AN ABSTRACT OF THE THESIS OF

MARK STEPHEN ASELTINE for the degree of MASTER OF SCIENCE

in Animal Science presented on April 11, 1977

Title: THE EFFECT OF FEEDING TALLOW, UREA AND PROTECTED TALLOW ON *IN VIVO* NUTRIENT DIGESTION IN SHEEP

Abstract approved: Redacted for Privacy
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Five sheep digestion trials with four animals per treatment and three treatments per trial were conducted to determine if feeding protected tallow and/or protein would alter the deleterious effects of feeding urea and tallow together. Apparent digestibility coefficients, nitrogen retention and biological values were calculated.

An additional trial was also conducted with five animals per treatment and four treatments per trial with a high level of roughage (47-50 percent ryegrass straw) and a moderate level of tallow (3 percent) with supplemental nitrogen being supplied by urea (control) soybean meal (SBM), Starea, or hydrolyzed feather meal. Higher dry matter (DM) digestibility, nitrogen retention and biological values resulted when feather meal and the SBM diets were compared to the Starea diet or the urea control. All diets were higher ($P < .05$) in fat digestion when compared with the urea control without tallow.

Animals consuming diets of tallow and urea together resulted in lower ($P < .05$) digestibility of dry matter, ash, acid detergent fiber (ADF), digestible energy (DE), and crude protein (CP). When the tallow was protected from rumen microbial metabolism, nitrogen retention, DE and CP were improved ($P < .05$). Diets of protected tallow and protected tallow + protected protein showed increased ($P < .05$) fat digestibility over a control diet without fat. Negative nitrogen retention occurred when the protected tallow diet was fed. When urea was consumed at high levels (2.5 percent) + straw + tallow, the digestibility of DM, ash, and DE improved ($P < .05$) over a diet with low urea (1 percent) + alfalfa + tallow. The addition of protected tallow to the high urea diet resulted in an increase in DM and DE digestibility compared with the low urea + alfalfa + tallow diet. The protected tallow diet again resulted in lower ($P > .05$) nitrogen retention and biological value. When a commercially protected fat product (Alta Lipid) was compared to diets of urea + tallow or urea absorbed in the grain + tallow, digestibility differences were slight.

The Effect of Feeding Tallow, Urea and Protected Tallow on *In Vivo* Nutrient Digestion in Sheep

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of the requirements for the degree of

Master of Science

June 1978

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Date thesis is presented April 11, 1977

Typed by Deanna L. Cramer for Mark Stephen Aseltine

ACKNOWLEDGEMENTS

I wish to express thanks to Dr. D. C. Church, my major professor, for assistance and guidance thoroughout my graduate study. I would also like to thank Drs. Oldfield and Arscott for serving as members of the graduate committee.

I would also like to thank the Experimental Station for the assistantship received, and the financial assistance given by the Fats and Protein Research Foundation.

To my wife, Elena, a special thanks for her patience and love over the years.

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# THE EFFECT OF FEEDING TALLOW, UREA AND PROTECTED TALLOW ON *IN VIVO* NUTRIENT DIGESTION IN SHEEP

## INTRODUCTION

Urea is widely used as a supplementary nitrogen source in beef cattle rations. In areas where plant protein sources are expensive, the use of urea has resulted in reduced costs of cattle weight gain. Animal tallow is often fed to cattle in feedlot rations. Tallow affords a method of increasing the caloric density of the ration while controlling dust, increasing palatability and improving feed efficiency (National Research Council, 1976). The adverse effects of feeding tallow and urea togehter are documented in studies by Jones *et al*. (1961); Church *et al*. (1971); Bradley *et al*. (1966); Thompson *et al*. (1967); and Phillips and Church (1975).

One objective of this study was to determine if protecting the tallow and/or protein in the diets of sheep altered the deleterious effects of feeding tallow and urea together. Recently, Scott *et al*. (1970) presented a procedure for protecting fats from rumen microbial degradation. In this procedure, particles comprising oil droplets in casein were formed and the casein was treated with formaldehyde to prevent microbial attack in the rumen. Scott *et al*. (1971) demonstrated the effectiveness of this process by showing changes in the proportions of polyunsaturated fatty acids in plasma, milk and tissues of ruminants fed a protected lipid supplement.

Another objective of this study was to determine if feeding tallow added at the 3 percent level would be detrimental when feeding with supplemental nitrogen sources of soybean meal, feather meal, Starea, or urea with a moderate level of ryegrass straw (47-50 percent).

# REVIEW OF LITERATURE

It is not the intent of this thesis to exhaustively review all the literature on fat and urea. Several excellent reviews on the subject of nitrogen utilization and metabolism by ruminants have appeared in the literature (Reid, 1953; Hungate, 1966; Briggs *et al*., 1964; Chalupa, 1968; Helmer and Bartley, 1971; National Research Council, 1976). This paper will, however, discuss some of the factors associated with urea utilization, fat, fat plus urea, protected protein and protein-protected lipids as they relate to this study.

## Urea Utilization

### Feeding of Low Quality Roughage

In two feeding trials, Altona *et al*. (1960) demonstrated that supplemental urea improved the performance of cattle which consumed veld forage containing 3.5 percent protein and 54 percent total digestible nutrients (TDN) (dry basis). In a similar study, Briggs *et al*. (1947) fed mature, weathered prairie hay containing 3.5 percent protein and observed low or negative nitrogen retention when the hay was unsupplemented. Supplementing the hay with cottonseed meal, or with urea and cottonseed meal, nearly doubled nitrogen retention. Replacing all nitrogen of the cottonseed meal with urea, however, was less effective in increasing nitrogen retention. In another study wheat straw with and without small additions of cereal grains were supplemented with urea in diets containing 6.5 percent protein and 50-59 percent TDN. This resulted in improved cattle weight gains (McClymont, 1948).

Nitrogen intake was shown to be a major factor influencing the intake and digestibility of low quality roughages by ruminants. Increases in roughage intake and more efficient utilization of the roughage have resulted by increasing the nitrogen in the diet with non-protein nitrogen (Campling et al., 1962; Hemsley, 1968; and Coombe and Tribe, 1963).

## Starea

One of the problems involved with feeding urea in the diets of ruminants is the efficiency of urea utilization in the rumen due to the rapid release of ammonia. Bloomfield et al. (1960) demonstrated that urea hydrolysis occurred 4 times faster than the uptake of the liberated ammonia, thereby resulting in a partial loss of nitrogen available for microbial synthesis. One solution is to slow down the rate of hydrolysis to ammonia and carbon dioxide.

Favorable results using an expansion-processed mixture of grain and urea (Starea) were reported. The Starea mixture is produced by mixing finely ground grains (usually milo) with urea. This mixture is then passed through a cooker-extruder with moisture, temperature and pressure. The combination of moisture, temperature and pressure causes the starch to gelantinize.

Experiments with Starea indicate that ammonia release was slower from this product both in vitro and in vivo compared with a non-heated control mixture and; in addition, Starea was superior to urea as a nitrogen supplement for lactating cows and for growing, fattening cattle (Deyoe et al., 1968; and Helmer et al., 1970a).

