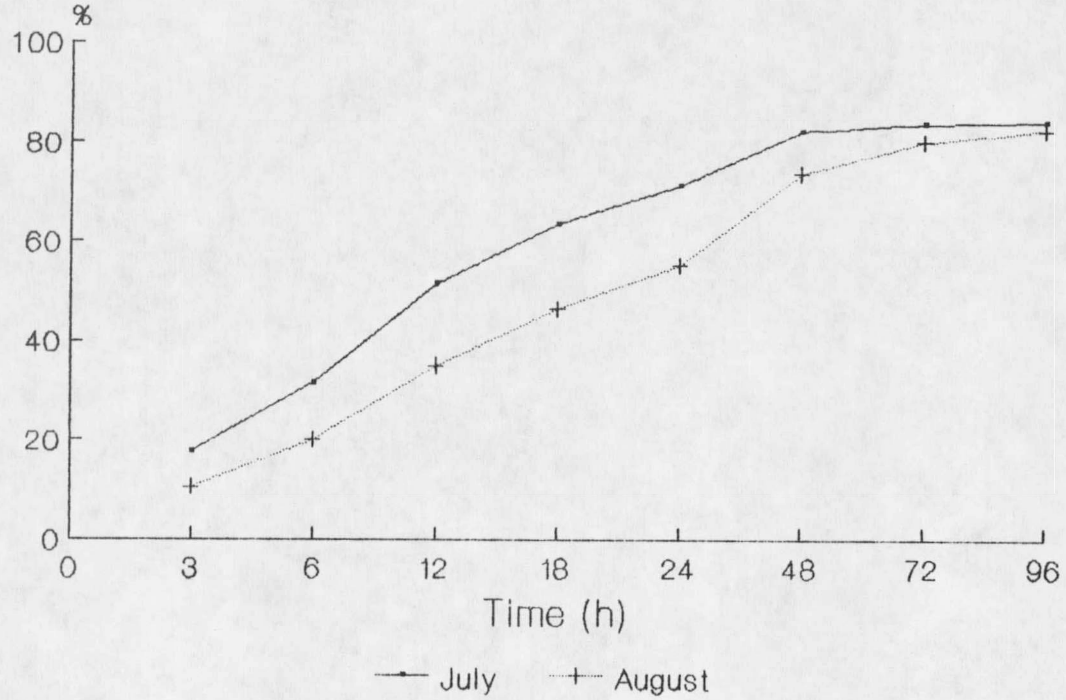

Figure 6. Pasture <u>in situ</u> N disappearance for two periods of the study.

Table 10. DM and N supplement disappearance (%).

Hour	DM	N
3	10.5	4.0
6	19.0	7.5
12	32.5	14.5
18	42.0	19.0
24	49.0	26.5
48	62.5	49.5
72	66.5	59.0
96	67.5	68.0

Supplementation Trial

Ewes weighed 55 kg at the initiation of the experiment, and supplemented and non-supplemented ewes weighed 67.5 and 65.5 kg, respectively, at the end of the experiment with no difference ($p > .10$) between treatment groups (Figure 7). Supplementation had no effect ($p > .10$) on the total ewe weight change (Table 11). All ewes gained weight during the 84-day grazing period.

