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AFFECT OF DIETS VARYING IN FORAGE CONTENT ON NUTRIENT DIGESTIBILITY, FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF LAMBS

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AFFECT OF DIETS VARYING IN FORAGE CONTENT ON NUTRIENT DIGESTIBILITY, FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF LAMBS

By

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ABSTRACT

AFFECT OF DIETS VARYING IN FORAGE CONTENT ON NUTRIENT DIGESTIBILITY, FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF LAMBS

By

Matthew Thomas Shane

A series of trials was conducted to determine nutrient digestibility, lamb performance and carcass characteristics by lambs fed pelleted diets containing 25, 62.5 or 100% forage. In the digestibility trial, dietary ME values and apparent digestibilities of DM, OM, NDF and ADF decreased as dietary forage level increased. In performance trial 1, lambs were fed either 25 or 100% forage diets at ad libitum or 85% of ad libitum levels of intake. Lambs fed diets at ad libitum levels of intake had greater ADG. Lambs fed 100% forage diets had lighter carcasses and less 12th rib fat. In performance trial 2, lambs were fed a 62.5% forage diet at ad libitum or 85% of ad libitum levels of intake. Lambs fed at ad libitum levels of intake had greater ADG, heavier carcasses and more 12th rib fat. In performance trial 3, lambs were fed 25,62.5 or 100% forage diets at ad libitum levels of intake. Lambs fed the 62.5% forage diet had the greatest ADG. As dietary forage level increased fat and carcass weight tended to decrease. An economic analysis indicated that cost of gain could be decreased by decreasing dietary forage level and(or) restricting feed intake to 85% of ad libitum levels.

DEDICATION

I would like to dedicate this manuscript to the many individuals

who have touched my life.

To my parents Rona and Tom who have given me their love and

have always encouraged me to pursue my dreams.

To my sister, Laura, whose love of family has inspired me.

And to Jackie who has shown me that laughter is the secret of life

and continues to share my dreams.

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INTRODUCTION

Beef and lamb producers traditionally feed their livestock a concentrate based diet to finish them for market. Rising grain prices, resulting in increased feed costs, have forced producers to look at alternative feeding strategies and ingredients. Not only do producers want to decrease their costs of production, they also want to maximize profits by receiving a premium price for their livestock. Producing lean carcasses with adequate muscling is one way producers can achieve optimum market prices. Diets with increased forage content may have the potential to reduce feed costs, and produce leaner animals at slaughter.

A unique advantage of ruminants, compared to monogastrics, is their ability to utilize forage to yield high quality carcasses (Bidner et al., 1986). In general, animals finished on lower-energy diets have a smaller proportion of carcass fat than comparable animals finished on higher energy diets (Bidner et al., 1986). Feeding practices that maximize forage and minimize cereal grain usage could be the most desirable feeding strategies, especially when the prices for feed grains are high.

Pelleting finely ground, dehydrated alfalfa may be a solution for producing leaner lambs while decreasing feed costs. Some researchers have fed pelleted hay or chopped hay in loose form to determine the effects on performance and carcass characteristics (Meyer et al., 1959 and Weir et al., 1959). Others have tested feeding pelleted alfalfa with or without concentrate supplementation to determine the effects on performance and carcass characteristics (Cate et al., 1959). Another theory that was developed was that feeding the animals at less than ad libitum levels of intake would improve performance and carcass characteristics (Murphy et al., 1994).

Hypothesis

Increasing forage content of lamb diets from 25 to 100% will decrease nutrient digestibility, decrease lamb performance, decrease carcass quality and increase cost of gain.

Objectives

A digestibility trial and three performance trials were designed to test the hypothesis that the level of pelleted alfalfa in the diet would influence nutrient digestibility, lamb performance and carcass characteristics. The objectives of these trials were:

1. To determine nutrient digestibility by lambs fed pelleted diets ranging from 25 to 100% forage.
2. To determine performance and carcass characteristics of lambs fed pelleted diets ranging from 25 to 100% forage, fed at ad libitum or 85% of ad libitum levels of intake.

CHAPTER 1

Literature Review

Feedlot Lamb Performance

Optimizing lamb performance means getting a lamb to market weight in the shortest time possible with the lowest input costs. The key to increasing performance is to feed diets that result in increased average daily gains (ADG), feed efficiency and decreased days on feed. This can be accomplished by several methods: pelleting, adjusting the forage:concentrate ratio and supplementing low quality forages.

Lamb Performance on Pelleted Diets

Increased lamb gain and improved feed efficiency resulting from pelleting feed have been reported by several authors (Cate et al., 1955; Weir et al., 1959 and Meyer et al., 1959) (Table 1). In these studies, improved performance in pellet-fed animals was due to increased feed consumption. When equal amounts of pelleted or ground feed were fed, no differences in performance were obtained.

The results of studies conducted by Cate et al., 1955; Weir et al, 1959 and Meyer et al., 1959 are shown in Table 1. In their studies feed intake was improved an average of 11.3% when lambs were fed diets in pelleted rather than chopped or meal form.

Table 1. Review of lamb performance on pelleted diets

Study	Diet*	Intake kg/d	ADG kg/d	Gain:Feed	Carcass fat %	DP %
Cate et al., 1955	Pelleted[1]	1.31	0.20	0.15		51.6
	Meal[1]	1.35	0.18	0.13		52.2
	Pelleted[2]	1.70	0.23	0.14		52.0
	Meal[2]	1.57	0.17	0.11		49.9
	Pelleted[3]	1.59	0.20	0.13		50.6
	Meal[3]	1.40	0.13	0.09		49.0
Meyer et al., 1959	Pelleted[4]	1.48	0.18	0.12	28.4	
	Pelleted - B[4]	1.14	0.12	0.10	30.8	
	Chopped[4]	1.14	0.12	0.11	30.8	
Weir et al., 1959	Pelleted[5]	1.68	0.18	0.11		53.1
	Chopped[5]	1.41	0.14	0.10		49.8
	Pelleted[6]	1.45	0.16	0.11		55.2
	Chopped[6]	1.27	0.14	0.11		52.4

*Diets fed at ad libitum levels of feed intake unless noted otherwise

[1] Pelleted - alfalfa and corn; Chopped - alfalfa and corn

[2] Pelleted - timothy, corn, molasses, soybean meal; Chopped - timothy, corn, molasses, soybean meal

[3] Pelleted - timothy and corn; Chopped - timothy and corn

[4] Pelleted - alfalfa hay; Pelleted - B - alfalfa hay fed at level of chopped hay consumption; Chopped - alfalfa hay

[5] Pelleted - alfalfa hay; Chopped - alfalfa hay

[6] Pelleted - alfalfa hay plus 30% barley; Chopped - alfalfa hay plus 30% barley

However in the Cate et al. (1955) study, the lambs fed the higher quality alfalfa and corn pellets consumed 3% less feed than the lambs fed the same diet in meal form. As a result of the increased feed intake, lambs consuming pelleted diets also had increased ADG. In the Meyer et al. (1959) study a group of pellet fed lambs was fed at the same intake level as the chopped hay fed lambs. In this case there was no increase in ADG or any other performance characteristics. All three authors reported little or no effect on feed efficiency by altering the form of the diet. Both Cate et al. (1955) and Weir et al. (1959) reported a 2% increase in dressing percent (DP) when pelleted diets were fed. However, no difference in DP was reported by Cate et al. (1955) when the high quality alfalfa and corn diet was fed. Similarly, Meyer et al. (1959) reported a 2.4% decrease in carcass fat when the pelleted diet was fed at ad libitum levels of intake.

Feeding alfalfa and corn in pelleted form did not result in significant changes in performance, therefore the increased cost of pelleting would not be justified. However, pelleting lower quality timothy did show an improvement in lamb performance. Lambs consuming these diets in pelleted form had increased feed intake resulting in increased ADG. However, gain to feed ratios were not affected by pelleting diets. Cate et al. (1955) suggested that increased feed intake of pellets was a result of increased palatability of the diet. Increased feed intake could be attributed to a decreased consumption time and increased rate of passage from the rumen when pelleted diets were fed (Cate et al., 1955; Weir et al., 1959 and Meyer et al., 1959).

Performance on Diets Varying in Forage Content

Several studies have shown an effect on feeder lamb performance based on the ratio of forage to concentrate in the diet (Table 2). The caloric content of the diet increases with increased level of concentrate, which causes an increase in energy retention and ultimately an increase in performance (Kromann et al., 1975). However, increasing concentrate levels too much can result in decreased feed intake and performance. High concentrate diets have been shown to increase lactic acid content and lower pH values in the rumen (Meyer et al., 1959). These authors suggest that an accumulation of lactic acid in the rumen tends to lower appetite.

In the studies conducted by Oltjen et al. (1971), Kromann et al. (1975), Thomas et al. (1984) and Glimp et al. (1989), increased forage levels caused an average of a 30% increase in feed intake. Decreased feed intake of the high concentrate diets was attributed to an excessive caloric content of these diets. These studies also showed a decrease in ADG as forage level in the diet increased. However, Kromann et al. (1975) and Glimp et al. (1989) did report a decrease in ADG when concentrate was increased above 85% and 72.5% of the diets, respectively. The increase in performance was described by a curvilinear relationship between energy gain and diet composition, which resulted from a decreased intake in high (65 – 100%) corn diets. The decreased intake was due to an increase in net energy (NE) retention as corn increased in the diet, since more NE was available for production (Kromann et al., 1975). Days on feed increased as forage level increased in the Oltjen et al. (1971) and Thomas et al. (1984) studies. However, days on feed were increased in the Glimp et al. (1989) study when forage level was decreased to 10% of the diet. Thomas et al. (1983) found no differences in intake, ADG or days on feed with increased forage content of the diet.

Table 2. Review of performance as forage content of the diet increases

Study	F:C* %	Intake kg/d	ADG kg/d	Days on feed	Carcass wt. kg	Carcass fat	DP %
Thomas et al., 1983	20 to 60	NS***	NS***	NS***	NS***	NS***	NS***
Thomas et al., 1984	20 to 80	linear increase	linear decrease	increased	decreased	decreased	decreased
Kromann et al., 1975	100:0	1.34	0.10	105	21.30	27.20%	
	80:20	1.15	0.10	105	20.10	25.10%	
	15:85	1.01	0.16	105	26.40	34.10%	
	0:100	0.80	0.11	105	22.70	29.90%	
Glimp et al., 1989	45:55	1.62	2.14	59	NS***		NS***
	27.5:72.5	1.45	2.31	58	NS***		NS***
	10:90	1.28	1.99	68	NS***		NS***
Oltjen et al., 1971**	100:0	10.59	1.05	203		9.4 mm	55.40
	0:100	7.26	1.27	168		17.0 mm	59.90

* Forage to Concentrate ratio

** Study conducted with cattle rather than sheep

*** No significant difference seen with changes in forage to concentrate ratio

These studies suggest that pelleted diets containing less than 15% forage and greater than 75% forage may result in lower ADG compared to when forage is included at more intermediate levels in the diets.

These same authors studied the significance of increasing forage content in the diet on carcass composition (Table 2). Studies conducted by Thomas et al. (1983) and Glimp et al. (1989) reported no differences in carcass weight, fat content or DP with increased dietary forage content. Thomas et al. (1984) found carcass weight, fat content and DP were decreased when forage content of the diet was increased. Kromann et al. (1975) reported a linear increase in carcass weight and linear decrease in carcass fat as forage content increased from 0 to 100%. Similarly, Oltjen et al. (1971) found steers fed 100% forage diets had 44.7% less fat and 4.5% lower DP than steers fed 100% concentrate diets. The decreased DP was attributed to decreased carcass fat. However, the decreases in DP reported by Oltjen et al. (1971) and Thomas et al. (1984) were likely a result of increased gut fill in animals fed high forage diets. Desired ADG and days on feed to produce properly finished animals must be considered when selecting dietary feed ingredients.

The results of these studies indicate that varying forage:concentrate ratio in diets fed to lambs and steers can impact performance. Increasing forage level in the diet tends to increase daily feed intake and reduce ADG resulting in increased days on feed. However, increasing the amount of concentrate in the diet to 90% and above had a negative affect on ADG and days on feed. This decrease in performance was likely a result of increased lactic acid production in the rumen causing a decrease in appetite (Meyer et al., 1959). Altering the forage:concentrate ratio produced inconsistent effects on carcass weights and DP, but animals fed high concentrate diets tended to have higher percentages of carcass fat. The increase in carcass fat can be attributed to the increased caloric content of the high concentrate diets, resulting in excess energy available for growth (Kromann et al., 1975).

Factors Affecting Intake and Digestibility of Diets Varying in Forage Content

The objective of this section is to show that the improvements in feed intake and performance shown previously are related to changes in the digestibility of the different feed components. There are several factors that affect the intake and digestibility of diets fed to ruminants. These factors include particle size of dietary components, pelleting of feed ingredients and the frequency of feeding. In addition, one of the most important factors is the amount of forage (vs. concentrate) in the diet. High forage diets contain more cell wall components than high concentrate diets. The primary cell wall components are cellulose, hemicellulose and lignin. Of these, cellulose and hemicellulose are potentially digested and the extent to which they are digested is important in determining the nutritive value of a diet. The lignin within the cell wall is indigestible and is thought to protect the cellulose from digestion (Van Soest and Wine, 1967). Cereal grains may reduce roughage intake due to the rapid fermentation of starch which lowers ruminal pH and, reduces or retards the digestion of cellulose (ARC, 1980).

Digestion trials are useful because indigestibility accounts for the largest single loss in nutrient utilization by ruminants (Colucci et al., 1989). Much of the digestibility data has been collected from trials with sheep and assumes that cattle and sheep are equal in their digestive capacity. The assumption is also made that variations in intake and type of diet produce similar changes in digestibility of energy and other feed fractions in both species. To validate the use of sheep as models for cattle in digestibility trials, Colucci et al. (1989) conducted a study in which both species were compared at 2 levels of feed intake (ad libitum and maintenance). At high dry matter intakes (DMI), Holstein cows digested less organic matter (OM), energy, crude protein (CP), starch and soluble detergent matter than wether lambs. When diets contained low, intermediate or high levels of concentrate (20, 45, and 70%, respectively) the digestibility of DM, OM and energy were positively and linearly related to the proportion of concentrate in the diet for both cows and lambs fed at maintenance and ad libitum levels of intake. Cell wall digestibility by both species exhibited a positive relationship with proportion of concentrate at low intakes. At high intakes, cell wall digestibility by lambs was not affected by forage level, whereas a negative relationship was seen in cattle. Although concentrates are usually more digestible than forages, and diet digestibility generally increases with increased concentrate in the diet; a positive relationship between, OM digestibility or energy and amount of concentrate in the diet does not always occur. When forages are replaced by concentrates in the diet, there is a change in type and amount of fiber, which can change ruminal environment and retention time of the feedstuffs (Colucci et al., 1989). The depression of digestibility of different feed fractions with increasing intake was greater for cows than for sheep. For this reason, sheep may not be accurate models for predicting digestibility in cattle, particularly at high intakes.

The impact of forage:concentrate ratio on dietary intake and digestibility was examined in several studies (Table 3). In general, decreased forage content in the diet decreased digestibilities of neutral detergent fiber (NDF), acid detergent fiber (ADF) and increased organic matter digestibility (OMD). In studies conducted by Weir et al. (1959), Kromann et al. (1975), Reynolds et al. (1991) and Murphy et al. (1994), increased forage content of the diets resulted in increases in DMI.

Table 3. Review of the effect of forage to concentrate ratio (F:C) on diet digestibility

Study	DMI kg/d	F:C	Intake* %	Apparent digestibility, % DMD**	OMD***	NDF	ADF
Reynolds et al., 1991[a]	5.1	25:75	100	77.0	77.6	49.2	42.1
	6.3	75:25	100	65.2	66.4	39.7	34.2
Kromann et al., 1975	0.8 to 1.36	0 to 100[2]	100			decreased	decreased
Lambert et al., 1987	NS[1]	0:100	90	82.8		73.8	81.5
	NS[1]	60:40	90	64.5		56.2	55.0
	NS[1]	30:70	90	72.6		59.1	63.1
	NS[1]	100:0	90	61.5		63.8	60.6
Murphy et al., 1994	1.14	78:22	100	44.1	44.9	31.5	29.4
	1.01	61:39	95	52.7	53.6	32.4	30.3
	0.90	39:61	80	62.7	63.8	35.5	32.4
	0.78	8:92	70	80.3	82.2	45.8	51.6
Merchen et al., 1986	0.72	100:0	2.7% BW	59.1		46.7	47.9
	0.79	50:50	2.7% BW	72.3		45.4	40.3
Weir et al., 1959	1.68	100:0[3]	100			47.0	
	1.41	70:30[3]	100			42.0	
	1.45	100:0[4]	100			51.0	
	1.27	70:30[4]	100			53.0	

* Percent of ad libitum

**DMD - Dry matter digestibility

***OMD - Organic matter digestibility

[1]NS - No significant difference in DMI among dietary treatments ($P < .05$)

[2]5% increments from 0 to 100

[3]Pelleted diet

[4]Chopped diet

[a]Cattle study

Differences in DMI of these diets could affect their rate of passage, which may explain the decreased digestibility of the higher forage diets. It was also suggested by Kromann et al. (1975), that as concentrate level increased above 85%, the fiber content of the diet decreased to a level at which normal rumen function was likely impaired, resulting in decreased DMI. In contrast to these studies, Merchen et al. (1986) and Lambert et al. (1987) reported no differences in DMI with increasing dietary forage content.

As expected, dry matter digestibility (DMD) of the diets decreased with decreasing proportions of concentrate, since concentrates generally contain more highly digestible cell solubles than do forages (Merchen et al., 1986; Lambert et al., 1987; Reynolds et al., 1991 and Murphy et al., 1994). However Lambert et al. (1987), reported that the DMD of their two intermediate forage diets were 6.5% lower than would be expected if the response were linear. This non-linearity may be explained by increased DMI and DMD associated with reduced dietary NDF content. A similar trend was reported by Reynolds et al. (1991) and Murphy et al. (1994) for organic matter digestibility (OMD) which was attributed to increased OM content of the high concentrate diets. It has been estimated that two-thirds of OM digestion can occur in the rumen (Faichney and Gherardi, 1986) and a negative relationship was reported between OMD and DMI. In addition, as intake increased towards ad libitum levels, mean ruminal retention time in sheep fed lucerne hay decreased more rapidly when the hay was ground and pelleted than when it was chopped (Faichney and Gherardi, 1986). Beardsley et al. (1959) also reported that elevated intakes on pelleted diets were associated with increased rates of passage and decreased digestibility of finely ground and pelleted feedstuffs.

