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THE EFFECT OF DIETARY ENERGY LEVEL ON FEEDLOT PERFORMANCE, VISCERAL ORGAN MASS, CARCASS COMPOSITION, AND ACCRETION RATES OF GROWING LAMBS

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THE EFFECT OF DIETARY ENERGY LEVEL ON FEEDLOT PERFORMANCE, VISCERAL ORGAN MASS, CARCASS COMPOSITION, AND ACCRETION RATES OF GROWING LAMBS

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Kelly Wayne Bruns

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ABSTRACT

THE EFFECT OF DIETARY ENERGY LEVEL ON FEEDLOT PERFORMANCE, VISCERAL ORGAN MASS, CARCASS COMPOSITION, AND ACCRETION RATES OF GROWING LAMBS

By

Kelly W. Bruns

Thirty crossbred (Suffolk X Dorset X Rambouillet) wethers were used to compare performance, visceral organ mass, carcass composition and accretion rates while consuming either a high concentrate (CONC) or a 100% alfalfa (ALFA) diet. Diets were fed to appetite with daily feed (FI) intake measured. Metabolizable energy values were 2.79 and 2.17 Mcal/kg for CONC and ALFA, respectively. Lambs were started at 30 kg and slaughtered at 52 kg. Internal organs and fat associated with each organ were weighed. Carcasses were separated into cuts, and boneless tissue analyzed for dry matter, fat and crude protein content. Total FI and days on feed were lower ($P<.05$) and average daily gain higher ($P<.05$) for CONC-fed lambs. No differences were found for carcass characteristics. Alfalfa-fed lambs had heavier ($P<.05$) weights than CONC-fed lambs for: liver, empty gastrointestinal tract, empty small and large intestine. Protein and fat concentrations in the carcass were unaffected. Accretion rates of tissue were greater for CONC- than ALFA-fed lambs.

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LIST OF ABBREVIATIONS

ADF . . . . . acid detergent fiber
ADG . . . . . average daily gain
ALFA . . . . . alfalfa diet
B . . . . . body weight
°C . . . . . degree Celsius
cm . . . . . centimeter
CONC . . . . . concentrate diet
CP . . . . . crude protein
d . . . . . day
DM . . . . . dry matter
DMI . . . . . daily dry matter intake
FI . . . . . feed intake
g . . . . . gram
GLM . . . . . General linear model
h . . . . . hour
kg . . . . . kilogram
km . . . . . kilometer
L . . . . . liter
m . . . . . meter
Mcal . . . . . megacalorie
NDF . . . . . neutral detergent fibre
SEM . . . . . standard error of the mean
TDN . . . . . total digestible nutrients
wt . . . . . weight
yr . . . . . year

INTRODUCTION

The livestock and meat industries have been highly focused on lean animal growth for the past three decades. Livestock producers have placed considerable emphasis on reducing the time required for animals to reach a desired market weight. Rapidly-growing animals generally are biologically and economically more efficient than their slower-growing contemporaries. Since the late 1960s, a high priority has been placed by the meat animal industry on maximizing lean growth and limiting excess fat production. Carcass fat has a negative influence on the amount of lean product in sheep (Carpenter, 1966; Smith et al., 1969; Smith and Carpenter, 1973). With the development of the Lean Lamb Certification Program (USDA, 1989) by the American Sheep Producers Council (ASPC, 1988), a greater effort has been made by producers to market leaner carcasses. The Lamb Market Basket Survey (Harris et al., 1990) revealed that primal cuts are being trimmed to .35 cm of fat to gain consumer acceptability. Excess fat in lamb carcasses was reported from an intensive national survey by Tatum et al. (1988). The author evaluated 6,224 head of lambs, from seven major packing plants across the United States. It was reported that 40 percent of the lambs surveyed had yield grades (USDA, 1982) of 4 or higher. This is approximately twice as many yield grade 4 and 5 carcasses than there were in 1968 and 1971.

Carpenter et al. (1968) found 21.3% yield grade 4s and above in 1968. Two years later, Field et al. (1971) reported a slightly lower proportion of yield grade 4 and 5 carcasses at 19.8%. At the time of Tatum's et al. (1988) survey only one-third of the supply of lambs would have met the proposed Lean Lamb Certification specifications (ASPC, 1988). The American meat producer should be well aware of the fact that consumers reluctance towards fat has doubled in the 1980s (NRC, 1988). Because of this, the American sheep producer can no longer ignore the fact that they must produce leaner lambs. The concern about over finished lambs is well documented by Nancy Yanish, a representative for the Food Marketing Institute, who said, "Retailers, actually supermarket operators, would rather work with those in the beef industry - who have an over-fat product but who want to do something about it - than with those in the lamb industry - who have an over-fat product but who refuse to do anything about it" (Heaton et al., 1993). Why then has the American sheep producer not responded to the demand for a leaner product? Producers have not responded to consumer concerns because it is common practice to price lambs on a guaranteed yield or dressing percent with seasonal weight docks (Ward and Detten, 1984). When demand for heavy lambs is high, producers push lambs to heavier weights by putting on excess fat gain to receive better prices. Packing plants are only docking lambs that are yield grade 4 and higher which is in excess of .91 cm (.36 in.) of 12th rib back fat. This is 2.6 times more fat than the .35 cm that Harris et al. (1990) reported as a maximum to gain consumer acceptability and .27 cm higher than that eligible for Lean Lamb Certification. Since over 50% of the lambs on feed are either owned or contracted to packers, fewer incentives are offered to private producers for leaner lambs.

In order to survive, producers must take it upon themselves to produce a carcass that is free of excess fat. Thus, the lamb industry must move more in the direction of producing lean, heavy muscled carcasses. The traditional method to increase lean percent in the carcass of ruminants has been to breed and feed larger framed, later maturing animals, while still slaughtering them at traditional weights (Bergen and Merkel, 1991). Baird (1988) reported that lambs that were larger in their skeletal size in relation to lambs of the same age had lower back fat measurements. For the livestock production system to obtain a larger mature body weight animal implies that a larger framed, later maturing cow or ewe is needed versus an earlier maturing, smaller framed dam. These larger framed dams will have a greater mature weight and thus require more feed for maintenance. It has been consistently shown that large framed cows require more feed and are less efficient than more moderate framed cows (Fox et al., 1988).

Ruminant nutritionists embarked on extensive research to improve carcass leanness by reducing the energy level of the diet through alternative feedstuffs or by reducing daily intake. Much work has been conducted in varying the concentrate to roughage ratio as well as evaluating alternative roughage sources (Garret et al., 1960; Osborne et al., 1961; Donefer et al., 1963; Ringkob et al., 1964; Ray and Mandigo, 1966; Burton and Reed 1969; Glimp, 1971; Craddock et al., 1974; Rattray et al., 1974; Van Keuren, 1985; Ross et al., 1985; Kinser et al., 1988; Oliverous et al., 1989; Weichenthal et al., 1991; Mader, 1992; Dahlquist and Mader, 1993). Additionally, studies using feed intake reduced to lower levels than that of ad libitum have also been done (Crouse et al., 1978; Fortin et al., 1980; Fortin et al., 1981; Notter et al., 1984). Reduced intake, however, has not been a practical approach; even though feed efficiency is increased, average daily gains tend to decrease. Feeders, however, have found it more profitable to focus on higher daily gains because, to this date, packers are not rewarding producers for higher percentages of lean. Many of the trials varied energy level in the diet by restricting intake and did not allow animals to consume ad libitum. Those that did provide ad libitum intakes did not assess carcass composition or reported conflicting results. Osborne et al., (1961) and Ray and Mandigo (1966) reported that lambs fed low-energy diets had less carcass fat than those fed high-energy diets when slaughtered at similar weight endpoints. Similar studies by Ringkob et al. (1964) and Burton and Reid (1969), found that dietary energy levels did not significantly affect fat content in the carcass. Both trials used lambs of similar genetic make up and similar body weight endpoints. In a more recent study, that not only varied the energy composition of the feedstuffs but also the level of intake, Crouse et al. (1978) reported that carcass composition was not affected by dietary treatment; however, internal fat was higher in lambs fed the high-concentrate diet and thus they had slightly higher yield grades. Because of the importance of carcass composition in the market place, as well as conflicting research reports regarding energy level in diets and its affect on body composition, this study was designed to evaluate the effects of a high energy diet versus one of a lower energy density on performance and carcass composition of crossbred feeder lambs. The experimental strategy was to target a heavier body weight endpoint to better fit the demands of the industry, which is calling for producers to market heavier lambs. All lambs would also have ad libitum access to the respective diets.

The primary objective of the study was to examine the effects of energy content in the diet upon whole carcass composition at a specific weight endpoint when lambs had ad libitum access to dietary treatments.

LITERATURE REVIEW

Definition of growth

As early as 1911, growth was defined as an increase in the mass of a body during definite intervals of time (Schlose, 1911). Hammond (1955) defined growth as an increase in body weight until maturity is attained. There does not appear to be a universal agreement on a definition of growth. Many researchers prefer the definition proposed by Maynard and Loosli (1969), that true growth is an increase in muscle, bone, and vital organs and should be distinguished from any increase in adipose tissue. This definition implies that fattening should be evaluated separately when studying the production of meat-producing animals. Judge et al., (1994) proposed that growth can be defined as a normal process of increase in size, produced by accretion of tissues similar in composition to those of the original tissue or organ. Growth can be achieved by one or a combination of the following processes: 1) hyperplasia, an increase in cell number by cell division, characterized by an increase in tissue DNA content which is also a reflection of nuclei number; (2) hypertrophy, which is an increase in size of existing cells, expressed as a ratio of tissue protein to DNA, which is a measure of amount of cytoplasm per nucleus; and (3) accretionary growth, which is an increase in non-cellular structural material (Judge et al., 1994; Grant and

Helferich, 1991).

Growth can be divided into two phases, prenatal and postnatal. Prenatal growth is accomplished primarily by hyperplasia. Differentiation of tissues, organs, and systems take place at this time (Widdowson, 1980). Postnatal growth of individual tissues and vital organs can be represented by a sigmoidal curve of age versus body weight (Hammond et al., 1983). Various tissues however develop at different times. An example of this phenomenon is that of muscle and adipose growth. On a normal plane of nutrition during growth of the animal, muscle growth exceeds fat accretion. As age and body weight increase, muscle growth slows and the rate of fat accretion surpasses that of muscle. The order of development of tissue has been characterized by Hammond (1932) and McMeekan (1940) to be that of skeleton, muscle, and fat with vital organs being relatively well developed by the time of birth. The plane and level of nutrition greatly affects the growth rates of organs and tissues (McMeekan, 1940; Hammond et al., 1983). McMeekan (1940) found that reduced feed intake delayed maturity of later developing tissues. Additionally, energy intake had a greater effect on the later developing depot of subcutaneous fat than that of intermuscular fat. From this he concluded that development of tissues can be regulated by the level of nutrition provided. He also showed that by altering the growth curve of the whole body, one may change the body ratio of lean to fat. Because of this, many researchers have studied means of altering the growth curve to produce a higher percentage of lean and at the same time achieve an acceptable rate of gain to maximize profitability.

Measurement of growth

As noted above, growth has been defined in various ways; consequently, the preferred measurement of growth will vary among researchers. The accumulation of total body mass from birth to market or maturity is generally an accepted means of measuring growth. Rate of gain is calculated from a specific starting point to a specific endpoint. Variation of digestive tract fill and body composition make full weight an imprecise indicator of growth. Thus, shrunk weight is a preferred method of measuring accrued growth, because it allows for the subtraction of apparent digestive tract fill (Tolley et al. 1988). However, full, shrunk, and empty body weight can change independently of muscle mass and may not fully reflect a change in lean mass. Consequently, growth is measured by some researchers as an increase in lean body mass. This does not take into account the protein content of vital organs (digestive tract, liver, ect.) which may increase independently of carcass lean mass (Carstens et al., 1991).

Overview of Energy in the Growing and Finishing Diet

Consumption of dietary net energy for gain ultimately influences the composition of meat producing animals (Mersmann, 1991). It has been established by Searle et al., (1972) and Bergen (1974) that fat gain becomes a large and constant fraction of weight gain beyond a certain body weight. Mersmann (1990, 1991) explained how early work by McMeeken (1940), as well as his own (Mersmann, 1987), relates to feeding systems in the United States. He attributed the use of feeding ad libitum, allowing animals to consume their desired intake freely, as a common agricultural practice in more developed countries. The United States has an abundance of relatively low cost grains that are of high energy value. Which has allowed many feeding operations to be successful and profitable. The strategy of ad libitum intake generally results in maximum average daily gain and profitability, when marketing on a live or carcass weight basis (Smith et al., 1977; Bennet, 1988). Palatability of the product is also increased due to a higher degree of intramuscular fat. Mersmann (1991) stated if payment to producers is based on retail product weight, diets that utilize lower energy densities can reduce carcass fat and increase retail product yield. The result is an increase in carcass value (Bennet, 1988; Loy et al., 1989) due to a relative increase in the amount of lean product. Profit per head, however, may not necessarily be increased.