Stiles (1969) demonstrated that Starea improved the utilization of urea nitrogen and the palatability of urea containing rations.

Helmer et al. (1970b) demonstrated that Starea was approximately equal to soybean meal as a protein supplement for lactating cows. Cows were fed grain rations supplemented with either soybean meal or Starea and consumed more grain and produced more milk than cows fed the same grain ration supplemented with urea.

Shiehzadeh and Harbers (1974) compared soybean meal, Starea and urea as nitrogen supplements to high-roughage rations fed to lambs. In one experiment, Starea (44 percent crude protein) was compared with soybean meal. Nitrogen retention was identical in both supplements. In a second experiment, urea was compared to Starea with 44 or 70 percent crude protein. Nitrogen retention for the Starea diet was twice as great as when the urea was fed. Stiles et al. (1970) showed that, although Starea was superior to urea or unprocessed grain plus urea as a protein supplement, little benefit was obtained with finely ground pelleted grain or expanded grain.

## Fat

Feeding fat increases the rations caloric density and some beneficial results have been reported. Bohman et al. (1957) reported significant increases in daily weight gain and decrease in feed required per pound of gain when finishing beef steers were fed a ration containing 5 percent animal fat. Lucas and Loosli (1944) reported large differences in the digestibility of fat of rations fed. High fat diets were more digestible than low fat rations. When rations with low fat were fed, extremely low and negative digestion coefficients were calculated. Erwin et al. (1956) reported a significant increase in daily gains of steers receiving a ration containing alfalfa hay plus 7 percent tallow; however, when straw replaced the alfalfa hay, he observed a significant reduction in rate of gain. Dyer et al. (1957) observed no significant increase in rate of gain when 7 percent animal tallow was fed to steers. Hubbert et al. (1961) studied the effects of feeding feedlot steers 10 and 13 percent protein and 0 and 4 percent tallow, and found that protein level significantly altered average daily gain. The addition of 4 percent tallow depressed slightly feed intake but had no significant influence on rate of gain. However, the addition of tallow to the diets produced more efficient conversion of feed to gain.

Esplin *et al.* (1963) demonstrated that when 4 percent animal fat fed with a 30 percent alfalfa ration, increased digestible energy and total digestible nutrients but the added tallow had no effect on the digestibility of other feed fractions.

Bohman and Lesperance (1962) found that 0.5 pounds of fat added to a grass hay diet decreased digestion of fiber and organic matter and increased ether extract and nitrogen-free extract digestion; however, the added fat had no effect on gross energy digestion. In the same experiment, 0.5 pounds of fat plus 3 pounds of alfalfa hay added to the same grass hay diet, decreased nitrogen-free extract and crude protein digestion.

Swift *et al.* (1947) observed that low levels of dietary fat (3.6 percent) improved the apparent digestibility of sheep rations which contained alfalfa hay; however, a higher level of fat (7 percent) had the reverse effect.

When hydrolyzed animal fat was fed at levels of 0, 2, 3, 4 and 6 percent in practical feedlot rations, Brent *et al.* (1971) observed that up to 6 percent hydrolyzed animal and vegetable fat could be added without reducing animal performance or carcass quality. Figroid et al. (1971) reported that adding 5 percent fat to milo finishing beef rations produced no effect on weight gains, feed efficiency or gross energy digestion, but the addition of 10 and 15 percent added fat resulted in reduced weight gains, feed efficiency and gross energy digestion. In 3 experiments with 256 finishing beef steers, Perry et al. (1976) reported that the daily feeding .4 lb (192 g) of feed grade fat per head along with a high moisture diet (ensiled high moisture corn, corn silage) did not improve rate of gain or feed efficiency. The same authors observed that addition of 3 percent feed-grade fat in a dry diet of ground corn, ground corn cobs and soybean meal depressed digestibility of crude fiber by lambs.

Johnson and McClure (1972) fed lambs high corn rations and reported faster gains than lambs which were fed a roughage ration without partially hydrolyzed animal and vegetable fat (HEF). However, lambs which were fed HEF and a high roughage ration gained faster than lambs on the high corn diets. Addition of fat to the high concentrate ration had no effect on digestion of dry matter, organic matter, or cellulose; however, crude protein digestion was reduced in the high grain diets.

## Fat Plus Urea

Jones *et al*. (1961) reported that fat plus urea fed to hereford steers in a feedlot trial resulted in depressed gains and feed efficiency. In 1966 Bradley *et al*. reported on three feedlot trials and one metabolism trial which were designed to evaluate the relationship between animal fat and urea. When 1.5 percent urea and/or approximately 5 percent fat were fed, the authors reported depressed rate of gain, digestibility of dry matter, energy and nitrogen-free extract, and increased ether extract digestibility. Phillips and Church (1975) also reported that protein digestibility and nitrogen retention were depressed when 1.5 percent urea and 5 percent tallow were fed in sheep digestion trials. Embry *et al*. (1957) demonstrated that animal fat at the 5 percent level when fed with urea (.9 percent of total ration) gave similar nitrogen retention values compared with rations without added urea. Animal fat improved digestibility of protein in the rations with urea to about the same extent as those without urea. Church *et al*. (1971) reported that steers fed a basal ration of barley containing 3 percent fat and 1 percent urea, were less efficient in the conversion of digestible energy into weight gains compared with steers fed diets with only fat or urea alone. Hatch *et al*. (1972) published results of two metabolism studies and two feedlot trials with steers and concluded that animal performance was depressed when diets containing urea had 3, 6 or 9 percent fat added. It was also reported that when 3 percent fat was substituted for the same amount of corn in a urea containing ration, there was no difference in nitrogen retention, dry matter digestibility or digestible energy.

## Protected Protein

It is known that the rumen microflora have a considerable modifying effect on the utilization of dietary nitrogen. The nature and extent of this modification are largely dependent upon the ratio and origin of the constituent materials in the diet. Under certain conditions, i.e. when the diet contains mainly poor quality protein or a non-protein nitrogenous material such as urea, this modifying effect may be advantageous to the animal. Conversely, this modifying effect may not be advantageous when protein of high quality is fed.

When different sources of protein were infused directly into the duodenum or abomasum of sheep, improved utilization was obtained. This indicates that microbial degradation of proteins is essentially wasteful (Little and Mitchell, 1967; Colebrook and Reis, 1969; Reis and Downes, 1971). This is due to the rapid deamination of readily soluble proteins by the rumen microorganisms and the subsequent loss of nitrogen in the urine (McDonald, 1952;

Chalmers and Synge, 1954; Chalmers, 1961). When dietary protein content is high, the extent of protein degradation probably exceeds protein synthesis by rumen microorganisms.

For high quality protein to be beneficial to the animal, a means of increasing the amount of protein reaching the intestines without destroying the value of the protein would be of great value in ruminant nutrition. One approach to the problem is chemical modification of good quality proteins or coated proteins to increase their resistance to microbial degradation in the rumen without reducing their nutritive value in the small intestines.