Due to increased fiber content and increased DMI of high forage diets, fiber digestibility was expected to decrease due to increased rates of passage from the rumen (Kromann et al. (1975). In studies conducted by Kromann et al. (1975), Lambert et al. (1987), Reynolds et al. (1991) and Murphy et al. (1994), there was an average decrease of 11.3% NDF digestibility and 17% ADF digestibility as dietary forage level increased. In contrast to their work, Weir et al. (1959) reported a 3.5% increase in crude fiber digestibility and Merchen et al. (1986) reported no difference in NDF digestibility and a 7.6% increase in ADF digestibility as dietary forage level increased. These differences in NDF and ADF digestibilities were attributed to decreased intake in corn supplemented lambs (Merchen et al., 1986).

The physical characteristics of the roughage component of a ruminant diet are important criteria in the animal's ability to utilize feedstuffs (Kerley et al., 1985). Pelleting prevents selectivity of the more palatable dietary ingredients by sheep. Paladines et al. (1964) found that pelleting of finely ground feeds increased feed intake of lambs as much as 22.6% compared to feeding the same diets in meal form. Similarly, Nocek and Kesler (1980) found that calves fed a pelleted hay and concentrate diet consumed 20% more DM than calves fed a similar conventional loose hay and concentrate diet. Pelleting increases palatability of fine dusty feeds. Meyer et al. (1959) demonstrated that increased gains from lambs fed a pelleted alfalfa hay diet compared to a chopped alfalfa hay diet was due to increased feed intake. This increased intake appeared to be caused by an increased rate of passage from the reticulorumen of the finely ground feedstuff. In addition, OMD of pelleted alfalfa hay did not differ from that of the chopped alfalfa hay.

Not only does pelleting or chopping affect intake and digestibility, but particle size of the chopped forage may also influence intake and digestibility (Table 4). A study to evaluate the influence of particle size of diets fed to cattle, conducted by Jaster and Murphy (1983), determined DMD decreased with increased DMI resulting in increased rate of passage. Dry matter intakes were greater when coarse and fine chopped hays were offered compared to hay fed in long stem form. Digestibilities of DM and NDF were decreased when comparing chopped hay to long hay. A trend for decreased fiber and DM digestibilities was also apparent as particle size decreased. A similar increase in DMI was seen in lambs fed ground alfalfa hay (1.91cm) which consumed 6.4% less DM than lambs fed low-moisture silage (0.64cm) (Merchen and Satter, 1983). However, they found that OMD was unaffected by diet. Lambs fed alfalfa hay consumed more ADF than lambs fed low-moisture silage (249 vs. 214 g/d), while ADF digestibility was identical for the two forages. These results showed that feeding dry ground alfalfa hay or chopped low-moisture alfalfa silage had no affect on OMD or ADF digestibilities due to the increased rate of passage associated with the 0.64cm forage.

Other studies, where pelleted lambs were fed corncob and concentrate diets varying in corncob particle size, found that DM, starch and NDF digestibilities did not differ (Kerley et al., 1985 and Kinser et al., 1985). However, ADF digestibilities varied with changes in particle size. Fecal DM excretion was highest for adult sheep fed the two diets containing the smallest (.8-mm) corncob particles, when fed at 90% of ad libitum intake levels (Kerley et al., 1985). Apparent total tract DM and NDF digestion varied little among diets.

Table 4. Review of the influence of dietary particle size on diet digestibility

Study	Particle size	DMI* kg/d	DMD**	Apparent digestibility, % OMD***	NDF	ADF
Merchen and Satter, 1983	1.91cm	0.575		62.8		54.0
	0.64cm	0.614		64.3		54.0
Jaster and Murphy, 1983[a]	Long hay	8.0	62.6		59.3	54.1
	Coarse chop	8.4	61.3		58.6	55.1
	Fine chop	8.5	56.3		57.6	52.8
Kinser et al., 1985[b]	6.5mm	0.513	69.9		31.5	23.3
	5.4mm	0.524	68.6		31.1	13.0
	1.4mm	0.520	69.4		45.1	36.3
	0.8mm	0.523	66.5		33.4	32.7
Kerley et al., 1985	Same as Kinser et al., 1985	NS[1]	NS[1]		NS[1]	

[a]Cattle study

[b]Average values of two experiments

[c]Coarse chop = >10.2cm particles; Fine chop = <10.2cm particles

*Ad libitum levels of intake

**DMD - Dry matter digestibility

***OMD - Organic matter digestibility

[1]NS - Not significant (P < .05)

The lack of a difference in fiber digestibility in this study indicated a possible interaction between animal size and fiber digestibility. Since, in two experiments conducted by Kinser et al. (1985), lambs consuming diets with 1.4-mm corncob particles digested 45.1% of dietary NDF compared to lambs with similar intakes of diets containing 6.5, 5.4 or .8-mm corncob particles with NDF digestibilities of 32.0%. Acid detergent fiber digestibilities did not differ between lambs consuming .8 and 1.4-mm corncob particles. However, ADF digestibilities were higher for the .8 and 1.4-mm corncob diets compared to the larger particle size diets. In general, decreasing the particle size of the diet will tend to increase ADF digestibilities by increasing the surface area of the feedstuff being digested.

Feeding frequency is another contributing factor affecting the digestibility of forage diets. Ruiz and Mowat (1987) concluded that eating patterns observed when feed was available at all times did not differ from patterns seen from animals fed once daily. Increasing feeding frequency from 1 to 4 times per day, had no affect on fiber digestion when steers had ad libitum access to feed, regardless of feeding frequency. Similarly, Bunting et al. (1987) found that apparent and total tract digestibility of DM, OM, and cell wall constituents were not affected by feeding 2, 4, 8, or 16 times daily. Gibson (1981) summarized data from 25 trials and concluded that animals fed more than 4 times daily, out-performed animals fed once or twice daily. Weight gain increased 16%, which was attributed to a 19% increase in feed efficiency. Therefore, increasing frequency of feeding to greater than once or twice daily may increase weight gain. However, these improvements are not attributed to an increase in fiber or DM digestibility, but are likely a result of increased feed efficiency when animals are fed at intake levels less than ad libitum.

Optimizing digestibility of diets fed to lambs appears to be dependent on several factors. Maintaining the level of forage in the diet between 25 and 50% had the most positive results on DM and fiber digestibilities. Feeding these pelleted diets at ad libitum levels of intake resulted in greater DMI. However, fiber digestibility was usually decreased due to an increased rate of passage from the rumen of the smaller particle sizes. This decrease was compensated for by increased DMI resulting in greater feed efficiency.

Nitrogen Balance of Diets Varying in Forage Content

The digestibility of nitrogen in lamb diets can be affected by some of the same factors that affect DM and fiber digestibility. Thirty-kg lambs of moderate growth potential require 191 grams of protein to gain 300 grams of body weight (BW) per day (NRC, 1985). Due to degradation of dietary protein in the rumen, a high dietary protein intake does not guarantee that animals have an adequate supply of needed amino acids at the small intestine (Church, 1988). Type of protein and the level at which it is fed has a profound impact on nitrogen (N) digestibility and N retention. Determining how different types of feeds (concentrates vs. forage) and levels of CP intakes affect N digestibility and N retention make N balance trials useful.

The source of forage can have a profound effect on N digestibility due to differences in CP levels. For example, alfalfa hay may have 17% CP, where as corncobs contain only 3.2% CP. Both are typical feed ingredients used as fiber sources in lamb diets. Several studies were conducted to determine if forage source affected N digestibility and metabolism (Kinser et al., 1988; Forster et al., 1991 and Gordon et al., 1995) (Table 5). Kinser et al. (1988) found that lambs consuming diets containing corncobs as a fiber source had 8% higher N intakes than lambs consuming diets containing cottonseed hulls.

Table 5. Review of the effect of forage source on nitrogen (N) balance

Study	Forage source	CP	N intake	DMI	N dig*	N ret**
		%	g/d	kg/d	%	%
Kinser et al., 1988	Corncobs	16.2	58.5	2.21	76.5	
	Cottonseed hulls	15.2	53.8	2.20	71.3	
Forster et al., 1991	Alfalfa hay	17.0	19.6	1.15		10.5
	Flatpea hay	22.2	25.7	1.15		9.0
Gordon et al., 1995[a]	Low DMD[1]		464	8.6	69.6	
	High DMD[2]		553	10.2	69.4	

[a]Cattle study

[1]Low dry matter digestibility grass silage (.677 g/kg DMD)

[2]High dry matter digestibility grass silage (.785 g/kg DMD)

*Nitrogen digestibility as a % of N intake

**Nitrogen retention as a % of N intake

Nitrogen digestion as a percent of N intake, was 5.2% higher for lambs consuming diets containing corncobs compared to cottonseed hulls. The decrease in N digestibility for lambs consuming diets containing cottonseed hulls as a fiber source was attributed to the increase in N intake. However, in the Forster et al. (1991) study feeding different ratios of alfalfa hay to flatpea hay, N intake of lambs on 100% flatpea hay was 23.7% higher than that of lambs fed 100% alfalfa. This difference was due to the difference in N content of the hays. No differences were found in N retention among the diets, since there was an excess of N in all diets. Similarly, Gordon et al. (1995) reported no differences in N digestibility in lactating dairy cows that showed a 16.1% increase in N intake when high DMD grass silage was compared to low DMD grass silage. Results of these studies indicate that when high quality forages (alfalfa hay) were fed at ad libitum levels of intake N retention was not affected because N intake was in excess of the required N levels.

As with forage source, differences in the forage to concentrate ratio influences N digestibility due to differences in N content of the forages compared to concentrates (Table 6). Nitrogen intakes were lower when lambs were fed a 75% concentrate compared to a 75% alfalfa diet (Reynolds et al., 1991). Lambs consuming the 75% alfalfa diet at low and high levels of intake digested less N, as a percent of N intake, than lambs consuming the 75% concentrate diet at the same intake levels. Also, lambs fed the 75% concentrate diet excreted an average of 31% less fecal N and 20% less urinary N. As a result, N retention was higher for lambs fed the 75% concentrate diet at low and high levels of intake. Similarly, Susin et al. (1995) fed ewe lambs either 80% alfalfa (high forage) diet or 10% alfalfa (high concentrate) diet at intakes to maintain similar growth rates. Lambs on the high forage diet consumed 9.6% more N and excreted 48.7% more fecal N.

Table 6. Review of the effect of forage to concentrate ratio (F:C) on nitrogen (N) balance

Study	F:C	Intake*	N intake g/d	DMI kg/d	N dig** %	N ret*** %
Reynolds et al., 1991[a]	75:25	Maint[1]	133.4	4.75	69.8	15.7
	25:75	Maint[1]	97.8	3.60	74.3	14.6
	72:25	2X maint[2]	208.6	7.78	66.7	8.8
	25:75	2X maint[2]	173.9	6.61	70.4	13.9
Susin et al., 1995	80:20	100	52.7	1.99	60.8	10.8
	10:90	Rest[3]	47.6	1.58	77.7	21.2
Murphy et al., 1994	78:22	100	23.4	1.14	57.0	4.7
	61:39	95	23.0	1.01	65.5	15.9
	39:61	80	20.9	0.90	65.8	16.4
	8:92	70	18.9	0.78	73.8	19.8

[a]Cattle study

[1]Cattle fed at maintenance

[2]Cattle fed at two times maintenance

[3]Rest= restricted intake, sheep fed to gain the same as 80:20 group

*Intake level as a % of ad libitum unless otherwise noted

**Nitrogen digestibility as a % of N intake

***Nitrogen retention as a % of N intake

Urinary N did not differ between diets. As seen in the Reynolds et al. (1991) study feeding high concentrate diets resulted in increased N digestibility and retention. Murphy et al. (1994) also found a decrease in N intake as concentrate in the diet increased from 22 to 92% and feeding level was decreased from 100% to 70% of ad libitum. Apparent N digestibility and N retention increased linearly as the amount of dietary concentrate increased and feeding level decreased. The results of these studies indicate that increasing the forage content of the diet can increase N intake, however increases in fecal and/or urinary N losses resulted in decreased N digestibility and retention. However, these authors attributed variability in dietary N digestion to differences in dietary crude protein content.

Feeding supplemental N when diets contain low quality forages (less than 4% CP) improves N retention (Table 7). Supplementation of 0, 5 and 10 g N/d increased total daily N intake from 2.8 to 8.9 and 13.4 grams, respectively which is considerably below the 30.6 g/d of N required for 300 g/d BW gain (Martin et al., 1981). Total N retained was lower at the 0 and 5 g levels of N supplementation than at the 10 g level, due to the low N intakes. Similarly, Hill et al. (1996) reported that steers consuming corn-soybean (C-SBM) grain sorghum-corn (GSC) or pearl millet-corn (PMC) had similar N intakes. Nitrogen digestibility and N retention did not differ among dietary treatments. Petit and Veira (1994) found that feeding 15% canola meal (15C) with timothy silage compared to 7.5% canola meal (7C) with timothy silage increased N intake. Canola meal supplementation resulted in higher N intake than molasses supplementation or feeding silage alone. However, when timothy silage was supplemented with molasses, there was no difference in N intake when compared to steers fed unsupplemented silage. This affect on N intake would be expected when comparing a protein supplement to an energy supplement.

Table 7. Review of the effect of feeding supplemental nitrogen (N) on N balance

Study	CP %	N intake g/d	DMI kg/d	N dig* %	N ret** g/d
Martin et al., 1981	3.6	2.8		0.0	-1.88
	8.3	8.2		50.9	-0.40
	12.8	13.4		69.9	0.79
Hill et al., 1996[a]	9.2	77.8		58.8	23.9
	12.5	82.1		54.2	21.7
	14.1	80.8		55.4	20.6
	Diet				
Petit and Veira et al., 1994[a]	Silage[1]	149	6.67	65.9	33.8
	7M[2]	152	6.97	64.6	32.8
	15M[3]	163	7.54	64.8	37.8
	7C[4]	180	6.89	68.9	48.0
	15C[5]	203	6.87	72.4	40.4

[a]Cattle study

[1]Timothy silage

[2]Timothy silage plus 7.5% molasses supplementation

[3]Timothy silage plus 15% molasses supplementation

[4]Timothy silage plus 7.5% canola supplementation

[5]Timothy silage plus 15% canola supplementation

*Nitrogen digestibility as a % of N intake

**Nitrogen retention

Nitrogen digestibility and N retention were similar among treatments. Results of these studies demonstrated that protein supplementation of low-quality, forage-based diets increased N retention. However, when diets contained adequate levels of N, supplementation had little effect.

The size of forage particles in the diet may affect N digestibility. Kerley et al. (1985) reported that DM (1,623 g/d) and N (36 g/d) intakes were similar in lambs fed corncobs ranging from .8-mm to 6.5-mm particle size. However, lambs consuming pelleted corncobs, which had 1.4-mm particle size had 7.6% lower apparent total tract N digestion (70.1 vs. 77.7%) when compared to the other treatments. This decrease was attributed to shorter remastication time of the smaller particle size diets resulting in a faster rate of passage from the rumen and lower N digestion. Diets containing the .8-mm particle sizes passed more quickly from the rumen, but increased surface area for bacterial attachment allowed for increased N digestion. In contrast with Kerley et al. (1985), N metabolism was unaffected by particle size of the roughage component of pelleted concentrate : corncob diets when particle sizes ranged from .8 to 6.5-mm (Kinser et al., 1985). These results indicate that varying roughage particle size has little effect on N digestibility.

The frequency of feeding forage-based diets may affect N excretion and ultimately N retention (Ruiz and Mowat, 1987). In this work, cattle were fed alfalfa hay or corn silage diets and feeding frequency increased from one to four times per day. Nitrogen retention was not improved when expressed on a g/100 kg BW basis, however, when expressed as a proportion of N intake, N retention was improved with more frequent feedings (32.2 to 34.7%). This increase was primarily due to a decrease in fecal nitrogen excretion. Urinary N excretion was 17.1 g/100 kg BW/d for all cattle. In contrast, Bunting et al. (1987) found that when feeding tall fescue hay, fecal N increased linearly (5.7 to 6.3 g/d) as feeding frequency increased from 2 to 16 times per day. The increase in fecal N observed with increased frequency of feeding may have reflected the washout of potentially digestible feed organic matter from the rumen. Neither urinary N nor N retention was effected by meal frequency. The results of these studies indicate that increased feeding frequency had little effect on N retention. However, when feeding frequency was increased from 4 to 16 times per day an increase in fecal N was observed. When feeding frequency was less than 4 times per day, fecal N was decreased.

Energy Balance of Diets Varying in Forage Content

Differences in dietary digestible and metabolizable energy utilization can be influenced by forage type, forage vs. concentrate level and energy supplementation levels. The need for energy balance studies, which determine how efficiently dietary energy is utilized, has been based on three points (Church, 1988). First, supplying energy to an animal is more costly both biologically and economically than supplying any other nutrient. Second, the primary factors that determine the efficiency of utilization of feed energy are the energy losses in feces and heat production. Finally, the efficiency of converting feed energy to products for human consumption is low. For example, a 30 kg early-weaned lamb must consume 4,400 kcal of digestible energy/d or 3,600 kcal of metabolizable energy/d to support 300 g average daily gain (NRC, 1985). These requirements are high when compared to a monogastric animal. A pig of similar BW, gains 300 g/d with digestible energy or metabolizable energy intake of 2,769 or 2,657 kcal/d, respectively (NRC, 1988).

The conventional scheme of energy metabolism is illustrated in Figure 1 (NRC, 1966 and NRC, 1985). Gross energy (GE) intake is the heat of combustion of the feed ingested (ARC, 1980).