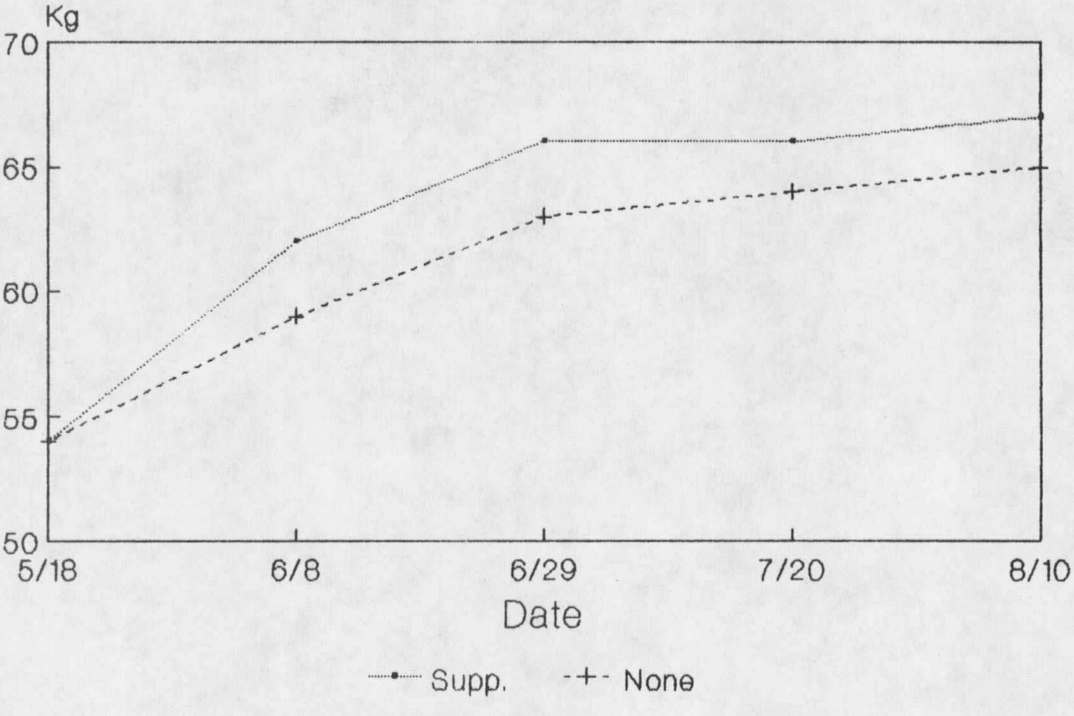

Figure 7. Influence of supplementation on ewe weights (kg).

Table 11. Least square means of the influence of supplementation on ewe live weight change (kg).

		Supplementation		
Period	Days	None	Supp.	SE[a]
1	21	5.06	7.54	1.0
2	21	3.98	3.77	0.6
3	21	1.50	0.19	0.6
4	21	0.05[b]	1.16[c]	0.3
Total	84	10.60	12.62	1.0

[a]Standard error of the least square mean.
[b,c]Means within the same row with an uncommon superscript differ ($p < .05$).

weight losses for ewes with forage allowances of 40 g $OM \cdot ewe^{-1} \cdot d^{-1}$ during 12 weeks of lactation, but ewes with allowances of 160 g $OM \cdot ewe^{-1} \cdot d^{-1}$ started to regain weight by the fourth week. High forage allowance (150 g $OM \cdot ewe^{-1} \cdot d^{-1}$) and good forage quality in our study probably were responsible for positive weight gain and compensated for previous losses during the first month of lactation. Weight change differences ($P < .05$) during period four may be due to compensation between periods three and four, although the difference between treatments in period three was not different ($P > .10$).

Supplementation of a corn gluten meal/blood meal supplement had no effect on milk yield ($P > .10$; Table 12). Ewes had an average milk volume of 1319, 1035, 810 and 655 ml for periods one, two, three and four, respectively. Supplemented ewes tended to produce more milk during period four than non-supplemented ewes (724 vs. 586 $ml \cdot d^{-1}$; $P > .10$). Supplemented ewes appeared to be more persistent in milk production.

Table 12. Least square means of the influence of supplementation on milk volume ($ml \cdot d^{-1}$).

	Supplementation		
Period	None	Supp.	SE[a]
1	1398	1241	84
2	999	1071	68
3	795	826	56
4	586	724	46

[a]Standard error of least square mean.

When protein, fat, lactose and SNF content of milk were reported as a percentage (Table 13), no differences were detected between treatment groups (P> .10). However, when expressed as grams per day, supplemented ewes had greater yields of protein, fat and SNF during period four than non-supplemented ewes (Table 14). These results, combined with the trend for increased milk production during period four, suggest supplementation may have been influencing milk production in a positive manner in late lactation.

Most studies showing a positive response to supplementation of bypass protein have been conducted in early lactation when nutrient demands for milk production were greatest (Thomas et al.,1984; Loerch et al., 1985). Gonzalez et al. (1982) reported that ewes had greater milk yields and increased protein content of milk when fed protein sources such as fish meal or blood meal, which are not readily degraded in the rumen. However, their study was conducted when ewes were in early lactation, in contrast to the study under discussion in which ewes were in mid-to-late lactation and nutrient demands were declining. A diminished response to feeding a bypass protein

Table 13. Least square means of the influence of supplementation on milk composition (%).

Period	None	Supp.	SE[a]	None	Supp.	SE[a]
		Supplementation				
		Protein			Fat	
1	5.3	5.0	.2	6.9	6.8	.5
2	5.4	5.2	.2	7.5	7.1	.6
3	6.1	5.6	.2	7.0	8.7	.7
4	6.2	5.8	.2	7.9	8.7	.8
		Lactose			Solids	
1	4.4	4.6	.1	18.4	18.2	.6
2	3.7	4.2	.1	18.7	18.3	.6
3	3.8	3.8	.1	18.6	20.4	.8
4	3.6	3.6	.1	19.6	20.3	.9

[a]Standard error of least square mean.