Several methods have been examined to overcome the problem of excessive degradation of proteins in the rumen. Some of the most promising of these methods involve the application of dry heat (Glimp et al., 1967; and Hudson et al., 1969, 1970), of steam heat (Tillman and Kruse, 1962; Sherrod and Tillman, 1962, 1964) and, recently, of formaldehyde treatment (Ferguson et al., 1967; Reis and Tunks, 1970; Falchney, 1974). Any protection procedure must leave the protein in a form capable of being digested in the intestines. The difference in pH between the rumen (normally above pH 6) and the abomasum (normally below pH 3) allows for the reversal of the effects brought about by treating chemically or coating the protein with vegetable tannins (Leroy et al., 1965).

When casein was treated with formaldehyde and fed to sheep, at least 80 percent of the nitrogen could be digested and absorbed by the animals, resulting in an increase in wool growth by 70 percent (Ferguson et al., 1967). Digestion in the lower gut seemed unimpaired. The formaldehyde treatment of casein is believed to cause the formation of methylene bridges and other cross-linkages between protein chains. These changes brought about by formaldehyde render the protein undegradable by the rumen microbes but utilizable in the small intestine. The apparent reason for the success of this method is the change of pH from about 6 in the rumen to about 3 or less in the abomasum and proximal duodenum.

Reis and Tunks (1969) studied the effects of 3 types of casein supplements in an all-roughage diet on wool growth, body weight gain and nitrogen retention. The supplements consisted of untreated casein in the diet, untreated casein given by abomasal cannula and formaldehyde treated (4 percent) casein in the diet. The results indicated that the formaldehyde treated casein and casein by abomasum were similar in nutritional value, and both were superior to untreated casein in the diet for all parameters studied. The treated casein was 90 percent digestible. In a 1970 study, Reis and Tunks found that treated casein in the diet and casein by abomasum increased the concentration of plasma amino acids and caused proportional increases in essential amino acids. Untreated casein in the diet had little effect upon either the concentration or proportions of amino acids in the plasma.

Zelter et al. (1970) indicated that formaldehyde, glyoxal and glutaraldehyde, in concentrations from 0.5 percent to 3 percent, were effective agents for reducing bacterial breakdown of protein in peanut, soybean, linseed, rapeseed, sunflower and alfalfa meals, dried skim milk and casein.

The treatment of casein with formaldehyde generally resulted in increased nitrogen retention, wool growth and muscle growth (Barry, 1972; Faichney, 1971; Mac Rae et al., 1972; Reis and Tunks, 1969; and Wright, 1971).

In a study by Faichney (1974), formaldehyde treatment of casein reduced nitrogen digestibility but reduced urine nitrogen excretion to a greater extent so that nitrogen retention actually increased.

The methods of producing formaldehyde-treated proteins are varied. Faichney (1974) sprayed casein with 10 percent w/v formaldehyde solution while continuously mixing; 19 mg of formaldehyde was then added per gm of dry casein and the treated casein was sealed in a plastic bag for 10 days.

Ferguson et al. (1967) soaked casein in diluted aqueous formaldehyde then he washed and dried the product.

## Protein-Protected Lipids

The rumen microflora have a regulatory function on the lipid utilization by the ruminant. The rumen microflora are responsible for the hydrolysis, hydrogenation and isomerisation of dietary lipids, and also for the synthesis of microbial lipids from components of the diet. One of the problems with this type of digestive system is the sensitivity of the ruminant animal to the addition of fat in the diet. When the addition of approximately 8 percent fat is added to the existing diet, reduction of intake, animal performance, and the digestibility of cellulose have been reported (Brooks *et al*., 1954; Ward *et al*., 1957; Johnson, 1972; Johnson and McClure, 1972). The performance of the animal depends upon factors such as: (1) the type of basal ration, (2) the amount and fatty acid composition of the lipid supplement, and (3) the method of feeding the added lipid. Diets of ruminants, therefore, only contain limited amounts of supplementary lipids and their main function is to aid in pelleting, improve palatability, reduce dust, and provide a small amount of energy to the diet.

Recently a new technique was found to protect dietary fats and oils from rumen microbial degradation (protein-protected lipids). This process protects the lipids from degradation in the rumen without interfering with their absorption from the small intestines. This system would allow increased levels of fat to be fed and would possibly utilize more efficiently dietary fat.

Protein-protected lipids are oil or fat droplets that are encapsulated in a layer of aldehyde treated protein which, because of the cross-linking between free amino groups, is relatively resistant to microbial degradation in the rumen. Like protected proteins, the protein-protected lipids are digested and absorbed in the small intestines.

The protein-protected lipids also provide a method of increasing the caloric density of the ration without interfering with the digestion in the rumen (Faichney et al., 1972; Hogan et al., 1972). However, Lodge et al. (1972) has reported that an increase in the caloric density of the diet may increase the amount of fat deposited in the body.

# MATERIALS AND METHODS

Twelve crossbred wethers with four animals per treatment and three treatments per trial were used in five digestion trials. Each trial consisted of a control and two test diets. In addition, one digestion trial was completed using a combination of 20 crossbred ewes and wethers with five animals per treatment and four treatments per trial. Each trial consisted of one control and three test diets. All rations were prepared in the Oregon State University Animal Science feedmill and mixed in a small batch mixer. Composition and nutrient composition of diets I through VI are shown in Tables 1-6.

The animals were housed in metabolism cages designed to allow separation of the urine from the feces. Animals were fed 500 g twice daily, trace mineralized salt and water were available at all times. Each trial consisted of a 10-day preadjustment period, a 10-day adjustment period and an 8-day collection period. During the preadjustment period all lambs received the control ration.

The protected tallow complex (80 percent tallow-20 percent casein) was prepared according to the general procedure of Scott _et al_. (1971). Acid-precipitated casein was dissolved in water at 10°C, using sodium hydroxide to adjust the pH to 6.8. Tallow was steam heated, added to the mixture and homogenized in a two-stage homogenizer (Manton-

Table 1. Composition and nutrient composition of rations for Trial I.

| Item | Basal + SBM % | Basal + Urea (1.7%) | Basal + SBM + Tallow (4.7%) |
|---|---|---|---|
| Alfalfa | 6.59 | 5.93 | 6.28 |
| Beet pulp, shredded | 11.53 | 11.63 | 10.98 |
| Barley, rolled | 61.80 | 74.78 | 58.88 |
| Molasses, cane | 4.16 | 4.94 | 3.96 |
| Soybean meal (SBM) | 14.93 | -- | 14.23 |
| Limestone | .99 | .99 | .95 |
| Urea | -- | 1.73 | -- |
| Tallow | -- | -- | 4.72 |
| Analytical Values | | | |
| Dry matter (DM), % | 88.39 | 88.19 | 88.94 |
| Ash, % of DM | 5.15 | 4.20 | 4.30 |
| Crude protein, % of DM | 16.61 | 16.37 | 14.45 |
| Acid detergent fiber, % of DM | 13.33 | 10.88 | 12.52 |
| Fat, % of DM | 1.06 | 1.19 | 6.13 |
| NFE[a], % of DM | 52.24 | 55.55 | 51.54 |
| Gross energy kcal/g | 4.02 | 3.78 | 4.22 |