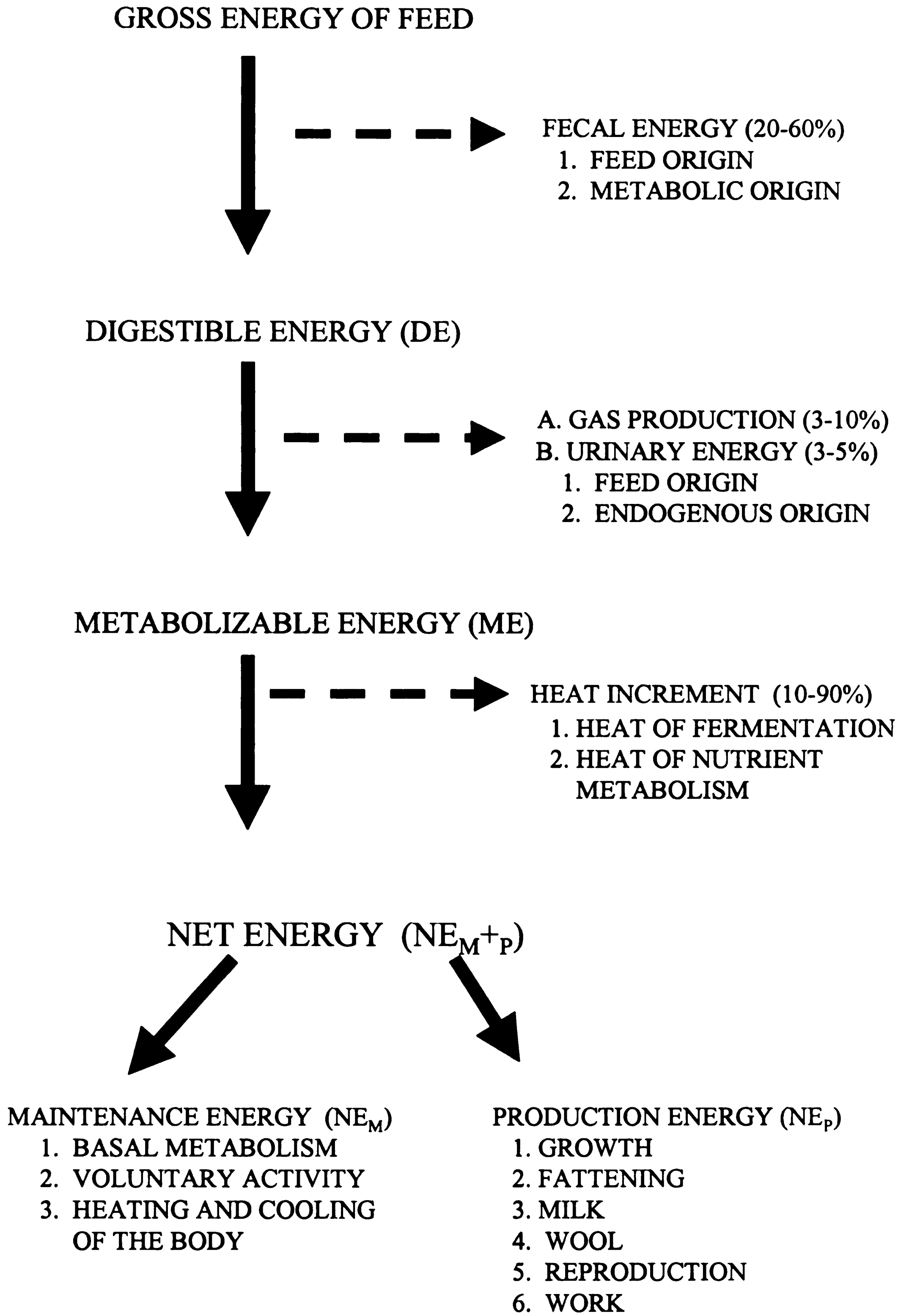

Figure 1. Scheme of energy metabolism (NRC, 1966) with expected losses (NRC, 1985)

Digestible energy (DE) is the GE content of the feed minus the energy content of the feces. Metabolizable energy (ME) is the DE of the feed minus the energy content of urine and combustible gases, of which methane is quantitatively most important. Net energy represents the amount of energy actually available to the animal for maintenance (NEm) and productive processes (NEp) and is calculated by subtracting the heat increment, from ME. The heat increment is the increase in heat produced as a result of digestive and metabolic processes in response to increased ME intake (NRC, 1985).

The rate and extent of digestion of a feedstuff is primarily influenced by its chemical and physical nature (Church, 1988). Feedlot lambs are fed a wide variety of diets ranging from 100% concentrate to 100% forage. The energy density of these diets will also vary greatly. A 100% concentrate diet may contain approximately 3.8 kcal/g DM DE while 100% forage may contain 2.5 kcal/g DM DE. Therefore, knowing the energy values of dietary components is important in identifying the nutritive value of a feedlot diet.

The DE content of a diet varies with different forage sources. Several studies were conducted to determine the nutrient utilization of diets containing different forage sources (Kinser et al., 1988; Forster et al., 1991 and Gordon et al., 1995) (Table 8). Forster et al., 1991 reported that as the percentage of flatpea hay in the diet increased from 0 to 100%, DE decreased linearly and ranged from 58.1% to 53.3%. Since all diets were formulated to contain 4.5 kcal/g GE, the decrease in DE values was attributed to a 4.3% decrease in DMD. Similarly, Kinser et al. (1988) found lambs consuming corncobs, compared to cottonseed hulls, as a fiber source had 8.3% greater GE intakes, excreted 34% less fecal energy which resulted in 10.7% higher DE values. However, Gordon et al. (1995) reported that feeding a low digestibility grass silage to lactating dairy cattle had no effect on GE intake, fecal energy or DE values compared to feeding a high digestibility grass silage.

Table 8. Review of the effect of forage type on energy balance

Study	Forage source	GE intake	Fecal Energy	Apparent digestibility Energy DE %	Apparent digestibility DMD* %
Kinser et al., 1988	Corncobs	6,702 kcal/d	1,549 kcal/d	73.2	72.7
	Cottonseed hulls	6,144 kcal/d	2,362 kcal/d	62.5	72.5
Forster et al., 1991	Alfalfa hay			58.1	59.9
	Flatpea hay			53.3	55.6
Gordon et al., 1995[a]	Low DMD[1]	316 MJ/d	88 MJ/d	72.2	.677 g/kg
	High DMD[2]	344 MJ/d	90 MJ/d	73.8	.785 g/kg

[a]Cattle study

[1]Low dry matter digestibility grass silage

[2]High dry matter digestibility grass silage

*DMD- Dry matter digestibility

The results of these studies indicate that some correlation exists between DMD and energy utilization of diets containing different forages. The results of the Gordon et al. (1995) study indicate that during different stages of production which require more energy, for example lactation, energy utilization of a diet is virtually unaffected by DMD.

Adding concentrate to forage-based diets increases the dietary energy content. The effect of altering forage:concentrate ratio on energy utilization was determined by several authors (Wainman et al., 1970 & 1975; Kromann et al., 1975 and Reynolds et al., 1991) (Table 9). These authors found that as the forage to concentrate ratio increased there was an increase in DE values due to an increase in GE intakes. Kromann et al. (1975) reported DE values for dehydrated alfalfa and corn were 2.67 and 4.07 kcal/g, respectively. This compares to current NRC (1985) values for these same feedstuffs 2.65 and 3.84 kcal/g, respectively. Based on the Kromann et al. (1975) curvilinear equation, the maximum energy retention (96.7 Mcal/d) occurred when a diet consisting of 80% corn and 20% alfalfa was fed. These studies also indicated that as forage to concentrate ratio increased there was an increase in ME value, except in the Reynolds et al. (1991) work, which reported no differences in ME value. As reported by studies comparing forage sources, these authors found that there was a direct correlation between DMD and energy utilization. These results would be expected since an increase in forage content of the diet tends to decrease DMD and lowers the energy value of the diet being consumed.

The affects of feeding corncobs of varying particle sizes on digestive and metabolic characteristics of GE were studied using early-weaned lambs (15.3 kg and 61 ± 5d of age) fed a pelleted 74.9% concentrate and 25.1% corncob diet (Kinser et al., 1985). The particle

Table 9. Review of the effect of forage to concentrate ratio (F:C) on energy balance

Study	F:C	Intake level	GE intake MJ/d	DE value MJ/d	ME value MJ/d	Apparent digestibility Energy %	Apparent digestibility DMD* %
Reynolds et al., 1991[a]	75:25	Maint[1]	87.43	55.27	44.97	63.4	65.5
	25:75	Maint[1]	65.03	50.74	44.52	77.8	79.7
	75:25	2X maint[2]	144.27	90.83	77.18	63.3	54.8
	25:75	2X maint[2]	119.83	86.61	76.90	71.9	74.2
Kromann et al., 1975	0 to 100[3]	Ad libitum		increased	increased		
Wainman et al., 1970	40:60	4 levels[4]	increased	increased	increased	decreased	decreased
Wainman et al., 1975	30:70	2 levels[5]	increased	increased	increased	decreased	decreased

[a]Cattle study

[1]Cattle fed at maintenance

[2]Cattle fed at two times maintenance

[3]5% increments from 0 to 100

[4]4 levels of intake from 527 to 2078 g/d

[5]2 levels of intake from 860 to 2094 g/d

*DMD- Dry matter digestibility

sizes of the corncobs in the diet were either 6.5, 5.4, 1.4 or .8 mm. No differences were reported in GE intake, DE or urinary energy excretion based on particle sizes when fed at 90% of ad libitum levels of intake. Later, the same lambs (16.8 kg and 82 ± 5d of age) were fed the same four diets. The 6.5-mm particle size resulted in the highest digestible energy values. The larger particle size of the fibrous feedstuffs is thought to have stimulated salivation and resulted in greater buffering capacity in the rumen. It has been postulated that there was an increase in energy efficiency when the proportion of ruminal propionate to acetate was increased. However, older lambs fed the 6.5 and 5.4-mm diets had the highest molar proportion of acetic acid (59.4 and 56.4 mol/100 mol, respectively) and lowest proportion propionic acid (26.2 and 29.2 mol/100 mol, respectively). For younger lambs no differences were found in molar proportions of acetic or propionic acid. No differences were found in molar proportions of butyric acid for either age group.

Altering the forage to concentrate ratio has been shown to affect energy retention in both heifers and lambs (Reynolds et al., 1991 and Kromann et al., 1975; Wainman et al., 1970 & 1975, respectively). Although ME responses differed between the two studies both authors concluded that increasing the level of concentrate in the diet improved DMD which increased energy utilization.

Economic Analysis of Feeder Lamb Production

The United States sheep industry is in a state of decline (Purcell, 1995). Inventory numbers that exceeded 50 million in the 1940s have declined to less than 9 million in 1997. For many sheep producers sales of slaughter lambs constitute much of the revenue flow. When adjusted for inflation, slaughter lamb prices have declined over 60% from 1978 to the early 1990s. A major problem effecting slaughter lamb prices is a low and static demand for lamb. Per capita consumption over the last several decades was estimated at .68 kg/year

(Purcell, 1995). Another factor that continues to affect lamb prices is the seasonality of lamb availability. Prices are typically highest in the spring and lowest in the summer and fall months, which corresponds with the seasons in which lamb supply is lowest and highest, respectively (Ward and Hildebrand, 1993).

According to the SID Sheep Production Handbook (1992), 68% of the variable costs associated with sheep production are feed costs followed by: labor-13%; transportation, utilities and veterinary costs-9%; and shearing, bedding and miscellaneous costs-10%. With farm production expenses rising, it is imperative that component strategies of a farming system that utilize resources most efficiently be selected. Packer demand for leaner meat and market resistance to lambs that are too heavy and/or too fat are key incentives for producers to develop new production systems. Therefore, it is important that producers identify feed ingredient combinations that will allow lambs to attain optimum performance and carcass potential, while minimizing production costs. Historically, production, storage and feeding of forages has been a topic of considerable analysis by animal scientists and agricultural economists (Knoblauch et al., 1981). In today's economic environment, selection of a forage-based system for a sheep operation may be even more critical to farm productivity. However, utilization of processed forages, such as alfalfa pellets may increase feed costs. Utilization of pasture may be an effective way to decrease feed costs. Feeding different forage:concentrate ratios has a profound effect on performance and carcass traits of feeder lambs (Oltjen et al., 1971; Glimp et al., 1989 and Blackburn et al. 1991). The performance factors with the most economic impact on lamb production include: days on feed, gain to feed ratios and ADG.

Minimizing the days that a lamb is on feed is one way to increase profitability. To decrease days on feed and increase profitability, an increase in lamb performance must occur. The average costs to maintain a lamb in a feedlot or on pasture were $0.12/d, not including feed cost (Blackburn et al. 1991) as shown in Table 10. Yardage cost included utilities, equipment repairs and labor expenses. Pasture expense covered comparable expenses for pasture production.

Table 10. Non - feed cost associated with lamb production*

Feedlot	$/hd/d	Pasture	$/hd/d
Yardage	0.05	Yardage	0.05
Veterinary	0.06	Veterinary	0.06
Mineral	0.01	Mineral	0.01
Total	0.12	Total	0.12

*Adapted from Blackburn et al. (1991)

Using these values in a computer simulation, Blackburn et al. (1991) estimated lamb performance and feeding costs (Table 11). Average days on feed for lambs fed a standard feedlot ration (Feedlot) was 94d, for lambs on alfalfa pasture 30d followed by Feedlot was 102d and for lambs on alfalfa 60d followed by Feedlot was 116d. This difference in days on feed was a result of a 30 g/d decrease in ADG as days on alfalfa pasture increased from 0 to 60 days. The key to increasing ADG is to choose feed ingredient combinations that maximize BW gain per unit of feed consumed. Blackburn et al. (1991) found lambs averaged .160, .153 and .142 kg gain/ kg DMI for Feedlot, alfalfa 30d/Feedlot, and alfalfa 60d/Feedlot, resulting in costs of gain of $0.68, $0.72, and $0.77/kg gain, respectively when the cost of Feedlot was $.11/kg. Feeding lambs on alfalfa pasture for 0 to 60 days increased total daily costs from $0.23 to $0.46/hd/d due to the increased days on feed.

Table 11. Lamb performance and cost of gain - computer simulation

	Diet		
	Feedlot[1]	alfalfa 30d/Feedlot[2]	alfalfa 60d/Feedlot[3]
Trait			
Days on feed	94	102	116
ADG, kg	0.160	0.153	0.142
Cost of gain, $	0.68	0.72	0.77

Data from Blackburn et al. (1991)

[1]Feedlot - Standard commercial feedlot diet

[2]Alfalfa pasture for 30d then finished on Feedlot

[3]Alfalfa pasture for 60d then finished on Feedlot

In a feedlot trial, lambs consumed 1.3, 1.5 and 1.6 kg/d when fed diets containing 90, 72.5 and 55% concentrate with alfalfa hay, respectively (Table 12; Glimp et al. 1989). Days on feed were least for lambs fed the 72.5 and 55% concentrate diets (58 and 59d, respectively) and were greatest for lambs fed the 90% concentrate diet (68d). Average daily gain was greatest (231 g/d) in lambs fed a 72.5% concentrate diet compared to 199 and 214 g/d for lambs consuming 90 and 55% concentrate diets, respectively. Lambs consuming 72.5 and 90% concentrate diets gained .16 kg/ kg DM consumed, where as lambs consuming 55% concentrate diets gained .13 kg/ kg DM consumed. When applying a feed cost of $0.11/kg from Blackburn et al. (1991), calculated cost of gain was $0.85, $0.69 and $0.69/ kg BW gain for 55, 72.5 and 90% concentrate diets, respectively. Oltjen et al. (1971) found feeding all forage diets increased days on feed (203 vs. 168d) compared to feeding an all concentrate diet to beef cattle to gain 213 kg BW. Similarly, they reported that steers consuming all concentrate diets gained .17 kg/ kg feed consumed compared to .10 kg/ kg feed consumed for steers fed all forage diets. When using a feed cost of $0.11/kg from Blackburn et al. (1991) calculated cost of gain was $0.65 and $1.10/ kg BW gain for all concentrate compared to all forage diets, respectively. Feeding diets with forage levels greater than 50% have been shown to increase feed intake, decrease gain : feed ratios and decrease ADG, which increased days on feed.

Table 12. Lamb performance and cost of gain - feedlot trial

	Concentration level, %		
	55	72.5	90
Trait			
Days on Feed	59	58	68
ADG, g/d	214	231	199
Feed Intake, kg/d	1.6	1.5	1.3
Cost of Gain, $[a]	0.79	0.71	0.72

Adapted from Glimp et al. (1989)
[a] Based on Blackburn et al. (1991) feed costs

Overly fat lamb carcasses and inconsistent, low-quality, non-uniform lamb are cited as major marketing/merchandising problems for the US sheep industry (Umberger, 1994). Pricing lambs "on the average" has led to numerous production and marketing inefficiencies, because all lambs are marketed by an average market price regardless of potential yield grade. Lambs marketed on the basis of measurable differences in quality and composition send more accurate signals from the marketing sector back to the producer. A move towards value-based marketing has occurred in some segments of the lamb industry. Carcass characteristics have become a more important factor in selling live lamb since the establishment of a mandatory yield grading rule issued by the USDA in 1992. The yield grading system is based on the percentage of boneless closely trimmed retail cuts and is determined solely by fat thickness taken at the 12th and 13th rib as shown in Table 13 (American Lamb Council, 1994).

Table 13. Fat thickness requirements of the yield grading system*

Yield Grade	Fat Thickness (cm)
1	0 - .06
2	.06 - .10
3	.10 - .14
4	.14 - .18
5	.18 +

*Adapted from The American Lamb Council (1994)

Implementation of value-based marketing is found in the mid-Atlantic region of the US where a value-based marketing system was developed to provide differential payments for a product based on a set of economically important measurements: carcass weight, quality grade and yield grade (Umberger, 1994). With two years data collected from this program it was found that dressing percent had a greater impact on income than lamb cutability. In the value-based marketing system lambs are sold electronically. The base price is set for yield grade 1 to 3 carcasses, 18 kg and up. Carcasses which fall in the yield grade 4 or 5 range are discounted \$-0.05 and \$-0.20/cwt., respectively. Carcasses that fall below 18 kg or fail to grade choice are also discounted (\$-0.05 and \$-0.15/ cwt., respectively). Umberger (1994) also reported that although over-finished carcasses were a national issue, the primary concern identified in this program was the marketing of lambs that were too lean. With a shift towards value-based marketing systems, producers may have an incentive to produce lambs that will produce yield grade 2 or 3 carcasses.

Since feed costs constitute 68% of lamb production it is necessary to develop feeding systems that optimize productivity to maximize profits. In general, feeding 50% to 75% concentrate in the diet reduced days on feed, increased ADG, and decreased the cost of gain (Glimp et al., 1989 and Blackburn et al., 1991). The goal of producers is to select a feeding system that will maximize profits.

CHAPTER 2

Materials and Methods

This research was conducted under the approval of the Michigan State University All-University Committee on Animal Use and Care (AUF # 07/96-086-00).