Limit feeding has been shown to produce leaner animals (Crouse et al., 1978; Fortin et al., 1980; Fortin et al., 1981; Whittemore, 1986). In addition to producing leaner carcasses, restricted intake was conducive to greater gain and improved feed efficiency (Glimp et al. 1989). Glimp et al., (1989) lambs fed a 90% concentrate diet at 92.5%, ad libitum experienced greater average daily gain and increased feed efficiency than lambs fed ad libitum (Glimp et al. 1989). This supports work by Old and Garret (1987), who found that when steers were fed at 85% ad libitum, there was a 20% increase in feed efficiency. When feeding large numbers of animals in one pen this method may not be as successful because some animals may consume more than their allocated amount, while others consume less than desired. Thus, limit feeding is more successful when done individually (Mersmann, 1991). Limit feeding can be accomplished successfully by using electronically controlled feeders or individual feeding chutes. Both systems are expensive to install and, despite being automated, are still labor intensive. Additionally, slower daily gains and lengthened feeding periods result in lower turnover of animals within the feeding system, resulting in potentially less revenue under our current economic structure. Because of these problems, livestock producers in the United States have not been able to justify implementing limit feeding programs. Utilizing lower energy feedstuffs, such as use of high quality roughage, while still maintaining sufficient average daily gain, could prove beneficial to cattle feeders as well as lamb producers. Studies done by Ely et al. (1979) showed that lambs grazing bluegrass-clover pasture plus a 13% crude protein supplement diet had similar gains to lambs fed a concentrate diet in a dry lot situation. The utilization of 100% forage diets fed ad libitum has been well documented in relationship to performance levels (Van Keuran et al, 1969). However, less research has been conducted on the effect of 100% forage diets on carcass characteristics. Roughages are of practical use in sheep diets because sheep appear more efficient than beef cattle at utilizing forages in pasture situations (Van Keuran et al., 1969). In a grazing study, Van Keuran et al. (1969) reported that feeder lambs produced more animal product per hectare than yearling steers. Parker (1982) and Ely et al. (1979) concluded that even though average daily gain is reduced, lambs may economically be fed to slaughter on pasture alone. Researchers have recommended that the feeding or grazing of legumes offers a higher degree of performance than grasses (Marten and Jordon, 1979; Murphy et al., 1994). Average daily gain was increased because a greater amount of net energy was consumed by lambs grazing legumes (Waldo and Jorgensen, 1981). Additionally, pelleting of forage diets increased feed intake and average daily gain in studies with feeder lambs (Shain and Stock, 1992). Pelleting diets, however, increased cost per unit of feed.

Tatum et al. (1988) conducted a nationwide survey on sheep feeding and marketing. They reported that 18% of the lambs surveyed were fed on pasture while the remainder were fed in feedlots. Lambs had to be on feed from 30 to 60 days and fed on a high concentrate diet prior to slaughter to be classified as feedlot lambs (Tatum et al. 1988). Feeding lambs in a feedlot situation enables the feeder to make the most of his facilities while feeding a varitety of grains. A rapid turnover of lambs can then be attained thus, resulting in a reduction of fixed costs and an increase in efficiency. When feeding concentrate feedlot diets, there is a greater chance that metabolic disorders may occur, possibly resulting in reduced lamb performance (Krehbiel et al., 1994). Thus, it has been the common practice in the livestock feeding industry to feed combinations of concentrates and roughages to prevent feedlot related disorders and to insure profitability. There are however, differences among data between researchers on how diets varying in energy affect the lean to fat ratio in carcasses.

Effect of Energy Density on Carcass Composition.

Much work has been done with alternating the nutrient density of the diet, by varying the concentrate to roughage level, and to study its interrelationships to growth and body composition in sheep and cattle. Early studies only analyzed the effect of energy density on overall development of the carcass (Wellington et al., 1954; Hammond, 1955) and did not study the rate of deposition of fat and lean. Many researchers (Field et al., 1963; Guenther et al., 1965; Burton and Reid, 1969; Ørskov, 1983) reported that nutritional treatment did not affect body composition. Field et al. (1963), Winter et al. (1976) and Theriez et al. (1981) found that age or nutritional treatment did not affect body composition of lambs that were of the same breed and sex, when slaughtered at the same weight endpoint. Field et al. (1963) fed lambs sired by slow, average, and fast gaining Southdown rams. Lambs were fed to a constant slaughter weight endpoint of 35 kg. The authors reported that type of birth (single or twin) or age did not affect carcass composition within each group. The faster gaining rams sired lambs that gained faster and had a greater percent lean. Winter et al. (1976) fed 35 kg Corriedale wethers three levels of energy. The first group was fed continuously while the second and third groups were fed a energy restricted diet to lose 20% and 28% of their body weight before being fed to a constant weight endpoint of 63 kg. Winter et al. (1976) concluded that age or nutritional treatment had no affect on final body composition when finished lambs were of the same breed and sex. Burton and Reid (1969) fed lambs at two different levels of energy and slaughtered them at both an age and a weight constant endpoint. Both diets were formulated to exceed maintenance requirements for growing lambs. Lambs fed the lower energy diet took a substantial number of days longer to reach the desired endweight. The authors concluded upon regression analysis that the variation in body composition was mostly influenced by carcass weight. Additionally, Ørskov (1983) reported that when lambs were slaughtered at identical weights, the age at slaughter had little or no effect on chemical composition. It was also suggested by McC. Graham (1982) that the greatest variability in fat and protein ratios of the carcass was attributed to carcass weight. Carcass weight in turn affects the length of the feeding period. In a study by Glimp et al. (1989), 298 head of Rambouillet ewes and wether lambs were fed one of three diets, varying in the level of energy (55%, 72.5%, or 90% concentrate). Lambs consuming the high concentrate diets were fed three levels of intake (ad libitum, 92.5% ad libitum, and 85% ad libitum). Level of concentrate affected days on feed, average daily gain, feed efficiency, and average daily feed intake. Lambs consuming the high concentrate diet had the highest, most desirable, feed efficiency. The poorest feed efficiency was that of the lambs consuming the low concentrate diet who had the greatest daily feed intake. Yield grade was unaffected by dietary treatment. Diets varying in energy density have had dramatic effects on feedlot performance; however, carcass characteristics were virtually unaffected in some cases.

Nutritional treatment did affect carcass composition in studies done by Ray and Mandigo (1966), Searle, McC. Graham and O'Callaghan (1972), Fortin et al.

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(1980 & 1981), Turgeon et al. (1986), Zinn (1987), Mersmann (1991), and Murphy et al. (1994). Mersmann (1991) stated that if animals are to be raised for lean muscle mass, they should be fed at less than maximum intake. Searle, McC. Grahm, and O'Callaghan (1976) reported that lambs fed diets that produce slower gains will have a greater proportion of their gain as protein. Additionally, lambs fed for maximum gain had a greater amount of fat gain. This was also demonstrated by Fortin et al. (1980, 1981). These authors allowed Angus and Holstein steers to consume a finishing diet at either ad libitum or 70% ad libitum. They concluded that cattle consuming greater amounts of energy had higher percentages of fat and lower percentages of muscle when slaughtered at a constant carcass weight basis compared to cattle on a lower plane of nutrition. The work of Turgeon et al. (1986) studied the effect of slow versus fast growth rate on lamb carcass composition. They found that the lambs that experienced slower growth had similar amounts of protein gain but substantially less fat when compared to lambs fed for fast growth on a concentrate diet. Mersmann (1991) suggested that when feeding a balanced diet at restricted energy levels, fat accretion will be reduced, but muscle deposition will remain at the same rate providing that energy intake does not drop below maintenance. He based this suggestion on observations made by Smith et al. (1977), Crouse et al. (1978), and Whittemore (1986). However, in studies done by Smith et al. (1977), low energy diets consisted of cattle grazing pasture at ad libitum levels. Thus, animals may have adjusted for the reduced energy level by consuming more feed (Mersmann, 1991).

In a two-year study, Ray and Mandigo (1966) fed diets varying in energy level. Lambs were allowed ad libitum intakes of a 70% alfalfa and 30% concentrate pelleted diet versus a 100% alfalfa pellet diet. The lambs were slaughtered at similar weight endpoints. The authors reported that lambs consuming the higher energy diet had a greater fat content as a result of an increase in subcutaneous fat. The authors reported that weight of kidney fat was not different. Days on feed was not reported for either treatment. Without days on feed being reported, and dietary treatments being fed in different calendar years to different lamb crops, environmental factors may have influenced the data. Whittemore (1986) showed that as feed intake (kg/d) was reduced, muscle and fat gains (kg/d) were also reduced. Crouse et al. (1978) fed diets that varied in energy level and amount to feeder lambs to insure differences in energy intake. Three diets containing metabolizable energy values of 2.18, 2.39, and 2.80 Mcal, respectively, were used and the feeder lambs were slaughtered at four different weight endpoints of 32, 42, 54, and 66 kg. Crouse et al. (1978) reported that although percent of carcass protein decreased slightly ($P<.01$), as energy density of the diet increased, there was little effect on overall carcass composition. Yield grade (USDA, 1969) was higher for lambs consuming the higher energy diets. On the present yield grading system (USDA, 1989), however, dietary treatment would not have affected yield grade because it was reported that 12th rib fat thickness was unaffected by dietary treatment. Additionally, leg conformation score was not influenced by dietary treatment (Crouse et al. 1978). Thus, the change in yield grade can be attributed to a greater amount of internal fat found in lambs consuming the higher energy density diet.

Guenther et al. (1965) designed an experiment to permit the comparison of carcass composition on both an age- and weight-constant basis. In these studies, Hereford-sired calves were fed at different energy intakes. No difference was found in the lean content when the calves were compared on a weight-constant basis. The research group found significant differences in percentages of fat within the carcass. Cattle fed on a higher plane of nutrition had higher percentages of fat and lower percentages of muscle on a carcass weight basis than did cattle consuming a lower energy level diet. Interestingly, the muscle to bone ratios in the experiments did not differ among dietary treatments.

More recently, Murphy et al., (1994) fed 40 crossbred lambs (20 wethers and 20 ewes) three dietary treatments. Lambs were slaughtered at a common endpoint of 42 kg. The two phase experiment (phase I, d 0 to 42; phase II, d 43 to slaughter) examined finishing systems of grazed alfalfa, 100% concentrate diet fed drylot, and grazed ryegrass for 42 d followed by the 100% concentrate diet in drylot. Rotational grazing systems were used for forage management. Alfalfa and ryegrass paddocks were grazed by lambs for 3 to 4 days. Lambs consuming the 100% concentrate had greater average daily gains in phase I of the study. In the second half of the study average daily gain was not different among dietary treatments. Lambs consuming the 100% concentrate diet had greater average daily gains over the entire trial than for the lambs that grazed ryegrass the first 42 d. No difference, however, was found for average daily gain between lambs grazing alfalfa or lambs consuming the 100% concentrate diet. The difference in days on feed was due in part to the wider range of average daily gain in phase II of the study. Energy intake was not measured in the study and, thus, the authors made the assumption that differences in average daily gain were due to differences in the energy density of the feed consumed and total energy intake. Lambs grazing alfalfa had lower dressing percentages and decreased carcass weights. Lambs grazing alfalfa also had less total carcass fat with similar amounts of lean tissue than lambs fed concentrate in both phase I and phase II, as well as lambs consuming the concentrate diet only in phase II. Daily accretion rates of fat were greater for lambs consuming the concentrate diet. No differences were reported for the daily accretion of protein or bone between lambs grazing alfalfa or lambs on the 100% concentrate diet. Murphy et al., (1994) reported that it has been well documented (Rouse et al., 1970) that energy intake would be deposited in the order of bone, lean, and fat, until the specific tissue had reached maximal deposition. Thus, the authors concluded that daily energy intake for the lambs grazing alfalfa may have been sufficient to meet energy needed for bone and lean tissue while providing less energy to be partitioned toward fat accretion. Because of the various suggestions made concerning the effect of energy level on carcass composition, further research is needed to allow a more complete understanding of the relationship of high- and low-energy diets to carcass development.