Table 14. Least square means of the influence of supplementation on milk composition ($g \cdot d^{-1}$).

Period	None	Supp.	SE[a]	None	Supp.	SE[a]
		Supplementation				
		Protein			Fat	
1	72	62	3.7	93	93	9.2
2	51	59	3.6	74	82	9.6
3	48	48	3.7	56	74	8.9
4	35[b]	43[c]	3.1	46[d]	64[e]	3.8
		Lactose			Solids	
1	62	57	4.3	250	239	18.5
2	38	45	3.5	183	201	16.1
3	31	31	2.4	149	170	15.2
4	21	27	2.5	114[d]	146[e]	6.5

[a]Standard error of least square means.
[b,c]Means within same row with an uncommon superscript differ ($P < .10$).
[d,e]Means within same row with an uncommon superscript differ ($P < .05$).

supplement in this study may have been due to adequate protein being provided by the forage component of their diet for the level of milk being produced. At the beginning of July, forage intake was estimated using chromic oxide. Supplemented ewes consumed forage DM at approximately 4% of their body weight. This would provide 317 g of CP (2.64 kg DM x 12% CP), which is approximately 100 g more than the NRC (1985) requirements for ewes suckling twins in the last four to six weeks of lactation. Therefore, protein intake of supplemented ewes was adequate from forage alone. Non-supplemented ewes were consuming approximately 1% more of their body weight in DM than supplemented ewes. Considering intake estimates and weight gains, ewes were probably not in a negative energy balance. Protein supplementation in a negative energy balance situation would increase milk production with a body reserve depletion (Peart, 1982).

Gibb et al. (1980) reported that intake increased steadily from 1.69 to 2.59 kg $OM \cdot d^{-1}$ in week 7 of lactation, as daily herbage allowance increased from 27 to 56 $g \cdot kg^{-1}$ live weight and then fell to 1.55 kg $OM \cdot d^{-1}$ in week 9 when herbage availability and OM digestibility decreased. In our study, OM availability and diet digestibility were still high in July.

The primary factors affecting lamb growth are the quantity and the quality of the feed available during lactation (Owen, 1957; Armstrong et al., 1977). Milk is important for lamb growth but becomes less important as lactation progresses and lambs start to consume more forage. Correlations between milk intake and live weight gain are approximately 0.9 in the first stages of lactation and decline to 0.7 after the fourth month (Wallace, 1948). Doney and Peart (1976) found energy derived from the milk fraction of the diet declined from 88% at five weeks to 34% at 10 weeks of age; and intake of solid food on a weight basis increased proportionately. Lamb weight change and daily gains were not affected ($P > .10$) by supplementation of the ewes. Lambs from supplemented and non-supplemented ewes gained 22.0 and 20.5 kg during the 84 d grazing period, and average daily gains were 0.26 vs. 0.24 $kg \cdot d^{-1}$ (Table 15). Gibb et al. (1980) reported average daily gains of 0.20 $kg \cdot d^{-1}$ for twin lambs grazing a ryegrass pasture. Thomas et al. (1987) suggested lambs are able to maintain their growth rate by increasing forage consumption. Forage availability and quality were adequate for lambs reared by non-supplemented ewes to compensate with forage intake for the difference observed in the milk quality. Also, Penning et al. (1979) reported that after approximately eight weeks of age, absolute intakes of herbage were influenced more by weight of the lamb than by level of milk intake.

Table 15. Least square means of the effect of protein supplementation on lamb weight change and average daily gain (kg).

	Periods				
Supplementation	1	2	3	4	Total
		Lamb Weight Change			
None	5.5	6.0	4.5	4.0	20.5
Supp.	6.5	5.5	5.5	4.0	22.0
SE[a]	0.4	0.2	0.4	0.4	0.8
		Average Daily Gain			
None	0.27	0.29	0.22	0.19	0.24
Supp.	0.31	0.25	0.27	0.21	0.26
SE[a]	0.02	0.01	0.02	0.02	0.01

[a]Standard error of least square means.

CHAPTER FIVE

CONCLUSION

In conclusion, there was no benefit to supplementation of lactating ewes grazing a high quality pasture during the summer when rainfall did not limit forage growth and subsequent forage allowance. However, supplementation did increase protein, fat and SNF yields during the last period when forage quality and allowance were lower than in previous periods. Therefore, supplementation may be beneficial in years when a lack of moisture limits forage growth or the pasture is of poorer quality.

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