Digestibility Trial

To test the hypothesis that the level of pelleted alfalfa in the diet would influence nutrient digestibility in lambs, a digestibility trial was conducted. Twenty-four crossbred (Suffolk x Dorset x Rambouillet) wether lambs were blocked by weight into two replications (40.1 and 45.6 kg) and randomly assigned to 3 dietary treatments: a pelleted alfalfa diet, which contained 100% forage (ALFA), a pelleted concentrate-based diet, which contained 25% forage (CONC) and a 1:1 mixture of these two diets, which contained 62.5% forage (50/50). The composition of these diets is shown in Tables 14, 15 and 16. Diets were formulated to meet or exceed NRC (1985) requirements for 40-50 kg lambs to support gains of 300 - 345 g/d. Prior to placement in metabolism stalls, lambs were fed their respective diets for a minimum of 14d and ad libitum levels of feed intake were determined for each lamb. Lambs were then moved and housed in elevated, aluminum metabolism stalls (1.5 x .45 m), which allowed separate total collection of feces and urine. Lambs were given a 7d adaptation period in the stalls prior to the sampling period, during which time intake was adjusted to 90% of their ad libitum intake levels. Lambs had access to water throughout the study. Lambs were fed twice daily at 0800 and 1600. Feed samples were collected on the first day of each collection period for compositional analysis.

During the 7d collection period, total feces and urine were collected daily, 2 hrs after the 0800 feeding.

Table 14. Diet composition (DM basis) - digestibility trial

Ingredient	ALFA[1]	Diet 50/50[2]	CONC[3]
		% DM	
Alfalfa	100.0	63.0	25.0
Corn	0.0	25.5	51.6
Soybean meal	0.0	5.8	11.8
Molasses	0.0	3.5	7.0
Supplement[a]	0.0	2.3	4.6

[a] Supplement included: soy hulls, binder, limestone, salt, Ammonium chloride, dical, vitamin premix and lasalocid sodium

[1]ALFA – Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 15. Diet chemical composition (DM basis), digestibility trial - lightweight lambs

	Diet		
Ingredient	ALFA[1]	50/50[2]	CONC[3]
DM, %	90.7	90.1	89.5
CP, %	16.9	15.9	14.8
GE, kcal/g	4.09	4.16	4.22
ME, kcal/g[a]	2.04	2.20	2.36
NDF, %	46.5	36.3	26.0
ADF, %	32.0	22.1	12.1
ADL, %	7.6	5.0	2.3

[a]ME – calculated from tabular values (NRC, 1985)

[1]ALFA – Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 16. Diet chemical composition (DM basis), digestibility trial - heavyweight lambs

	Diet		
Ingredient	ALFA[1]	50/50[2]	CONC[3]
DM, %	92.2	90.7	89.3
CP, %	18.3	16.9	15.6
GE, kcal/g	4.20	4.17	4.14
ME, kcal/g[a]	2.04	2.20	2.36
NDF, %	43.2	33.3	23.3
ADF, %	29.2	20.4	11.6
ADL, %	7.2	4.7	2.1

[a]ME – calculated from tabular values (NRC, 1985)

[1]ALFA – Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

Urine was acidified with 6 N HCl to maintain a pH < 3 and thereby preventing N losses due to volatilization. Collected feces and urine were weighed and a subsample (10% of total weight) weighed and frozen. Daily subsamples of feces and urine were each pooled over the 7d collection period. After the 7d collection period, lambs were removed from the metabolism stalls and a 10 ml ruminal fluid sample was collected using Tygon tubing fitted with a sieve attached to a 60-cc catheter tip syringe. The 10 ml sample was acidified using .2 ml 6 N HCl and stored frozen until analyzed. Pooled feces and feed samples were dried in a forced air oven at 55° C for 48 hrs and ground through a Wiley mill (1-mm screen) for storage and subsequent compositional analysis. Duplicate samples of the feed and feces (2 g each) were used to determine DM by drying in a forced air oven at 105° C (AOAC, 1990). Urine DM was determined with triplicate samples of urine (4 g each) added to .4g of cotton in the bomb capsules and freeze dried. Samples were freeze-dried in a Virtis shelf type freeze-drier. Samples were placed in the freeze-drier, frozen at -15° C and the temperature was increased under vacuum, 15° C at 12 hour intervals to a final temperature of 30° C. Total time in the freeze-drier was approximately 96 hours. Triplicate samples of the diet and feces (1 g each) were also analyzed for NDF, according to Goering and Van Soest (1970), modified by the addition of 4ml of a 2% α-amylase solution (Sigma A - 3306, Sigma Chemical Co., St. Louis, Mo.) to each sample, substitution of triethylene glycol for 2 ethoxyethanol, and omission of decahydronaphthalene and sodium sulfite (Van Soest et al. 1991). The NDF residues were sequentially analyzed for ADF and acid detergent lignin (ADL) according to Goering and Van Soest (1970). Ash was determined following sample ignition at 500°C for 6hr (Goering and Van Soest, 1970). Organic matter content of the diets and feces was determined by subtracting the ash values from the respective diet and fecal sample weights. Duplicate samples were used to determine the N content of the diets (1 g each), feces (1 g each) and urine (3 g each) using the Kjeldahl N method (AOAC 1984). Triplicate samples of diets and feces were pelleted (1 g each) and triplicate freeze dried urine samples (.5 g each) were used to determine the GE content using a 1241 Parr adiabatic bomb calorimeter (Parr Instrument Co. Moline, IL). A standard curve for cotton, with the freeze-dried urine samples, was determined using duplicate cotton samples from .1g to 1g in the Parr bomb calorimeter. The GE of the cotton was determined from this standard curve and then subtracted from the GE of the entire urine and cotton sample to determine the GE of the urine. Rumen fluid samples were thawed, decanted into plastic centrifuge tubes and centrifuged at 26,000 x gravity for 30 minutes. A 1 ml sample of the supernatant was analyzed for acetate, propionate and butyrate concentrations using a water high performance liquid chromatography (HPLC) system with a Bio-rad HPX-87H organic acid column (Waters Associates Inc., Milford, Mass.) following the general procedures of

Canale et al. (1984). The analysis was replicated and the results were quantified using PC Nelson turbochromic HPLC software (T. E. Nelson, Cupertino, CA).

Digestible energy intakes (kcal/d) were determined by subtracting fecal energy from GE intake. Metabolizable energy was determined by subtracting urinary energy and CH_4 losses from DE intake. Methane loss was estimated using two methods, (Wolin, 1960 and Johnson et al., 1991). The Wolin (1960) method uses relative proportions of acetate, propionate and butyrate to estimate methane while the Johnson et al. (1991) method is based on DE intake levels. The ME values were compared to estimates from NRC (1985) which were calculated using DE * .82.

Wolin (1960) Equation:

$$\text{Methane (M)} = 0.5A + 0.5B - 0.25P$$

Where: A= Relative proportion of ruminal acetate
B= Relative proportion of ruminal butyrate
P= Relative proportion of ruminal propionate

Energy lost as methane:

$$(M * .2108) * 1000 = \text{kcal lost}$$

Johnson et al. (1991) equation:

$$\text{Methane as \% of GE} = 5.5 + .06\ (DE) - 2.25\ (\text{level of intake})$$

Where: DE = % DE in the diet
level of intake = multiple of maintenance

Energy lost as methane:

$$\text{GE intake (kcal)} * \text{methane as \% of GE} = \text{kcal lost}$$

Data were analyzed using General Linear Model (GLM) procedures of SAS® (1989). ANOVA tables are shown in Appendix A. Digestibility, N metabolism and GE metabolism data were analyzed separately using the model statements which included weight (block), dietary treatment and weight x treatment interactions as class variables. Differences in digestibility were determined using DMI, fecal DM, DMD, OM intake, fecal OM, OMD, NDF digestibility and ADF digestibility as dependent variables in the model statement. Differences in N balance were determined using DMI, fecal N, urinary N, N intake, N digestibility (g/d and % of intake) and N retention (g/d, % N digestibility and % N intake) as dependent variables in the model statement. Differences in GE balance were determined using DMI, GE intake, fecal E, DE, urinary E, CH_4 estimates and ME estimates as dependent variables in the model statement.

Performance Trial 1

The objective of performance trial 1 was to determine performance and carcass composition of lambs fed diets containing 25% or 100% forage at ad libitum or 85% of ad libitum levels of feed intake. In trial 1, 79 crossbred (Suffolk x Dorset x Rambouillet) ewe and wether lambs (31.3 kg) were housed in 8 pens (4.3 x 18.3 m), in a 2 x 2 factorial design. Lambs were blocked by weight and sex (10 lambs / pen) and randomly assigned to 2 diets: a pelleted concentrate-based diet, which contained 25% forage (CONC) and a pelleted alfalfa diet, which contained 100% forage (ALFA) fed at 2 levels of intake: ad libitum (A) and 85% of ad libitum (R). The ingredient and chemical composition of these diets are shown in Tables 17 and 18. Lambs were fed twice daily at 0700 and 1500 and orts were measured prior to each 0700 feeding. The R intakes were adjusted daily as determined by the previous days' consumption by lambs fed at A levels of intake. Water and trace mineralized salt were available to all lambs throughout the trial. Diets were sampled every 14d for compositional analysis. Samples were dried in a forced air oven at 55° C for 48 hrs and ground through a Wiley mill (1-mm screen). Analyses were conducted as in the digestibility trial and included: 105° C DM (AOAC, 1990), Kjeldahl N (AOAC, 1984), modified NDF, ADF, ADL and ash (Goering and Van Soest, 1970). Lamb weights were recorded every 7d. Lamb were removed from the study when an average pen off-test final weight (FW) of 52.3 kg was attained. Lambs were on feed for 63d. Lambs were transported from campus to Manchester, MI where they were sold through commercial channels and processed the following day at Wolverine Packing, Inc., Detroit MI. Carcass data were collected at the plant and included: hot carcass weight (HCW), loineye area (LEA) and 12th rib fat thickness (FAT). In addition, HCW expressed as a percent of FW was calculated (DRESS). One lamb on the ALFA diet, heavyweight block died of urinary calculi on the last day of the trial, therefore carcass data averages were based on 1 less lamb for that pen.

Table 17. Diet composition (DM basis) – performance trials 1, 2 and 3

	Diet		
	ALFA[1]	50/50[2]	CONC[3]
Ingredient		% DM	
Alfalfa	100.0	63.0	25.0
Corn	0.0	25.5	51.6
Soybean meal	0.0	5.8	11.8
Molasses	0.0	3.5	7.0
Supplement[a]	0.0	2.3	4.6

[a] Supplement includes: soy hulls, binder, limestone, salt, Ammonium chloride, dical, vitamin premix and lasalocid sodium

[1]ALFA – Pelleted, 100% dehydrated alfalfa

[2]50/50 – 1:1 mixture of ALFA and CONC, Not used in performance trial 1

[3]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 18. Diet chemical composition (DM basis), performance - trials 1 and 2

	Diet		
Ingredient	ALFA[1]	50/50[2]	CONC[3]
DM, %	95.0	94.0	93.0
CP, %	13.5	14.2	14.8
TDN, %	57.0	62.9	68.8
ME, kcal/g[a]	2.04	2.20	2.36
Calcium, %[a]	1.37	1.11	0.85
Phosphorus ,%[a]	0.24	0.27	0.30

[a]Tabular values (NRC, 1985)

[1]ALFA – Pelleted, 100% dehydrated alfalfa

[2]50/50 – 1:1 mixture of ALFA and CONC, Not used in performance trial 1

[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Performance Trial 2

The objective of performance trial 2 was to determine performance and carcass characteristics when lambs were fed diets containing 62.5% forage at ad libitum or 85% of ad libitum levels of intake. In trial 2, 42 crossbred (Suffolk x Dorset x Rambouillet) wether lambs (30.9 kg) were housed in 4 pens (4.3 x 18.3 m), blocked by weight (11 lambs / pen, lightweight pens and 10 lambs / pen, heavyweight pens) and randomly assigned to 2 dietary treatments. Dietary treatments consisted of a 1:1 mixture of CONC and ALFA pellets, which contained 62.5% forage (50/50) fed at A or R intakes. Ingredient and chemical composition of the diets is shown in Tables 17 and 18. Lambs were fed twice daily at 0700 and 1500 and orts were measured once daily prior to the 0700 feeding. The R intakes were adjusted weekly as determined by the previous weeks' consumption by lambs fed at A levels of intake. Water and trace mineralized salt were available to all lambs throughout the trial. Diets were sampled every 14d for compositional analysis. Compositional analyses followed the same procedures as defined in performance trial 1. Lamb weights were measured and recorded every 7d. Lambs were removed from the study when each pen attained an average FW of 63.6 kg Lambs were on feed for 96d. Lambs were commercially processed at Wolverine Packing Inc. Marketing procedures and carcass data collection were the same as in performance trial 1.

Performance Trial 3

The objective of performance trial 3 was to determine performance and carcass characteristics when lambs were fed diets containing 25, 62.5 or 100% forage at ad libitum levels of intake. In performance trial 3, 42 crossbred (Suffolk x Dorset x Rambouillet) ewe and wether lambs (33.0 kg) were housed in 6 pens (2.5 x 2.5 m), blocked by weight (7 lambs / pen) and randomly assigned to 3 dietary treatments: ALFA, CONC and 50/50 (25, 100 and 62.5% forage, respectively). Ingredient and chemical composition of the diets is shown in Tables 17 and 19. Lambs were fed twice daily at 0700 and 1500 and orts were measured once daily prior to the 0700 feeding. Diets were sampled every 14d for compositional analysis. Compositional analyses followed the same procedures as defined in performance trial 1. Lamb weights were measured and recorded every 14d. Lambs were removed from the study when each pen attained an average FW of 56.0 kg. Lambs were on feed for 70 to 84d depending on dietary treatment. Lambs were commercially processed at Wolverine Packing Inc. Marketing procedures and carcass data collection were the same as in performance trial 1.

Table 19. Diet chemical composition (DM basis), performance – trial 3

	Diet		
Ingredient	ALFA[1]	50/50[2]	CONC[3]
DM, %	91.5	90.4	89.4
CP, %	17.6	16.4	15.2
TDN, %	57.0	62.9	68.8
ME, kcal/g[a]	2.04	2.20	2.36
Calcium, %[a]	1.37	1.11	0.85
Phosphorus ,%[a]	0.24	0.27	0.30

[a]Tabular values (NRC, 1985)

[1]ALFA – Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

A feed cost analysis was conducted using dietary ingredients valued at average feed costs as shown in Table 20. These feed costs were then divided by the average feed : gain ratio to determine the average cost of gain for an individual lamb on each dietary treatment.

Data from the three performance trials were analyzed using GLM procedures of SAS® (1989). ANOVA tables are shown in Appendices B - D. To identify differences in feed intake, the model included dietary treatment as a class variable and pen intake and daily lamb intake as the dependent variables. To determine differences in performance and carcass characteristics, the model included weight (block) and dietary treatment as class variables with HCW, LEA, FAT, initial weight, FW, ADG and DRESS as dependent variables. Where significant ($P < .05$) weight x treatment interactions were found, weight x treatment was used as a class variable.

Table 20. Feed costs of dietary ingredients

	Diet composition			Diet cost		
	ALFA[1]	50/50[2]	CONC[3]	ALFA[1]	50/50[2]	CONC[3]
Ingredient	%			$/kg		
Alfalfa meal	100.0	62.5	25.0	0.165	0.103	0.041
Corn	0.0	32.5	65.0		0.043	0.085
Soybean meal	0.0	5.0	10.0		0.017	0.035
Pelleting cost				0.022	0.022	0.022
Total	100.0	100.0	100.0	0.187	0.185	0.183

[1]ALFA - Pelleted, 100% dehydrated alfalfa
[2]50/50 - 1:1 mixture of ALFA and CONC
[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

CHAPTER 3

Results and Discussion

Diet Digestibility

A digestibility trial was conducted to determine nutrient digestibility and utilization by lambs fed diets ranging from 25 to 100% forage fed at ad libitum levels of intake. Data from one lightweight lamb fed ALFA was removed from the analyses due to errors in sample collection. All diets were pelleted and met or exceeded the nutrient requirements of 40 - 50 kg lambs to support weight gains of 300 to 345 g/d according to NRC (1985) (Table 21). The ALFA diet contained 100% alfalfa and the CP content of the diet fed to lightweight lambs was 16.9% and 18.3% CP fed to the heavyweight lambs.

Table 21. Daily nutrient requirements for 40 and 50 kg lambs gaining 345 and 300 g/d[a]

Weight	ADG, g/d	DMI, g/d	DE, kcal/d	ME, kcal/d	CP, g/d
40 kg	345	1,500	5,100	4,200	202
50 kg	300	1,500	5,100	4,200	181

[a]NRC, 1985

This range in CP is typical when purchasing large quantities of alfalfa pellets from a commercial feed mill. The CONC diet contained 25% alfalfa, 52% corn and 12% soybean meal with molasses and supplement making up the balance of the diet. The CP content of the CONC diet fed to the lightweight lambs was 14.8% and 15.6% when fed to the heavyweight lambs. This diet is a typical corn-soybean meal diet used commercially to produce market lambs.

The 50/50 diet was a 1:1 mixture by weight, of the ALFA and CONC diets. The ME values were calculated from NRC (1985) values and as expected the ME value for the CONC diet (2.36 kcal/g) was higher than the ALFA diet (2.04 kcal/g). Fiber content of the diets decreased as level of concentrate in the diets increased as shown with NDF, ADF and ADL values (Tables 15 and 16). ALFA values of NDF (43.2 and 46.5) and ADF (32.0 and 29.2) are representative of book values for 17% CP dehydrated alfalfa (SID Sheep Production Handbook, 1992).

Lambs weights at the beginning of the digestion trial replicates were 40.1 kg and 45.6 kg for the lightweight and heavyweight blocks, respectively (Tables 22 and 23). Average ad libitum intakes by lambs immediately prior to the adaptation period in the metabolism stalls were 1,307, 1,727 and 1,380 g/d for the lightweight lambs consuming ALFA, 50/50 and CONC diets, respectively (Table 22). This is equivalent to 3.3, 4.3 and 3.4% of BW, respectively. Average ad libitum intakes were 2,434, 2,233 and 1,576 g/d for heavyweight lambs consuming ALFA, 50/50 and CONC, respectively (Table 23). This is equivalent to 5.3, 4.9 and 3.5 % BW, respectively. The corresponding intakes of light- and heavyweight lambs during the digestion study (90% of ad libitum) are shown in Tables 22 and 23, respectively. When feeding 31 kg lambs a 100% alfalfa pellet or an alfalfa pellet that contained 30% barley, Weir et al. (1959) found that lambs consumed the diets at 5.5 and 4.8% of BW, respectively. Other studies (Cate et al., 1955 and Meyer et al., 1959) have also shown that lambs consumed pelleted alfalfa diets at 4.3% BW when diets were offered at ad libitum levels of intake.