Effect of Energy Density on Visceral Organ Mass

The mass of visceral components is greatly influenced by nutritional factors (Murray and Slezacek, 1980; Koong et al., 1983; Ferrell and Koong, 1985). Nutritional depression can be influenced by the quantity or quality of feed that the animal consumes. Nutritional depression results in the inability of an animal to express its full potential for genetic growth. Animals that do not meet their nutritional requirments experience reduced growth rate or in severe cases live weight loss (Hogg, 1991). Most notable losses occur in the liver, gut components, and intestines (Winter et al., 1976; Ferrell et al., 1986; Burrin et al., 1988). By increasing dietary bulk, Ferrell et al. (1986) as well as Jacobs and Lupton (1984), reported an increase in the weight of the large intestine. The researchers attributed this to hypertrophy of the intestinal tissue. Conflicting reports have appeared concerning the effect of dietary bulk on the small intestine. Jacobs (1983) and Jacobs and White (1983) reported that increasing the level of dietary fiber increased cell proliferation of the small intestine. In contrast Goodland and Wright (1983) showed that an increase in dietary bulk decreased the weight of the small intestine. Ferrell et al. (1986) reported that an increase in dietary bulk can increase the energy requirement of the animal irrespective of energy intake. Johnson et al. (1985) however, reported as the amount of roughage in the diet increased from 10% to 80%, with metabolizable energy intake remaining relatively constant, there was only a small effect on visceral organ mass. Johnson et al. (1985) also reported a greater increase in gastrointestinal tracts of cattle fed grass hay versus alfalfa. In a similar study, Rompala et al. (1988) fed cattle diets containing low to high energy densities. When cattle were slaughtered at the same weight endpoint, the authors reported greater weights of the large intestine and stomach components, while the weight of the small intestine was unaffected. Drouillard et al. (1991) concluded that results from Burrin (1988) and Rompala et al. (1988) suggest that the stomach and large intestine are influenced more by changes in the amount of bulk consumed in the diet while the small intestine is more sensitive to the amount of available nutrients.

Estimation of Body Composition

Many researchers have been and are still investigating methods that accurately estimate body composition. As early as 1893, Iowa State researchers Wilson and Curtis reported results of performance and carcass traits of cattle in the Iowa Agricultural Experiment Station Bulletin (Schroeder, 1990). Over the past hundred years, numerous methods have been proposed and investigated without much application and yet others (Hankins and Howe, 1946) are still being utilized today. Valid estimation of carcass composition that is reliable as well as rapid and simple, is needed to establish the value of an animal's carcass. This estimation needs to be fast and simple, so it can be utilized by packing plants that process hundreds of amimals per hour. The reliability of this measurement is economically important, as it will be used not only for sorting carcasses into respective yield groups for processing and fabrication, but also to assess total product percent. Having a reliable estimate of total carcass value would be true value based marketing. Currently the pork industry is successfully estimating the composition of hot carcasses on line with ultrasound (Liu and Stouffer, 1994). While the beef or lamb industry has yet to perfect this method, researchers (Zhang, 1994) are making progress. Producers would then have an incentive to produce a leaner more muscular product. The use of new technologies and past research data is bringing scientists closer to accurately estimating composition in an indirect, expedient manner.

Linear measurements

To assess growth, workers (Cook et al., 1951; Kidwell, 1955; Bush et al., 1969) experimented with various anatomical measurements of live animals. These measurements were related to weight and skeletal size, but were not useful in estimating fat content and muscle size. Before studying growth measurements in live animals, workers measured the depth, width, and circumference of various locations on the carcasses in an attempt to correlate these measurements to carcass composition. These researchers realized that by measuring back fat thickness, as well as length and width of the longissimus muscle, a crude estimate of percentage fat and muscle content of a carcass could be predicted. Measurements of fat depth and muscle area was first done by Hirzel (1939), Palson (1939), and McMeekan (1941) in beef, sheep and swine carcasses, respectively. Early studies by these researchers laid the groundwork for later research to come. Brozek (1961), Zobrisky (1963), Kauffman (1971), and extensive work by Berg and Butterfield (1976), as well as Kempster (1986), documented that backfat thickness and ribeye area are good indicators of carcass composition. Rouse et al. (1970) reported that a single linear fat measurement at the 12th rib medially over the longissimus muscle was the best indicator of total carcass fat in lambs. Additionally, the area of the longissimus muscle was just as reliable a predictor of total lean deposition as percent lean in the carcass. All these measurements are predictors and are not 100% reliable (Topel and Kauffman, 1988). Thus, the search continues for the ultimate method to predict carcass composition in live animals.

Whole body composition analyses

Because of variability found when measuring carcass measurements subjectively, researchers realized that to effectively and accurately evaluate nutrition or genetic experiments, whole body composition must be done. Whole body composition analysis entails the physical dissection and subsequent chemical analysis (water, protein, or ether extract) of all carcass components, or the grinding of the whole carcass. Jesse et al. (1976) completely dissected beef carcasses, determined water, protein and fat content and concluded that complete dissection is an acceptable form of estimating carcass composition when whole carcass grinding can't be done. Jesse et al. (1976) findings supported previous research done by Haecker (1914, 1916, 1920) and Trowbridge (1919). There are, however, disadvantages to using total body composition. Williams et al. (1974) reported that between researchers and facilities, results on lipid and moisture content may change. The variability in moisture content is due in part to the amount of time taken to dissect a cut, as well as environmental effects such as humidity, and temperature. Thus, Kempster (1984) outlined specific steps for proper dissection. Another disadvantage of whole body dissection is extremely high cost. Time and the amount of labor needed to carry out a project having an adequate number of replications is immense. Cost becomes an important factor, not only because of labor, but also because of loss of animal product. Because whole dissection of large animals is cost prohibitive, other methods of estimation are generally used. However, research done with small animals should utilize whole dissection methods whenever possible (Schroeder, 1990).

Although whole body composition studies are very reliable to measure aspects of protein and fat deposition, the resale value of the carcass is lost. Thus many workers have experimented with correlating composition of a specific cut of meat to that of the whole carcass. The first documented data where researchers were successful in finding a correlation between wholesale rib and carcass composition was that of Hall and Emmett (1912). The wholesale rib was chosen because of its ease of removal. Other workers (Moulton et al. 1922; Lush, 1926; Hopper, 1944) also found a good relationship between composition of the wholesale rib and the carcass. More recently, Moran (1982 and 1983) found significant variation in wholesale rib composition to carcass composition.

In his study, he used animals that had been raised differently since birth and were of different genetic make-up. He concluded that fat and protein are not proportional from carcass to carcass. Therefore equations developed by Hopper (1944) may need further refinement. Although the use of the wholesale rib has declined because its removal substantially lowers the value of the carcass, other methods have been proposed that utilize only components of the rib.

9-10-11 rib section

Hankins and Howe (1946) conducted an in-depth study comparing the composition of various cuts of meat within the carcass to that of the whole carcass. They found high correlations between the 9-10-11 rib section to the whole carcass and wholesale rib. Thus the 9-10-11 rib section composition analysis is frequently often employed to estimate composition of the whole carcass. Studies conducted by Jones (1985), Lunt et al. (1985), and Miller et al. (1988) reported findings that support work by Hankins and Howe (1946) and the use of the 9-10-11 rib section to be a vaild estimation of carcass composition. However, other researchers (Berg and Butterfield 1976; Moran, 1982), found it to be less successful when used on heifers versus steers of the same breed or on cattle of *Bos Indicus* breeding. Additionally, Allen (1966) studied carcasses from two different weight groups (227 to 250 kg and 312 to 340 kg). The author found the correlations of percent muscle, fat and bone to be lower (.4, .4, and .3, for muscle, fat, and bone respectively) in heavy versus light carcasses. Thus, fat deposition and muscle growth may not be proportional throughout the carcass from lighter to heavier weights. However, this may be attributed to the fact that animals were slaughtered at different physiological ages. There would most likely be different rates of fat and protein deposition between the two groups (Bergen and Merkel, 1991). In a more recent study by Nour and Thonney (1994) Holstein and small framed Angus steers where utilized. It was found that Hankins and Howe's (1946) equations slightly over estimated water and protein while underestimating lipid. This is in agreement with similar results found by Crouse and Dikeman (1974) and Schroeder (1990). More accurate estimates of carcass composition can be found using slightly adjusted equations (Nour and Thonney, 1994). However, Schroeder (1990) pointed out that the 9-10-11 rib section is a widely accepted method of estimating carcass composition and is relatively cost-effective. Accurate estimations of carcass composition rely on precise prediction equations.

Wholesale cuts

Research has been done correlating the percent yield of various cuts to the percent yield and composition of the carcass. Early research by Cole et al. (1960), Hedrick (1968), Miller (1965) Tuma et al. (1967) and more recently by Hedrick (1983) showed that percent trimmed round was highly correlated to boneless retail yield of primal cuts as well as the whole carcass. Cole et al., (1960) reported that total separable muscle in the carcass could be 90%

accounted for by separable muscle in the round. Crouse and Dikeman (1976) and Rouse et al. (1989) found high correlations for percentage of trimmed round to percentage of retail product. However, because of the high percentage of saleable meat that comes from the round, its use in estimating carcass composition has not been popular.

The flank is of less monetary value than either the rib or the round and has proven to be a good indicator of whole carcass composition (Hankins and Howe, 1946; Allen, 1966; Dikeman, 1968). Hankins and Howe (1946) reported a correlation between percent fat of the flank to that of the carcass of .95, which was comparable to the 9-10-11 rib section at .93. Additionally, Allen (1966) reported correlations of .91 for both percent fat and muscle in the flank to that of the carcass. Dikeman (1968), in a study involving wholesale cuts, reported results similar to those of Allen (1966). Dikeman (1968) reported that flank composition had the highest correlation to the amount of fat trim within the carcass compared to any of the other wholesale cuts. Correlations for composition were not only the highest for within-weight groups, but also across weight groups. It was noted that there are variations in flank removal across the industry. Thus, the wholesale flank may not be a totally reliable indicator of carcass composition. In the same study, Dikeman (1968) also found that the wholesale plate was the second most highly correlated cut to fat yield and percent retail product.

Serial slaughter

Serial slaughter techniques are presently the preferred method for researchers to map the growth and development of the animal (Anderson, 1988). Even though serial slaughter techniques are expensive, they are often used because methods for assessing composition of the live animal are still being tested (Rouse et al., 1992). The group of animals used in the study must be genetically, as well as phenotypically, similar and raised in the same environment. Preferably, animals from the same contemporary group, that are of the same size and genetic potential, should be used. Animals must be similar because they are slaughtered throughout the trial to plot composition. These animals are assumed to not only be similar in composition but they are expected to grow and respond to treatments like the remainder of the group throughout the trial so that accurate growth and composition points can be plotted. However, there are some complications to this method. Extremely large numbers of animals are needed to give validity to these types of studies. Although animals may be similar, variation can occur between animals and not be a true representation of all animals in the study or the cattle population in general (Anderson, 1988). Methods that may be used to estimate body composition of live animals are needed. Presently, researchers are attempting to accomplish this goal.

Estimating Carcass Charteristics of the Live Animal

Many research reports have discussed the relationship between body water, body fat and the weight of the fat free body in the animal (Sheng and Huggins, 1979; Schroeder, 1990). Researchers have experimented with various dilution techniques and compounds to estimate total body water content in the live animal. The most often used tracers are antipyrine, urea, and deuterium oxide (Schroeder, 1990)

Widdowson (1968) made the assumption that the fat free body is relatively constant in water, protein and ash (Schroeder, 1990). Thus, when the animal reaches its chemical maturity, an in vivo measurement of water can be used to determine composition. The measurement is accomplished by first injecting a bolus of tracer into the body water of the animal. Blood is then sampled after equilibration of the tracer in the body pools has occurred. The blood is then analyzed to determine the concentration of the tracer. Shipley and Clark (1972) reported that the volume of fluids (water) can be calculated by dividing amount of tracer injected by the concentration of the tracer at the time of equilibration (Schroeder, 1990).