[a]Nitrogen free extract

Table 2. Composition and nutrient composition of rations for Trial II.

| Item | Basal + SBM % | Basal + Urea (1.6%) + Tallow (4.7%) | Basal + Urea (1.6%) + Protected Tallow (5.4%) |
|---|---|---|---|
| Alfalfa | 6.59 | 5.65 | 5.53 |
| Beet pulp, shredded | 11.53 | 11.08 | 10.84 |
| Barley, rolled | 61.80 | 71.25 | 69.73 |
| Molasses, cane | 4.16 | 4.71 | 4.61 |
| Soybean meal | 14.93 | -- | -- |
| Limestone | .99 | .95 | .92 |
| Urea | -- | 1.65 | 1.61 |
| Tallow | -- | 4.71 | 5.40 |
| Casein | -- | -- | 1.36 |
| Analytical Values | | | |
| Dry matter (DM), % | 85.43 | 84.04 | 86.00 |
| Ash, % of DM | 4.29 | 3.21 | 3.14 |
| Crude protein, % of DM | 12.7 | 12.0 | 17.09 |
| Acid detergent fiber, % of DM | 11.88 | 8.10 | 6.45 |
| Fat, % of DM | .88 | 3.04 | 3.34 |
| NFE[a], % of DM | 55.68 | 57.69 | 55.98 |
| Gross energy, kcal/g | 3.73 | 3.78 | 3.88 |

[a]Nitrogen free extract

Table 3. Composition and nutrient composition of rations for Trial III.

| Item | Basal + SBM % | Basal + SBM + Protected Tallow (5.4%) | Basal + Protected Protein + Protected Tallow (5.3%) |
|---|---|---|---|
| Alfalfa | 6.59 | 6.15 | 6.04 |
| Beet pulp, shredded | 11.53 | 10.75 | 10.56 |
| Barley, rolled | 61.80 | 57.61 | 58.38 |
| Molasses, cane | 4.16 | 3.88 | 3.81 |
| Soybean meal (SBM) | 14.93 | 13.92 | 13.67 |
| Limestone | .99 | .92 | .90 |
| Urea | -- | -- | -- |
| Tallow | -- | 5.41 | 5.31 |
| Casein | -- | 1.36 | 1.33 |
| Analytical Values | | | |
| Dry matter (DM), % | 88.43 | 84.69 | 84.85 |
| Ash, % of DM | 4.73 | 4.67 | 4.45 |
| Crude protein, % of DM | 13.3 | 13.04 | 12.51 |
| Acid detergent fiber, % of DM | 11.24 | 11.04 | 9.12 |
| Fat, % of DM | .82 | 2.49 | 2.24 |
| NFE[a], % of DM | 58.34 | 53.45 | 56.53 |
| Gross energy, kcal/g | 3.81 | 3.78 | 3.91 |

[a]Nitrogen free extract.

Table 4. Composition and nutrient composition of rations for Trial IV.

| Item | Low Urea (1%) + Alfalfa + Tallow (5%) | High Urea (2.5%) + Straw + Tallow (5%) | High Urea (2.5%) + Straw + Protected Tallow (5%) |
|---|---|---|---|
| Alfalfa | 27.40 | -- | -- |
| Beet pulp, shredded | 9.90 | 10.00 | 10.00 |
| Barley, rolled | 45.24 | 65.79 | 65.79 |
| Straw, ryegrass | -- | 10.71 | 10.71 |
| Molasses, cane | 5 | 5 | 5 |
| Soybean meal | 5.46 | -- | -- |
| Limestone | 1 | 1 | 1 |
| Urea | 1 | 2.5 | 2.5 |
| Tallow | 5 | 5 | 5 |
| Analytical Values | | | |
| Dry matter (DM), % | 86.98 | 85.70 | 86.46 |
| Ash, % of DM | 7.09 | 5.02 | 5.03 |
| Crude protein, % of DM | 13.77 | 14.67 | 14.74 |
| Acid detergent fiber, % of DM | 17.53 | 12.11 | 11.80 |
| Fat, % of DM | 4.30 | 3.63 | 3.49 |
| NFE[a], % of DM | 44.29 | 50.27 | 51.40 |
| Gross energy, kcal/g | 4.13 | 4.15 | 4.21 |

[a]Nitrogen free extract

Table 5. Composition and nutrient composition of rations for Trial V.

| Item | Basal + Urea (1.6%) + Tallow (4.7%) | Basal + Urea (1.6%) Adsorbed on Grain + Tallow (4.7%) | Urea (1.6%) + Commercial Protected Fat |
|---|---|---|---|
| Alfalfa | 28.61 | 28.61 | 26.48 |
| Beet pulp, shredded | 10 | 10 | 9.45 |
| Barley, rolled | 49.03 | 49.03 | 45.38 |
| Molasses, cane | 5 | 5 | 4.63 |
| Limestone | 1.0 | 1.0 | .93 |
| Urea | 1.65 | 1.65 | 1.53 |
| Tallow | 4.71 | 4.71 | 11.80* |
| Analytical Values | | | |
| Dry matter (DM), % | 86.13 | 87.01 | 88.40 |
| Ash, % of DM | 7.07 | 7.57 | 7.43 |
| Crude protein, % of DM | 13.46 | 14.30 | 16.42 |
| Acid detergent fiber, % of DM | 14.01 | 14.99 | 14.24 |
| Fat, % of DM | 5.70 | 5.82 | 5.20 |
| NFE[a], % of DM | 45.89 | 44.33 | 45.11 |
| Gross energy, kcal/g | 4.29 | 4.1 | 4.13 |

*Alta-Lipid product = 4.71% Tallow

[a]Nitrogen free extract

Table 6. Composition and nutrient composition of rations for Trial VI.

| Item | Urea Control % | SBM Diet 1 % | Starea Diet 2 % | Feather Meal Diet 3 % |
|---|---|---|---|---|
| Barley, rolled | 35 | 15 | 18 | 22 |
| Beet pulp, shredded | 10 | 10 | 10 | 10 |
| Straw, ryegrass | 47 | 50 | 50 | 50 |
| Urea | 2 | -- | -- | -- |
| Molasses, cane | 5 | 5 | 5 | 5 |
| Limestone | 1 | 1 | 1 | 1 |
| Feather meal | -- | -- | -- | 9 |
| Soybean meal (SBM) | -- | 16 | -- | -- |
| Tallow | -- | 3 | 3 | 3 |
| Starea | -- | -- | 13 | -- |
| Analytical Values | | | | |
| Dry matter (DM), % | 87.24 | 87.56 | 87.25 | 88.13 |
| Crude protein, % of DM | 13.34 | 11.49 | 11.33 | 13.07 |
| Acid detergent fiber, % of DM | 24.08 | 23.27 | 29.34 | 24.04 |
| Ash, % of DM | 4.65 | 6.0 | 4.93 | 4.94 |
| Fat, % of DM | .97 | 3.64 | 4.91 | 5.77 |
| NFE[a], % of DM | 44.20 | 43.16 | 36.74 | 40.31 |
| Gross energy, kcal/gm | 3.86 | 4.06 | 4.00 | 4.15 |

[a]Nitrogen free extract

Gaulin). After homogenation, 2 percent formalin (37 percent formaldehyde) by weight of casein was added. The mixture was allowed to react for 20 minutes after which it was mixed with rolled barley. This mixture was dried at 50°C in a forced air oven. The protected protein was prepared by spraying formaldehyde on casein and allowing it to react in a plastic bag before adding it to the diet.