Table 22. Feed intake prior to and during the digestibility trial – lightweight lambs

	Diet		
	ALFA[1]	50/50[2]	CONC[3]
N	3	4	4
Initial weight, kg	38.8	40.9	40.6
Intake:			
ad libitum, g/d	1,307	1,727	1,380
90% ad libitum, g/d	1,176	1,554	1,242

[1]ALFA - Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 23. Feed intake prior to and during the digestibility trial – heavyweight lambs

	Diet		
	ALFA[1]	50/50[2]	CONC[3]
N	4	4	4
Initial weight, kg	42.9	46.5	47.5
Intake:			
ad libitum, g/d	2,434	2,233	1,576
90% ad libitum, g/d	2,191	2,010	1,418

[1]ALFA - Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Among the lightweight lambs, DMI was highest ($P < .01$) for lambs consuming the 50/50 diet (1,554 g/d) compared to ALFA (1,176 g/d) and CONC (1,242 g/d) (Table 24). Although DMI of lambs consuming ALFA and CONC were lower than 1,500 g/d suggested by NRC requirements, for lambs gaining 345 g/d (Table 20), lambs fed those diets still consumed amounts of CP (219 and 206 g/d, respectively) to meet or exceed those requirements based on diet compositional analysis (Table 25). Results of the performance trials (discussed in a later section) indicated that these lambs had moderate growth potential according to NRC (1985) requirements (345 g/d).

Based on DMI requirements (NRC, 1985), lambs fed ALFA and CONC consumed enough feed to support 270 and 285 g/d gain, respectively. The ME intakes, using DE * .82 (NRC, 1985) were 2,350, 3,351 and 3,318 kcal/d for ALFA, 50/50 and CONC, respectively. All lambs had ME intakes lower than the 4,200 kcal/d suggested by NRC (1985). Lambs fed ALFA excreted 480 g/d of fecal DM, the 50/50 lambs excreted 575 g/d and lowest ($P < .01$) fecal DM excretion was seen with CONC fed lambs (281 g/d). Digestibilities of DM, OM, NDF and ADF fractions of the diets are presented in Table 24. Apparent DM digestibilities (DMD) ranged from 59.4% to 77.0% for ALFA to CONC fed lambs, respectively and increased as level of alfalfa in the diet decreased. A similar response was seen with organic matter (OM) where apparent OM digestibility (OMD) ranged from 61.1% to 79.0%. These data agree with Kromann et al. (1975), Lambert et al. (1987) and Reynolds et al. (1991) who reported increased DMD and OMD with increased proportions of concentrate in the diet, which was attributed to increased digestibility of cell solubles with added concentrate. Lightweight lambs consuming ALFA diets consumed 547 g of NDF/d (Table 25) with an apparent NDF digestibility of 43.3% (Table 24). Lambs consuming the CONC diet had a higher ($P < .01$) apparent NDF digestibility (53.5%) while consuming approximately 1/2 as much NDF (323 g NDF/d). Acid detergent fiber digestibility was also higher ($P < .05$) for CONC fed lambs (44.3%) compared to 50/50 fed lambs (30.8%).

Table 24. Least square means for dry matter, organic matter, and fiber digestibilty - lightweight lambs*

Diet	n	DMI (g/d)	SEM	Fecal DM (g/d)	SEM	Apparent digestibility, % DMD[4]	SEM	OMD[5]	SEM	NDF	SEM	ADF	SEM
ALFA[1]	3	1,176[a]	90.8	480[a]	42.1	59.4[a]	2.1	61.1[a]	2.0	43.3[a]	3.4	40.3[a,b]	4.0
50/50[2]	4	1,554[b]	78.6	575[a]	36.5	63.0[a]	1.8	64.9[a]	1.7	37.8[a]	3.0	30.8[a]	3.5
CONC[3]	4	1,242[a]	78.6	281[b]	36.5	77.0[b]	1.8	79.0[b]	1.7	53.5[b]	3.0	44.3[b]	3.5

[a,b]Means within columns differ ($P < .05$)

* One ALFA fed lamb was removed from the study

[1]ALFA - Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

[4]DMD - Dry matter digestibility

[5]OMD - Organic matter digestibility

Table 25. Least square means for CP, ME, NDF and ADF intakes, lightweight lambs*

Diet	n	DMI (g/d)	CPI[1] (g/d)	MEI[2] (kcal/d)	NDFI[3] (g/d)	ADFI[4] (g/d)
ALFA[5]	3	1,176	219	2,350	547	377
50/50[6]	4	1,554	275	3,351	563	343
CONC[7]	4	1,242	206	3,318	323	151

*One ALFA fed lamb removed from the study

[1]CPI - Crude protein intake

[2]MEI - ME intake (NRC, 1985)

[3]NDFI - NDF intake

[4]ADFI - ADF intake

[5]ALFA - Pelleted, 100% dehydrated alfalfa diet

[6]50/50 - 1:1 mixture of ALFA and CONC

[7]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

In the heavyweight block (Table 26), lambs consuming the ALFA and 50/50 diets had higher ($P < .0001$) DMI (2,191 and 2,010 g/d, respectively) than lambs consuming the CONC diet (1,418 g/d). Crude protein intakes were 438, 375 and 250 g/d for ALFA, 50/50 and CONC fed lambs, respectively (Table 27). Using DE * .82 to estimate ME intake only the 50/50 fed lambs (4,238 kcal/d) met the 4,200 kcal/d ME intake requirement (NRC, 1985) compared to ALFA (4,011 kcal/d) and CONC (3,641 kcal/d). Lambs fed the ALFA diet had the highest ($P < .0001$) fecal DM excretion (1,036 g/d) compared to lambs fed 50/50 (764 g/d) and CONC (335 g/d) diets. Digestibility of DM, OM, NDF and ADF fractions of the diets are presented in Table 26. As alfalfa content of the diet decreased, DMD increased ($P < .01$) from 52.7% to 62.0% to 76.4% for ALFA, 50/50 and CONC diets, respectively. Lambs consuming ALFA diets consumed 947 g of NDF/d with an apparent NDF digestibility of 26.7% (Table 27). Lambs consuming the CONC diet had a higher ($P < .001$) apparent NDF digestibility (44.1%) while consuming approximately 1/3 as much NDF (331 g NDF/d). Apparent ADF digestibility by lambs on the all forage ALFA diet (20.7%) was also lower ($P < .01$) than by lambs on the CONC diet (39.0%).

Table 26. Least square means for dry matter, organic matter, and fiber digestibilty - heavyweight lambs

						Apparent digestibility, %							
Diet	n	DMI (g/d)	SEM	Fecal DM (g/d)	SEM	DMD[4]	SEM	OMD[5]	SEM	NDF	SEM	ADF	SEM
ALFA[1]	4	2,191[a]	78.6	1,036[a]	36.5	52.7[a]	1.8	55.8[a]	1.7	26.1[a]	3.0	20.7[a]	3.5
50/50[2]	4	2,010[a]	78.6	764[b]	36.5	62.0[b]	1.8	63.5[b]	1.7	27.2[a]	3.0	19.2[a]	3.5
CONC[3]	4	1,418[b]	78.6	335[c]	36.5	76.4[c]	1.8	77.0[c]	1.7	44.1[b]	3.0	39.0[b]	3.5

[a,b,c]Means within columns differ ($P < .05$)

[1]ALFA - Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

[4]DMD - Dry matter digestibility

[5]OMD - Organic matter digestibility

Table 27. Least square means for CP, ME, NDF and ADF intakes, heavyweight lambs

Diet	n	DMI (g/d)	CPI[1] (g/d)	MEI[2] (kcal/d)	NDFI[3] (g/d)	ADFI[4] (g/d)
ALFA[5]	4	2,191	438	4,011	947	640
50/50[6]	4	2,010	375	4,238	669	410
CONC[7]	4	1,418	250	3,641	331	164

[1]CPI - Crude protein intake

[2]MEI - ME intake (NRC, 1985)

[3]NDFI - NDF intake

[4]ADFI - ADF intake

[5]ALFA - Pelleted, 100% dehydrated alfalfa diet

[6]50/50 - 1:1 mixture of ALFA and CONC

[7]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Regardless of weight, apparent DMD and OMD increased as the level of alfalfa in the diet decreased from 100% to 25%. With the lightweight lambs, the lowered DMD seen with ALFA fed lambs compared to CONC may be attributed to more highly digestible feed components in the CONC diet as similar intakes were attained on both diets. Intakes by heavyweight lambs however, were higher ($P < .05$) on ALFA fed lambs than on CONC and therefore it is reasonable to expect the rate of passage may also play a role in limiting DMD of these high forage fed lambs. These results agree with data from Reynolds et al. (1991) who found that DM, OM, NDF and ADF digestibilities decreased as level of alfalfa in the diet increased.

Lightweight lambs consuming ALFA diets consumed 1,176 g DM/d (2.9% BW) and had DMD of 59%, whereas heavyweight lambs consumed 2,190 g DM/d (4.8% BW) and had DMD of 52%. These results suggest that DMI may explain differences in DMD by lambs consuming the ALFA diet. A similar study by Lambert et al. (1987) found that 40 kg lambs fed rape supplemented, orchardgrass hay had increased DMD (65 to 73%) as the proportion of rape supplemented in the diet was increased from 40 to 70% when consuming feed at 3.5% BW. The work by Lambert et al. (1987) suggests that DMD may also be attributed to differences in concentrate level of the diet.

Nitrogen Balance

Nitrogen balance data are shown in Tables 28 and 29. Lightweight lambs fed the 50/50 diet had the highest ($P < .05$) N intake (44 g/d) compared to lambs fed ALFA and CONC at 35 and 33 g/d, respectively. These intakes meet the CP requirements of 202 g/d for a 40 kg lamb gaining 345 g/d, which is equivalent to 32 g N/d (NRC, 1985). Nitrogen digestibilities (g/d) did not differ among dietary treatments, and ranged from 25 g/d for

ALFA and CONC diets to 30 g/d for 50/50 diets. When expressed as a percent of N intake, digestibility of the 50/50 diet (67.6%) was lower ($P < .05$) than the CONC lambs (74.4%) and was a result of a 37.3% greater ($P < .05$) fecal N excretion by the 50/50 lambs. Lambs fed ALFA diets had similar N digestibilities to lambs fed the other two diets (72.4%) when expressed as a percent of N intake. Lambs retained an average of 7 g of N/d regardless of dietary treatment. Nitrogen retention, when expressed as a percent of N intake or N digestibility did not differ among dietary treatments. Although lambs consuming the 50/50 diet had the highest ($P< .05$) DM intakes, increased fecal and urinary excretions resulted in lower N digestibilities and similar N retentions to lambs consuming the CONC diet. For the lightweight lambs, forage content of the diet had little effect on N digestibility or N retention. This was probably a result of all diets meeting or exceeding the N requirements of the lambs and therefore N was not a limiting factor in nutrient utilization by these lambs.

The high CP content of the alfalfa pellets combined with high dietary feed intake, resulted in the heavyweight ALFA fed lambs having the highest ($P < .05$) N intake (70 g/d) followed by 50/50 (60 g/d) and CONC (40 g/d). Digested N (g/d) was also highest ($P < .01$) for lambs fed the ALFA diet (50 g/d) followed by 50/50 (41 g/d) and CONC (30 g/d). However, when expressed as a percent of N intake, N digestibilities did not differ among dietary treatments. This differs from data of Susin et al. (1995) who found that as concentrate level in the diet increased from 20 to 90%, N intake decreased from 53 g/d to 48 g/d and N digestibility (% of N intake) increased from 61 to 78%, respectively when lambs were fed to a similar level of gain. Retained N was higher ($P < .05$) in lambs fed the ALFA diet (17 g/d) compared to lambs fed the CONC diet (9 g/d) and as with N digestibility when expressed as a percent of N digested or percent of N intake, there were no differences in N retention among dietary treatments. The differences in N digestibility and retention appear to be related to increased N intake rather than any change in efficiency of N utilization.

These results differ from other studies, which have shown N retention to increase for animals fed high concentrate diets (Susin et al., 1995). Susin et al. (1995) showed that lambs consuming 80% (16.2% CP) or 10% (22.8% CP) forage diets retained 18% and 27% N as a percent of N intake. Even though the other studies showed decreases in fecal and urinary N losses as forage content of the diet decreased, the changes in N retention were attributed to differences in dietary CP levels rather than any N digestibility differences.

Table 28. Least square means for nitrogen balance - lightweight lambs*

										Nitrogen digestibility				Nitrogen retention					
Diet	n	DMI (g/d)	SEM	NI[1] (g/d)	SEM	Fecal N (g/d)	SEM	Urinary N (g/d)	SEM	g/d	SEM	% I	SEM	g/d	SEM	% I	SEM	% dig	SEM
ALFA[2]	3	1,176[a]	90.8	35[a]	2.6	10[a]	1.3	20[a,b]	1.6	25	2.3	72.4[a,b]	2.4	5	2.5	14.1	5.4	19.5	6.5
50/50[3]	4	1,554[b]	78.6	44[b]	2.2	14[b]	1.1	22[a]	1.4	30	1.9	67.6[a]	2.1	8	2.2	17.6	4.7	25.0	5.7
CONC[4]	4	1,242[a]	78.6	33[a]	2.2	8[a]	1.1	17[b]	1.4	25	1.9	74.4[b]	2.1	8	2.2	23.3	4.7	30.2	5.7

[a,b]Means within columns differ ($P < .05$)

* One ALFA fed lamb was removed from the study

[1]NI - Nitrogen intake

[2]ALFA - Pelleted, 100% dehydrated alfalfa

[3]50/50 - 1:1 mixture of ALFA and CONC

[4]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 29. Least square means for nitrogen balance - heavyweight lambs

										Nitrogen digestibility				Nitrogen retention					
Diet	n	DMI (g/d)	SEM	NI[1] (g/d)	SEM	Fecal N (g/d)	SEM	Urinary N (g/d)	SEM	g/d	SEM	% I	SEM	g/d	SEM	% I	SEM	% dig	SEM
ALFA[2]	4	2,191[a]	78.6	70[a]	2.2	20[a]	1.1	33[a]	1.4	50[a]	1.9	70.6	2.1	17[a]	2.2	22.9	4.7	32.5	5.7
50/50[3]	4	2,010[a]	78.6	60[b]	2.2	19[a]	1.1	27[b]	1.4	41[b]	1.9	69.0	2.1	14[a,b]	2.2	23.6	4.7	34.1	5.7
CONC[4]	4	1,418[b]	78.6	40[c]	2.2	10[b]	1.1	21[c]	1.4	30[c]	1.9	74.2	2.1	9[b]	2.2	21.0	4.7	28.3	5.7

[a,b]Means within columns differ ($P < .05$)

[1]NI - Nitrogen intake

[2]ALFA - Pelleted, 100% dehydrated alfalfa

[3]50/50 - 1:1 mixture of ALFA and CONC

[4]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Energy Balance

Energy balance data are shown in Tables 30 and 31. According to NRC (1985), 40 - 50 kg early-weaned lambs require 5,100 kcal/d DE and 4,200 kcal/d ME to attain 300 to 350 g/d weight gain. Gross energy content of the diets in this trial, fed to lightweight lambs ranged from 4.09 kcal/g for ALFA to 4.22 kcal/g for CONC diets (Table 15). Gross energy content of the diets fed to heavyweight lambs ranged from 4.20 kcal/g for ALFA to 4.14 kcal/g for CONC diets (Table 16). Based on these dietary compositions and feed intakes, among lightweight lambs, GE intakes were lower ($P < .05$) for lambs fed ALFA (4,815 kcal/d) and CONC (5,244 kcal/d) diets compared to lambs fed the 50/50 (6,460 kcal/d) diet when consuming 1,176 and 1,242 g DM/d, compared to 1,554 g DM/d, respectively. With similar GE densities of the diets, this increase in GE intake is the result of higher ($P < .01$) DMI of lambs fed the 50/50 diet. After accounting for fecal energy losses, DE intakes were greater ($P < .01$) for lambs fed CONC (4,046 kcal/d) and the 50/50 (4,087 kcal/d) diets compared to 2866 kcal/d for lambs fed ALFA. Lambs consuming the CONC diet had 45% lower fecal energy losses, compared to lambs consuming ALFA or 50/50 diets. These DE intakes were less than the 5,100 kcal/d requirement to support the desired gains. In the digestion study, lambs were restricted in feed intake to 90% of ad libitum levels, but even accounting for this would not bring DE intakes up to the recommended levels.

The effects of dietary forage content on energy balance in heavyweight lambs is shown in Table 31. Heavyweight lambs fed ALFA (9,193 kcal/d) and 50/50 (8,379 kcal/d) diets had higher ($P < .0001$) GE intakes compared to CONC fed lambs (5,871 kcal/d).

Table 30. Least square means for energy balance - lightweight lambs*

Diet	n	DMI (g/d)	SEM	GEI[1] (kcal/d)	SEM	Fecal E (kcal/d)	SEM	DEI[2] (kcal/d)	SEM
ALFA[3]	3	1,176[a]	90.8	4,815[a]	379.5	1,949[a]	169.8	2,866[a]	310.5
50/50[4]	4	1,554[b]	78.6	6,460[b]	328.6	2,373[a]	147.1	4,087[b]	268.9
CONC[5]	4	1,242[a]	78.6	5,244[a]	328.6	1,198[b]	147.1	4,046[b]	268.9

[a,b]Means within columns differ (P < .05)

* One ALFA fed lamb was removed from the study

[1]GEI - Gross energy intake

[2]DEI - Digestible energy intake

[3]ALFA - Pelleted, 100% dehydrated alfalfa

[4]50/50 - 1:1 mixture of ALFA and CONC

[5]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 31. Least square means for energy balance - heavyweight lambs

Diet	n	DMI (g/d)	SEM	GEI[1] (kcal/d)	SEM	Fecal E (kcal/d)	SEM	DEI[2] (kcal/d)	SEM
ALFA[3]	4	2,191[a]	78.6	9,193[a]	328.6	4,302[a]	147.1	4,892	268.9
50/50[4]	4	2,010[a]	78.6	8,379[a]	328.6	3,211[b]	147.1	5,168	268.9
CONC[5]	4	1,418[b]	78.6	5,871[b]	328.6	1,431[c]	147.1	4,440	268.9

[a,b,c]Means within columns differ (P < .05)

[1]GEI - Gross energy intake

[2]DEI - Digestible energy intake

[3]ALFA - Pelleted, 100% dehydrated alfalfa

[4]50/50 - 1:1 mixture of ALFA and CONC

[5]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

The increase in GE intake on the 100% forage diet was due to a 33% increase ($P < .01$) in DMI for ALFA and 50/50 fed lambs compared to CONC fed lambs. There was, no difference in DE intakes (4,833 kcal/d) among dietary treatments due to the 62% increase in fecal energy losses for ALFA and 50/50 fed lambs, compared to CONC fed lambs.