Antipyrine was used extensively by early researchers (Krabill et al., 1951 and Wellington et al., 1954). However, more precise results were obtained by using urea in cattle by Preston and Koch (1973). More recently, Hammond (1984; 1988) suggested that urea dilution is a useful method in determining body composition and is a relatively quick and simple method. Also, deuterium oxide (D_2O) has been used to measure total body water space. Deuterium oxide was first used in humans and extensively studied by Pinson (1952). Much work has been done in sheep (Till and Downes, 1962; Foot and Greehalgh, 1970; Farrell and Reardon, 1972; Trigg et al., 1978). These experiments used deuterium oxide to estimate total body water in an effort to predict body composition. The reseachers looked at the ruminant water space as one pool, combining both gut water and empty body water into the total body water pool. The combination of pools introduced a large degree of error, because water in the digestive tract is not related to carcass or empty body components (McCarthy, 1981). In an effort to find a more reliable predictor of body water, Byers (1979) developed a procedure to estimate both gut water and empty body water by using a two-pool system. Byers (1979) used tracer kinetics, formulated by Shiply and Clark (1972), to aid in the separation of the pools. Byers (1979) reported the two-pool system to be highly correlated (r^2=.965) to chemical analysis. The two-pool system was then successfully used with cattle (Byers, 1979; McCarthy, 1983; Ferrell and Jenkins, 1984; Miller et al., 1988). In an extensive review by Schroeder (1990), it was suggested that because of numerous and conflicting results, further studies need to be conducted on the best experimental procedures for using deuterium oxide.

Recently, ultrasound has gained popularity, and this approach appears to have many applications in the livestock industry (Turner et al., 1990; Wilson, 1992). The use of ultrasonics was first documented by Wild (1950). Other researchers (Clause, 1957; Panier, 1957; Price et al., 1958) used ultrasound for estimating carcass composition. Ultrasonics is the act of passing high-frequency sound signals through tissues. As the sound signals pass through the tissues, they reflect back when encountering different densities of tissue. These signals are then transmitted into a visual form by an oscilloscope (Topel, 1988). Through the use of real-time ultrasound or B-mode visualization, an accurate, instantaneous picture of the depth of subcutanous fat as well as an outline of the loin eye can be produced (Whittaker et al., 1992). It has been documented that highly trained personnel can accurately predict fat and muscle measurements by the use of ultrasound (Bass, 1982; Miller et al., 1986; Recio et al., 1986; Robinson et al., 1992). Extensive research using ultrasound measurements as an indicator of muscle and fat was reported for sheep (Gooden et al., 1980; Bass, 1982; Kempster et al., 1982; Cameron and Smith, 1985; Edwards et al., 1989; Turlington, 1990; Ramsey, 1991), as well as cattle (Smith et al., 1988; Dolezal et al., 1989; Duello et al., 1990; Houghton et al., 1990; Perry et al., 1990; Cross and Whittaker, 1992; Rouse et al., 1992). Edwards et al. (1989) studied various ultrasound measurements to determine composition of lamb carcasses. The authors reported that because ultrasonic measurements could not give a measurement of internal fat it was not a reliable indicator of carcass composition, and that more accurate ultrasonic measurements were needed. The researchers (Edwards et al., 1989) concluded that a visual estimation of body fat by a trained livestock evaluator is still a preferred the best predictor of lamb cutability. These findings were based on the past grading system where kidney, pelvic and heart (KPH) fat were factors in determining yield grade. Presently, KPH is removed during the slaughter process before hot carcass weights are taken. The present method of assigning yield grades in lambs is based solely on 12th rib fat depth (Boggs and Merkel, 1993). Turlington (1990) scanned 160 ram lambs for 12th rib back fat and then slaughtered them. The author reported acceptable accuracy in measuring backfat could be obtained. Because lambs were of a narrower range in fat depth, the accuracy of predicting extremes in fat depth is limited (Houghton and Turlington, 1992). Ramsey et al., (1991) found that a single ultrasonic measurement was a better indicator of percent carcass fat than that of a needle probe at the at the dorsal midline. The workers concluded that the best indicator of percentage carcass fat was an ultrasound measurement of shoulder fat over the 5th rib. More success has been found in measuring fat and muscle in cattle (Kempster, 1981; Rouse et al., 1992). More recently, research has focused on measuring marbling (Brethour, 1990; Zhang, 1994), as well as total carcass composition and retail value. If this research proves successful, a true estimation of composition of an animal and its value can be made without damaging the carcass or the animal's value (Cross and Whittaker, 1992).

OBJECTIVE

The ever increasing demand by the consumer for leaner meat products has left sheep producers faced with the problem of marketing leaner lambs that still grow rapidly and efficiently. Since the 1960's, the consumer's pressure on the meat animal industry has slowed the production of fat. However, excess fat still has the most influence on the amount of saleable product within a carcass (Smith and Carpenter, 1973). The sheep industry has been notorious for producing lambs with excess fat. Tatum et al. (1988), in a national survey, reported that over 40% of the lambs surveyed were yield grade 4 and above. For the sheep industry to maintain, as well as gain market share, steps must be taken to reduce the amount of fat on lamb carcasses.

Many Midwestern producers are examining different feeding regimes in an effort to market leaner carcasses. To accomplish this, numerous Michigan producers are feeding 100% alfalfa dehydrated pellets. Many of these producers have assumed that feeding a 100% forage diet will result in leaner carcasses and somewhat slower growth with less risk of lambs going off feed. The present study was developed to examine effects of energy density in the diet upon total body composition when lambs have ad libitum access to dietary treatments. This experimental design would allow maximum average daily gain, but would presumably provide a better understanding of the role that a forage diet plays in reducing fat content of the carcass as well as its effect on visceral organ mass.

The null hypothesis of the experiment was:

Lambs consuming a 100% forage diet will have (1) a greater average daily gain, (2) lighter gastrointestinal component weights, and (3) a greater percentage of carcass lean than lambs fed a concentrate diet when both are slaughtered at a similar weight endpoint.

MATERIALS AND METHODS

Experiment I - Individually fed lamb feeding study.

Lambs used in this study were selected from the Michigan State University commercial ewe flock. Thirty-six Suffolk X Dorset X Rambouillet wether lambs two months of age were used. All lambs were born twin or triplet within a 10-d period. Siblings were allocated to different dietary treatments. From birth to weaning, a pelleted creep diet was available to lambs. After lambs were weaned, the creep diet and alfalfa hay were fed free choice for the two-week period prior to the start of the trial. Lambs were vaccinated for enterotoxemia and tetanus at 30 d of age and again at weaning. Lambs were dewormed at weaning and at the onset of the trial. Lambs were shorn prior to the initiation of the trial. Initial weights were taken following a 24-h fast. Six lambs were randomly selected from the 35 lambs for determination of initial carcass characteristics and composition.

Lambs were assigned to one of two dietary treatments. The high concentrate (CONC) diet (Table 1) was formulated and processed as a complete pelleted ration that consisted of a 75% corn-soybean meal mixture and 25% roughage. Metabolizable energy (ME) content of the CONC diet was calculated from NRC (1985) to be 2.79 Mcal/kg. The 100% forage (ALFA) diet consisted of 100% dehydrated alfalfa pellet. The 100% dehydrated alfalfa pellet had a metabolizable energy (ME) value (NRC, 1985) of 2.17 Mcal/kg for a pellet containing 17% CP. The dehydrated alfalfa pelleted diet was obtained from a commercial source that utilized second and third crop hay. Both diets were formulated to contain a crude protein content that was in excess of the requirement for early weaned lambs with moderate growth potential (NRC, 1985), so that dietary protein would not be a limiting factor in this study.

Table 2 shows the chemical analysis of each diet. The CONC diet had a calculated ME content that was in excess of the NRC requirement for ME of early weaned lambs with moderate growth potential, whereas the ALFA diet was calculated to have less than the daily requirement of ME. Lambs were individually fed one of the two diets at 12-h intervals. Diets were fed ad libitum amounts twice daily with orts measured at each feeding. Trace mineral salt, as well as clean H_2O, were available at all times. Feedstuffs were collected at weekly intervals and analyzed for dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) (AOAC. 1984). Total feed, average daily feed, and ME intakes were determined from individual feed consumed.

Lambs were individually housed in 1.4 x 1.4 m^2 pens. Lambs were weighed every 7 d prior to the a.m. feeding to monitor weight gain. A final weight of 52 kg was chosen as the targeted endpoint of the feeding period. The endpoint selection was based on the body type and frame size of the lambs in this study to ensure that a majority of the lambs would reach a quality grade of choice and a yield grade 2. As lambs attained the targeted weight endpoint of 52 kg , they were slaughtered 48 h after the weekly weigh date.

Table 1. Composition of Concentrate diet

Item	% dry matter
Corn meal	44.88
Dehydrated alfalfa meal	25.50
48 % soybean meal	18.73
Cane molasses	7.3
Pellet binder	1.7
Limestone	.55
Dical 18.5	.55
Ammonium chloride	.39
Salt	.39
Vitamin E	.06

Table 2. Chemical analyses of dietary treatments

	Dietary treatment	
Item	CONC	ALFA
Dry matter, %	88	93
Crude protein, %	21.0	17.2
NDF	19.5	40.7
ADF	9.7	25.9
Nem[a]	1.83	1.34
Neg[a]	1.21	0.77
Metabolizable energy, Mcal/kg[a]	2.79	2.17

[a] Calculated from NRC (1985) values.

As lambs that attained the final targeted weight were fasted 24 h and transported to Michigan State University's meat laboratory. Prior to slaughter, a final shrunk weight was obtained. Euthanasia was accomplished through use of electrical stimulation. Exsanguination was done by severing the carotid artery and jugular vein. Following exsanguination, the pelt and head were removed and weighed. The gastro-intestinal tract (GIT) and liver were removed, weighed to the nearest pound and converted to the nearest .1 kg. The GIT was then ligated into the following components: rumino-reticulum, omasum, abomasum, small intestine, and large intestine. After individually weighing each component, contents were removed and empty weights and weights of dissected fat associated with each component were recorded. All GIT component weights were measured to the nearest .1 g. Heart and lung weights were also obtained and weighed to the nearest .1 g.

The carcasses were washed and a hot carcass weight was obtained. Following a 24-h chill at 2°C, carcasses were weighed to the nearest .5 kg and ribbed between the 12th and 13th ribs. Carcass data were collected by trained university personnel. Backfat was determined by averaging measurements over the center of the right and left longissimus muscles between the 12th and 13th ribs. A lower rib fat measurement, taken 4 cm ventral to the longissimus muscle, was also taken. Areas of the right and left longissimus (ribeye) muscles were measured using a grid with 20 dots per square inch. Mean longissimus muscle area was calculated using the measurements obtained from the right and left sides. Leg conformation was subjectively evaluated and carcasses were assigned a numerical leg score that corresponded to prime, choice, good, or utility, with 11=choice$^{\circ}$, 12=choice^{+}, etc. (USDA, 1969). Yield grade was determined (USDA, 1989) by the following equation: yield grade = .4 + (10 x average backfat thickness (inches)). Quality grade was based on a composite evaluation of conformation, maturity, and quality of lean flesh. Conformation included an assessment of overall muscling with emphasis on the greatest development of muscling in the highest priced primal cuts: leg, loin, rack, and shoulder. Conformation was assigned a numerical score that corresponded to prime, choice, good, or utility grades (17=choice$^{\circ}$, 18=choice^{+}). Maturity, an assessment of the physiological age of the animal, was determined by an assessment of the break joint as well as shape and color of the ribs. Maturity was scored from 1 to 5, with 5 having the surface of the break joint moist, and porous, as well as bright red; also the ribs would be red. A score of 1 would be progressively less red, with drier and harder appearing break joints and ribs. Quality of lean flesh was evaluated by the quantity of fat streaking on the inside of the flank muscles, firmness of the lean flesh and external fat. Lambs were assigned a numerical quality grade that corresponded to prime, choice, good, or utility grade (17=choice$^{\circ}$, 18=choice^{+}) (Boggs and Merkel, 1993).

For compositional analyses, carcasses were halved. Care was taken in splitting the carcass to ensure minimal deviation from the medial plane of the vertebrae. Any deviation from the medial plane was instantly corrected by repositioning the carcass before proceeding. However, if any unevenly spilt bone did occur, it was removed from the corresponding side and added to the other side. The carcasses were separated into fore- and hind-saddles between the 12th and 13th ribs. Kidneys and kidney and pelvic fat was removed and weighed. Percent kidney and pelvic fat was determined by dividing the amount of fat removed from the abdominal cavity and pelvic area by chilled carcass weight.

Two methods were used to calculate dressing percent. First, dressing percent was calculated as carcass weight with kidney fat intact because kidney fat was included in the overall compositional analysis of the carcass. Current industry standards require kidney fat to be removed at slaughter before hot carcass weight is obtained. Thus, a dressing percent with kidney and pelvic fat removed from the carcass was also calculated. The right side of the carcass was fabricated into wholesale, retail, and miscellaneous cuts, according to the National Association of Meat Purveyors buyers guide (NAMP, 1992) and used to determine yields and compositional analyses. The following cuts were fabricated: square cut four-rib shoulder, neck removed; eight-rib rack; one-rib loin; leg; foreshank; breast; and miscellaneous cuts (flank, neck, kidney and pelvic, fat). The cuts were vacuumed packed and stored at -25° C. The left side of the carcass was marketed through Michigan State University meats lab to compensate for lamb cost.

