THE UNIVERSITY OF MANITOBA

WHEY WITH UREA OR PROCESSED FABABEAN STARCH WITH UREA AS A LIQUID PROTEIN SUPPLEMENT FOR GROWING FINISHING LAMBS

by

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ABSTRACT

Two experiments were conducted using 96 crossbred lambs to study the potential of mixtures of whey, or processed fababean starch,with added urea as liquid supplements. Treatments included whey mixtures containing 6 or 25 percent dry matter with urea added to supply 25 or 40 percent of the protein in the diet and fed free choice, and processed fababean starch with urea added to provide a 32 percent protein liquid supplement which was poured over the dry feed. All treatments were formulated to be isonitrogenous at 14 percent protein and were approximately equicaloric. Measurements included growth rate, feed consumption, feed efficiency, nitrogen utilization and serum and rumen metabolites. Experiment I included 80 lambs on a 58 day growth trial, with Experiment 2 having 16 lambs on a metabolism trial.Lambs in Experiment I fed urea only mixed with the feed showed decreased growth rate ($P< 0.05$) and had decreased dry matter consumption and feed efficiency. In Experiment 2, dry matter intake, blood ammonia concentration, total rumen VFA's and percent isobutyric, butyric and isovaleric acids showed no difference among treatments. Nitrogen retention improved ($P< 0.05$) for the 25 percent dry matter whey supplement supplying 40 percent of the total dietary protein, and all other treatments improved($P< 0.01$) compared to the urea control. Significant differences among treatments were noted for percent protein digestibility($P< 0.01$)

percent dry matter digestibility($P< 0.01$), rumen ammonia ($P <0.05$) and serum urea($P<0.01$) concentrations and percent acetic, propionic and valeric acid ($P<0.01$) in the rumen. Fababean supplement providing 40 percent of the dietary protein resulted in improved N retention, lower rumen ammonia and serum urea, decreased acetic and increased percentages of propionic and valeric acid.

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LIST OF ABBREVIATIONS

ADG	-	average daily gain
BAN	-	blood ammonia nitrogen
BUN	-	blood urea nitrogen
CHO	-	carbohydrate(s)
C_4	-	butyric and isobutyric acids
C_5	-	valeric and isovaleric acids
DM	-	dry matter
g	-	gram(s)
L	-	liter(s)
kcal	-	kilocalories
kg	-	kilograms
mg	-	milligrams
ml	-	milliliters
mmoles/liter	-	millimoles/liter
NH_3	-	ammonia
NPN	-	nonprotein nitrogen
PUN	-	plasma urea nitrogen
PER	-	protein efficiency ratio
SBM	-	soybean meal
TDN	-	total digestible nutrients
Trt	-	treatment
VFA(s)	-	volatile fatty acid(s)
FSLPS	-	fababean starch liquid protein supplement
WLPS	-	whey liquid protein supplement

INTRODUCTION

If ruminant animals are to continue to be an integral component in the human food supply, full advantage must be taken of their unique physiological and biochemical capabilities. They are able to synthesize protein of high biological value from nonprotein nitrogen sources and utilize carbohydrate sources which mammalian species with less adapted digestive systems cannot use.

From an economic viewpoint, it is important to make maximum use of nonprotein rather than protein nitrogen sources and also to derive a considerable portion of dietary carbohydrates (CHO) from sources that cannot, or are not, being used to optimum advantage elsewhere. Utilization of urea mixed with whey or fababean starch combines two such feed sources and demonstrates the possibility of utilizing the unique attributes of rumen metabolism. Advantage is taken of improvements in technology in an attempt to increase CHO availability by gelatinization and enzymatic predigestion of the fababean starch in this study.

This investigation consisted of a feeding trial to examine the potential of urea combined with whey or fababean starch as liquid protein supplements for ruminant animals and a nitrogen balance study to attempt to explain the results of the feeding trial.

REVIEW OF LITERATURE

Weiske et al. (1879) may have been the first to suggest using nonprotein nitrogen (NPN) compounds as protein substitutes in ruminant rations. This is feasible because of the ability of the rumen microorganisms to synthesize rumen ammonia (NH_3) into microbial protein in the presence of a suitable energy source. While it has not proven practical to determine directly the biological value of microbial protein to ruminants, feeding experiments with monogastric animals have indicated that the protein is of high nutritive quality and may have a biological value equivalent to that of casein (Helmer and Bartley 1971). Microbial protein becomes very important to protein nutrition in ruminant animals when considering findings (Weller et al. 1962) that approximately 80 percent of the nitrogen passing into the omasum of sheep is microbial nitrogen. Helmer and Bartley (1971) cite work showing that direct evidence has been obtained through isotope studies that ruminant animals are capable of converting NPN into animal protein. Various NPN sources have been examined. Although numerous products and urea coatings having varying rates of hydrolysis in the rumen appeared to have possibilities,at the time they were investigated economic conditions did not suggest that further development to a marketable product was warranted (Johnson 1976). Consequently, urea has been and is the major source of NPN used in diets for ruminant animals.