Metabolizable energy determinations require the accounting of urinary and gaseous losses. For lightweight lambs, urinary energy losses (Table 32) were higher ($P < .05$) for lambs fed the 50/50 diet (294 kcal/d) compared to lambs fed the CONC diet (215 kcal/d). Methane was used to represent gaseous losses and estimated using two equations. The Wolin (1960) equation uses VFA concentrations in the rumen to estimate methane. Volatile fatty acid concentrations are shown in Appendix E. Using this method, lambs fed the ALFA diet were found to have 48% higher ($P < .0001$) methane production (599 kcal/d) than lambs consuming the 50/50 (322 kcal/d) or CONC (300 kcal/d) diets. This was expected since feeding high forage diets results in increased ruminal acetate ratios relative to propionate while high concentrate diets results in increased propionate concentrations and the equation associates greatest methane production with higher acetate and(or) butyrate concentrations relative to propionate concentrations. Using this method, ME intakes were lower ($P < .01$) for lambs consuming the ALFA diet (1,995 kcal/d) compared to 3,471 kcal/d and 3,530 kcal/d for 50/50 and CONC fed lambs, respectively (Table 32). Using another method to estimate methane based on DE intake (Johnson et al., 1991), methane production by lambs fed the ALFA diet (204 kcal/d) did not differ from the lambs fed the 50/50 diet (187 kcal/d), but was 25% higher ($P < .0001$) than for lambs consuming the CONC diet (153 kcal/d). Using these methane losses to calculate ME intake, ALFA lambs had lower ($P < .01$) ME intakes (2,390 kcal/d) than 50/50 lambs (3,606 kcal/d) and CONC lambs (3,678 kcal/d). Metabolizable energy can also be estimated by using the equation DE*0.82 (NRC 1985). Using this method, ALFA fed lambs again had lowest (P < .01) ME intakes (2,350 kcal/d) compared to 50/50 fed lambs (3,351 kcal/d) and CONC fed lambs (3318 kcal/d). The lower DE and ME intakes by ALFA fed lambs agrees with data from Kromann et al. (1975) who determined that as the proportion of alfalfa in the diet increased from 0 to 100% there was a decrease in both DE (5360 to 2160 kcal/d) and ME (4690 to 1920 kcal/d) intakes. Regardless of method of estimation, ME intake of lambs consuming ALFA was at least 30% lower than the other diets.

Fewer differences were found in ME intakes among dietary treatments for heavyweight lambs. Using the Wolin (1960) equation, ALFA fed lambs had higher (P < .0001) methane production (677 kcal/d), followed by 50/50 (387 kcal/d) and were lowest for lambs fed CONC (261 kcal/d) diets (Table 33). However, ME intake did not differ among dietary treatments and averaged 4,048 kcal/d. Using the Johnson equation (1991), no differences among diets were found in estimated methane losses or ME intakes, which averaged 209 kcal/d and 4,351 kcal/d, respectively. The average ME intake when calculated as a multiple of DE (NRC 1985) was 3,963 kcal/d, and did not differ among dietary treatments.

Since there was no differences in DMI between light and heavyweight lambs fed CONC, gross energy intake (kcal/d) did not increase when feeding heavy compared to lightweight lambs. Heavyweight lambs, fed ALFA and 50/50 diets, averaged a 36% increase (P < .0001) in GE intake but DE and ME intakes did not differ among dietary treatment. At lighter weights however, DE and ME intakes were increased (P < .05) by feeding CONC or 50/50 diets, compared to ALFA. Data from the lightweight lamb trial differ with data from Reynolds et al. (1991) who reported increased DE (90.8 to 86.6 MJ/d) in heifers fed 75% alfalfa compared to 75% concentrate diets.

Table 32. Least square means for fermentation balance and ME estimation - lightweight lambs*

Diet	n	Urinary E (kcal/d)	SEM	CH_4 Loss-W[1] (kcal/d)	SEM	MEI - W[2] (kcal/day)	SEM	CH_4 Loss-J[3] (kcal/d)	SEM	MEI - J[4] (kcal/d)	SEM	MEI - DE[5] (kcal/d)	SEM
ALFA[6]	3	273[a,b]	24.5	599[a]	39.5	1,995[a]	316.2	204[a]	14.0	2,390[a]	315.6	2,350[a]	254.6
50/50[7]	4	294[a]	21.3	322[b]	34.2	3,471[b]	273.8	187[a]	12.1	3,606[b]	273.3	3,351[b]	220.5
CONC[8]	4	215[b]	21.3	300[b]	34.2	3,530[b]	273.8	153[b]	12.1	3,678[b]	273.3	3,318[b]	220.5

[a,b]Means within columns differ ($P < .05$)

* One ALFA fed lamb was removed from the study

[1]CH_4 Loss-W - Estimate of methane losses based on Wolin (1960) equation

[2]MEI - W - Estimate of ME intake based on Wolin (1960) equation

[3]CH_4 Loss-J - Estimate of methane losses based on Johnson et al. (1991) equation

[4]MEI - J - Estimate of ME intake based on Johnson et al. (1991) equation

[5]MEI - Estimate based on DE * 0.82 (NRC, 1985)

[6]ALFA - Pelleted, 100% dehydrated alfalfa

[7]50/50 - 1:1 mixture of ALFA and CONC

[8]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 33. Least square means for fermentation balance and ME estimation - heavyweight lambs

Diet	n	Urinary E (kcal/d)	SEM	CH_4 Loss-W[1] (kcal/d)	SEM	MEI - W[2] (kcal/day)	SEM	CH_4 Loss-J[3] (kcal/d)	SEM	MEI - J[4] (kcal/d)	SEM	MEI - DE[5] (kcal/d)	SEM
ALFA[6]	4	451[a]	21.3	677[a]	34.2	3,763	273.8	139	12.1	4,301	273.3	4,011	220.5
50/50[7]	4	342[b]	21.3	387[b]	34.2	4,439	273.8	127	12.1	4,699	273.3	4,238	220.5
CONC[8]	4	238[c]	21.3	261[c]	34.2	3,941	273.8	150	12.1	4,052	273.3	3,641	220.5

[a,b,c]Means within columns differ ($P < .05$)

[1]CH_4 Loss-W - Estimate of methane losses based on Wolin (1960) equation

[2]MEI - W - Estimate of ME intake based on Wolin (1960) equation

[3]CH_4 Loss-J - Estimate of methane losses based on Johnson et al. (1991) equation

[4]MEI - J - Estimate of ME intake based on Johnson et al. (1991) equation

[5]MEI - Estimate based on DE * 0.82 (NRC, 1985)

[6]ALFA - Pelleted, 100% dehydrated alfalfa

[7]50/50 - 1:1 mixture of ALFA and CONC

[8]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

The calculated ME values of the diets were compared to NRC (1985) table values and are shown in Tables 34 and 35. These values were determined by dividing ME intake by DMI for lambs fed each diet. These values, for each diet were compared to NRC (1985) values for the same feedstuffs to determine if ME table values of the diets were similar to ME values of the diets consumed by the lambs. For lightweight lambs, the ME values of the diets were 1.70, 2.23 and 2.84 kcal/g when using ME intake estimated from the Wolin (1960) equation for ALFA, 50/50 and CONC diets, respectively. Using ME intake estimates from the Johnson et al. (1991) equation the ME values were 2.03, 2.32 and 2.96 kcal/g for ALFA, 50/50 and CONC diets, respectively. Using DE * 0.82 (NRC, 1985) the ME values were 2.00, 2.16 and 2.67 kcal/g for ALFA, 50/50 and CONC diets, respectively. For heavyweight lambs, ME values were 1.72, 2.21 and 2.78 kcal/g, using ME intake estimates from the Wolin (1960) equation for ALFA, 50/50 and CONC diets, respectively. Using ME estimates from the Johnson equation (1991) the ME values were 1.96, 2.34 and 2.86 kcal/g for ALFA, 50/50 and CONC diets, respectively. Using DE * 0.82 (NRC, 1985) the ME values were 1.83, 2.11 and 2.57 for ALFA, 50/50 and CONC diets, respectively. For light and heavyweight lambs these data indicate that the NRC (1985) table values may underestimate the ME value of the CONC diet.

Table 34. Estimation of the ME values of the diets - lightweight lambs

Diet	ME - W[1]	ME - J[2]	ME - DE[3]	NRC, (1985)[4]
		kcal/g		
ALFA[5]	1.70	2.03	2.00	2.04
50/50[6]	2.23	2.32	2.16	2.20
CONC[7]	2.84	2.96	2.67	2.36

[1]ME – W – Estimation of ME values of the diets using the Wolin (1960) equation

[2]ME - J – Estimation of ME values of the diets using the Johnson et al. (1991) equation

[3]ME – DE – Estimation of ME values of the diets using 0.82* DE (NRC, 1985)

[4]NRC, (1985) - Calculated ME from tabular values

[5]ALFA – Pelleted, 100% dehydrated alfalfa

[6]50/50 - 1:1 mixture of ALFA and CONC

[7]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

Table 35. Estimation of the ME values of the diets – heavyweight lambs

Diet	ME - W[1]	ME - J[2]	ME - DE[3]	NRC, (1985)[4]
		kcal/g		
ALFA[5]	1.72	1.96	1.83	2.04
50/50[6]	2.21	2.34	2.11	2.20
CONC[7]	2.78	2.86	2.57	2.36

[1]ME – W - Estimation of ME values of the diets using the Wolin (1960) equation

[2]ME - J – Estimation of ME values of the diets using the Johnson et al. (1991) equation

[3]ME – DE - Estimation of ME values of the diets using 0.82* DE (NRC, 1985)

[4]NRC, (1985) - Calculated ME from tabular values

[5]ALFA – Pelleted, 100% dehydrated alfalfa

[6]50/50 - 1:1 mixture of ALFA and CONC

[7]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

These results suggest that the diets are used with similar efficiencies of energy utilization by both lightweight and heavyweight lambs. This is indicated by similar ME values of the diets for both weight classes within a given method of estimation. It would also appear that using the Wolin (1960) equation for estimating methane losses, tends to underestimate the ME value of the diets compared to other methods. Using the Johnson et al. (1991) equation for estimating methane losses, ME values of the diets were similar to NRC estimates for the ALFA and 50/50 and also closely associated with NRC estimates for the CONC diet. This is not unexpected as the Johnson et al. (1991) equation used to determine methane loss was derived from high forage diets and less appropriate for use with high concentrate diets.

Feedlot Performance and Carcass Characteristics

The purpose of a performance trial is to gain applied data based on the information obtained in digestibility trials. Performance trials are beneficial, since they provide information on how a group of animals respond to a given feedstuff or level of feeding. Producers want data that shows improved performance at a reduced cost. Traditionally, producers feed their livestock a concentrate-based diet. Some studies have shown that increasing the level of forage in a finishing diet will reduce carcass fat (Kromann et al., 1975 and Thomas et al., 1984). These authors also reported increased feed intakes on the high forage diets. Others have also reported decreased DP lambs fed high forage diets due to increased gut fill (Thomas et al., 1984). In some studies feeding forage diets with concentrate supplementation, lambs had similar or greater performance than lambs fed high concentrate diets due to increased feed intake (Cate et al., 1955, Meyer et al., 1959 and Weir et al., 1959). How these factors effect the producer's cost of gain is the true measure of how successful a feeding strategy will be.

Performance Trial 1

The objective of performance trial 1 was to determine the effects on performance and carcass characteristics of lambs fed ALFA or CONC diets (100 or 25% forage) at A or R levels of intake (Table 36). Lambs fed the ALFA diet consumed 22% more ($P < .01$) feed (2.48 kg/d) than lambs fed the CONC diet (1.84 kg/d) at A intakes. By design lambs fed at A levels of intake consumed 15% more feed than lambs fed at R levels of intake. Average daily gains were higher ($P < .01$) for lambs consuming ALFA (.35 kg/d) and CONC (.36 kg/d) at A intakes compared to lambs consuming the same diets at R intakes (.30 and .31 kg/d, respectively). Intake level had no significant effect on gain to feed (G:F) ratios (.20 vs. .15) for lambs fed the CONC diet compared to lambs fed the other diet. After 63 days on feed, FW were higher ($P < .01$) for lambs fed at A intakes (54.3 kg) compared to 50.3 kg for lambs fed at R intakes. Lambs fed at A levels of intake out-performed lambs fed at R levels of intake. However, lambs fed ALFA diets at A or R levels of intake had similar ADG when compared to their CONC fed counterparts. These results agree with data from Weir et al. (1959) who found that lambs consuming alfalfa pellets or alfalfa pellets plus 30% barley had similar ADG (.18 and .16 kg/d, respectively) and lambs fed alfalfa pellets consumed 14% more feed/d. Although feeding at R levels of intake reduced feed intake by 15%, the practicality of implementing this in a large-scale feedlot is low due to an increased labor cost. Carcass weights were heavier ($P < .01$) for lambs fed CONC at A intakes (26.2 kg) followed by CONC at R intakes (24.4 kg) and ALFA at A intakes (23.2 kg) and were lowest ($P < .0005$) for lambs fed ALFA at R intakes. CONC lambs at A intakes had more ($P < .05$) FAT (.47 cm) than did lambs on the other dietary treatments. Lambs fed ALFA at A intakes and CONC at R intakes had similar FAT (.31 and .37 cm, respectively). Lambs fed ALFA at R intakes had the least ($P < .05$) FAT (.21

cm). Lambs fed ALFA at R intakes also had the smallest ($P < .01$) LEA (13.1 cm^2) compared to the other dietary treatments (15.6 cm^2). The differences in FAT and LEA would account for the differences in carcass weight. DRESS values were determined by dividing HCW by the off test weight. This calculation is not intended to reflect standard DP used by the industry, where the live weight would be determined immediately prior to slaughter. DRESS values were higher ($P < .0001$) for lambs fed CONC at A and R intakes (48.1%) compared to lambs fed ALFA at A and R intakes (42.1%). A contributing factor to the differences in DRESS values was the difference in FAT. However, the differences in DRESS values were primarily attributed to an increase in gut fill in lambs on the ALFA diets.

Table 36. Least square means for lamb feed intakes, ADG and feed conversions (G:F) HCW, LEA, FAT and DRESS values – performance trial 1

	Diet				
	ALFA[2]	ALFA[2]	CONC[3]	CONC[3]	SEM[*]
Intake level[1]	A	R	A	R	
Lambs	19	20	20	20	
Pens/trt	2	2	2	2	
Initial wt., kg	31.9	31.2	31.6	31.2	0.57 (0.60)
Final wt., kg	53.9[a]	49.9[b]	54.2[a]	50.8[b]	0.93 (0.99)
Days on feed	63	63	63	63	
Lamb intake, kg/d	2.48[a]	2.00[a,b]	1.84[b]	1.56[b]	0.15 (0.15)
ADG, kg/d	0.35[a]	0.30[b]	0.36[a]	0.31[b]	0.02 (0.02)
G:F	0.14	0.15	0.20	0.20	
HCW[4], kg	23.0[b]	20.7[a]	26.2[c]	24.4[b,c]	0.47 (0.50)
LEA[5], cm^2	15.1[a]	13.1[b]	16.0[a]	15.5[a]	0.55 (0.58)
FAT[6], cm	0.30[a,b]	0.21[a]	0.47[c]	0.37[b]	0.03 (0.04)
DRESS[7], %	42.5[a]	41.6[a]	48.3[b]	48.0[b]	0.004 (0.005)

[a, b]Means within rows differ (P<.05)

[*]SEM where n = 20, where n = 19 SEM value in ( )

[1]Intake level - A = ad libitum, R = 85% of ad libitum

[2]ALFA – Pelleted, 100% dehydrated alfalfa

[3]CONC – Pelleted, 75% concentrate: 25% dehydrated alfalfa

[4]HCW – Hot carcass weight

[5]LEA – Loineye area

[6]FAT – 12[th] rib fat

[7]DRESS – HCW as a percent of off test weight

Performance Trial 2

The objective of performance trial 2 was to determine the effects on performance and carcass characteristics of lambs fed 50/50 diets (62.5% forage) at A or R levels of intake. In performance trial 2, 31 kg lambs were fed the 50/50 diet at A and R levels of intake for 96 days (Table 37). With level of intake adjusted weekly, rather than daily as in trial 1, lambs fed at the A level of intake consumed 11% more feed per day than lambs fed at the R intake level. Average daily gains were higher ($P < .05$) for lambs fed at A intakes compared to lambs fed at R intakes (.35 kg/d and .33 kg/d, respectively). This meant that lambs fed at the A level of intake gained 5.7% faster than lambs fed at the R level of intake. Although lambs consumed 11% more feed at A levels of intake, the 5.7% increase in gain may justify feeding at this level since it would result in less days on feed and the ease of feeding at A levels compared to feeding at R levels. Gain to feed ratios were similar (.15) for lambs fed at both levels of intake. After 96 days on feed, FW did not differ by intake level although after 96 days on feed ad libitum fed lambs weighed 2.4 kg more (64.7 and 62.3 kg) for A and R intakes, respectively. However lambs fed at A intakes had larger ($P < .001$) HCW (29.4 kg) compared to 27.1 kg for lambs fed at R intakes. As a result of increased carcass weights lambs fed at A intakes had greater ($P < .001$) DRESS values than lambs fed at R intakes (45.4 vs. 43.4%, respectively). This increase in HCW and DRESS was attributed to the increased ($P < .01$) FAT for lambs fed at A vs. R intakes (.63 vs. .43 cm, respectively). In a study by Kromann et al. (1975), lambs offered diets that contained 80% alfalfa and 20% corn at ad libitum levels of intake had a lower carcass fat percentage (25.1%) compared to lambs offered diets that contained 15% alfalfa and 85% corn at ad libitum levels of intake (34.1%).