Cuts were thawed at 4°C for 24 to 36 h. Cuts were weighed and separated into tissue and bone. Bones were dissected completely free of muscle, fat, tendons, and ligaments, but not cartilage. Tissue weights were recorded for each cut. Soft tissue was then ground three times through a .5 cm plate and mixed thoroughly by hand between grindings to assure a representative sample was taken. A 400 to 500 g sample was collected and stored in a whirl-pac bag at -30° C until further preparation. Samples were thoroughly homogenized in 1 to 2 l of liquid nitrogen in a Waring blender until a powdered substance was obtained. Powdered samples were placed in whirl-pac bags and left open in a -30°C cooler for 24 h to allow carbon dioxide sublimation prior to sealing. After sealing, samples were stored at -30°C until analyses.

Duplicate samples were analyzed for dry matter (DM), protein and ether extract. One- to 2- g samples were measured into dried aluminum pans and dried at 60°C for approximately 15 to 18 h. Weight loss was recorded after cooling the samples in a desiccator and dry matter was calculated (AOAC, 1984). Dried samples were stored for ether extract determination in a dry room at 46°C. Duplicate samples were analyzed for fat content for 12-h in a Soxhlet apparatus followed by a 12 h evaporation period. Samples were then dried at 60°C for 12 h before reweighing, and fat content was calculated (AOAC, 1984). Crude protein of duplicate samples was calculated from total nitrogen. Total nitrogen (Kjeldahl) was determined using a Technicon auto-analyzer system (AOAC, 1984). Samples weighing 1 to 2 g were analyzed. Analyses of DM, ether extract, and nitrogen samples were repeated until a difference of less than 1.5 % from the mean was obtained. Percentage DM, protein and fat were used to determine the total composition of each cut.

To calculate accretion rates of protein and fat, equations were adopted from Anderson et al. (1988). The equation adopted is as follows:

$$a = ((bc) - (def))/g$$

where:

a = estimated accretion rate of carcass fat or protein (g/d) for a particular lamb

b = carcass weight (g)

c = estimated carcass fat or protein (%)

d = initial live weight (g)

e = average dressing percentage of initial slaughter group

f = initial estimated carcass protein or fat (%)

g = number of days on feed

Data were analyzed using analysis of variance, with diet as the main effect. Analysis was performed using General Linear Models of SAS (SAS, 1987). Differences between diets were tested using Bonferroni t test. Least square means and standard errors are presented in the tables that follow. The ANOVA model for the trial was as follows: $Y_{ij} = u + Ti + E_{ij}$

where: Y_{ij} = Variable being measured (i.e., performance & carcass data).

u = Overall mean.

T_i = Effect of treatment (ALFA or CONC).

E_{ij} = Experimental Error.

Experiment II - Group-fed lamb feeding study.

Lambs used in this study were ofspring selected from the Michigan State University commercial ewe flock. Forty-eight Suffolk X Dorset X Rambouillet wether lambs 2 mo of age were used. All lambs were born within a 10-d period of each other. From birth to weaning, lambs were fed a pelleted creep ration. Lambs were weaned at 60 d of age. The pelleted creep diet and alfalfa hay were fed free choice for 2 wk prior to the start of the trial. Lambs were vaccinated for enterotoxemia and tetanus at 30 d of age and again at weaning. Lambs were wormed at weaning and at the onset of the trial. Lambs were shorn prior to the initiation of the trial. Initial weights were taken following a 24-h fast.

Lambs were blocked by weight and randomly assigned to one of two dietary treatments. Six weight blocks with eight lambs/block and four lambs/pen were randomly assigned to pen. The high concentrate (CONC) diet (Table 1) was formulated and processed as a complete pelleted ration that consisted of a 75% corn-soybean meal mixture and 25% roughage. The ME content of the CONC diet was calculated from NRC (1985) feed values to be 2.79 Mcal/kg (NRC, 1985). A 100% forage (ALFA) diet consisted of 100% dehydrated alfalfa pellet. The 100% pellet had a NRC (1985) book value of 2.17 Mcal ME/kg for a pellet containing 17% crude protein. The dehydrated alfalfa pelleted diet was obtained from a commercial source that utilized second and third crop hay. Both diets were formulated to have a CP content in excess of the requirement for early weaned lambs with moderate growth potential (NRC, 1985) so that dietary protein would not be a limiting factor in this study. Table 2 shows the chemical analysis of each diet. The CONC diet had a calculated ME content that was in excess of the NRC (1985) requirement for ME of early weaned lambs with moderate growth potential, whereas the ALFA diet was calculated to have less than the daily requirement of ME. Diets were fed ad libitum amounts twice daily with orts measured at each feeding. Lambs were fed at 12-h intervals at 6:00 A.M. and P.M. Trace mineral salt, as well as clean water, was available free choice at all times. Feedstuffs were collected at weekly intervals and analyzed for DM, CP, NDF and ADF (AOAC. 1984).

Four lambs per group were penned in 3.7 x 1.8 m^2 pens. Lambs were weighed every 7 d prior to the A.M. feeding to monitor weight gain. A final weight of 52 kg was chosen as the targeted weight endpoint. This was based on the body type and frame size of the lambs in this study to ensure that a majority of the lambs would reach a quality grade of choice and a yield grade of 2.

Lambs were slaughtered in two groups. Both groups were slaughtered at the targeted weight endpoint of 52 kg. Lambs that had attained final weight were transported 106 km to Wolverine Packing, Detroit, Michigan. Euthanasia was accomplished through use of electrical stimulation. Exsanguination was done by severing the carotid artery and jugular vein. Following exsanguination, the pelt and head were removed. The GIT was removed followed by removal of the kidneys and kidney and pelvic fat from the carcass. These operations were accomplished by trained personnel manually removing the fat. The carcass was then washed and a hot carcass weight was obtained. Kidneys and kidney and pelvic fat were bagged and identified after removal from the carcass. The sample was transported back to Michigan State University where they were allowed to chill at 4°C. Kidneys were then removed from fat and kidney and pelvic fat was weighed to the nearest .1 g. Following a 24-h chill at 2°C, lamb carcasses were ribbed between the 12th and 13th ribs. Carcass data were collected by trained university personnel. Average backfat was measured over the center of the right and left longissimus muscle between the 12th and 13th ribs. Areas of the right and left longissimus muscles were measured using a grid with 20 dots / square inch. Mean longissimus muscle area was calculated using the measurements obtained from the right and left sides. Leg conformation was subjectively evaluated and carcasses were assigned a numerical score that corresponded to prime, choice, good, or utility, with 11=choice°, 12=choice⁺, etc. (USDA, 1969). Yield grade was determined (USDA, 1989) by the following equation: yield grade = .4 + (10 x average backfat thickness (inches)). Quality grade was based on a composite evaluation of conformation, maturity, and quality of lean flesh. Lambs were assigned a numerical quality grade that corresponded to prime, choice, good, or utility grades (17=choice°, 18=choice⁺).

Data were analyzed by analysis of variance with diet as the main effect. Analysis was performed using General Linear Models of SAS (SAS, 1987). Least square means and standard errors are presented in the tables. The interaction of treatment and block was used as error term for each varrible measured. The ANOVA model for the trial was as follows: $Y_{ijk} = u + T_i + B_j + TxB_{ixj} + E_{ijk}$

where: Y_{ijk} = the varrible measured.

u = Overall mean.

T_i = Diet (main effect).

Bj = Pen

TxB_{ixj} = Interaction of treatment and block.

E_{ijk} = Experimental Error.

RESULTS

Experiment I - Individually fed lamb feeding study.

Feedlot performance for each dietary treatment, CONC and ALFA, is shown in Table 3. Mean starting weights of lambs were the same; 30.5 kg for CONC-fed lambs and 30.6 kg for ALFA-fed lambs. There was no difference in mean final weight of lambs off-test, since lams were slaughtered at a constant weight endpoint. Thus, total live weight gain was not impacted by treatment; however, as time on feed increased, ADG decreased. Concentrate-fed lambs required 10 fewer days (P<.05) to reach the targeted weight endpoint of 52 kg than lambs fed the ALFA diet (Table 3). Average daily gains of lambs were higher (P<.01) for CONC at 425 g/d than ALFA fed lambs at 344 g/d. Feed efficiency, expressed as live animal gain per kg of feed, favored the CONC-fed lambs (Table 3).

Both daily and total dry matter feed intakes on are shown in Table 4. ALFA-fed lambs consumed more (P<.01) dry matter, both on a daily basis and over the duration of the trial. Metabolizable energy intakes were similar on a daily basis, and for the duration of the trial. Results of slaughter data between dietary treatments are given in Table 5. Because lambs were slaughtered at a constant weight endpoint no differences were found between treatments for slaughter

Table 3. Effect of dietary treatment on lamb performance

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Initial wt, kg	30.5	.70	30.6	.70	.94
Final wt, kg[a]	52.4	.30	51.8	.30	.19
Gain, kg	21.9	.70	21.3	.70	.53
Days on feed	53	3.0	63	3.0	.04
ADG, g/d	425	15	344	16	.001
Gain/feed, kg/kg	.26	.01	.18	.01	.0001

[a] Final wt was measured after a 24 h fasting period.
[b] Feed efficiency is expressed as kg gain / kg feed intake.

Table 4. Effect of dietary treatment on total and daily feed intake of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Total intake					
As fed, kg	100.8	6.2	133.4	6.5	.001
Dry matter, kg	86.2	5.6	124.0	5.8	.0001
ME, Mcal[a]	247.5	13.7	268.9	14.1	.29
Average daily intake					
As fed, kg	1.91	.02	2.11	.03	.0001
Dry matter, kg	1.64	.02	1.96	.02	.0001
ME, Mcal[a]	4.89	.32	4.35	.33	.25

[a] Metabolizeable energy content of feed was calculated from NRC (1985) values.

weight when expressed as a shrunk live weight prior to slaughter. Hot carcass weights were not affected by treatment. When expressing chilled carcass weight with the kidney and pelvic fat as a component of the carcass, CONC-fed lambs had significantly heavier carcasses (P<.05). Thus, dressing percentage was greater (P<.07) for CONC-fed lambs.

Weights for liver, lungs and heart are shown in Table 6. Lambs consuming the ALFA diet had heavier (P<.05) liver weights. No differences were found for lung and heart weights between dietary treatments. Table 7 presents full (including digesta) weight of the components of the GIT. The omasum, and small and large intestine weights were heavier (P<.01) for ALFA. Full weights (FW) for rumino-reticulum and abomasum were unaffected by dietary treatment. Empty weights of the GIT and corresponding components,shown in Table 8, followed the pattern of gut component weights including contents. There were no differences between rumino-reticulum or abomasum empty weights. Mean empty weight of GIT was heavier (P<.01) in ALFA fed lambs. Likewise, omasum (P<.01) and small and large intestine empty weights were greater (P<.05) for ALFA-fed lambs.

Fat associated with the whole GIT, as well as separate GIT components, is shown in Table 9. Visceral fat associated with the rumino-reticulum, omasum, abomasum, small intestine and large intestine was similar amoung lambs from both treatments. Omental fat expressed as the sum of the rumino-reticulum, omasum and abomasum was also similar. Collectively, the total amount of fat associated with GIT was similar (1.6 kg) for lambs on both treatments, which is

Table 5. Effect of dietary treatment on slaughter measurements of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Slaughter wt, kg	49.4	.5	48.8	.5	.40
Hot carcass wt, kg	26.5	.4	25.6	.4	.10
Chilled carcass wt, kg	26.2	.3	25.2	.3	.04
Dressing %[a]	53.1	.5	51.7	.5	.07
Dressing %[b]	52.0	.5	50.5	.5	.05

[a] Dressing percent calculated with kidney and pelvic fat within the carcass.
[b] Dressing percent calculated with kidney and pelvic fat removed from the carcass.

