RUMEN BYPASS OF PROTECTED CORN IN LAMBS AND STEERS

by

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B.S., Ahmadu Bello University, 1979

A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree
MASTER OF SCIENCE
Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1982

Approved by:

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TABLE OF CONTENTS

DEDICATION

Dedicated to my parents (Deceased), with the hope and Prayers that the Almighty Allah (SUBHANAHU WA TA'ALA) is pleased with them.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank Dr. Len Harbers, my major professor, for his tireless advice, assistance, encouragement, tolerance and understanding, not only during the course of preparation of this thesis, but throughout my stay at Kansas State University. Without his able mentorship, it would have been very difficult to conduct the research and collect, compile and organize the data into a thesis.

Appreciation is extended to Dr. Keith Behnke and his crew both in the Grain Science & Industry Department and the feed mill for helping me mix the feed supplements whenever the occasion arose. I am also grateful to the entire faculty, staff and students of the Department of Animal Sciences & Industry, but especially to the staff at the Sheep, Beef, Dairy and Range Research Units of K.S.U., not only for their help and cooperation in conducting the research, but also for their hospitality. Particular mention must be made of Dr. Don L. Good, Department Head, Barry Robinson and Edgar Arcila, for showing extra interest in my research.

To my friends and well wishers all over the world, not just in the USA and Nigeria, I owe a great deal, to the extent that I can hardly thank them enough.

INTRODUCTION AND LITERATURE REVIEW

All living organisms are remarkable eating machines. They consume nutrients from the environment and transform them into energy or structural material. Nutrients are the chemical substances found in feed materials that can be used and are necessary for the maintenance, production and health of animals (Ensminger and Olentine, 1978). The chief classes of nutrients are carbohydrates and fats (energy), proteins, minerals, vitamins and water.

Energy is required for practically all life processes - including protein and fat synthesis, the secretion of milk and production of eggs, wool and power (Ensminger and Olentine, 1978). As a result, supply of energy to farm animals seems to determine their productivity. For instance, Webster (1980) has ascertained that the efficiency with which the growing farm animal converts the feed it eats into meat for human consumption is determined overwhelmingly by the efficiency with which it uses the major nutrient (energy); even though Orskov and Grubb (1977) have indicated that the limiting factor for milk yield in early lactation can be protein, since it apparently stimulates mobilization of body energy reserves. Carbohydrates are the most important nutrients in terms of supplying normal energy needs of animals, more of them being consumed than any other compound. Carbohydrates provide the primary source of energy for both the rumen organisms and the

host ruminant animal.

Utilization of Energy

Through the various digestive and metabolic processes, much of the energy in feed is dissipated as it passes through the animal's digestive system. About 60% of the total combustible energy in grain and about 80% of that in roughage is lost as feces, urine, gases and heat (Ensminger and Olentine, 1978). Of all the gross energy and protein consumed by farm animals as feed, only 3 to 20 % of the energy and 4 to 36% of the protein is recovered (Maynard et al, 1979).

During rumen fermentation, short chained fatty acids and microbial cells are formed from feedstuffs, and these products serve as sources of energy and protein, respectively, to the animal. Methane, heat and ammonia are evolved as well, and these products can represent a loss of energy and nitrogen for the animal. The efficiency of nutrient utilization by ruminants is determined largely by the balance of these fermentation products (Russell and Hespell, 1981).

As a result of losses associated with the microbial fermentation in the rumen, ruminants are innately less efficient than other classes of livestock in utilization of energy (Trenkle, 1980).

The fermentation of dietary carbohydrates before being digested by the animal is unique to ruminant species - a digestive process that has advantages and disadvantages. The primary advantage is that a wide variety of feeds, especially roughages, can be utilized, whereas the main disadvantages are

losses of energy from the fermentation in the form of heat and gases and the dependence of the host upon the metabolism of volatile fatty acids (VFA) as a source of energy for growth and fattening (Trenkle, 1980).

Metabolizable energy is the physiological fuel for the body (Webster, 1980). Ruminants obtain their metabolizable energy mostly from carbohydrates. Starch and cellulose are hydrolyzed to glucose by enzymes from the rumen microorganisms. Glucose is then fermented to the VFA's, acetate, propionate and butyrate, with trace amounts of other acids (Trenkle, 1980).

The fermentation of feeds to VFA provides energy for maintenance and growth of rumen microorganisms and the VFA, which are end products of microbial fermentation, are absorbed from the rumen and used by the animal for about 60 to 80% of its total energy needs (Annison, 1965; Trenkle, 1980).

Due to the fermentation of dietary carbohydrates to VFA, only about 10% of the glucose requirement of ruminants is absorbed from the ruminant digestive tract. As a result, gluconeogenesis must provide up to 90% of the necessary glucose in ruminants (Young, 1977). Gluconeogenesis is the formation of glucose from nutrients other than carbohydrates. The liver is the main site for gluconeogenesis. Amino acids are the primary precursors in gluconeogenesis. Among the VFA, only propionate contributes to gluconeogenesis (Young, 1977).

During rumen fermentation, the relative proportions of each acid produced will depend upon the nature of the diet, primarily the amount of roughage or concentrate, which

influences the pH and turnover of liquid and solid fractions in the rumen, and, thereby, determining the species of microorganisms capable of inhabiting the rumen (Russell and Hespell, 1981; Trenkle, 1980).

Efficiency of Energy Utilization

Many factors, including genetic ability, the adequacy of nutrition and management determine the efficiency of animals as food producers (Maynard et al, 1979).

Fermentation in the rumen is more efficient (i.e., there is less loss of energy from glucose during fermentation) when the proportion of propionate is increased. The greatest energy losses due to the fermentation of feeds are associated with rations that produce high acetate. These are normally rations containing greater quantities of roughage (Trenkle, 1980).

A major improvement in understanding the causes of variation in energy efficiency of animals fed different diets was the demonstration by Armstrong and Blaxter (1957a, 1957b, 1957c) and Armstrong et al (1958) that the heat increment of mixtures of VFA was influenced by the proportion of acetate in fattening sheep but has less effect in sheep at maintenance (Moe, 1981). The energy of VFA infused singly into the rumen of fattening sheep was used with efficiencies of 32.9% for acetic acid, 56.3% for propionic acid and 61.9% for butyric acid. Mixtures of VFA containing 75% and 25% acetic acid were used with 31.8 and 58.1% efficiency, respectively. Other studies (Moe, 1981) showed a lower efficiency (54.5%) for glucose

infused into the rumen than for that infused into the abomasum(71.5%) or jugular vein (72.8%).