Records were kept of feed offered and feed refused during the entire test period. Feed samples were collected daily and held for analysis. Feces were collected daily, weighed, and a 10 percent sample was removed and stored in a cooler at 4°C. Urine was collected daily and a 10 percent sample was composited for analyses. To minimize urinary nitrogen losses, 2 ml of phosphoric acid was added to the collection buckets before each collection. Urine samples also were stored in a refrigerator at 4°C until analyzed.

Data obtained from the chemical analyses and energy determinations of the feed and feces were used to calculate nitrogen retention, biological value, and digestibilities of dry matter, ash, acid detergent fiber, fat, digestible energy and crude protein for all treatment rations.

Total nitrogen, dry matter, ash, and fat in the feed and feces, and total urinary nitrogen were determined by methods described in A.O.A.C. (1971). Acid detergent fiber (ADF) of feed and feces was determined using the method of

Van Soest (1963) as described in the modified micro-procedure of Waldern (1971). Gross energy in the feed and feces was determined in a Parr oxygen bomb calorimeter. Sample sizes were about .5 gram and oxygen pressure was at 20 atmospheres. No problems were encountered with complete combustion when these amounts were used. Biological value (BV) was calculated by use of a method described by Maynard and Loosli (1969). The data in each trial were statistically analyzed by use of a one-way analysis of variance procedure as outlined by Steel and Torrie (1960). Means were compared by use of the least-significant difference (LSD) as described by Cochran and Cox (1957). Objectives for the 6 trials are hown in Table 7.

Table 7. Diets and objectives for Trials I through VI.

| Diets | Objective |
|---|---|
| Trial I | |
| Basal + SBM<br>Basal + Urea<br>Basal + SBM + Tallow | To determine if feeding tallow and urea separately produced negative effects of digestibility |
| Trial II | |
| Basal + SBM<br>Basal + Urea + Tallow<br>Basal + Urea + Protected Tallow | To determine if protected tallow altered the adverse effects of tallow and urea together |
| Trial III | |
| Basal + SBM<br>Basal + SBM + Protected Tallow<br>Basal + Protected Protein + Protected Tallow | To determine if protected tallow produced a different response than feeding protected tallow plus protected protein |
| Trial IV | |
| Low Urea + Alfalfa + Tallow<br>High Urea + Straw + Tallow<br>High Urea + Straw + Protected Tallow | To determine if feeding tallow or protected tallow with different sources of roughages had any effect on digestibility |
| Trial V | |
| Basal + Urea + Tallow<br>Basal + Urea on grain + Tallow<br>Urea + Alta Lipid | To determine the effects of feeding protected fat (Alta Lipid) compared with diets of urea + tallow and slow release urea |
| Trial VI | |
| Urea control<br>SBM + Tallow<br>Starea + Tallow<br>Feather Meal + Tallow | To determine the effects of adding 3% tallow in combination with feather meal, soybean meal, or Starea compared with a urea control without tallow |

# RESULTS AND DISCUSSION

## Trial I

The ration containing tallow had a higher fat digestibility in comparison with diets without added tallow ($P < .05$) (Table 8). This is in agreement with the work by Bohman and Lesperance (1962) who reported increased ether extract digestion when .5 of a pound of fat was added to a grass hay diet. Moody (1971) also reported increased ether extract digestion when 6 percent tallow was fed with alfalfa plus barley, milo, and cottonseed meal.

Digestibility of acid detergent fiber was higher ($P < .05$) for the soybean meal and the soybean meal + tallow diets compared with that of the urea diet. The addition of tallow to the diet also caused an increase ($P > .05$) in the dry matter, digestible energy, crude protein, and biological value compared with the diets having no added tallow. This is in agreement with the work done by Esplin *et al.* (1963). Figroid *et al.* (1971) also reported that an addition of 5 percent fat to milo finishing rations did not alter gross energy digestion.

## Trial II

The results of Trial II are given in Table 9. When animals consumed 1.6 percent urea and 4.7 percent tallow, there was a decrease ($P < .05$) in digestible dry matter,

Table 8. Apparent digestibility coefficients, nitrogen retention and biological values for Trial I.

| Treatment | Dry Matter % | Ash % | Acid Detergent Fiber % | Fat % | Digestible Energy % | Crude Protein % | Nitrogen Retention gms | Biological Value |
|---|---|---|---|---|---|---|---|---|
| Basal + SBM* | 82.62 | 52.17 | 61.61$^{A}$ | 62.37$^{A}$ | 82.13 | 83.05 | 58.97 | 37.61 |
| Basal + Urea | 81.14 | 44.73 | 53.32$^{B}$ | 68.27$^{A}$ | 80.59 | 83.72 | 63.75 | 41.29 |
| Basal + SBM + Tallow | 84.81 | 47.87 | 65.86$^{A}$ | 92.37$^{B}$ | 85.22 | 84.76 | 62.15 | 44.50 |

$^{A,B}$Significantly different within each trial ($P < 0.05$).

*Soybean meal.

ash, acid detergent fiber, energy, crude protein and reduced values for nitrogen retention and biological value compared with the basal + soybean meal diet. These results are similar to those of Phillips and Church (1975) who reported that protein digestibility and nitrogen retention were depressed when 1.5 percent urea and 5 percent tallow were fed in sheep digestion trials. Bradley et al. (1966) also reported that 1.5 percent urea and/or 5 percent fat depressed rate of gain, digestibility of dry matter, energy and nitrogen retention. In two metabolism studies with steers Hatch et al. (1972), observed that addition of 6 percent fat to diets containing 1.5 percent urea decreased nitrogen retention.

By protecting the tallow from rumen microbial degradation there was an increase ($P < .05$) in digestible energy, crude protein and nitrogen retention compared with the nonprotected tallow diet. There was also a trend for increased digestibility of dry matter, acid detergent fiber, and an increase in biological value. Animals consuming tallow in both diets resulted in higher ($P < .05$) digestibility of fat compared with the diet without tallow.

## Trial III

The digestibility of fat was improved ($P < .05$) with diets of protected protein and protected tallow + protected protein compared with a diet of soybean meal without added

Table 9. Apparent digestibility coefficients, nitrogen retention and biological values, for Trial II.

| Treatment | Dry Matter % | Ash % | Acid Detergent Fiber % | Fat % | Digestible Energy % | Crude Protein % | Nitrogen Retention gms | Biological Value |
|---|---|---|---|---|---|---|---|---|
| Basal + SBM* | 84.69$^{A}$ | 41.68$^{A}$ | 59.22$^{A}$ | 49.92$^{A}$ | 83.59$^{A}$ | 81.55$^{A}$ | 23.09$^{A}$ | 20.49 |
| Basal + Urea + Tallow | 79.12$^{B}$ | 22.22$^{B}$ | 17.53$^{B}$ | 85.78$^{B}$ | 75.83$^{B}$ | 75.19$^{B}$ | 7.92$^{A}$ | 8.90 |
| Basal + Urea + Protected Tallow | 81.63 | 22.37$^{B}$ | 31.18$^{B}$ | 88.68$^{B}$ | 80.12$^{A}$ | 84.90$^{A}$ | 55.58$^{B}$ | 34.77 |

$^{A,B}$Significantly different within each trial ($P < 0.05$).