Table 6. Effect of dietary treatment on liver, lung and heart weights of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Liver, g	922.9	18.8	986.6	18.8	.02
Lungs, g	803.7	27.3	768.6	28.3	.38
Heart, g	378.9	11.9	376.7	12.3	.90

Table 7. Effect of dietary treatment on full stomach weights of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Rumino-reticulum, g	5230.4	309.9	5426.3	320.8	.66
Omasum, g	228.6	11.5	298.9	11.9	.0002
Abomasum, g	604.6	42.7	569.9	44.2	.58
Small intestine, g	1698.4	54.7	1992.7	56.6	.001
Large intestine, g	12240	289	13095	299	.05

Table 8. Effect of dietary treatment on empty stomach weights of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Rumino-reticulum, g	893.1	24.8	958.7	25.7	.08
Omasum, g	110.7	5.8	137.7	6.0	.003
Abomasum, g	181.4	8.1	178.4	8.4	.80
Small intestine, g	852.9	31.7	976.4	32.8	.02
Large intestine, g	417.7	23.0	488.9	23.8	.04
Gasto-intestinal tract, g	2455.7	66.5	2740.1	68.8	.01

Table 9. Effect of dietary treatment on associated fat of the gastro-intestinal tract of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Rumino-reticulum, g	693.4	65.7	782.9	68.0	.35
Omasum, g	19.5	3.4	23.6	3.4	.42
Abomasum, g	126.0	12.0	127.7	11.7	.93
Omental, g[a]	835.3	39.7	892.1	41.2	.60
Small intestine, g	427.3	25.1	478.1	26.0	.17
Large intestine, g	256.6	16.1	265.1	16.7	.72
Gastro-intestinal tract, g	1538.5	88.7	1642.6	92.4	.42

[a]Sum of fat associated with the rumino-reticulm, omasum and abomasum.

approximately 3% of the body weight of the lambs.

Carcass cutability measurements summarized by dietary treatment are shown in Table 10. No differences were found between treatments for backfat thickness, lower rib fat and yield grade. Ribeye area and leg conformation score were also similar. Total amount of kidney and pelvic fat removed from the carcasses as well as the percentage of kidney and pelvic fat in the carcasses were similar across dietary treatments.

Quality parameters were not affected by dietary treatment as shown in Table 11. Flank streaking, lean color, rib color and conformation scores were the same between treatments. Thus, quality grades between CONC and ALFA-fed diets were not different.

Percentages of fat, protein, bone, and water in carcasses are given in Table 12. When expressing the amount of fat and protein as a percentage of carcass weight, no differences were found between dietary treatments.

Daily accretion rates of fat, protein, bone and water are presented in Table 13. Total grams of fat deposited within the carcass on a daily basis were greater ($P<.05$) for CONC-fed lambs. Lambs consuming the CONC diet also deposited greater ($P<.05$) amounts of protein than ALFA-fed lambs. Greater amounts of water were deposited per d for the CONC than for the ALFA-fed lambs. Thus, lambs consuming the CONC diet had greater ($P<.01$) rates of total carcass gain than the ALFA-fed lambs. When expressing daily accretion as a ratio of the kg of fat deposited per kg of protein, no difference was found between treatments.

Table 10. Effect of dietary treatment on carcass cutability measurements of lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Backfat thickness, cm	.38	.04	.46	.05	.17
Lower rib fat thickness, cm	1.21	.10	1.17	.10	.77
Yield grade	1.89	.17	2.24	.18	.17
Ribeye area, cm^2	15.4	.5	14.1	.5	.07
Leg score	12.0	.1	11.8	.1	.25
Total kidney fat, g	560.0	52.4	566.0	54.2	.94
Total kidney fat, % ccw	2.10	.18	2.24	.19	.61

[a] 10 = choice$^-$; 11= choice$^\circ$; 12 = choice$^+$.

Table 11. Effect of dietary treatment on quality characteristics of lamb carcasses

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Flank streaking[a]	3.20	.17	3.14	.18	.82
Lean color[a]	3.20	.15	3.21	.15	.95
Rib color[a]	3.27	.18	3.29	.19	.94
Conformation[b]	12.00	.13	11.79	.13	.25
Quality grade[c]	17.93	.07	18.07	.07	.17

[a] 1 = least desirable; 5 = most desirable.
[b] 10 = choice$^-$; 11 = choice^o ; 12 = choice $^+$.
[c] 17 = choice$^-$; 18 = choice^o ; 19 = choice $^+$.

Table 12. Effect of dietary treatment on percent composition of removed carcass tissue

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Fat, %	22.23	.92	22.37	.95	.92
Protein, %	11.63	.16	11.53	.16	.67
Moisture, %	48.20	.51	48.04	.53	.83
Bone, %	17.93	.44	18.06	.45	.84

Nine cuts were analyzed to determine composition of the carcass. Each cut's bone-in and boneless tissue weight is recored. Boneless tissue was individually analyzed for DM, fat, and protein. Total composition of the cut was then calculated and reported in each table. Values for shoulder and leg weights are shown in Table 14 and 15, respectively. Concentrate-fed lambs had heavier ($P<.01$) shoulder cut weights than ALFA-fed lambs. Boneless tissue weights were heavier ($P<.01$) for CONC-fed lambs. Chemical analyses for DM, fat and protein of shoulder tissue did not differ between dietary treatment. When expressing the total composition of the cut, dietary treatment had no effect on the proportions of fat, protein, bone, or water within each cut.

Effect of dietary treatment on the leg cut (Table 15) was similar to results of the shoulder cut. Dietary treatment affected leg cut weight as well as boneless tissue weight. Concentrate-fed lambs had 3.5 % heavier ($P<.05$) leg cut weights than ALFA-fed lambs. Boneless tissue weights were 4.0 % heavier ($P<.01$) for CONC-fed lambs. Dietary treatment did not affect chemical analyses of boneless tissue for DM, fat, or protein. Treatment had no effect on the percentage of fat, protein, bone or water found in the leg cut.

Values for the rack and loin are shown in tables 16 and 17, respectively. Concentrate-fed lambs tended to have heavier ($P<.10$) cut weights for both the rack and loin.; however, boneless tissue weights for each cut were unaffected by treatment. Chemical analyses of boneless tissue of the seperate cuts, as well as composition of those cuts, were not affected by dietary treatment.

Table 13. Effect of dietary treatment on daily tissue daily accreation rates

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Fat, g	75.6	4.2	59.5	4.4	.01
Protein, g	22.8	1.1	16.4	1.1	.0003
Bone, g	17.1	1.9	10.7	2.0	.03
Moisture, g	91.7	4.2	66.7	4.3	.0003
Carcass gain,g	207.5	7.0	157.0	7.3	.0001
Fat / protein	3.35	.27	3.84	.28	.222
Days on Feed	53	3.0	63	3.0	.04

Table 14. Effect of diet on composition of shoulder cut

Item	CONC	SEM	ALFA	SEM	*P*
	Dietary treatment				
Shoulder cut wt, kg	2.87	.05	2.64	.05	.01
Boneless shoulder cut tissue wt, kg	2.35	.03	2.18	.03	.002
% dry matter, boneless tissue	39.8	.7	38.9	.7	.34
Analysis of boneless tissue, DM					
% fat	59.9	1.1	59.5	1.1	.81
% protein	35.5	1.1	36.7	1.1	.46
Composition of shoulder cut, fresh basis					
% fat	19.6	.7	19.2	.7	.68
% protein	11.5	.2	11.7	.2	.58
% water	49.4	.7	50.5	.7	.23
% bone	16.6	.5	16.7	.5	.86

Table 15. Effect of diet on composition of leg cut

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Leg cut wt, kg	4.00	.04	3.86	.04	.02
Boneless leg cut tissue wt, kg	3.23	.04	3.08	.04	.01
% dry matter	34.3	.6	35.3	.6	.25
Analysis of boneless tissue, DM					
% fat	47.1	1.4	48.2	1.5	.58
% protein	47.0	1.3	45.4	1.3	.38
Composition of leg cut, wet basis					
% fat	13.1	.7	13.7	.7	.52
% protein	13.0	.2	12.7	.2	.34
% water	53.0	.5	51.7	.5	.05
% bone	19.3	.3	19.6	.3	.54

Table 16. Effect of diet on composition of rack cut

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Rack cut wt, kg	1.46	.04	1.34	.04	.07
Boneless rack cut tissue wt, kg	1.19	.04	1.11	.04	.14
% dry matter	49.6	1.2	5.5	1.2	.61
Analysis of boneless tissue, DM					
% fat	71.9	1.3	72.7	1.3	.66
% protein	25.0	1.2	24.0	1.2	.58
Composition of rack cut, wet basis					
% fat	29.2	1.4	30.3	1.5	.59
% protein	10.0	.2	9.7	.2	.37
% water	40.8	.7	40.2	.8	.57
% bone	18.0	.8	16.9	.8	.33

Table 17. Effect of diet on composition of loin cut

Item	Dietary treatment				
	CONC	SEM	ALFA	SEM	*P*
Loin cut wt, kg	1.40	.05	1.28	.05	.08
Boneless loin cut tissue wt, kg	1.15	.04	1.08	.04	.17
% dry matter, boneless tissue	44.6	1.0	45.2	1.0	.65
Analysis of boneless tissue, DM					
% fat	64.8	1.6	65.4	1.7	.81
% protein	32.0	1.4	31.5	1.4	.79
Composition of loin cut, wet basis					
% fat	24.1	1.3	25.4	1.4	.51
% protein	11.8	.3	11.7	.3	.92
% water	45.8	1.0	46.1	1.1	.86
% bone	14.3	.9	14.9	.9	.64

Tables 18,19, 20, 21, and 22 present cut weights and boneless cut weights, as well as chemical analyses of the boneless tissue and composition of each cut for breast, flank, shank, neck, and kidney fat, respectively. Dietary treatment had no effect on cut or boneless cut weights of these cuts. Chemical analysis of each cut was unaffected by dietary treatment. Additionally, the proportion of fat, protein, bone, and water in each cut was unaffected by diet.

Table 18. Effect of diet on composition of breast cut

	Dietary treatment				
Item	CONC	S EM	ALFA	SEM	*P*
Breast cut wt, kg	1.17	.05	1.20	.06	.77
Boneless breast cut tissue wt, kg	.97	.04	.96	.04	.96
% dry matter	49.9	.9	49.7	1.0	.88
<u>Analysis of boneless tissue, DM</u>					
% fat	74.3	1.0	73.8	1.1	.75
% protein	23.3	.9	23.4	1.0	.96
<u>Composition of breast cut, wet basis</u>					
% fat	30.7	1.1	29.8	1.1	.58
% protein	9.5	.23	9.3	.24	.66
% water	41.3	.8	40.7	.9	.64
% bone	16.9	.8	17.3	.8	.70

Table 19. Effect of diet on composition of flank cut

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Flank cut wt, kg	.489	.020	.474	.021	.63
Boneless flank cut tissue wt, kg	.488	.020	.474	.021	.62
% dry matter	48.71	1.17	46.69	1.22	.24
Analysis of boneless tissue, DM					
% fat	71.48	1.52	69.05	1.57	.28
% protein	25.95	1.34	27.96	1.41	.31
Composition of flank cut, wet basis					
% fat	35.1	1.5	32.4	1.6	.23
% protein	12.4	.4	12.9	.4	.40
% water	51.2	1.2	53.2	1.2	.25
% bone	0	0	0	0	0

Table 20. Effect of diet on composition of shank cut

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Shank cut wt, kg	.533	.01	.523	.01	.54
Boneless shank cut tissue wt, kg	.332	.01	.324	.01	.59
% dry matter	32.8	.5	32.9	.5	.94
Analysis of boneless tissue, DM					
% fat	41.5	1.6	42.4	1.6	.70
% protein	53.5	1.5	51.0	1.6	.25
Composition of shank cut, wet basis					
% fat	8.6	.5	8.7	.5	.86
% protein	10.9	.3	10.3	.3	.15
% water	41.7	.6	41.5	.7	.78
% bone	37.6	1.1	37.6	1.1	.97

Table 21. Effect of diet on composition of neck cut

	Dietary treatment				
Item	CONC	S EM	ALFA	SEM	*P*
Neck cut wt, kg	.390	.01	.370	.01	.28
Boneless neck cut tissue wt, kg[b]	.286	.01	.274	.01	.37
% dry matter	39.7	1.1	39.6	1.1	.94
Analysis of boneless tissue, DM					
% fat	60.1	1.6	57.0	1.6	.19
% protein	37.3	1.3	38.4	1.4	.59
Composition of neck cut, wet basis					
% fat	17.7	1.0	16.9	1.0	.58
% protein	10.8	.4	11.1	.4	.55
% water	44.3	.84	44.5	.87	.85
% bone	24.8	1.3	24.6	1.4	.90

Table 22. Effect of diet composition of kidney fat

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Kidney fat cut wt, kg	.297	.027	.285	.028	.76
Boneless kidney fat cut tissue wt, kg	.297	.027	.285	.028	.76
% dry matter	84.1	1.1	82.3	1.1	.27
Analysis of boneless tissue, DM					
% fat	97.6	.3	97.2	.3	.23
% protein	2.7	.2	2.9	.2	.42
Composition of kidney fat cut, wet basis					
% fat	82.1	1.2	80.2	1.2	.24
% protein	2.3	.2	2.4	.2	.53
% water	15.9	1.1	17.6	1.1	.27
% bone	0	0	0	0	0

Experiment II-Group fed lamb feeding study.