Table 37. Least square means for lamb feed intake, ADG and feed conversions (G:F), HCW, FAT and Dress values - performance trial 2

	Diet		
	50/50[2]	50/50[2]	SEM
Intake level[1]	A	R	
Lambs	21	21	
Pens/trt	2	2	
Initial wt., kg	30.8	30.9	0.46
Final wt., kg	64.7	62.3	0.89
Days on feed	96	96	
Lamb intake, kg/d	2.40	2.14	0.06
ADG, kg/d	0.35[a]	0.33[b]	0.01
G:F	0.15	0.15	
HCW[3], kg	29.4[a]	27.1[b]	0.44
FAT[4], cm	0.62[a]	0.43[b]	0.04
DRESS[5], %	45.5[a]	43.5[b]	0.004

[a, b]Means within rows differ ($P<.05$)

[1]Intake level - A = ad libitum, R = 85% of ad libitum

[2]50/50 – 1:1 mixture of ALFA and CONC used in trial 1

[3]HCW – Hot carcass weight

[4]FAT – 12[th] rib fat

[5]DRESS – HCW as a percent of off test weight

Performance Trial 3

The objective of performance trial 3 was to determine the effects on performance and carcass characteristics of lambs fed ALFA, 50/50 or CONC diets (100, 62.5 or 25% forage) at A levels of intake. In performance trial 3, all lambs were fed until an average pen FW of 56.2 kg was reached (Tables 38). Lambs fed the ALFA diet consumed 30% more feed than lambs fed the CONC diet before attaining that FW, which required 7d longer on feed. Lambs fed 50/50 required fewer days on feed (70d) to attain FW. This was accomplished since 50/50 lambs had higher ADG (.35 kg/d) than lambs fed the ALFA and CONC diets (.30 kg/d and .28 kg/d, respectively). The ADG for lambs fed the CONC diet was lower than seen in the previous two trials and was lower than expected. The CONC diet was delivered in two separate batches from a commercial feed mill. On day 56 of the trial, lambs began consuming feed from the second batch. Due to an error at the mill, a dairy supplement was mixed with the lamb diet. The two pellets were similar in size and color and were fed to the lambs over a 3d period before feed intake began to fall drastically and the error was recognized. The high fat content of the dairy supplement was believed to have caused the lambs to go off feed. The feed intake and ADG of lambs on the CONC diet before and after the feeding of the tainted feed is shown in Table 39. After day 56, lambs consumed 18.6% less feed and gained .14 kg/d less than before day 56 of the trial. Lambs fed the CONC and 50/50 diets had greater gain to feed ratios (.16) than lambs fed the ALFA diet (.12). All lambs were taken to a similar FW (56.2 kg). Lambs fed the CONC and 50/50 diets had greater ($P < .001$) carcass weights (27.6 and 27.2 kg, respectively) compared to lambs fed the ALFA diet (25.2 kg). Lambs fed ALFA diets had less ($P < .05$) FAT (.43 cm) than lambs fed CONC (.56 cm). CONC fed lambs also had a higher (P <

.0001) DRESS value (51.1%) compared to ALFA fed lambs (44.1%). The decreased DRESS value was probably a result of increased gut fill and decreased FAT seen in ALFA fed lambs.

Table 38. Least square means for lamb feed intakes, ADG and feed conversions (G:F), HCW, LEA, FAT and DRESS values - performance trial 3

	Diet			
	ALFA[2]	50/50[3]	CONC[4]	SEM
Intake level[1]	A	A	A	
Lambs	14	14	14	
Pens/trt	2	2	2	
Initial wt., kg	32.0[a]	32.4[a]	33.4[b]	0.47
Final wt., kg	57.0	56.7	54.9	0.83
Days on feed	84	70	77	
Lamb intake, kg/d	2.43[a]	2.18[a,b]	1.71[b]	0.12
ADG, kg/d	0.30[a]	0.35[b]	0.28[a]	0.01
G:F	0.12	0.16	0.16	
HCW[4], kg	25.2[b]	27.2[a]	27.6[a]	0.7
LEA[5], cm^2	14.8[b]	16.7[a]	17.8[a]	0.88
FAT[6], cm	0.43[a]	0.52[a,b]	0.56[b]	0.05
DRESS[7], %	44.1[a]	48.0[b]	51.1[c]	0.007

[a,b]Means within rows differ (P<.05)

[1]Intake level - A = ad libitum

[2]ALFA - Pelleted, 100% dehydrated alfalfa

[3]50/50 - 1:1 mixture of ALFA and CONC

[4]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

[4]HCW – Hot carcass weight

[5]LEA – Loineye area

[6]FAT – 12[th] rib fat

[7]DRESS – HCW as a percent of off test weight

Table 39. ADG and feed intake before and after day 56

Day	ADG (kg/d)	Feed Intake (kg/d)
0 - 56	0.35	1.9
57 +	0.21	1.5

Although lambs fed the CONC diet had lower performance in this trial, due to the feed mixing error, the carcass data was similar to the other two trials. Also, the feed intake and performance by lambs consuming the ALFA and 50/50 diets was similar to the other two trials. In this trial, lambs consuming the 50/50 diet had the highest ADG probably due to increased feed conversion since they consumed 250 g/d less and gained 500 g/d more than ALFA fed lambs. Although ALFA fed lambs had .09cm less fat than 50/50 fed lambs they also had lighter carcasses and smaller DRESS values resulting in lower overall yields.

Economic Analysis

An economic analysis was conducted for each of the 3 performance trials (Table 40). An average feed cost was determined for each of the 3 pelleted diets, and was based on bulk delivery of 5,455 kg (6 tons). The price determined for ALFA ($0.187/kg) and CONC ($0.183/kg), and were averaged to obtain the 50/50 price ($0.185/kg).

In performance trial 1, lambs fed ALFA at A and R intakes had feed : gain ratios of 7.08 and 6.67, which resulted in $1.32 and $1.25/ kg gain, respectively. Lambs fed CONC at A and R intakes had more efficient feed : gain ratios (5.10 and 5.03, respectively), which resulted in decreased cost of gain ($0.93 and $0.92/ kg gain) for CONC lambs fed at A and R intakes compared to lambs fed ALFA at A and R intakes. Although lambs consuming ALFA at A intakes had similar ADG to lambs consuming CONC at A intakes and had 11% higher ADG than lambs consuming CONC at R intakes, the increased feed intake by ALFA fed lambs, resulted in a 29.2% increase in cost of gain, when compared to lambs fed CONC at A and R levels of intake. Implementing a management plan to feed diets at 85% of ad libitum levels would cause a significant increase in labor costs. This type of feeding system requires that lamb feeding level be monitored more precisely. However, the cost of gain versus ADG benefits combined with labor costs would be key in determining the most beneficial feeding strategy.

In performance trial 2, lambs fed the 50/50 diet at A intakes had a feed : gain ratio of 6.87 compared to 6.48 for lambs fed at R intakes. This resulted in a 5.5% increase in cost of gain for lambs fed at A vs. R intakes ($1.27 / kg vs. $1.20 / kg).

In performance trial 3, lambs fed ALFA had the highest feed : gain ratio (8.10) followed by lambs fed 50/50 (6.22) and CONC (6.10). Lambs fed ALFA also had 24.8% higher cost of gain ($1.51/ kg) compared to lambs fed 50/50 ($1.15/ kg) and CONC ($1.12/ kg).

Overall, feeding lambs at R intakes lowered cost of gain 5.4% for lambs fed ALFA and 50/50 and 1.1% for lambs fed CONC, however increased labor cost and management inputs associated with limit feeding lambs makes this method seem impractical in a large feedlot setting. Feeding the CONC diet resulted in the most economical gains compared to feeding ALFA or 50/50 diets. Based on the results of these three trials it was determined that the price of the ALFA diet must be $0.05/kg less than the CONC diet to obtain an equivalent cost of gain. This was calculated using the feed: gain ratios, diet costs and costs of gain from performance trials 1 and 2 for ALFA and CONC diets at A levels of intake. The average cost of gain for CONC was $1.01/kg gain, with a feed cost of $0.183 /kg and the average feed: gain ratio was 5.61. The average feed: gain ratio for ALFA lambs was 7.60. Setting the costs of gain equal ($1.01/kg gain), the ALFA diet would have to cost $0.133 /kg to meet this cost of gain.

Table 40. Economic analysis of feedlot lamb production - performance trials 1, 2 and 3

	Trial 1				Trial 2		Trial 3		
	Diet				Diet		Diet		
	ALFA[1]	ALFA[1]	CONC[3]	CONC[3]	50/50[2]	50/50[2]	ALFA[1]	50/50[2]	CONC[3]
Intake level[a]	A	R	A	R	A	R	A	A	A
Lambs	19	20	20	20	21	21	14	14	14
Pens/trt	2	2	2	2	2	2	2	2	2
ADG, kg/d	0.35	0.30	0.36	0.31	0.35	0.33	0.30	0.35	0.28
Lamb intake, kg/d	2.48	2.00	1.84	1.56	2.40	2.14	2.43	2.18	1.71
Feed:Gain	7.09	6.67	5.11	5.03	6.87	6.48	8.10	6.23	6.11
Feed Cost, $/kg	0.187	0.187	0.183	0.183	0.185	0.185	0.187	0.185	0.183
Cost of Gain, $/kg	1.33	1.25	0.94	0.92	1.27	1.20	1.51	1.15	1.12
Cost of Gain, $/lb	0.60	0.57	0.43	0.42	0.58	0.55	0.69	0.52	0.51

[1]ALFA - Pelleted, 100% dehydrated alfalfa

[2]50/50 - 1:1 mixture of ALFA and CONC

[3]CONC - Pelleted, 75% concentrate: 25% dehydrated alfalfa

[a]Intake level - A = ad libitum, R = 85% of ad libitum

Although costs of gain were increased in these trials where lambs were fed primarily pelleted alfalfa diets, there is still producer interest. An advantage to feeding lambs on alfalfa pellets is lamb health. Lambs are not likely to develop acidosis when consuming alfalfa pellets. Lambs fed ALFA diets yielded leaner carcasses than their CONC fed counterparts. However, increased feed consumption and increased fecal output are important factors to consider before implementing a feeding system based solely on alfalfa pellets. Feeding lambs the 50/50 diets resulted in lamb performance and carcass characteristics equal to or above that seen by lambs on the other dietary treatments. The 50/50 feeding strategy may be the most beneficial in terms of optimizing production, minimizing costs and decreasing potential health problems.

CHAPTER 4

SUMMARY

A digestibility trial and three performance trials were conducted to determine nutrient digestibility, lamb performance and carcass characteristics of lambs fed pelleted diets containing 25, 62.5 or 100% forage (CONC, 50/50 and ALFA, respectively). In the digestibility trial, apparent digestibility of DM, OM and NDF decreased as dietary forage level increased. At lighter weights, lambs fed ALFA and 50/50 had similar apparent digestibilities, which were lower than seen from CONC fed lambs. Lightweight lambs fed ALFA and CONC had similar N intakes, whereas heavyweight lambs showed an increase in N intake as dietary forage level increased. The percent of nitrogen retained was unaffected by dietary forage level. Using three methods to estimate ME, ME intake for lightweight lambs was lowest in lambs fed ALFA. In heavyweight lambs ME intake was unaffected by dietary forage level. The ME values of the diets increased as dietary forage level decreased. Using the Wolin (1960) equation seemed to underestimate methane losses, resulting in decreased ME intakes compared to ME intakes when using the other two methods of estimation.

In performance trial 1, lambs were fed either CONC or ALFA diets at ad libitum or 85% or ad libitum levels of intake. Lambs fed diets at ad libitum levels of intake had larger

FW and greater ADG. Lambs fed ALFA had lower G:F ratios, lighter HCW, less FAT and lower DRESS values.

In performance trial 2, lambs were fed the 50/50 diet at ad libitum or 85% of ad libitum levels of intake. Lambs fed at ad libitum levels of intake had greater ADG, heavier HCW, more FAT and higher DRESS values, but had similar G:F ratios compared to lambs fed at 85% of ad libitum levels of intake.

In performance trial 3, lambs were fed CONC, 50/50 or ALFA diets at ad libitum levels of intake. Lambs fed the 50/50 diet had greatest ADG. Lambs fed ALFA consumed the most feed and had the lowest G:F ratio. As dietary forage level increased FAT, HCW and DRESS values tended to decrease.

An economic analysis of the three performance trials indicated that cost of gain could be decreased by decreasing dietary forage level to 62.5 or 25% when compared to 100% forage. Cost of gain could also be decreased by feeding lambs at 85% of ad libitum levels of intake.

APPENDICIES

APPENDIX - A

ANOVA Tables - Digestibility Trial

Dependent Variable: DMI

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	3255073.370	651014.674	26.33	0.0001
Error	17	420279.500	24722.324		
Corrected Total	22	3675352.870			

R-Square	C.V.	Root MSE	DMI Mean
0.885649	9.725599	157.2333	1616.696

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	1712186.684	1712186.684	69.26	0.0001
TRT	2	894870.581	447435.291	18.10	0.0001
REP*TRT	2	665213.081	332606.541	13.45	0.0001

Dependent Variable: FECAL DM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1594917.928	318983.586	59.97	0.0001
Error	17	90431.255	5319.486		
Corrected Total	22	1685349.182			

R-Square	C.V.	Root MSE	FECDM Mean
0.946343	12.51183	72.93480	582.9270

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	401767.0723	401767.0723	75.53	0.0001
TRT	2	871813.7764	435906.8882	81.95	0.0001
REP*TRT	2	245283.5476	122641.7738	23.06	0.0001

Dependent Variable: DMD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1844.339595	368.867919	28.49	0.0001
Error	17	220.098892	12.946994		
Corrected Total	22	2064.438487			

R-Square	C.V.	Root MSE	DMDIG Mean
0.893386	5.508819	3.598193	65.31696

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	42.614232	42.614232	3.29	0.0873
TRT	2	1689.001646	844.500823	65.23	0.0001
REP*TRT	2	41.783203	20.891602	1.61	0.2282

Dependent Variable: OM INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2883335.174	576667.035	27.55	0.0001
Error	17	355800.260	20929.427		
Corrected Total	22	3239135.433			

R-Square	C.V.	Root MSE	FEEDASH Mean
0.890156	9.755501	144.6701	1482.959

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	1427762.217	1427762.217	68.22	0.0001
TRT	2	766315.226	383157.613	18.31	0.0001
REP*TRT	2	704578.250	352289.125	16.83	0.0001

APPENDIX - A

ANOVA Tables - Digestibility Trial (cont'd)

Dependent Variable: FECAL OM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1223570.941	244714.188	60.12	0.0001
Error	17	69199.305	4070.547		
Corrected Total	22	1292770.247			

R-Square	C.V.	Root MSE	FECASH Mean
0.946472	12.57923	63.80084	507.1919

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	318342.4283	318342.4283	78.21	0.0001
TRT	2	665580.0761	332790.0380	81.76	0.0001
REP*TRT	2	182805.7241	91402.8621	22.45	0.0001

Dependent Variable: OM DIGESTIBILITY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1647.991001	329.598200	28.86	0.0001
Error	17	194.161893	11.421288		
Corrected Total	22	1842.152894			

R-Square	C.V.	Root MSE	OMDIG Mean
0.894601	5.034628	3.379540	67.12590

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	48.172632	48.172632	4.22	0.0557
TRT	2	1528.712343	764.356171	66.92	0.0001
REP*TRT	2	16.106205	8.053102	0.71	0.5079

Dependent Variable: NDF DIGESTIBILITY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2219.026095	443.805219	12.50	0.0001
Error	17	603.660392	35.509435		
Corrected Total	22	2822.686487			

R-Square	C.V.	Root MSE	NDFDIG Mean
0.786140	15.48714	5.958979	38.47696

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	875.218527	875.218527	24.65	0.0001
TRT	2	1228.823801	614.411900	17.30	0.0001
REP*TRT	2	62.801108	31.400554	0.88	0.431

Dependent Variable: ADF DIGESTIBILITY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	2180.617695	436.123539	9.16	0.0002
Error	17	809.031592	47.590094		
Corrected Total	22	2989.649287			

R-Square	C.V.	Root MSE	ADFDIG Mean
0.729389	21.53575	6.898557	32.03304

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	846.307600	846.307600	17.78	0.0006
TRT	2	1142.433066	571.216533	12.00	0.0006
REP*TRT	2	190.256566	95.128283	2.00	0.1661

APPENDIX - A

ANOVA Tables - Digestibility Trial (cont'd)

Dependent Variable: FECAL N

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	497.3343500	99.4668700	20.54	0.0001
Error	17	82.3084500	4.8416735		
Corrected Total	22	579.6428000			

R-Square	C.V.	Root MSE	FECN Mean
0.858001	16.03776	2.200380	13.72000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	188.5884632	188.5884632	38.95	0.0001
TRT	2	233.0366331	116.5183166	24.07	0.0001
REP*TRT	2	70.7664981	35.3832491	7.31	0.0051

Dependent Variable: URINARY N

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	681.9478054	136.3895611	16.99	0.0001
Error	17	136.4451250	8.0261838		
Corrected Total	22	818.3929304			

R-Square	C.V.	Root MSE	URIN Mean
0.833277	12.05643	2.833052	23.49826

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	318.5300882	318.5300882	39.69	0.0001
TRT	2	257.1775000	128.5887500	16.02	0.0001
REP*TRT	2	75.3544000	37.6772000	4.69	0.0238

Dependent Variable: N INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	4183.236952	836.647390	41.71	0.0001
Error	17	341.017692	20.059864		
Corrected Total	22	4524.254643			

R-Square	C.V.	Root MSE	NINT Mean
0.924625	9.460450	4.478824	47.34261

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	2086.645011	2086.645011	104.02	0.0001
TRT	2	1311.614501	655.807250	32.69	0.0001
REP*TRT	2	706.517028	353.258514	17.61	0.0001

Dependent Variable: N DIGESTIBILITY (g/d)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	1854.248595	370.849719	24.52	0.0001
Error	17	257.076692	15.122158		
Corrected Total	22	2111.325287			

R-Square	C.V.	Root MSE	NDIG Mean
0.878239	11.56565	3.888722	33.62304

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	1020.191421	1020.191421	67.46	0.0001
TRT	2	459.391703	229.695852	15.19	0.0002
REP*TRT	2	331.461266	165.730633	10.96	0.0009

APPENDIX - A

ANOVA Tables - Digestibility Trial (cont'd)

Dependent Variable: N DIGESTIBILITY (% N INTAKE)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	160.8014703	32.1602941	1.91	0.1460
Error	17	286.6560167	16.8621186		
Corrected Total	22	447.4574870			

R-Square	C.V.	Root MSE	NDIGP Mean
0.359367	5.751437	4.106351	71.39696

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.4743860	0.4743860	0.03	0.8688
TRT	2	151.2207883	75.6103942	4.48	0.0273
REP*TRT	2	9.3649883	4.6824942	0.28	0.7609

Dependent Variable: N RETENTION (g/d)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	333.8025551	66.7605110	3.56	0.0219
Error	17	318.4355667	18.7315039		
Corrected Total	22	652.2381217			

R-Square	C.V.	Root MSE	NRET Mean
0.511780	42.75201	4.327991	10.12348

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	198.8000439	198.8000439	10.61	0.0046
TRT	2	33.9541165	16.9770582	0.91	0.4227
REP*TRT	2	106.9481165	53.4740582	2.85	0.0853

Dependent Variable: N RETENTION (% N DIGESTED)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	496.2434703	99.2486941	0.78	0.5790
Error	17	2168.6608167	127.5682833		
Corrected Total	22	2664.9042870			