*Soybean meal.

tallow (Table 10). Ash digestibility decreased ($P < .05$) with the protected protein + protected tallow diet. Crude protein, digestible energy, dry matter and acid detergent fiber were essentially the same for all diets which were fed. When the protected tallow diet was fed, negative nitrogen retention and biological values were observed. These results differ from the previous trial in which there was a positive nitrogen retention and biological value when the tallow was protected. Cuitun *et al*. (1975) reported increased digestibility of dry matter and fat when they fed protected protein and protected fat together compared with diets without protected fat. Faichney (1971) also reported a trend for improved nitrogen retention and Reis and Tunks (1969) found a significant ($P < .01$) improvement in nitrogen retention when protected protein was fed to sheep.

## Trial IV

When high amounts of urea (2.5 percent) + ryegrass straw were fed with either tallow or protected tallow, increased ($P < .05$) dry matter, ash and digestible energy resulted compared to the diet of low urea (1 percent) + alfalfa + tallow (Table 11). The diet of high urea + straw + protected tallow resulted in lower nitrogen retention and biological value.

Table 10. Apparent digestibility coefficients, nitrogen retention and biological values for Trial III.

| Treatment | Dry Matter % | Ash % | Acid Detergent Fiber % | Fat % | Digestible Energy % | Crude Protein % | Nitrogen Retention gms | Biological Value |
|---|---|---|---|---|---|---|---|---|
| Basal + SBM* | 84.42 | $79.02^{A}$ | 58.93 | $54.73^{A}$ | 85.17 | 80.61 | 18.12 | 15.04 |
| Basal + SBM + Protected Tallow | 83.10 | $78.64^{A}$ | 51.34 | $81.32^{B}$ | 81.11 | 79.92 | -19.41 | -17.69 |
| Basal + Protected Protein + Protected Tallow | 83.60 | $73.70^{B}$ | 48.32 | $78.80^{B}$ | 82.78 | 79.66 | 20.88 | 19.67 |

$^{A,B}$Significantly different within each trial ($P < 0.05$).

*Soybean meal.

Table 11. Apparent digestibility coefficients, nitrogen retention and biological values for Trial IV.

| Treatment | Dry Matter % | Ash % | Acid Detergent Fiber % | Fat % | Digestible Energy % | Crude Protein % | Nitrogen Retention gms | Biological Value |
|---|---|---|---|---|---|---|---|---|
| Low Urea + Alfalfa + Tallow | $77.91^{A}$ | $36.74^{A}$ | 47.72 | 84.67 | $79.46^{A}$ | 82.15 | 21.70 | 17.15 |
| High Urea + Straw + Tallow | $82.82^{B}$ | $49.22^{B}$ | 51.50 | 88.11 | $82.82^{B}$ | 84.15 | 19.41 | 14.39 |
| High Urea + Straw + Protected Tallow | $81.39^{B}$ | 45.73 | 48.05 | 87.42 | $81.81^{B}$ | 82.66 | 1.49 | .98 |

$^{A,B}$Significantly different within each trial ($P < 0.05$).

## Trial V

A control diet was fed that contained the same amount of urea (1.6 percent) and tallow (4.7 percent) that caused reduced digestibilities in Trial II. This diet was compared with a diet where the amounts of urea and tallow were the same as the control except that the urea was put into a water solution and absorbed by the barley to produce a slow release effect. A third diet was fed that contained the same amount of urea and fat as the control except that the fat was a commercially made protected safflower meal product (Alta Lipid). Results of the trial (Table 12) indicated that when the commercial fat diet was fed there was no significant ($P > .05$) increases in the digestibility of dry matter, ash, acid detergent fiber and crude protein; there was an increase in nitrogen retention and biological value. Absorption of the urea by the barley improved retention of nitrogen over the urea + tallow diet but not significantly ($P > .05$). The feeding of urea and tallow did not result in any adverse effects on digestibility when compared with the other diets being fed. However, values were lower for nitrogen retention and biological value when compared with the diet of urea and tallow that was fed in Trial II.

Table 12. Apparent digestibility coefficients, nitrogen retention and biological values for Trial V.

| Treatment | Dry Matter % | Ash % | Acid Detergent Fiber % | Fat % | Digestible Energy % | Crude Protein % | Nitrogen Retention gms | Biological Value |
|---|---|---|---|---|---|---|---|---|
| Basal + Urea + Tallow | 76.72 | 36.12 | 35.85 | 87.34 | 79.59 | 81.11 | 1.00 | 1.00 |
| Basal + Urea on grain + Tallow | 76.27 | 26.56 | 39.38 | 86.66 | 77.66 | 81.46 | 20.63 | 16.65 |
| Urea + Commercial Protected Fat | 78.08 | 42.92 | 42.00 | 89.35 | 79.39 | 83.89 | 48.33 | 30.79 |

## Trial VI

In Trial VI urea (control) was fed with a high level of straw (47 percent). The remaining diets consisted of a high straw ration with the supplemental nitrogen source being supplied by either soybean meal, Starea, or hydrolyzed feather meal plus 3 percent added tallow. Results of the trial (Table 13) showed that fat digestibility was higher ($P < .05$) for all the diets containing added tallow compared with the urea control. When the hydrolyzed feather meal diet was compared with the soybean meal diet, an increase ($P < .05$) in fat digestibility also occurred. The diet containing feather meal compared favorably with the soybean meal diet concerning the digestion of dry matter and acid detergent fiber. Crude protein digestibility was lowest for the feather meal diet; however, nitrogen retention and biological value were highest. Shiehzadeh and Harbers (1974) also compared soybean meal, Starea, and urea as nitrogen supplements to high roughage rations fed to lambs. In one experiment, Starea (44 percent crude protein) was compared with soybean meal. Nitrogen retention was identical for both supplements.

## Summary of Results

Results from the *in vivo* metabolism trials indicated that urea and tallow when fed alone produced no adverse effects upon any apparent digestibility coefficients

Table 13. Apparent digestibility coefficients, nitrogen retention and biological values for Trial VI.

| Treatment | Dry Matter % | Ash % | Acid Detergent Fiber % | Crude Protein % | Fat % | Digestible energy % | Nitrogen Retention gms | Biological Value |
|---|---|---|---|---|---|---|---|---|
| Urea control | 70.34 | 34.87 | 52.21 | 76.57 | 61.63[A] | 74.30 | 13.87 | 12.98 |
| SBM* + 3% Tallow | 73.94 | 49.94 | 54.44 | 76.74 | 84.60[B] | 76.37 | 24.02 | 27.73 |
| Starea + 3% Tallow | 71.14 | 41.21 | 60.56 | 75.21 | 90.70[B,C] | 70.35 | 11.18 | 13.20 |
| Feather meal + 3% Tallow | 75.54 | 36.67 | 60.61 | 71.25 | 92.89[C] | 76.58 | 28.53 | 30.96 |

[A,B]Significantly different within each trial ($P < 0.05$).