Performance data for dietary treatments, CONC and ALFA, are shown in Table 23. Starting weights of lambs were identical at 26.1 kg for lambs in each of the treatments. No differences were found for final weight of lambs off-test as lambs were slaughtered at a constant weight endpoint. Thus, total live weight gain was not affected by treatment. Alfalfa-fed lambs reached the final slaughter weight at 81.0 d versus 78.6 d for the CONC. However, neither days on feed nor ADG were affected by dietary treatment.

Total and daily feed intakes are presented in Table 24. Intakes are expressed on a per lamb basis calculated from the average intake per lamb per pen. ALFA-fed lambs consumed more ($P<.01$) feed, both on a daily basis and for the entire trial. When expressing intake on a DM basis, ALFA lambs consumed more ($P<.01$) feed for the whole trial and on a daily basis.

Differences between dietary treatment for carcass measurements are shown in Table 25. Hot carcass weights were heavier ($P<.05$) for CONC than for ALFA-fed lambs. Dressing percentage, when calculated using hot carcass weight with kidney and pelvic fat removed, was greater ($P<.05$) for CONC-fed lambs. Ribeye area and leg conformation score were unaffected by dietary treatment. Dietary treatment did not affect backfat but yield grade was shown to be lower ($P<.05$) for ALFA-fed lambs even though they differed only .01 of a yield grade. Diet had no effect on the weight of kidney and pelvic fat of each carcass. Quality grade of lambs was not affected by dietary treatment.

Table 23. Effect of dietary treatment on performance measurements of lambs group fed in pens

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Initial wt, kg	26.13	.06	26.11	.07	.97
Final wt, kg	50.50	.48	50.19	.52	.76
Gain, kg	24.36	.48	24.07	.52	.71
Days on feed	78.6	1.6	81.0	1.8	.38
Avg daily gain, g/d	310	8	298	9	.41

Table 24. Effect of dietary treatment on total and daily feed intakes of goup fed lambs[a]

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Total intake					
As fed, kg	135.7	3.5	169.7	3.5	.0001
Dry matter, kg	119.4	3.2	157.8	3.2	.0001
ME, Mcal[b]	333.1	7.9	342.5	7.9	.41
Average daily intake					
As fed, kg	1.73	.04	2.11	.04	.0001
Dry matter, kg	1.52	.04	2.0	.04	.0001
ME, Mcal[b]	4.25	.09	4.2	.09	.98
Feed efficiency[c]	.18	.004	.14	.004	.0001

[a] Values expressed per individual lamb represent a pen average of 4 lambs.
[b] Metabolizeable energy content of feed was calculated by from NRC(1987) book values.
[c] Feed efficiency is expressed as kg gain / kg feed intake.

Table 25. Effect of dietary treatment on carcass characteristics of group fed lambs

	Dietary treatment				
Item	CONC	SEM	ALFA	SEM	*P*
Hot carcass wt, kg	25.25	.54	24.97	.66	.03
Dressing %[a]	50.01	.70	49.35	.86	.04
Rib eye area, cm^2	15.08	.40	15.72	.49	.21
Leg score[b]	12.3	.1	12.4	.1	.71
Back fat, cm	.56	.05	.47	.06	.09
Yield grade	2.59	.17	2.58	.21	.05
Kidney fat, g	283	28	265	34	.23
Quality Grade[c]	18.25	.07	18.04	.08	.72

[a] Dressing percent calculated with kidney and pelvic fat removed from the carcass.
[b] 10 = choice$^-$ = ; 11 = choice$^{\circ}$; 12 = choice$^+$.
[c] 17 = choice$^-$ = ; 18 = choice$^{\circ}$; 19 = choice$^+$.

DISCUSSION

Experiment I - Individually-fed lamb feeding study.

Increasing lean tissue and decreasing fat associated with retail product is extremely important in today's fat conscious society. B - agonists and growth hormone have been used extensively in research to maximize lean production while simultaneously reducing fat; however, these agents have yet to approved by the FDA for on-farm use. To meet market demands for lean, less-fat meat products, producers have been selecting for larger framed later maturing animals for the past 30 years. This method of selection has increased lean to fat ratios from about 1.0 to approaching 2.0 (Bergen and Merkel, 1991). Producers and researchers alike have experimented with feeding diets that limit the amount of energy an animal receives in an effort to decrease fat production. An objective of the present study was to determine if energy density has an effect on performance and carcass characteristics when lambs were slaughtered at a constant weight endpoint.

In the present study, all lambs were of the same breed cross and sex, plus they were raised and managed at the same location and under the same conditions throughout the trial. Thus, the trial was designed to have dietary treatment as the only varrible in the experiment. Differences in the present study reflect solely differences in energy density of the diet. Although diets were formulated to have different ME values (ME mcal/kg; CONC 2.79, ALFA 2.17) lambs nearly consumed the same daily ME since ALFA-fed lambs increased their DM intake. Results agree with similar studies by Glimp et al. (1989) and Crouse et al. (1978) who showed that altering energy density of the diet did not reduce energy intake because lambs consuming the lower energy density diet compensated by increasing feed intake. Because ME intakes were similar it would be anticipated that ADG would be the same; however the net energy (NE) values of the diets differed. The ALFA diet had lower net energy for maintenance (NEm) and lower net energy for gain (NEg) values. Thus the efficiency of utilization of ME was greater for CONC-fed lambs.

Lambs in this trial were started on feed at the same weight and age and slaughtered at a similar weight endpoint. Thus, no differences were found in total gain or final weight of lambs; however, days on feed and ADG were affected by dietary treatment. Lambs consuming the ALFA diet had lower ADG than the CONC fed lambs, which is consistent with data reported by Crouse et al. (1978). Lambs consuming the lower energy density diet experienced decreased ($P<.05$) daily gain and thus needed extra ($P<.05$) days to reach the targeted weight endpoint. Similar results were found by Burton and Reid (1969) comparing low versus high energy diets. The authors reported lambs consuming a lower energy diet experienced reduced gains and took a greater amount of time on feed to reach the targeted weight endpoint. The results in the present study are also in agreement with those reported by Crouse et al. (1989) and Hart et al. (1989) with sheep. Jesse et al. (1976) and Guenther et al. (1965) reported slower gains and increased days on feed when feeding diets varying in energy density to steers.

Lambs were slaughtered at the same weight endpoint. Hot carcass weights, however, followed a numerical trend to be heavier ($P<.10$) for CONC-fed lambs; thus, chilled carcass weights were also heavier ($P<.05$) for CONC-fed lambs than for ALFA-fed lambs. When dressing percentage was calculated with kidney and pelvic fat in the carcasses (Boggs and Merkel, 1993), CONC-fed lambs followed a numerical trend to have higher ($P<.10$) dressing percentages. Murphy et al. (1994) reported lambs consuming a 100% forage diet had lower dressing percentages than lambs comsuming a concentrate diet. When removing kidney and pelvic fat from the carcass, as practiced by the industry (USDA, 1992), CONC-fed lambs had higher ($P<.05$) dressing percentages. The difference in dressing percentage between treatments can be attributed to the effect of diet on visceral organ mass. Although dressing percentage of CONC-fed lambs is statistically different, the numerical difference is 1.5% different between treatments. Because lambs on both treatments had the same starting and final weights and were handled the same, dressing percentages were consistantly 1.5% different from each other. Thus, when tested statistically, a small difference becomes significantly different.

Increasing dietary bulk in the diet has been shown to increase the weight of visceral components (Murray and Slezacek, 1980; Koong et al., 1983; Ferrell and Koong, 1985). In the present study, ALFA-fed lambs consuming greater amounts of feed both on a daily basis and for the duration of the trial had heavier ($P<.05$)

empty GIT weights. Rompala et al., (1988) and Ferrell and Koong (1985) found similar results when comparing lambs fed a low energy diet versus a high energy diet.

Alfalfa-fed lambs had heavier (P<.01) empty omasum weights, whereas the rumino-reticulum and abomasum were similar between treatments. In contrast to the data reported in the present study, Rompala et al., (1988) reported an increase in all stomach components of the lamb. However, lambs were fed for a longer period of time in the study conducted by Rompala (1988). ALFA-fed lambs consuming a higher level of bulk feed had heavier (P<.05) intestinal weights. These results are consistent with observations by Ferrell et al. (1986) and Jacobs and Lupton (1984), who found that increasing dietary bulk caused hypertrophy of the large intestine. Small intestine weights were affected by treatment in a manner similar to large intestine. Alfalfa-fed lambs had heavier (P<.05) small intestine weights. This is in agreement with studies by Jacobs (1983), Jacobs and White (1983), and Johnson et al. (1985), who reported that increasing dietary bulk increased the weight of the small intestine due to an increase in cell proliferation. However, results in the present study are in contrast with those of Goodland and Wright (1983) who reported that an increase in dietary bulk decreased the weight of the small intestine. Rompala et al. (1988) also found that when feeding diets that differed in energy density, the small intestine was unaffected. Webster et al., (1994), restricting dietary energy to growing lambs, by restricting feed intake, found no increase in weight of the small intestine. The data reported in the present study show that small intestine weights increased 13% when raising the level of roughage from 25% to 100% while simultaneously maintaining the level of ME intake and more than doubling the NDF content of the diet. In a similar study, Johnson et al. (1985) reported that by increasing the level of roughage in the diet from 10% to 80%, while ME intake remained relatively constant and NDF more than doubled, the weight of the small intestine increased ($P<.05$) by 17%.

Dietary treatment did not affect heart or lung weights which is contrary to results reported by Rompala et al., (1988), who noted that a 10% increase in dietary bulk to the diet increased ($P<.05$) weights of these organs. However, the results in this study were similar to those found by Aziz et al. (1993), who concluded that severe energy restriction may reduce heart weight during periods of weight loss but that dietary intake of similar energy levels should have no effect on heart or lung weights.

Liver weights for ALFA-fed lambs were heavier ($P<.05$) than for CONC-fed lambs. Contrary to the findings reported here, dietary bulk did not increase liver weights in studies conducted by Ferrell and Koong (1985), Rompala et al., (1988), Drouillard et al. (1991), Aziz et al. (1993) and Webster et al., (1994) when feeding diets of lower energy content. Webster (1994) noted a 40% decrease in liver mass of energy-restricted lambs, but after 2 d of realimentation, liver mass was similar to those on unrestricted energy. Differences in results between previous investigations and results presented here are likely due to the quality and quantity of feed the animals were offered or the method that livers were removed from the carcass.

No differences were found between dietary treatments for fat associated with the GIT. Values reported here are higher than those reported by Aziz et al. (1993). In the study reported here, lambs were slaughtered 20 kg heavier than those slaughtered in the study conducted by Aziz et al. (1993). Thus, weight of fat in the GIT would be expected to be higher. No differences were found between treatments in either study for fat associated with the rumino-reticulum, omasum, abomasum and small intestine. However, Aziz et al. (1993) found greater amounts of fat associated with the large intestine of lambs experiencing live weight loss than those undergoing live weight gain.

In the present study dietary, treatment did not affect carcass cutability (P<.05). Thus, data reported here are in agreement with studies by Field et al. (1963), Burton and Reid (1969), Winter et al. (1976), and Therize (1981), who reported that age or nutritional treatment had no effect on carcass composition. The authors also reported that carcass weight had the greatest influence on carcass composition. In contrast to findings reported here, Murphy et al. (1994) reported that finishing lambs on a 100% forage diet versus a concentrate diet can result in decreased fat production when lambs were slaughtered at similar weights.

Backfat thickness between the 11th and 12th ribs was unaffected by dietary treatment in the present study which was similar to results obtained by Field et al. (1963) and Crouse et al. (1978). Results reported here are in contrast to those of Osborne et al. (1961), Ray and Mandigo (1966) and Murphy et al., (1994) who concluded that a reduction in dietary energy intake would ultimately lead to leaner carcasses with less backfat when slaughtered at a similar weight endpoint.