R-Square	C.V.	Root MSE	NRETP Mean
0.186214	39.39941	11.29461	28.66696

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	258.6459018	258.6459018	2.03	0.1726
TRT	2	57.6913883	28.8456942	0.23	0.8000
REP*TRT	2	228.5911008	114.2955504	0.90	0.4266

Dependent Variable: N RETENTION (% N INTAKE)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	248.4748562	49.6949712	0.57	0.7241
Error	17	1489.7076917	87.6298642		
Corrected Total	22	1738.1825478			

R-Square	C.V.	Root MSE	NRETPI Mean
0.142951	45.23592	9.361082	20.69391

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	99.6470741	99.6470741	1.14	0.3012
TRT	2	48.7616915	24.3808457	0.28	0.7605
REP*TRT	2	125.5533415	62.7766707	0.72	0.5027

APPENDIX - A

ANOVA Tables - Digestibility Trial (cont'd)

Dependent Variable: GE INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	58237238.05	11647447.61	26.96	0.0001
Error	17	7344411.42	432024.20		
Corrected Total	22	65581649.46			

R-Square	C.V.	Root MSE	GEI Mean
0.888011	9.751082	657.2855	6740.641

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	30295369.40	30295369.40	70.12	0.0001
TRT	2	15145733.78	7572866.89	17.53	0.0001
REP*TRT	2	13240973.73	6620486.86	15.32	0.0002

Dependent Variable: FECAL ENERGY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	27230870.63	5446174.13	62.95	0.0001
Error	17	1470749.61	86514.68		
Corrected Total	22	28701620.25			

R-Square	C.V.	Root MSE	FECE Mean
0.948757	12.10061	294.1338	2430.735

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	7406252.02	7406252.02	85.61	0.0001
TRT	2	14253233.79	7126616.89	82.37	0.0001
REP*TRT	2	4329002.51	2164501.25	25.02	0.0001

Dependent Variable: DE INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11102852.31	2220570.46	7.68	0.0006
Error	17	4917029.18	289237.01		
Corrected Total	22	16019881.49			

R-Square	C.V.	Root MSE	DE Mean
0.693067	12.47841	537.8076	4309.906

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	7743307.771	7743307.771	26.77	0.0001
TRT	2	2078976.485	1039488.242	3.59	0.0499
REP*TRT	2	2462909.695	1231454.847	4.26	0.0317

Dependent Variable: URINARY ENERGY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	145181.4552	29036.2910	16.07	0.0001
Error	17	30710.3673	1806.4922		
Corrected Total	22	175891.8225			

R-Square	C.V.	Root MSE	URINE Mean
0.825402	14.00224	42.50285	303.5432

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	39383.89743	39383.89743	21.80	0.0002
TRT	2	72108.49315	36054.24657	19.96	0.0001
REP*TRT	2	25402.32593	12701.16297	7.03	0.0060

APPENDIX - A

ANOVA Tables - Digestibility Trial (cont'd)

Dependent Variable: METHANE ESTIMATION (WOLIN, 1960)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	561275.8950	112255.1790	23.95	0.0001
Error	17	79670.0770	4686.4751		
Corrected Total	22	640945.9721			

R-Square	C.V.	Root MSE	CH4W Mean
0.875699	16.42870	68.45783	416.6965

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	6901.7308	6901.7308	1.47	0.2415
TRT	2	514382.9512	257191.4756	54.88	0.0001
REP*TRT	2	15987.7725	7993.8862	1.71	0.2113

Dependent Variable: METHANE ESTIMATION (JOHNSON ET AL., 1991)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	15049.13370	3009.82674	5.11	0.0048
Error	17	10014.14377	589.06728		
Corrected Total	22	25063.27747			

R-Square	C.V.	Root MSE	CH4J Mean
0.600446	15.34959	24.27071	158.1196

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	10077.71011	10077.71011	17.11	0.0007
TRT	2	1529.27249	764.63625	1.30	0.2988
REP*TRT	2	4556.83020	2278.41510	3.87	0.0413

Dependent Variable: ME ESTIMATION (JOHNSON ET AL., 1991)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	10610972.70	2122194.54	7.10	0.0009
Error	17	5078654.85	298744.40		
Corrected Total	22	15689627.55			

R-Square	C.V.	Root MSE	MEJ Mean
0.676305	14.20324	546.5752	3848.244

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	7207152.420	7207152.420	24.12	0.0001
TRT	2	2443051.060	1221525.530	4.09	0.0355
REP*TRT	2	2179712.641	1089856.321	3.65	0.0489

Dependent Variable: ME ESTIMATE (WOLIN 1960)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	11204167.07	2240833.41	7.47	0.0007
Error	17	5098750.40	299926.49		
Corrected Total	22	16302917.46			

R-Square	C.V.	Root MSE	MEW Mean
0.687249	15.25644	547.6555	3589.667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	6255749.436	6255749.436	20.86	0.0003
TRT	2	4678535.671	2339267.835	7.80	0.0039
REP*TRT	2	1707130.427	853565.214	2.85	0.0859

APPENDIX - A

ANOVA Tables - Digestibility Trial (cont'd)

Dependent Variable: ME = DE * .82 (NRC, 1985)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	7465557.966	1493111.593	7.68	0.0006
Error	17	3306210.400	194482.965		
Corrected Total	22	10771768.366			

R-Square	C.V.	Root MSE	MEDE Mean
0.693067	12.47841	441.0022	3534.123

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	5206600.049	5206600.049	26.77	0.0001
TRT	2	1397903.896	698951.948	3.59	0.0499
REP*TRT	2	1656060.566	828030.283	4.26	0.0317

APPENDIX - B

ANOVA Tables - Performance Trial 1

Dependent Variable: PEN INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	262164.7826	87388.2609	8.04	0.0361
Error	4	43450.2477	10862.5619		
Corrected Total	7	305615.0303			

R-Square	C.V.	Root MSE	PENINT Mean
0.857827	8.539367	104.2236	1220.508

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRT	3	262164.7827	87388.2609	8.04	0.0361

Dependent Variable: DAILY LAMB INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.90223750	0.30074583	6.76	0.0480
Error	4	0.17805000	0.04451250		
Corrected Total	7	1.08028750			

R-Square	C.V.	Root MSE	DLAMINT Mean
0.835183	10.70285	0.210980	1.971250

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRT	3	0.90223750	0.30074583	6.76	0.0480

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.08066865	0.01152409	4.94	0.0001
Error	70	0.16332750	0.00233325		
Corrected Total	77	0.24399615			

R-Square	C.V.	Root MSE	ADG Mean
0.330614	14.68885	0.048304	0.328846

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.00221523	0.00221523	0.95	0.3332
TRT	3	0.05634621	0.01878207	8.05	0.0001
REP*TRT	3	0.02375250	0.00791750	3.39	0.0226

Dependent Variable: CARCASS WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	754.9085297	107.8440757	24.35	0.0001
Error	70	309.9757575	4.4282251		
Corrected Total	77	1064.8842872			

R-Square	C.V.	Root MSE	CARCWT Mean
0.708911	8.922684	2.104335	23.58410

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	414.9718273	414.9718273	93.71	0.0001
TRT	3	323.9516674	107.9838891	24.39	0.0001
REP*TRT	3	9.4077954	3.1359318	0.71	0.5504

Dependent Variable: LOINEYE AREA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	203.0935779	29.0133683	4.88	0.0002
Error	70	416.1481400	5.9449734		
Corrected Total	77	619.2417179			

R-Square	C.V.	Root MSE	LOINEYE Mean
0.327971	16.35412	2.438232	14.90897

APPENDIX - B

ANOVA Tables - Performance Trial 1 (cont'd)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	88.89951030	88.89951030	14.95	0.0002
TRT	3	98.18296943	32.72765648	5.51	0.0019
REP*TRT	3	16.39210771	5.46403590	0.92	0.4362

Dependent Variable: 12TH RIB FAT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.96173538	0.13739077	5.81	0.0001
Error	70	1.65563000	0.02365186		
Corrected Total	77	2.61736538			

R-Square	C.V.	Root MSE	FAT Mean
0.367444	45.69808	0.153792	0.336538

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.23041939	0.23041939	9.74	0.0026
TRT	3	0.69342486	0.23114162	9.77	0.0001
REP*TRT	3	0.03530086	0.01176695	0.50	0.6852

Dependent Variable: INITIAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1141.766211	163.109459	25.18	0.0001
Error	70	453.516538	6.478808		
Corrected Total	77	1595.282749			

R-Square	C.V.	Root MSE	INIT Mean
0.715714	8.094577	2.545350	31.44513

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	1122.461267	1122.461267	173.25	0.0001
TRT	3	14.381130	4.793710	0.74	0.5318
REP*TRT	3	5.416423	1.805474	0.28	0.8406

Dependent Variable: FINAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	1730.123395	247.160485	14.29	0.0001
Error	70	1210.480740	17.292582		
Corrected Total	77	2940.604135			

R-Square	C.V.	Root MSE	FINAL Mean
0.588356	7.976636	4.158435	52.13269

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	1364.000691	1364.000691	78.88	0.0001
TRT	3	315.135323	105.045108	6.07	0.0010
REP*TRT	3	92.164703	30.721568	1.78	0.1596

Dependent Variable: DRESS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	0.08129333	0.01161333	31.52	0.0001
Error	70	0.02579000	0.00036843		
Corrected Total	77	0.10708333			

R-Square	C.V.	Root MSE	DRESS Mean
0.759160	4.249703	0.019194	0.451667

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.00512121	0.00512121	13.90	0.0004
TRT	3	0.07330286	0.02443429	66.32	0.0001
REP*TRT	3	0.00209371	0.00069790	1.89	0.1385

APPENDIX - C

ANOVA Tables - Performance Trial 2

Dependent Variable: PEN INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	72043.92810	72043.92810	17.85	0.0517
Error	2	8073.55250	4036.77625		
Corrected Total	3	80117.48060			

R-Square	C.V.	Root MSE	PENINT Mean
0.899229	2.774894	63.53563	2289.660

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRT	1	72043.92810	72043.92810	17.85	0.0517

Dependent Variable: DAILY LAMB INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.07022500	0.07022500	8.86	0.0968
Error	2	0.01585000	0.00792500		
Corrected Total	3	0.08607500			

R-Square	C.V.	Root MSE	DLAMINT Mean
0.815858	3.908780	0.089022	2.277500

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRT	1	0.07022500	0.07022500	8.86	0.0968

Dependent Variable: CARCASS WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	94.22176385	31.40725462	7.81	0.0004
Error	38	152.80619131	4.02121556		
Corrected Total	41	247.02795516			

R-Square	C.V.	Root MSE	CARCWT Mean
0.381421	7.104655	2.005297	28.22511

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	38.34679601	38.34679601	9.54	0.0038
TRT	1	55.69789464	55.69789464	13.85	0.0006
REP*TRT	1	0.60172463	0.60172463	0.15	0.7010

Dependent Variable: 12TH RIB FAT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.49541166	0.16513722	4.50	0.0085
Error	38	1.39398548	0.03668383		
Corrected Total	41	1.88939714			

R-Square	C.V.	Root MSE	FAT Mean
0.262206	36.40270	0.191530	0.526143

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.10208400	0.10208400	2.78	0.1035
TRT	1	0.39179156	0.39179156	10.68	0.0023
REP*TRT	1	0.00008728	0.00008728	0.00	0.9614

APPENDIX - C

ANOVA Tables - Performance Trial 2 (cont'd)

Dependent Variable: INITIAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	345.2504436	115.0834812	26.52	0.0001
Error	38	164.8872601	4.3391384		
Corrected Total	41	510.1377037			

R-Square	C.V.	Root MSE	INIT Mean
0.676779	6.760616	2.083060	30.81169

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	345.1246079	345.1246079	79.54	0.0001
TRT	1	0.1209109	0.1209109	0.03	0.8683
REP*TRT	1	0.0028665	0.0028665	0.00	0.9796

Dependent Variable: FINAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	206.6386496	68.8795499	4.16	0.0121
Error	38	629.4271332	16.5638719		
Corrected Total	41	836.0657828			

R-Square	C.V.	Root MSE	FINAL Mean
0.247156	6.408595	4.069874	63.50649

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	144.8953215	144.8953215	8.75	0.0053
TRT	1	61.4284506	61.4284506	3.71	0.0616
REP*TRT	1	0.0350747	0.0350747	0.00	0.9635

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.01195162	0.00398387	3.04	0.0407
Error	38	0.04982991	0.00131131		
Corrected Total	41	0.06178153			

R-Square	C.V.	Root MSE	ADG Mean
0.193450	10.63281	0.036212	0.340569

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.00464022	0.00464022	3.54	0.0676
TRT	1	0.00726758	0.00726758	5.54	0.0238
REP*TRT	1	0.00000652	0.00000652	0.00	0.9442

Dependent Variable: DRESS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.00436960	0.00145653	4.56	0.0080
Error	38	0.01214394	0.00031958		
Corrected Total	41	0.01651354			

R-Square	C.V.	Root MSE	DRESS Mean
0.264607	4.023162	0.017877	0.444345

Source	DF	Type III SS	Mean Square	F Value	Pr > F
REP	1	0.00016042	0.00016042	0.50	0.4830
TRT	1	0.00413637	0.00413637	12.94	0.0009
REP*TRT	1	0.00013423	0.00013423	0.42	0.5208

APPENDIX - D

ANOVA Tables - Performance Trial 3

Dependent Variable: PEN INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	272729.8096	136364.9048	7.17	0.0720
Error	3	57090.7785	19030.2595		
Corrected Total	5	329820.5881			

R-Square	C.V.	Root MSE	PENINT Mean
0.826904	12.10725	137.9502	1139.402

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	2	272729.8096	136364.9048	7.17	0.0720

Dependent Variable: DAILY LAMB INTAKE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.49990000	0.24995000	8.73	0.0562
Error	3	0.08590000	0.02863333		
Corrected Total	5	0.58580000			

R-Square	C.V.	Root MSE	DLAMINT Mean
0.853363	7.981786	0.169214	2.120000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	2	0.49990000	0.24995000	8.73	0.0562

Dependent Variable: CARCASS WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	77.78279048	15.55655810	4.50	0.0027
Error	36	124.37074286	3.45474286		
Corrected Total	41	202.15353333			

R-Square	C.V.	Root MSE	CARCWT Mean
0.384771	6.972717	1.858694	26.65667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	3.08343810	3.08343810	0.89	0.3511
TRT	2	47.59693333	23.79846667	6.89	0.0029
REP*TRT	2	27.10241905	13.55120952	3.92	0.0288

Dependent Variable: LOINEYE AREA

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	115.2179262	23.0435852	4.22	0.0040
Error	36	196.5660571	5.4601683		
Corrected Total	41	311.7839833			

R-Square	C.V.	Root MSE	LOINEYE Mean
0.369544	14.22937	2.336700	16.42167

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	0.60720238	0.60720238	0.11	0.7407
TRT	2	62.10923333	31.05461667	5.69	0.0071
REP*TRT	2	52.50149048	26.25074524	4.81	0.0141

Dependent Variable: DRESS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.03074286	0.00614857	18.02	0.0001
Error	36	0.01228571	0.00034127		
Corrected Total	41	0.04302857			

R-Square	C.V.	Root MSE	DRESS Mean
0.714475	3.895013	0.018473	0.474286

APPENDIX - D

ANOVA Tables - Performance Trial 3 (cont'd)

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	0.00015238	0.00015238	0.45	0.5083
TRT	2	0.02588571	0.01294286	37.93	0.0001
REP*TRT	2	0.00470476	0.00235238	6.89	0.0029

Dependent Variable: INITIAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	245.1015619	49.0203124	16.04	0.0001
Error	36	109.9960000	3.0554444		
Corrected Total	41	355.0975619			

R-Square	C.V.	Root MSE	INIT Mean
0.690237	5.362303	1.747983	32.59762

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	221.1691524	221.1691524	72.39	0.0001
TRT	2	15.5008905	7.7504452	2.54	0.0932
REP*TRT	2	8.4315190	4.2157595	1.38	0.2646

Dependent Variable: FINAL WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	74.44181905	14.88836381	1.56	0.1967
Error	36	343.90722857	9.55297857		
Corrected Total	41	418.34904762			

R-Square	C.V.	Root MSE	FINAL Mean
0.177942	5.498460	3.090789	56.21190

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	18.90743810	18.90743810	1.98	0.1680
TRT	2	34.94453333	17.47226667	1.83	0.1752
REP*TRT	2	20.58984762	10.29492381	1.08	0.3511

Dependent Variable: 12TH RIB FAT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.14576190	0.02915238	0.97	0.4512
Error	36	1.08588571	0.03016349		
Corrected Total	41	1.23164762			

R-Square	C.V.	Root MSE	FAT Mean
0.118347	34.40759	0.173676	0.504762

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	0.00915238	0.00915238	0.30	0.5851
TRT	2	0.12779048	0.06389524	2.12	0.1350
REP*TRT	2	0.00881905	0.00440952	0.15	0.8645

Dependent Variable: ADG

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	0.05009762	0.01001952	9.54	0.0001
Error	36	0.03780000	0.00105000		
Corrected Total	41	0.08789762			

R-Square	C.V.	Root MSE	ADG Mean
0.569954	10.46084	0.032404	0.309762

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	0.01339286	0.01339286	12.76	0.0010
TRT	2	0.03190476	0.01595238	15.19	0.0001
REP*TRT	2	0.00480000	0.00240000	2.29	0.1163

APPENDIX E

Average volatile fatty acid production - Digestibility Trial

Lightweight lambs

Lamb #	Treatment	Acetic Acid %	Propionic Acid %	Butyric Acid %
599	ALFA	50.52	22.08	7.96
609	ALFA	54.86	24.35	10.20
615	ALFA	53.13	18.56	9.26
606	50/50	39.37	21.91	15.40
617	50/50	33.62	14.78	10.58
623	50/50	43.06	21.41	15.47
640	50/50	32.54	11.98	14.84
613	CONC	19.62	22.97	9.91
636	CONC	27.71	18.21	6.79
653	CONC	16.21	17.68	4.01
674	CONC	13.88	12.10	15.14

Heavyweight lambs

Lamb #	Treatment	Acetic Acid %	Propionic Acid %	Butyric Acid %
635	ALFA	56.59	20.36	7.89
645	ALFA	53.12	23.82	7.38
646	ALFA	37.57	16.76	5.57
661	ALFA	49.22	19.02	7.99
598	50/50	41.39	18.88	8.28
664	50/50	42.01	16.36	15.69
682	50/50	43.64	18.48	12.68
683	50/50	37.09	21.38	13.58
597	CONC	17.18	18.01	5.79
626	CONC	19.73	9.80	10.53
632	CONC	15.10	17.50	3.17
637	CONC	31.42	11.09	10.08

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