More recent experiments indicated that the proportion of acetate of the rumen fermentation products may not explain fully the variation in use of metabolizable energy and that in some circumstances acetate may be used efficiently for body gain. Tyrrell et al (1979) reviewed several experiments in which acetate apparently was used with relatively high efficiency for body gain and reported the results of calorimetric investigations with VFA infusion in mature cows. They found a difference from the nature of the basal diet in the partial efficiency of acetate for body gain. Use of metabolizable energy from infused acetic acid was 27% for cows fed 100% hay and 69% for cows fed a diet of 30% hay.

Orskov et al (1979) reported experiments in which lambs were sustained entirely by intragastric infusion of VFA, protein, minerals and vitamins. For mixtures of VFA with 450 to 750 mmol acetate/ mol, efficiency of use was 57 to 64%. They concluded that the effect of proportion of acetate on efficiency of energy use in growing animals was too small to be of practical significance.

The portion of metabolizable energy deposited as new tissue growth, or recovered as a product such as milk or wool, is known as the net energy for that particular process. Since the animal's maintenance needs for energy are mandatory, the efficiency of energy utilization can be expressed as the ratio of the energy deposited to the metabolizable energy intake

corrected for maintenance costs (Knox, 1979). The efficiencies for deposition of body tissue appear to be lower for ruminants than for nonruminants.

The energetic efficiency of milk synthesis is greater than the efficiency for synthesis of depot fat (Knox, 1979).

Utilization of Energy for Protein and Fat Synthesis

During growth, energy is deposited in the body tissues as protein and fat primarily. Several investigators have shown that the relationship between energy retention and metabolizable energy intake above maintenance is approximately linear. Overall efficiency estimates for metabolizable energy utilization above maintenance for growth range from about 60 to 80% (Knox, 1979). Baldwin (1968) calculated the theoretical partial efficiency for synthesis of milk fat to be 72%, 84% for protein and 78% for lactose. The amount of metabolizable energy required in excess of maintenance to deposit 1 g of protein or fat is the same, i.e., 55 KJ (Trenkle, 1980). Fat contains 39 MJ of energy per kg whereas protein contains 24 MJ. The heat losses associated with the synthesis of fat and protein are 16 and 31 MJ per kg, respectively. Thus the total energy required to deposit 1 kg of fat or protein is the same or about 55 MJ per kg.

Volatile Fatty Acid Utilization

Acetic acid is the major end product of rumen digestion and is also the largest single contributor to the metabolic

energy supply of the ruminant (Smith, 1972). There appears to be definite limitations to the pathways in which acetate can be utilized. For instance, it is generally recognized that ruminant tissues do not have mechanisms for net synthesis of glucose from acetate (Smith, 1972).

Propionate is the second most abundant VFA produced in the rumen and together with the essential amino acids are the main sources of glucose (Smith, 1972; Young, 1977).

Butyrate is the third most important VFA produced in the rumen. It is metabolized by the rumen epithelium to ketone bodies - beta-hydroxybutyrate and acetoacetate - which may have glucose sparing action although there does not appear to be net synthesis of glucose (Smith, 1972).

Volatile fatty acids can be oxidized through the TCA cycle so that adenosine triphosphate (ATP) is formed. At maintenance these pathways are the commonly assumed mechanisms for the oxidation of the VFA. The net yield of ATP from acetate is 10; propionate, 18; and butyrate, 27 (Smith, 1972).

While propionate is metabolized mainly by the liver, acetate is mainly utilized by extrahepatic tissues and is taken up by adipose tissue for fat synthesis (Cook and Miller, 1965). The pathway for the synthesis of fatty acids from acetate starts as acetyl-CoA and proceeds via malonyl-CoA with the subsequent addition of 2-carbon groups derived from an additional acetyl-CoA which serves to elongate the chain (Smith, 1972). Acetate may contribute as much as one-half of the fatty acids in milk, especially those up to a chain length

of 16 (Smith, 1972); the remainder of the fatty acids are supplied by the fat in plasma chylomicrons (Hardwick et al, 1961). Synthesis of fatty acids requires the concurrent metabolism of glucose to provide NADPH for reduction reactions; this may be the primary factor limiting the usefulness of acetate for fattening processes (Smith, 1972).

The efficiency of utilizing metabolizable energy (ME) from rations containing different amounts of roughage differs. Garrett (1979) has reported that as the amount of roughage in the ration is increased (from 8.7 to 78.3%), ME intake is reduced (from 86.7 to 80.0%), mainly due to increased bulk, the lower digestibility of roughages and greater fermentation losses associated with production of acetic acid (Trenkle, 1980). The efficiency of utilization of ME is decreased (from 30.8 to 18.4%) as the amount of roughage in the ration is increased. It has been suggested that the poorer use of ME in roughages is due to a higher proportion of acetate produced in the rumen and that as the percent acetate in the VFA mixture is increased, the efficiency with which acetate is utilized is decreased (Trenkle, 1980).

Importance of Glucose

Although little glucose is found in the blood of ruminant animals, glucose is still an important metabolite in the metabolic processes that occur within the ruminant body. Armstrong (1965) concluded that rates of glucose utilization in ruminants are comparable to those of nonruminant animals.

Glucose can be oxidized via the TCA cycle so that ATP is produced. Glucose can also be oxidized via the hexose monophosphate shunt which takes place outside the mitochondria. NADPH is intimately involved in the process of fat synthesis in which acetyl-CoA units are condensed to form long-chain fatty acids after catalytic condensation with carbon dioxide (Armstrong, 1965). Glucose is also utilized for production of lactose, glycerol, as well as certain nonessential amino acids (Armstrong, 1965; Clark, 1975).

It appears as if glucose, or its precursors, is/or are the limiting nutrient(s) for fattening of ruminants on a high roughage diet (Trenkle, 1980).

Rumen Bypass

Ruminants tend to be inefficient in utilization of nutrients because of rumen microbial fermentation. This inefficiency has prompted nutritionists to start looking into ways for improving the utilization of nutrients fed to ruminants. Most of the work thus far has been centered around proteins. Protein supplements are generally the most expensive ingredients in ruminant rations, hence the interest in maximizing their utilization. A considerable body of evidence has been accumulated in recent years to clearly show that infusions via the abomasum of high quality protein, such as casein, will result in improved nitrogen retention, more rapid wool growth, greater milk production, and so forth (Church, 1979). These data indicate that rumen degradation and resynthesis into bacterial and protozoal protein (or loss of

ammonia) has been detrimental to maximum utilization. Means of achieving protein protected from rumen degradation include heat damaging of the proteins (Church, 1979), encapsulation of specific nutrients such as methionine (Neudoerffer et al, 1971) and treatment with tannic acid and aldehydes (Church, 1979). Formaldehyde has been favored because of cost (Church, 1979).