*Soybean meal

calculated. The tallow and urea diets were compared with a control diet of SBM without tallow or urea.

Results also indicate that the addition of 5 percent tallow and 1.6 percent urea may show a tallow-urea interaction which results in a reduction of the digestibility of dry matter, crude protein and energy. The amount of nitrogen retained by the sheep also was lower for animals consuming diets of 1.6 percent urea and 5 percent tallow.

Results also indicated that when tallow was added to the diets of sheep, there was no reduction in fat digestibility. In addition, the amount of urea in combination with the tallow had no effect on fat digestibility.

To overcome the problem of the tallow-urea interaction, protected tallow was added to the diets of the sheep. When the protected tallow complex was fed along with urea, improved digestibilities resulted. However, the protected tallow complex did not function as well when SBM was the principle supplementary nitrogen source. This can be illustrated in Trial III where there was a negative nitrogen retention and biological value when protected tallow was consumed by the animals.

In Trial II the protected tallow diet resulted in a positive nitrogen retention and biological value when rolled barley was the principle supplementary nitrogen source.

When a high level of urea (2.5 percent) is fed with straw and either tallow or protected tallow and then compared with a diet of low urea (1 percent), alfalfa and tallow, increased digestible energy and dry matter resulted.

The consumption by sheep of 1.6 percent urea and 5 percent tallow are known to cause reduced animal performance. In Trial V diets of urea and tallow at the 1.6 percent and 5 percent were fed. By absorbing the urea into the barley and producing a slow release effect of the urea in the rumen, greater nitrogen retention was possible. Diets containing hydrolyzed feather meal compared favorably with soybean meal and were superior to diets containing Starea or urea.

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# APPENDIX

Appendix Table 1. Feces and urine analytical data for Trial I.

| Diet | DM % | % of DM | | | | Urine CP % | Feces Gross Energy Kcal/Gm |
|---|---|---|---|---|---|---|---|
| | | ASH | ADF | FAT | CP | | |
| Basal + SBM | | | | | | | |
| 1 | 35.4 | 14.77 | 28.16 | 7.76 | 18.49 | 3.57 | 4.08 |
| 2 | 36.4 | 14.76 | 29.52 | 8.85 | 14.23 | 5.78 | 4.19 |
| 3 | 41.1 | 14.27 | 29.50 | 6.64 | 15.81 | 3.16 | 4.19 |
| 4 | 40.0 | 12.49 | 30.47 | 2.13 | 16.32 | 5.26 | 4.1 |
| Basal + Urea | | | | | | | |
| 1 | 39.5 | 11.55 | 28.76 | 2.22 | 14.73 | 6.18 | 4.19 |
| 2 | 39.2 | 14.50 | 31.77 | 1.90 | 15.73 | 6.74 | 4.01 |
| 3 | 42.0 | 12.08 | 28.79 | 2.10 | 13.73 | 7.32 | 4.11 |
| 4 | 36.1 | 14.20 | 28.55 | 2.25 | 15.85 | 6.64 | 4.12 |
| Basal + Tallow | | | | | | | |
| 1 | 42.3 | 14.56 | 28.31 | 3.87 | 15.72 | 3.06 | 4.01 |
| 2 | 43.2 | 13.68 | 26.33 | 2.85 | 14.78 | 4.11 | 4.2 |
| 3 | 35.6 | 15.29 | 28.55 | 1.83 | 14.32 | 2.86 | 4.0 |
| 4 | 43.3 | 15.51 | 29.54 | 3.93 | 13.55 | 7.50 | 4.16 |

Appendix Table 2. Feces and urine analytical data for Trial II.

| Diet | DM % | % of DM | | | | Urine CP % | Feces Gross Energy Kcal/Gm |
|---|---|---|---|---|---|---|---|
| | | ASH | ADF | FAT | CP | | |
| Basal + SBM | | | | | | | |
| 1 | 42.26 | 17.56 | 30.98 | 2.88 | 15.75 | 7.31 | 3.85 |
| 2 | 37.10 | 16.62 | 32.85 | 3.17 | 13.30 | 7.80 | 3.97 |
| 3 | 39.14 | 16.00 | 31.94 | 2.79 | 15.76 | 9.16 | 4.02 |
| 4 | 38.66 | 15.37 | 30.88 | 2.70 | 16.30 | 6.29 | 4.12 |
| Basal + Urea + Tallow | | | | | | | |
| 1 | 33.65 | 11.58 | 32.03 | 2.60 | 14.0 | 5.80 | 4.42 |
| 2 | 33.35 | 10.85 | 30.00 | 2.20 | 15.28 | 3.95 | 4.29 |
| 3 | 35.2 | 14.05 | 31.00 | 2.10 | 13.05 | 2.53 | 4.42 |
| 4 | 39.2 | 11.67 | 35.00 | 1.40 | 14.47 | 9.79 | 4.38 |
| Basal + Urea + Protected Tallow | | | | | | | |
| 1 | 49.4 | 13.38 | 32.90 | 1.80 | 13.57 | 5.85 | 4.22 |
| 22 | 40.01 | 12.74 | 30.40 | 2.10 | 14.80 | 7.66 | 4.21 |
| 3 | 35.30 | 13.14 | 33.90 | 2.20 | 14.40 | 6.62 | 4.21 |
| 4 | 39.40 | 13.82 | 33.50 | 2.20 | 14.51 | 9.63 | 4.14 |

Appendix Table 3. Feces and urine analytical data for Trial III.

| Diet | DM % | % of DM | | | | Urine CP % | Feces Gross Energy Kcal/gm |
|---|---|---|---|---|---|---|---|
| | | ASH | ADF | FAT | CP | | |
| Basal + SBM | | | | | | | |
| 1 | 32.96 | 16.33 | 33.15 | 2.27 | 15.22 | 3.73 | 3.66 |
| 2 | 35.64 | 15.32 | 28.09 | 2.68 | 18.18 | 4.98 | 3.83 |
| 3 | 29.95 | 14.27 | 30.04 | 2.09 | 17.5 | 4.06 | 3.97 |
| 4 | 30.37 | 15.06 | 27.69 | 2.61 | 15.70 | 6.42 | 3.93 |
| Basal + SBM + Protected Tallow | | | | | | | |
| 1 | 36.86 | 14.39 | 30.99 | 2.77 | 15.77 | 3.22 | 4.43 |
| 2 | 30.80 | 14.33 | 33.90 | 3.04 | 16.33 | 2.72 | 4.25 |
| 3 | 27.25 | 14.58 | 28.25 | 2.75 | 14.95 | 6.27 | 4.16 |
| 4 | 34.10 | 12.72 | 33.68 | 2.50 | 15.00 | 14.02 | 4.06 |
| Basal + Protected Protein + Protected Tallow | | | | | | | |
| 1 | 25.59 | 15.53 | 31.45 | 3.47 | 16.12 | 5.56 | 4.08 |
| 2 | 38.64 | 13.76 | 28.85 | 2.80 | 15.00 | 6.74 | 4.38 |
| 3 | 38.83 | 15.81 | 27.86 | 2.88 | 16.62 | 7.34 | 4.04 |
| 4 | 41.02 | 13.78 | 27.69 | 2.63 | 14.61 | 9.24 | 3.93 |