Murphy et al. (1994) reported that forage-fed lambs would result in a 10% reduction of fat on a carcass weight basis. However, carcass weights for forage fed lambs decreased 10% between treatments. If lambs fed by Murphy et al. (1994) had similar carcass weights there might have been a reduction in carcass fat. In the present study, because backfat is the sole indicator of lamb yield grade (USDA, 1992), yield grade was proportional to backfat and unaffected by treatment. However, Crouse et al. (1978) reported that higher yield grades were influenced by a higher ($P<.01$) degree of kidney and pelvic fat in lambs fed the higher-energy density diet. Ray and Mandigo (1969) reported that lambs consuming a diet higher in energy density had greater amounts of external fat, while kidney and pelvic fat was unaffected. Crouse et al. (1978) reported results for kidney and pelvic fat that are in contrast to those reported here. In the present study, dietary treatment did not affect the amount of kidney and pelvic fat of lambs expressed either as an absolute weight or as a percentage of carcass weight, which is consistent with Ray and Mandigo (1969).

Leg conformation scores and ribeye area were unaffected by dietary treatment which is consistent with results of Crouse et al. (1978).

Indicators of maturity and quality grade were unaffected by dietary treatment. Maturity measurements of rib and lean color were similar between treatments. In contrast, Crouse et al. (1978) reported that indicators of maturity were affected by energy intake over time or at a constant final weight endpoint. Increased maturity scores were primarily associated with increased feeding time required for lambs fed a lower-energy density diet to reach slaughter weight. The increased feeding time noted by Crouse et al. (1978) and Murphy et al. (1994) for lower-energy density diets was greater than the extra days required by ALFA-fed lambs in the present study. Scores for flank streaking, conformation, and quality grade were in agreement with those reported by Crouse et al. (1978) and were unaffected by dietary treatment.

The principle that carcass weight is directly related to composition of the carcass has been established (Bergen and Merkel, 1991). As weight increases past maturity, fat becomes a greater proportion of carcass weight while percentage of lean decreases. When animals are slaughtered at the same weight endpoint carcass composition should not be affected by diet. It has been well documented by Burton and Reid (1969), Winter (1976), McC. Graham (1982) and Ørskov (1983) that the greatest influence on carcass composition is weight. Murphy et al. (1994), Lambuth et al. (1970), and Kemp et al. (1976) concluded that percentage of carcass fat is directly related to carcass weight. Thus it can be concluded that carcass composition is directly related to absolute carcass weight. In the present study, lambs were slaughtered at the same weight endpoint; thus, no differences in total carcass composition were found between dietary treatments when expressing fat, protein, water, and bone on a percentage of the total carcass on a wet basis. Similar results were found by Burton and Reid (1969) and more recently McC. Grahm (1982) and Ørskov (1983) when using dietary treatments varying in energy density. In a more recent study, Murphy et al. (1994) concluded that as dietary energy increased percentage of carcass fat increased in lambs consuming a higher-energy density diet. Even though Murphy et al. (1994) reported similar slaughter weight endpoints, chilled carcass weights differed between treatments by 10%. Chilled carcass weights favored the lambs consuming the higher concentrate diet. Thus, if carcass weights had been similar, differences in carcass composition between dietary treatments may not have been shown (Burton and Reid, 1969; Winter, 1976; McC.Graham 1982; and Ørskov, 1983).

The density of dietary energy did affect daily protein and fat accretion rates. Concentrate-fed lambs deposited greater ($P<.01$) amounts of protein and water as well as greater ($P<.05$) amounts of fat and bone. The data presented, are in contrast to that by Murphy et al. (1994) who reported that lambs grazing alfalfa versus a 100% concentrate ration had similar daily rates of lean tissue deposition even though, daily fat accretion rates were greater for lambs consuming the 100% concentrate diet. Daily accretion rates were not reported in other previously mentioned studies. However, greater weight gains for lambs consuming the higher-energy density diets were found by Burton and Reid (1969), McC. Gram (1982) and Ørskov (1983). In the present study the amount of fat deposited per unit of protein was unaffected by dietary treatment. Thus, fat-to-protein ratios were similar between dietary treatments, which is in agreement with results reported by McC. Gram (1982).

When analyzing the nine cuts used to determine composition of the carcass, differences in weight of the cut were found for the shoulder and leg. No differences were found between cuts for analysis of tissue fat or protein. Thus, there were no differences in the composition of cuts, when composition was expressed as a percentage of cut weight. Heavier ($P<.01$) cut and boneless tissue weights were found for the shoulder, along with the leg cut having heavier cut ($P<.01$) and boneless tissue ($P<.05$) weights. Murphy et al. (1994) reported heavier primal weights for the leg, shoulder, rack, and loin. The authors also stated that lambs consuming the 100% concentrate diet had greater percentages of fat than those grazing alfalfa (Murphy et al. 1994). Similar results were found for weight and composition of cuts for the rack, loin, breast, flank, shank, neck, and kidney fat.

Economic analysis of individual fed lambs

Many producers believe that by feeding a 100% forage diet, they can produce a leaner, more marketable product. Producers also believe that by feeding a 100% forage diet, which costs less per unit of feed than that of a traditional high concentrate ration, that they can reduce feed costs per head. Breakeven lamb prices are presented in Table 26 for each diet. Diets were priced based on current 1995 spring ingredient prices in the Mid-Michigan area. Lambs consuming the CONC diet, which had a higher price per unit, consumed less feed and thus had a lower feed cost on a per head basis than ALFA-fed lambs ($15.17 vs $17.73, respectively). Lambs consuming the CONC diet were on feed 10 fewer days and thus had a lower yardage cost than ALFA-fed lambs. Fixed costs were the same between treatment and included the following: salt and mineral, death loss, vaccine, shearing, commission, and interest (13%). Feeder lamb prices were calculated by pricing a 75 lb lamb at $ 75.

Based on the current analysis, lambs consuming the CONC diet proved beneficial in feed efficiency and ADG. Thus the CONC diet reduced the breakeven price by $2.80 per head versus ALFA-fed lambs.

Lambs consuming the CONC diet converted feed more efficiently with higher average daily gains offered more potential for profit than 100% forage fed lambs. Although monitoring metabolic disorders was not part of this study, CONC-fed lambs may be more susceptible to metabolic disorders than ALFA-fed lambs. In feedlot situations the opportunity to reduce bunk management and feedlot disorders by feeding a 100% alfalfa pelleted diet may prove beneficial to producers, and thus outweigh the increased cost of feed per head.

Table 26. Effect of dietary treatment on breakeven price if lambs

	Dietary treatment	
Item	CONC	ALFA
Feed consumed	189.6 lbs	272.8 lbs
Feed cost/ton	161.00	130.00
Total feed costs/hd	15.17	17.73
Days on feed	53	63
Yardage $.025/hd/d	1.33	1.57
Fixed Costs	7.09	7.09
Production Costs	23.59	26.39
75 lb lamb @ $75/cwt	52.50	52.50
Total Costs	76.09	78.89
Wool sales	-2.00	-2.00
Breakeven price	$74.09	$76.89
Current Market Price $82/cwt	$92.40	$92.40
Profit/head	$24.31	$21.51

Experiment II - Pen-fed lamb feeding study.

Not all of the results presented in Experiment I are in agreement with results found in Experiment II. This difference may be caused by experimental design. The 48 ewe and wether lambs in Experiment II were lambs that were left over after 30 wether lambs and 15 replacement ewe lambs were selected from the group. Thus younger, slower growing lambs that weighed less were used in the trial explaining the increase in days on feed. Lambs were grouped four per pen, and slaughtered when the pen averaged approximatly 52 kg. Lambs were slaughtered on two dates when they were near the targeted weight endpoint to facilitate slaughter at Wolverine Packing, Detroit, Michigan. Thus, there was greater variation in slaughter weight of the lambs with less variation in days on feed. Because of greater number of lambs, less variation between treatments, and consistent results within treatment, small numerical differences when tested statistically become significant.

No differenes were found between treatments for average daily gain or days on feed. Differences were observed in feed intake and were similar to results reported in Experiment I. Alfalfa-fed lambs consumed more (P<.01) feed on a daily basis and for the duration of the trial, both on an as-fed and DM basis than CONC-fed lambs.

Similar relationships between treatments were observed for dressing percentage and carcass weight in Experiment II as in Experiment I. Higher (P<.05) dressing percentages (1.3%) were observed in the CONC fed lambs. Thus, CONC-fed lambs had 1.1% heavier (P<.05) hot carcass weights than

ALFA-fed lambs. Ribeye area and leg conformation score were not affected by dietary treatment, which is similar to results reported in Experiment I and those reported by Crouse et al. (1978).

Backfat thickness between the 11th and 12th ribs and yield grade were shown to be significantly different for dietary treatments. Concentrate-fed lambs had .09 cm more backfat which tended to be greater ($P<.09$) than ALFA-fed lambs. Comparing yield grades, the differences between dietary treatment means was a tenth of a yeild grade; yet when tested statistically CONC-fed lambs were shown to have higher ($P<.05$) yield grades. Although this difference is shown to be significant, a tenth of a yeild grade equates to .09 cm of backfat which may be attributed to rounding errors. Kidney fat was similar between treatments, but when comparing this to results in Experiment I, the weight of kidney fat for both treatments was much less. Lighter kidney fat weights may be due to less care in removing all the fat from the pelvic cavity when lambs were slaughtered.

IMPLICATIONS

Results from the individually-fed lamb feeding study provide support that moderate alterations in lamb growth does not affect overall composition of the carcass when lambs are fed to the same weight endpoint.

Feedlot performance favored CONC-fed lambs, as expected. However, acceptable levels of performance were observed for ALFA-fed lambs. Feed efficiency was improved in CONC-fed lambs because a greater amount of feed was needed to attain acceptable gains in ALFA-fed lambs. Although ALFA-fed lambs were consuming the diet with a lower cost per unit of feed, their feed costs were higher than CONC-fed lambs because of greater feed intake.

Visceral organ mass was affected when feeding a concentrate-based diet versus an all-forage diet. Lambs consuming the forage diet experienced heavier gasto-intestinal weights due to increased feed intake.

Diet did not affect total composition of gain of lambs consuming either diet. Daily accretion rates of fat and protein were greater for lambs on the higher plane of nutrition. However, the ratio of fat deposited per unit of protein deposited was similar. The similarity between treatments in fat and protein accretion ratios supports the data showing that lambs are similar in composition when slaughtered at a comparable weight endpoint.

Even though lambs consuming the lower-energy density diet exhibited lower performance, adequate performance levels were attained while carcass characteristics were unaffected. Thus, ALFA does have potential as a finishing lamb diet. However, profit per head is reduced when feeding diets that do not attain maximum daily gain or efficiency.

Accretion rates of fat and protein, combined with carcass composition data, would suggest that feeding a 100% ALFA diet does not result in leaner carcasses when lambs are slaughtered at a similar weight endpoint.

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MEMORANDUM

TO: Benson, Margaret
Animal Science
113 Anthony Hall

FROM: Richard J. Aulerich, Chairperson
All-University Committee on Animal Use and Care

R.J. Aulerich

DATE: July 13, 1993

SUBJECT: APPROVAL OF APPLICATION TO USE VERTEBRATE ANIMALS IN RESEARCH

This is to notify you that your recent application to use vertebrate animals in research or teaching has been approved by the All-University Committee on Animal Use and Care. This approval is for a one-year period, beginning on the date of approval by the committee. *For external funding agencies, if the Office of the Vice President for Research and Graduate Studies, or the Deans office notifies us if a funding date, your approval will be extended for one year following the funding date.*

Should your project extend beyond one year, you should resubmit your request to the committee. For your convenience, the new Yearly Renewal Form is designed so that resubmissions may be accomplished by merely identifying the earlier proposal and assuring that the proposal is being resubmitted with revisions.

The title of your approved proposal, the date of approval, and the tracking numbers assigned (both ORD and AUF numbers) are given below. You should return this information for future use. Please note that, according to University policy, no significant changes may be made to your animal-use plan without prior approval from the AUCAUC. Requests for review of proposed revisions may be made by submitting a new Animal Use Form or by sending a letter to the AUCAUC, C103 Clinical Center.

Title: LAMB PERFORMANCE AND CARCASS COMPOSITION ON LAMBS FINISHED ON PELLETED DIETS OF FORAGE (ALFALFA) OR CONCENTRATE

AUF #: 7/93-236-01   **ORD #:** N/A

Funded By: DEPARTMENT

Approved: 07/08/93   **Expires:** 07/08/94

RJA/cjf

CC: Dr. Maynard G. Hogberg, Chairperson
Animal Science
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