Ferguson of Australia was probably the person who first opened the new and exciting area of rumen bypass research (Ensminger and Olentine, 1978). Ferguson et al (1967) demonstrated that formaldehyde-treated protein was protected from degradation in the rumen but was digested and absorbed in the abomasum and small intestines of ruminants.

In the rumen-protected fat system, fat is emulsified with a protein, then the protein is treated with formaldehyde. The product cannot be digested in the rumen due to the formaldehyde linkage on the protein. However, the pH of the abomasum is such that the formaldehyde linkage to the protein is broken, with the result that the product will then be digested in the same manner as takes place in nonruminant animals (Ensminger and Olentine, 1978).

Studies reveal that the utilization of fat by the ruminant can be improved by the use of this system. McCartor et al (1979) used this technique on 200 steers. The formaldehyde-treated protein protected tallow product increased average daily gain ($P=.08$).

Little work has so far been done to improve energy utilization through rumen bypass. However, recently some

studies have attempted to enhance normal milk secretion by either bypassing ruminal fermentation (supplying additional nutrients for milk synthesis) or by administering exogenous hormones to elevate plasma concentrations of these nutrients (Peel et al, 1982).

Increases in milk production have been obtained when additional amino acids (Clark et al, 1977; Schwab et al, 1976) and fatty acids (Kronfeld et al, 1980) have been made available to the mammary epithelial cells. Clark (1975) administered additional glucose to bypass ruminal fermentation. This, however, resulted in no increase in milk production. Administration of exogenous growth hormone (bGH) has consistently resulted in dramatic increases in milk yield in both low-yielding cows (Bines et al, 1980) and more recently in high-yielding Holsteins (Peel et al, 1981) with no increase in feed intake.

There appears to be sufficient evidence to indicate that glucose can be absorbed from the small intestine of the ruminant. Duodenal infusion of glucose was found to increase the specific activities of some hepatic enzymes of glucose dissimilation (Unsworth and Pearce, 1977).

The increase in fattening efficiency is believed to be mostly due to enhanced uptake of glucose from the small intestine when changing from high roughage to high concentrate diets (Stokes and Thomas, 1978), even though other metabolites, propionate, lactate plus propionate, and glycerol contribute to the glucose pool (Baird et al, 1977). Lactating cows respond

better to amino acid infusion than to glucose (Farhan and Thomas, 1977; Orskov and Grubb, 1977). The output of acetate from the gut decreased during glucose infusion and this was accompanied by a decrease in blood acetate (Lomax et al., 1977). Surprisingly the infusion did not significantly affect the hepatic uptake of propionate. Clark (1975) has speculated that glucose, amino acids, hormone secretions or a combination of these factors may be responsible for the improved performance of lactating dairy cows, growing steers and sheep when nutrients such as casein are made to bypass the rumen through postruminal supplementation. Because energy is the most important single nutrient in the production of beef and dairy animals; and due to the fact that carbohydrates are the main sources of energy in ruminants, it is worthwhile to attempt bypassing the rumen with some readily available carbohydrates.

The objectives of this research were two-fold. First, we wanted to test the hypothesis that ruminants fed high roughage rations are metabolically limited in lipogenesis (synthesis of fat) due to inadequate ATP. Secondly, we wanted to attempt to develop a suitable feed supplement of glucogenic potential that could bypass rumen fermentation so that it could be released in the abomasum and/or small intestine. Lipogenesis is the process through which fatty acids and fat or lipids are synthesized.

MATERIALS AND METHODS

Small Scale Laboratory Preparations

A number of combinations of feedstuffs and protective ingredients were mixed in small batches of 100 g to 5 kg in the laboratory. Four to five gram samples were placed in dacron bags (43 microns mean pore size) for ruminal digestion. The dacron bags were incubated in the rumen of cannulated steers for 12 to 26 hours (Brazle and Harbers, 1977). Percentage retentions of dry matter were calculated, assuming no digestion of the protective coatings. Protective materials that were mixed with different carbohydrate sources included tallow, paraffin and formalin. Feedstuffs used included glucose, starch, pelleted alfalfa, and cracked, ground, cooked and pelleted corn. These preliminary data indicated that several combinations of ground corn, paraffin and tallow provided the best protection.

Mixing of Ground Corn, Paraffin and Tallow

A horizontal mixer (150 kg capacity) was used in mixing corn, paraffin and tallow for the feeding trials. Corn ground through a 1/8 inch screen was placed in the mixer, then 10% hot tallow was added using a stainless steel pressurized sprayer. Hot paraffin was poured in punched cans and the spreading was accomplished manually. About 45 to 114 kg of the supplement were mixed at a time. Attempts to pellet the supplements in a

pellet mill were unsuccessful because the paraffin melted and products would not pass through the die.

Lamb Growing Trial

Forty Western cross lambs averaging 29 kg were alloted by weight into four groups of ten animals each. They were group-fed dehydrated alfalfa pellets ad libitum. Each group received 680 g ground corn daily. Controls received that amount of corn while treated groups received the same amounts of corn plus the added tallow and paraffin combinations. Animals receiving the 80:10:10 combination received 680/.8 (850 g) of the product daily; those on the 75:15:10 diet, 910 g; and the group on the 70:20:10 combination, 970 g. Paraffin was obtained in 454 g boxes from a local grocery.

Animals were given the alfalfa pellets in the morning and evening and the supplement only with the evening feeding. The trial was started August 23, 1981 and lasted 49 days. Moderate weather was experienced throughout the trial.

Animal growth from fasted weights and feed intake were computed. One animal from each group was slaughtered and backfat thickness obtained. The backfat thickness of all 40 lambs was measured by Sona-Ray at the end of the trial.

The data were analyzed by analysis of variance on a Radio Shack TRS-80 Model III microcomputer.

Lamb Finishing Trial

Ten lambs averaging approximately 42 kg were obtained from

the animals used in the previous growing trial. They were divided into two groups of five lambs each. Each group was given ad libitum amounts of dehydrated alfalfa pellets. Animals were group-fed twice daily with supplement fed in the evening. The control group was given 340 g corn daily while the treated group received 455 g of the 75:15:10 corn:paraffin:tallow supplement. Paraffin was obtained from a local grocery.