Appendix Table 4. Feces and urine analytical data for Trial IV.

| Diet | DM % | % of DM | | | | Urine | Feces Gross Energy |
|---|---|---|---|---|---|---|---|
| | | ASH | ADF | FAT | CP | CP % | Kcal/Gm |
| Low Urea + Alfalfa + Tallow | | | | | | | |
| 1 | 43.92 | 19.51 | 43.13 | 2.71 | 10.12 | 3.21 | 3.94 |
| 2 | 40.34 | 19.30 | 41.83 | 3.21 | 12.46 | 4.10 | 3.96 |
| 3 | 35.21 | 19.51 | 41.64 | 2.47 | 10.74 | 2.00 | 3.63 |
| 4 | 31.46 | 22.81 | 42.50 | 3.52 | 11.19 | 1.96 | 3.82 |
| High Urea + Straw + Tallow | | | | | | | |
| 1 | 41.20 | 14.32 | 31.37 | 2.16 | 13.66 | 3.39 | 4.12 |
| 2 | 41.32 | 14.17 | 33.32 | 2.37 | 13.15 | 1.58 | 4.12 |
| 3 | 37.74 | 15.47 | 37.27 | 2.46 | 13.75 | 2.24 | 4.14 |
| 4 | 35.75 | 15.43 | 34.57 | 3.12 | 13.60 | 2.20 | 4.21 |
| High Urea + Straw + Protected Tallow | | | | | | | |
| 1 | 43.15 | 13.63 | 33.58 | 1.88 | 13.72 | 4.06 | 4.12 |
| 2 | 41.57 | 15.26 | 31.37 | 2.61 | 13.80 | 1.77 | 4.14 |
| 3 | 42.38 | 13.83 | 32.09 | 2.71 | 13.44 | 3.37 | 4.19 |
| 4 | 41.35 | 15.79 | 34.70 | 2.28 | 13.96 | 2.45 | 3.99 |

Appendix Table 5. Feces and urine analytical data for Trial V.

| Diet | DM % | % of DM | | | | CP % | Feces Gross Energy Kcal/Gm |
|---|---|---|---|---|---|---|---|
| | | ASH | ADF | FAT | CP | | |
| Basal + Urea + Tallow | | | | | | | |
| 1 | 53.34 | 19.92 | 38.97 | 2.95 | 11.68 | 5.27 | 3.75 |
| 2 | 48.45 | 19.98 | 40.43 | 3.27 | 10.92 | 2.88 | 3.72 |
| 3 | 48.06 | 19.80 | 37.21 | 3.06 | 10.29 | 3.53 | 3.77 |
| 4 | 42.99 | 17.60 | 37.64 | 3.12 | 10.80 | 3.76 | 3.82 |
| Basal + Urea on Grain + Tallow | | | | | | | |
| 1 | 48.57 | 21.07 | 38.38 | 2.93 | 10.98 | 5.07 | 3.63 |
| 2 | 43.97 | 21.00 | 37.69 | 3.61 | 12.49 | 2.30 | 3.88 |
| 3 | 43.01 | 19.63 | 37.01 | 2.89 | 10.60 | 3.88 | 4.05 |
| 4 | 42.13 | 19.17 | 39.77 | 3.64 | 10.55 | 2.67 | 3.88 |
| Urea + Commercial Protected Fat | | | | | | | |
| 1 | 42.30 | 20.04 | 37.90 | 2.56 | 11.68 | 2.62 | 3.76 |
| 2 | 50.25 | 15.26 | 37.50 | 2.44 | 11.71 | 1.08 | 4.01 |
| 3 | 43.18 | 20.80 | 35.91 | 2.59 | 12.47 | 3.72 | 3.77 |
| 4 | 44.93 | 20.90 | 39.29 | 2.51 | 12.41 | 1.92 | 4.01 |

Appendix Table 6. Feces and urine analytical data for Trial VI.

| Diet | DM % | % of DM | | | | Urine CP % | Feces Gross Energy Kcal/gm |
|---|---|---|---|---|---|---|---|
| | | ASH | ADF | FAT | CP | | |
| Urea Control | | | | | | | |
| 1 | 37.93 | 10.64 | 37.84 | 1.11 | 11.19 | 1.86 | 3.05 |
| 2 | 35.90 | 10.64 | 37.34 | 1.28 | 11.45 | 1.53 | 3.03 |
| 3 | 37.68 | 11.19 | 39.84 | 1.26 | 9.6 | 1.72 | 3.81 |
| 4 | 24.88 | 11.99 | 37.61 | 1.29 | 9.45 | 2.15 | 3.85 |
| 5 | 4.25 | 10.35 | 42.16 | 1.48 | 10.19 | 1.96 | 3.24 |
| SBM Diet | | | | | | | |
| 1 | 40.89 | 10.57 | 42.83 | 1.97 | 9.49 | 1.77 | 4.14 |
| 2 | 42.50 | 12.68 | 41.80 | 2.51 | 10.84 | 2.16 | 4.13 |
| 3 | 36.52 | 12.82 | 39.24 | 2.30 | 10.63 | 1.43 | 2.59 |
| 4 | 35.59 | 11.06 | 40.20 | 2.37 | 10.48 | .97 | 3.25 |
| 5 | 42.18 | 11.38 | 39.03 | 1.66 | 9.97 | 1.09 | 4.13 |
| Starea Diet | | | | | | | |
| 1 | 26.88 | 11.30 | 40.94 | 1.49 | 9.61 | 2.47 | 4.27 |
| 2 | 42.96 | 10.65 | 40.48 | 1.55 | 10.16 | 1.51 | 4.14 |
| 3 | 19.00 | 10.53 | 38.40 | 1.58 | 10.19 | 1.58 | 4.04 |
| 4 | 37.03 | 10.34 | 38.73 | 2.00 | 10.47 | 1.67 | 4.19 |
| 5 | 33.88 | 8.00 | 41.19 | 1.34 | 8.65 | 3.79 | 3.88 |
| Feathermeal | | | | | | | |
| 1 | 38.97 | 10.69 | 37.91 | 1.99 | 15.13 | 1.69 | 3.83 |
| 2 | 20.95 | 13.03 | 36.07 | 1.11 | 12.93 | 2.39 | 3.30 |
| 3 | 35.33 | 10.88 | 37.62 | 1.54 | 16.00 | 2.44 | 4.14 |
| 4 | 39.78 | 11.36 | 37.63 | 1.46 | 15.35 | 2.29 | 4.13 |
| 5 | 20.32 | 15.24 | 36.89 | 1.99 | 14.74 | 1.45 | 3.72 |