Animals were fed for 44 days (December 10 to January 26). They were kept in open pens and fed in a wooden trough kept under a roofed area with a southern exposure.

The animals were weighed individually after overnight fasting, feed intake calculated on a pen basis, and carcass data obtained at the departmental meats laboratory. Carcass data included carcass weight, yield grade, backfat thickness, loin-eye area and kidney fat. Loins were assayed for moisture, ether extract and protein (AOAC, 1980).

The data were analyzed as described previously.

Steer Feeding Trial

Twenty-one Hereford and Hereford x Angus cross steers averaging 334 kg were divided by weight into three groups. They were individually fed ad libitum silage and 900 g protein supplement (91.0% soybean meal, 4.0% dicalcium phosphate, 2.1% salt, 1.4% limestone, 1.0% fat, .25% trace minerals, .13% vitamin A premix) once daily. Individual steers received either 681 g ground corn, or 750 g of a 90:00:10 corn:paraffin:tallow combination, or 909 g of a 75:15:10 corn, paraffin, tallow

mixture. Each animal received 681 g of ground corn daily. Paraffin was obtained from the State Surplus Store in 22.7 kg blocks.

Animals were kept in two different barns at the Beef Research Unit (Barns B and E). They were fed for 58 days. Weight gain (fasted) and feed intake data were collected and subjected to analysis of variance as previously described.

Volatile Fatty Acid Profiles and Duodenal Glucose Measurements

Control and treated corn samples used in the lamb trials were fed to ruminally and duodenally cannulated steers to determine volatile fatty acid (VFA) profiles in the rumen and glucose present in the duodenum. Holstein steers kept in free stalls were fed either 682 g ground corn or 909 g of the supplement (75:15:10) used in the lamb finishing trial. Animals were fed ad libitum amounts of alfalfa hay.

After seven days, collections of ruminal and duodenal samples were made at 4 and 8 hours after feeding. Samples were centrifuged at 400 x g and frozen. Volatile fatty acids were determined by gas chromatography on a Hewlett Packard Model 7672A gas chromatograph equipped with a flame ionization detector and a column of chromosorb 101 (Brown, 1979). Glucose was determined by the glucose oxidase method (Sigma No. 15-UV).

Glucose present in duodenal samples was obtained on steers fed the supplements used in the steer feeding trial.

Steer Pasture Study

Thirty Hereford and Hereford x Angus cross steers averaging 330 kg were alloted by weight into two groups and allowed to graze 80-acre pastures at the Kansas State Univeristy Range Research Unit. Steers were group-fed either 6.81 kg ground corn or 9.09 kg of a 75:15:10 corn, paraffin, tallow mixture each morning. Paraffin was obtained as a wax from Farmland Industries, Coffeyville, Kansas. Feed was mixed fresh approximately every two weeks. Feed was mixed with 10% salt daily to limit intake by any one or only a few animals. Feed was offered first in mineral feeders, but because only two or three animals could eat at one time, long wooden troughs were ultimately used. The possibility of using self-feeders was considered but because of rusty conditions, they were not used.

Animals were kept from feed and water overnight for beginning and final weights. Sona-Ray was used to determine backfat thickness and loin-eye area of the steers at the end of the trial.

Data were subjected to analysis of variance as previously described.

RESULTS AND DISCUSSION

Small Scale Laboratory Preparations and In Vitro Digestibility

When soluble carbohydrate sources such as glucose, sucrose and starch were mixed with protective ingredients, they would not blend well. Cooked and extruded corn would mix with protective ingredients such as paraffin wax, tallow (yellow grease) and formalin, but little retention (protection) against rumen fermentation was offered (Appendix, Table 11). Ground and pelleted corn and alfalfa pellets would mix but the pellets, too, would break up in the rumen, leaving the insides of the pellets vulnerable to microbial degradation. Cracked corn gave better results, but differences in particle size produced uneven protection. The large particles may still be vulnerable to microbial degradation, especially if they get cracked or broken by chewing. Ground corn gave even distribution of protective coats and exposed large surface areas for coating (Appendix, Table 11).

An array of combinations of coatings and sequence of coatings was examined. Formalin apparently protects protein as shown by Ferguson et al. (1967), but might have not offered sufficient extra protection to warrant its use with carbohydrate-rich feedstuffs such as corn.

Combinations of tallow and paraffin apparently consistently gave best results (Table 1) in terms of amounts retained

after incubation in the rumen. Combinations that seemed to give the best results were 80:10:10, 75:15:10 and 70:20:10 corn:paraffin:tallow combinations.

TABLE 1. EFFECT OF VARYING RATIOS OF CORN, PARAFFIN, AND TALLOW ON THEIR RETENTION IN DACRON BAGS AT VARIOUS INCUBATION TIMES

Combinations			Time (hrs)					
Corn	Paraffin	Tallow	12	13.5	16.5	24	25	26
---- % ----			---- % Retained ----					
70	20	10[1]	85	76	76	75	70	65
70	15	15	81	82	75	71	60	49
75	20	05	84	84	74	72	64	56
75	15	10[1]	82	74	73	73	66	59
80	15	05	84	77	74	74	64	54
80	10	10[1]	81	77	72	74	59	64

[1]Ratios picked for lamb growing trial.

The percentages of the products available to the animal post-ruminally were not determined, but we presumed it to be high, even though Neudoeffer et al. (1971) have shown that only 60-65% encapsulated methionine becomes available for absorption in the intestine.

The 80:10:10, 75:15:10 and 70:20:10 corn:paraffin:tallow combinations were picked for large scale production in a lamb growing trial. For reasons beyond explanation, 10% tallow level seemed to give the best results in terms of in vitro retention. Long chained fatty acids will reduce fiber digestibility by inhibiting growth and metabolism of rumen microbes (Henderson, 1973) that may be overcome by formation of insoluble fatty acid soaps (Jenkins and Palmquist, 1982).

Lamb Growing Trial

The logic for feeding 68 g of corn to each lamb was based on differences in glucose utilization data from cattle fed high roughage verses high concentrate diets (Trenkle, 1980) and an educated guess based on metabolic body size.

Results of the growth trial are presented in Table 2 and Appendix Table 12. Animals fed the control supplement (ground corn) gained the least (219 g/day) and those receiving the 75:-15:10 combination, the most (281 g/day). The other two combinations were intermediate. The differences in growth were statistically significant (P=.011). The 75:15:10 combination produced a 28% increase in gain over controls. Lambs fed the treated grain ate more alfalfa pellets than controls, but the 75:15:10 and 70:20:10 fed groups were 19% more efficient in feed utilization.

TABLE 2. AVERAGE DAILY GAIN, FEED INTAKE, AND BACKFAT THICKNESS FROM LAMB GROWING TRIAL (FALL)

Treatment	Control	80:10:10	75:15:10	70:20:10
Animals	10	10	10	10
Days	49	49	49	49
ADG, g[1]	219±35[a]	234±37[a,b]	281±44[c]	271±58[b,c]
Daily feed, g	1634	1771	1771	1725
F/G	7.5	7.5	6.3	6.3
Backfat, cm[2]	.64	.51	1.02	.64
ADG, %	100	107	128	124
F/G, %	100	100	119	119

[1]Average starting weight = 28.5 kg.
[2]One animal slaughtered/ group.
[a,b,c]Means differing, P =.011.

The improvement in feed utilization and growth seemed to suggest that the lambs were benefiting through rumen bypass. The amount of product made available to the animals post-ruminally was not determined.

When the backfat thickness of all 40 lambs was measured using the Sona-Ray (at the end of the trial), there were no significant differences among groups. Means for the control, 75:15:10, 80:10:10 and 70:20:10 were 0.21, 0.21, 0.14 and 0.21 cm, respectively. However, when one animal was slaughtered from each group and the actual backfat thickness measured, a different story resulted. With the Sona-Ray, backfat thicknesses in control, 80:10:10, 75:15:10 and 70:20:10 were 0.38, 0.20, 0.45, and 0.38 cm, respectively. From the carcass data the thicknesses were 0.64, 0.51, 1.02 and 0.64 cm, respectively. In this case, one may say that the values measured by Sona-Ray might not have been true backfat thickness values for the animals. However, because backfat thickness was obtained from one lamb carcass per group, the data are probably unreliable.

Lamb Finishing Trial

Average daily gain (ADG) and feed utilization for animals used in the lamb finishing trial are in Table 3 and Appendix Table 13. Animals in the treated group gained more than controls (171 g/day vs. 132 g/day). This was a 30% improvement in gain, but because only five animals per group were used, this did not warrant statistical difference (P=.173). Feed utilization was 36% better in the treated group, but compared

to the first lamb trial, efficiency was lowered in both treated and control groups. When compared to the data obtained in the lamb growing trial, the daily gains were lowered by almost 50% (Tables 2 and 3). The feed to gain ratio also increased from 7.5 to 18.64 (149% increase) for controls and 6.33 to 13.48 (113% increase) for the treated group. This is in agreement with the work of Ames and Brink (1977) which showed that when lambs are subjected to extreme weather conditions, feed utilization and average daily gains go down drastically. The lambs were shorn a few weeks before the finishing trial began and during the harsh winter, they were probably doing all they could do to keep themselves alive.

TABLE 3. PRODUCTION DATA OF LAMB FINISHING TRIAL (WINTER)

Treatment	Control	75:15:10	P
Animals	5	5	
Days	44	44	
ADG, g[1]	132±19	171±56	.173
Daily feed, g	2.42	2.31	
F/G	18.33	13.48	
ADG, %	100	130	
F/G, %	100	136	

[1]Average starting weight = 42.4 kg.

The improvement in growth of the treated group over the control group is similar to the 28% growth response in the lamb growth trial.

Feed utilization was 36% more efficient with the group fed

the treated corn over the group fed plain corn. It is very difficult to relate this to the 19% improvement obtained during the lamb growing trial except that lambs in this trial were near mature weight.

Carcass data (Table 4 and Appendix Table 14) show that the treated lambs tended to have more fat, but there were no statistical differences in carcass yield (P=.641), carcass grade (P=.762), kidney knob (P=.647), loineye area (P=.707) and back-

TABLE 4. CARCASS DATA FROM LAMB FINISHING TRIAL

Treatment	Control	75:15:10	P
Carcass yield,%	51.76	54.06	.641
Carcass grade	Ch^{o}	Ch^{o}	.762
Backfat, cm	.523	.640	.120
Kidney knob,%	2.30	2.75	.647
Loin eye, cm^2	18.97	18.31	.707
Yield grade	2.92	3.45	.034

fat thickness (P=.120), even though most of these parameters individually tend to favor the lambs in the treated group. Yield grade was statistically different (P=.034), indicating that the treated group was fatter. Composition of lamb loins (Table 5 and Appendix Table 15) shows no differences in moisture, protein and fat content between treated and control groups, even though there was less variability (lower standard deviation) with animals fed the treated supplement.

TABLE 5. COMPOSITION OF LAMB LOINS (LAMB FINISHING TRIAL)

Treatment	Moisture,%	Protein,%	Fat,%
Control	72.90±1.19	22.27±.61	4.40±.96
Treated	72.29±0.33	22.36±.27	4.45±.26

Volatile Fatty Acid Profiles and Duodenal Glucose

VFA data (Table 6) show typical values for a high roughage ration with slight decreases at 8 hours for total acetate and propionate but with increased butyrate, valerate and isovalerate when control supplement was fed. The acetate to propionate (AP) ratio was 5.6, both at 4 and 8 hours after feeding. With steers fed the treated supplement, total VFA, acetate and AP ratios were lower than in control while propionate increased. No isobutyrate, valerate or isovalerate were detected with the treated supplement. This seems to contradict the assertion by Brown et al. (1962) that low roughage rations and dietary fat increase valerate and higher acids due to the presence of these acids and their precursors in the dietary fat. The AP ratio was lower in the treated group (3.6 vs. 5.6). Moody (1971) and Brown et al. (1962) reported lower ratios when cattle were fed lower roughage rations.

With regards to the total VFA, in both supplements the values obtained are slightly lower than those reported by Church (1979) who reviewed many values reported by other workers. Total VFA may range from 60 to 250 micromoles/ml, depending on the nature of the diet and period after feeding.

Concentrations of VFA will also vary. For instance, when sheep were fed alfalfa hay, the molar percentages of acetate, propionate and butyrate after .5, 4 and 8 hr of feeding were 71, 17, 12; 69, 19, 12; and 71, 19, 12, respectively.

TABLE 6. RUMINAL VFA CONTENT OF RUMEN CANNULATED STEER FED CRACKED CORN AND TREATED SUPPLEMENT

	Total	Ace	Pro	IBut	But	IVal	Val	A/P
Control								
4 hr	58.7	73.4	13.1	0.6	9.8	1.9	1.2	5.6
8 hr	53.1	72.3	12.9	0.5	10.8	2.0	1.6	5.6
Treated								
4 hr	56.9	71.0	19.9	0.0	9.1	0.0	0.0	3.6
8 hr	40.7	69.9	18.5	0.0	11.6	0.0	0.0	3.8

The increase in propionate and decrease in acetate and AP ratio does not agree with the findings of Moody (1971) who reported that added dietary fats had no effect on VFA amounts or ratios.

Duodenal glucose values (Table 7) suggest that very little grain from the control corn left the rumen while some amount from treated grain bypassed.

TABLE 7. STEER DUODENAL GLUCOSE LEVELS FROM CONTROL AND TREATED SUPPLEMENTS FED IN THE LAMB FINISHING TRIAL

Item	Glucose (mg/dl)
Control	
4 hr	0.4
8 hr	0.0
Treated	
4 hr	31.7
8 hr	44.9

Steer Feeding Trial

Weight gain and feed utilization data from the steer feeding trial are shown in Table 8 (Appendix Table 16). Within two weeks after the trial was begun, one steer from the 90:0:10 corn:paraffin:tallow group in barn E went off feed and contracted extreme diarrhea. The veterinary diagnosis was that of a viral infection due to extremely damp, wet and filthy conditions. Two animals from the 75:15:10 treatment also contracted diarrhea and went off feed about three weeks later. They were the immediate neighbors of the steer that had become sick earlier. In fact, most of the steers in barn E did not look well. We had to spend hours trying to clean their individual pens. At the end we had to move them to the open side of the barn because of lack of proper ventilation.

TABLE 8. AVERAGE DAILY GAINS, FEED INTAKE AND FEED EFFICIENCIES FROM THE STEER FEEDING TRIAL (SPRING)

Treatment	Control	90:00:10	75:15:10	P
Animals	7	6	5	
Days	58	58	58	
ADG, kg	.98±.16	1.08±.08	1.02±.10	.592
Daily feed, kg	7.47±.57	7.92±.34	8.01±.22	.085
F/G	7.71±.86	7.46±.55	7.90±.74	.619

Although the steers fed treated supplements gained more than those fed control corn (983 g/day for controls, 1075 g/day for the 90:00:10 corn:paraffin:tallow group, and 1022 g/day for the 75:15:10 corn:paraffin:tallow group which represent 9.4 and 4.0% improvement over control, respectively), statistically there was no significant difference (P=.592). Steers fed

treated supplements ate more than those fed control corn (P= .085). Feed efficiencies did not differ (P=.619).

The paraffin for the lamb studies was obtained in 454 g boxes from a local grocery store. This paraffin is normally used for canning. The 68 kg needed for the steer trial was obtained from the State Surplus in Topeka and was labeled candle wax. A local representative from Farmland Industries later mentioned that candle wax contains an additive that prevents the paraffin from sticking to surfaces. The treated corn may not have bypassed the rumen as expected.

Dacron bag and duodenal glucose tests were conducted to verify bypass potential of the supplement. The results (Table 9) show that this product was probably unsatisfactory and the paraffin with the additive probably did not adhere to the corn as expected. Both tallow and tallow plus paraffin did increase doudenal glucose levels but duplication of samples was too poor to make valid conclusions (Appendix Table 17).

TABLE 9. DACRON BAG RETENTION AND DUODENAL GLUCOSE CONTENTS OF GRAIN FROM STEER FEEDING TRIAL

Treatment	Dacron bag retention (%)[1]	Duodenal glucose (mg/dl) 4 hr	8 hr
Control	65	.09	.27
90:00:10[2]	56	.20	.59
75:15:10[2]	65	.65	.31

[1]Based on 17 hr incubation.
[2]Grain:paraffin:tallow ratio.

Steer Pasture Study

Growth, expressed as ADG, backfat thickness and ribeye area (Sona-Ray) data for the pasture trial are found in Table 10 (Appendix Table 18). The treated group gained more than the control group (761 g/day vs. 680 g/day). This represents a 12% improvement in growth, but was not statistically different (P= .169). One animal from the control group could not be located on the day steers were fasted for the final weighing. It turned up later and was sick, so it was not included.

Backfat thickness did not differ (P=.111) between control and treated groups, even though controls had higher values. However, I have some doubts about the accuracy of the Sona-Ray, especially when we got different results during the lamb growing trial.

TABLE 10. GAIN AND SONA-RAY DATA FROM THE STEER PASTURE TRIAL

Treatment	Control	75:25:10	P
Animals	14	15	
Days	63	63	
ADG,g	680±153	761±155	.167
Backfat,cm	.29±.12	.22±.12	.111
Ribeye area, cm^2	47±5	46±5	.711

Yang et al. (1982) have investigated the interaction between acetate and glucose metabolism in ovine adipocytes. Acetate increases glucose utilization apparently by increasing activity of the pentose pathway as a result of enhanced utilization for fatty acid synthesis. They speculated that certain metabolic characteristics in ruminant adipose tissue, which are not yet recognized, restrict glucose carbon flux

through key enzyme reaction step(s). Trenkle (1980) reported that efficient utilization of acetate for fattening should depend on the amount of precursors available for synthesis of glucose. We thought of using a glucose source (starch) directly. This gave us the 28% and 30% improvement in growth during the lamb growing and finishing trials, respectively. This was also equivalent to a 19 and 36% improvement of feed utilization for the respective lamb trials. With steers, the improvements were not as impressive. May be by using both protein and carbohydrate sources, better results may be obtained.

Trenkle (1980) and Peel et al. (1982) have suggested that certain key hormones may be limiting the efficient utilization of energy in ruminants. Growth hormone was more important than even potentially limiting nutrients, glucose and amino acids (Peel et al., 1982).

One of the key determinants of animal performance is palatability or acceptability of feed. Animals used in lamb growing, lamb finishing and steer pasture trials seemed to like the treated supplement better than plain corn. This was evident from the way they would rush when being fed, or in the case of steers, how they used to remain near the feeders on several occassions and how effectively they cleaned the feeders; and freshness of tallow seemed to be the key to acceptability. Tallow can easily become rancid and the animals may not accept it as pointed out by Ensminger and Olentine (1978). One time a non-fresh, smelly tallow was used during the lamb growing

trial. The animals refused to eat the supplement. Thus, fresh tallow should always be used so as to facilitate animal acceptance of the feed.

When one goes back into the literature, one will find that most of the impressive results were obtained when sheep were used. Ferguson et al. (1967), Armstrong and Blaxter (1957a, 1957b, 1957c) and Armstrong et al. (1958) all conducted their research with lambs. Perhaps lambs respond to rumen bypass better than cattle. However, McCartor and Smith (1978) have reported that steers fed a protected tallow product gained more ($P<.02$), consumed less ($P<.001$) feed per kg gain, had higher ($P<.10$) marbling score and USDA grade, and had greater ($P<.10$) amounts of fat in the longissimus muscle over steers fed the control diet.

The field of rumen bypass should continue to be an exciting one. I believe if a better means of protecting the starch is obtained so that it bypasses the rumen, better responses would result. The manner in which the feed supplement had been mixed could have altered the effectiveness of the rumen bypass. The horizontal mixer is relatively slow and the manner in which the paraffin was spread (manually using punched cans) could have resulted in decreased coating capability. Pelleting was tried without success due to sticking of the product in the die. If a device is obtained whereby the supplement is mixed very rapidly when the paraffin and tallow are still very hot, better coating and rumen bypass may be facilitated. That could result in a better means of fattening

ruminants.

Although impressive responses were obtained when lambs were used, results from the steer trials made it impossible for one to verify the assertion that ruminants fed high roughage rations are metabolically limited to lipogenesis due to inadequate grain bypassing the rumen.

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APPENDICES

TABLE 11. DACRON BAG RETENTION OF CORN (C), PARAFFIN (P), AND TALLOW (T) IN THE RUMEN: EFFECT OF VARIOUS COMBINATIONS AND LENGTHS OF INCUBATION PERIODS

C	P	T	Time (hr) in the rumen								
%			11	12	13	13.5	14.5	16	16.5	24	26
			% Retained								
82	12	6		45							
82	12	6		49							
80	15	5		83		75	77		74	74	54
80	15	5		86		80					
80	10	10		79		75	76		72	74	64
80	10	10		83*		79					
75	20	5		67*		84		75	74	72	56
75	20	5		77*		84					
75	20	5		86							
75	15	10		82		72		72	74	73	59
75	15	10				76					
70	20	10		81		75		75	76	7	65
70	20	10		88		77					
70	15	15	54*	75		80		76	75	71	49
70	15	15		87		84*					
65	20	15	83*	74	72*	75					
65	20	15		71							
65	17.5	17.5	72*								
65	15	20	74*	69*	71*	73					
65	15	20**		70							
80	15	5 **		67		67	55	55			
80	10	10**		64		66	51				
80	10	10**		45		45					
75	20	5**		68		61	54	64			
75	20	5 **				65					
75	15	10**		53		66	53	63			
75	15	10**				63					
70	20	10**		63		60		61	53		
70	20	10**				46					
70	15	15**		45		44*	54		49		
70	15	15**		67		45*					
65	20	15**		29*		20*					
65	15	20		31		27					
100	pelleted			53		52	60				

* Formalin added.

** Extruded material.

TABLE 12. INDIVIDUAL DATA FOR LAMB FEEDING TRIAL (FALL)

Initial wt. (kg)	Final wt. (kg)	Gain (kg)	ADG (kg)	Backfat (cm)
Control				
26.82	38.18	11.36	.232	.127
43.64	55.00	11.36	.232	.381
34.55	43.18	8.64	.176	.203
23.64	35.46	11.82	.241	.203
25.00	47.27	12.27	.250	.254
29.09	40.46	11.36	.232	.305
29.09	38.64	9.55	.195	.203
18.18	29.09	10.91	.223	.203
22.73	35.46	12.73	.260	.051
26.82	34.09	7.27	.148	.203
75:15:10	Corn, Paraffin, Tallow Combination			
32.27	43.64	11.36	.232	.203
25.91	41.36	15.46	.316	.127
29.55	45.46	15.91	.325	.254
37.73	52.73	15.00	.306	.457
22.73	34.55	11.82	.241	.178
24.55	40.91	16.36	.334	.127
22.00	33.64	13.64	.278	.127
28.64	38.64	10.00	.204	.127
28.18	40.91	12.73	.260	.203
35.46	50.91	15.46	.316	.305
70:20:10	Corn, Paraffin, Tallow Combination			
30.46	45.00	14.55	.297	.203
25.46	40.00	14.55	.297	.203
31.82	47.27	15.45	.315	.254
28.18	43.64	15.45	.315	.203
37.27	45.46	8.18	.167	.254
35.91	50.00	14.09	.288	.381
28.64	40.91	12.27	.250	.203
22.27	33.64	11.36	.232	.127
24.55	34.09	9.55	.195	.178
20.46	37.73	17.27	.353	.127
80:10:10	Corn, Paraffin, Tallow Combination			
37.27	47.27	10.00	.204	.254
36.36	49.09	12.73	.232	.203
28.64	39.09	10.46	.215	.127
20.91	31.82	10.91	.223	.051
28.64	40.46	11.82	.241	.254
30.91	42.73	11.82	.241	.127
25.00	38.18	13.18	.269	.127
31.82	45.91	14.09	.288	.127
20.46	32.73	12.27	.250	.127
25.00	32.73	7.73	.158	.203

TABLE 13. PRODUCTION DATA FROM LAMB FINISHING TRIAL

Initial wt. (kg)	Final wt. (kg)	Gain (kg)
Control		
39.55	45.46	5.91
42.73	47.27	4.55
45.46	51.36	5.90
45.46	51.36	5.90
40.00	46.82	6.82
Treated (75:15:10)		
39.09	46.82	7.73
45.46	50.00	4.55
40.46	47.73	7.27
43.18	54.55	11.36
43.18	50.00	6.82

TABLE 14. INDIVIDUAL CARCASS DATA FROM LAMB FINISHING TRIAL

Lamb No.	Carcass Yield(%)	Carcass Grade	Backfat (cm)	Kidney Knob(%)	Loineye Area(cm^2)	Yield Grade
Control						
4	52	Ch^{o}	.635	2.0	14.13	3.1
6	51	Ch^{o}	.635	1.0	13.23	2.5
7	54	Ch^{+}	.457	3.0	14.52	2.9
8	51	Pr^{-}	.559	3.0	12.90	3.2
21	51	Ch^{-}	.330	2.5	16.84	2.5
Treated						
1	50	Ch^{o}	.508	3.0	11.94	3.2
2	62	Pr^{-}	.762	3.5	11.55	4.0
3	50	Ch^{o}	.711	1.5	12.71	3.3
25	56	Ch^{+}	.584	3.0	16.32	3.3

TABLE 15. MOISTURE, PROTEIN AND ETHER EXTRACT OF LOINS FROM LAMB FINISHING TRIAL

Lamb no.	Moisture (%)	Protein (%)	Fat (%)
Control			
4	73.54	21.41	4.42
6	72.87	22.84	3.58
7	74.55	21.72	2.80
8	72.74	22.93	4.87
21	70.90	22.47	5.80
Treated			
1	72.32	22.17	5.60
2	72.91	22.08	5.60
3	71.84	22.29	4.99
5	73.74	22.27	3.72

TABLE 16. PRODUCTION DATA FROM STEER FEEDING TRIAL

Steer no.	ADG (kg)	Feed (kg/d)	F/G
Control			
77	.674	6.45	9.57
112	.940	7.12	7.57
42	1.019	7.83	7.69
45	1.176	8.07	6.86
11	1.003	7.55	7.53
66	1.003	7.28	7.26
91	1.066	8.00	7.51
Tallow			
5	1.058	7.43	7.39
7	.940	7.79	8.29
76	1.066	8.24	7.73
31	1.097	8.14	7.42
5+5	1.160	7.67	6.61
38	1.129	8.24	7.30
Tallow + Paraffin			
58	.893	8.02	8.97
20	1.144	8.36	7.31
86	1.019	8.04	7.88
16	1.097	7.83	7.14
88	.956	7.83	8.19

TABLE 17. STEER DUODENAL GLUCOSE FROM SUPPLEMENTS FED DURING THE STEER FEEDING TRIAL

Treatment	Time after Feeding (hr)	Glucose (mg/dl)
Corn	4	.090
	4	.000
	8	.180
	8	.360
Corn + Tallow	4	.180
	4	.225
	8	.585
	8	.585
Corn + Paraffin + Tallow	4	.810
	4	.495
	8	.495
	8	.135

TABLE 18. PRODUCTION DATA FROM STEER PASTURE TRIAL

Steer no.	Starting wt. (kg)	Final wt. (kg)	ADG (kg)	BF (cm)	LEA (cm^2)
Control					
251	288.64	315.91	.433	.254	7.1
307	302.27	331.82	.469	.381	7.6
102	413.64	465.91	.830	.127	8.8
289	354.55	384.09	.469	.254	7.0
141	359.09	404.55	.723	.381	7.2
091	313.64	361.36	.758	.127	6.8
063	63.64	406.82	.685	.254	7.4
078	322.73	363.64	.649	.381	7.4
073	315.91	363.64	.758	.127	6.5
098	340.91	388.64	.758	.381	6.5
052	347.73	411.36	1.01	.254	6.8
094	325.00	365.91	.649	.254	6.8
206	372.73	413.64	.649	.508	8.5
062	354.55	397.73	.685	.381	8.3
Treated (75:15:10)					
115	229.55	286.34	.902	.076	6.3
078	320.46	352.27	.505	.127	5.7
156	347.73	388.64	.649	.076	6.9
085	370.46	429.55	.938	.127	8.3
308	347.73	400.00	.830	.254	7.5
H31	334.09	377.27	.685	.381	7.4
581	359.09	413.64	.886	.254	7.2
168	395.46	461.36	1.05	.254	7.6
274	304.55	354.55	.794	.127	7.6
065	320.46	356.82	.577	.254	6.8
025	329.55	375.00	.723	.127	7.2
038	363.64	397.73	.541	.381	7.7
095	268.18	320.46	.830	.076	5.7
04H	306.82	350.00	.685	.381	7.2
173	356.82	409.09	.830	.381	8.4

RUMEN BYPASS OF PROTECTED CORN IN LAMBS AND STEERS

by

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B.S., Ahmadu Bello University, 1979

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1982

Laboratory experiments, two lamb trials, and two steer trials were used to test the value of bypassing the adult ruminant with grain.

A number of combinations of feedstuffs and protective ingredients were mixed and placed in dacron bags for ruminal digestion. Several combinations of corn, paraffin and tallow provided the best protection against ruminal degradation. Mixing of supplements was achieved by placing ground corn in a horizontal mixer and then successfully adding hot tallow and hot paraffin.

Forty lambs were divided into four groups and fed ad libitum dehydrated alfalfa pellets, with either corn, 80:10:10, 75:15:10, or 70:20:10 corn:paraffin:tallow (CPT) supplement for 49 days. The 75:15:10 combination had a 28% improvement in gain and a 19% improvement in feed efficiency over control. Growth was statistically different (P=.011). Feed intake and backfat thickness did not differ.

Ten lambs were divided into two groups and fed ad libitum alfalfa pellets and either corn or 75:15:10 CPT supplement for 44 days. The treatment group gained 30% and utilized the feed 36% better than controls. Carcass data indicated that the treated group did better than controls, though there was no statistical difference. Yield grade of carcasses differed (P= .034), indicating that animals in the treated group were fatter.

Samples of supplements fed to the lambs were fed to

ruminally and duodenally cannulated steers. Steers fed control supplement had higher total volatile fatty acids, higher acetate, higher acetate:propionate ratios, but lower propionate than those fed the 75:15:10 CPT supplement. While only small amounts of glucose were found in the duodenum of steers fed the control grain, glucose was detected in the duodenum of steers fed the treated supplement.

Twenty-one steers were divided into three groups and fed ad libitum sorghum silage and either corn, 75:15:10 or 90:0:10 CPT supplements for 58 days. Steers did not perform well, probably due to a viral infection. Steers fed the treatment supplements gained more than those fed corn, but this was not statistically significant. Average daily gain and feed to gain ratio did not differ, but steers fed treated supplements ate more (P=.085) than controls. Dacron bag and duodenal glucose tests indicated that the paraffin used during the steer feeding trial was probably unsuitable for coating to warrant rumen bypass.

Thirty steers were divided into two groups of fifteen and allowed to graze on pasture while receiving either corn or a 75:15:10 CPT supplement for 63 days. Steers receiving the treated supplement gained 12% better than controls, but the data were not statistically different (P=.167). Backfat thickness and ribeye area did not differ.

We could not support the assertion that ruminants fed a high roughage ration would respond to lipogenesis with corn bypass.