The amount of urea which can be fed, and the efficiency with which it is incorporated into animal protein normally depend on the amount and characteristics of the preformed protein, the amount and characteristics of the CHO, and the protein:CHO ratio in the ration.

INFLUENCE OF PROTEIN

The influence of protein on the efficiency of utilization of urea seems to be related to the amount of protein and its solubility.

Proteins are degraded in the rumen to amino acids, and further to NH_3, carbon dioxide and volatile fatty acids. NH_3 in the rumen is used by the microorganisms as a source of nitrogen during formation of microbial protein. Roffler and Satter (1975) reported that as long as the concentration of dietary protein remains low enough to prevent NH_3 accumulation, NPN and protein are nearly equal in terms of furnishing amino acids to the intestines. They found that when NPN was used as the sole source of supplementary nitrogen, the point of NH_3 accumulation coincided with the plateauing of the quantity of amino acids leaving the rumen.

With most normal diets, 20 to 50 percent- with an average of 40 percent - of the dietary protein escapes degradation in the rumen and becomes available to the animal postruminally (Roffler and Satter 1975b). They showed that above the point of NH_3 accumulation in the rumen, adding NPN had no beneficial effect but adding protein increased production as indicated by rate of growth. These results suggest that cattle required more amino acids

postruminally than could be supplied by microbial protein. Therefore, if amino acid requirements cannot be met with a dietary crude protein content below the point of NH_3 accumulation, either NPN or protein supplementation will increase the quantity of amino acids leaving the rumen and consequently improve production. However, if the amino acid requirement can only be met with amounts of dietary protein that exceed the point of NH_3 accumulation, only true protein supplements will improve production.

There is also a lower limit of dietary protein below which NPN supplementation will not produce satisfactory results. It appears that urea cannot be substituted isonitrogenously for all the isolated soybean protein in purified diets for lambs without adversely affecting growth rate (Price et al.1972). Clifford and Tillman(1968), feeding purified diets found that gains of lambs fed urea as the sole source of nitrogen were approximately 70 percent of those obtained on low or no urea. When part of the dietary protein was replaced by NPN, the amount of true dietary protein escaping ruminal degradation was reduced and the proportion of dietary nitrogen passing through the ruminal NH_3 pool was increased (Roffler and Satter 1975). Chalupa (1968) suggested that even though there is no question concerning the capacity of the rumen system to synthesize microbial protein from NPN, the inferior performance of animals fed diets containing high levels of urea may well be the result of a deficiency or imbalance of one or more amino acids.

Some proteins are more soluble in rumen fluid and are degraded more easily by rumen microbes than are other proteins (Wohlt et al. 1976a). Wohlt et al.(1976b) reported higher rumen NH_3

concentrations on diets high in solubility. Using normal feedstuffs, they fed mature wethers ad. lib. four diets made isonitrogenous at 15 percent crude protein, with protein solubilities of either 13 or 35 percent and amino acid profiles resembling either hominy or soybean meal. They found that water intake and urine volume were increased ($P< 0.01$) on the high solubility protein diets. Dry matter, fiber and cellulose digestibilities all tended to be lower for the high solubility diets, but gross energy digestion was significantly lower ($P<0.05$). Nitrogen intake, nitrogen absorbed, and urinary nitrogen excreted increased ($P<0.01$) with increasing solubility. Even though the animals were receiving in excess of suggested dietary requirements (N.R.C. 1968), the data demonstrate that protein solubility and amino acid profiles of diets formulated from feed ingredients commonly found in ruminant rations can influence rumen and animal nitrogen metabolism. Wohlt et al.(1976b) also report on studies with proteins treated to decrease solubility and suggest that the value of protein which by-passes rumen degradation may lie in its ability to complement the amino acid profile of microbial protein,and not necessarily in its biological value per se.

Meiske et al.(1955) added NPN or soybean meal to a basal lamb diet containing 7.13 percent crude protein and significantly increased average daily gain and feed efficiency. Braman et al.(1973) feeding high concentrate rations to lambs showed increased gains with up to 17 percent crude protein with soybean meal supplemented, but not with urea supplemented diets. They found that the greatest average daily gains and feed efficiencies were obtained with the 17 percent crude protein - soybean meal diet, and that concentration of

dietary protein had no significant effect upon daily feed consumption. Roffler and Satter (1975) report that for typical dairy and feedlot diets, preliminary observations suggest that ruminal NH_3 exceeds the needs of the bacteria at a lower dietary crude protein content for sheep than for cattle. They found that the point of NH_3 accumulation is approximately 13 percent dietary crude protein for cattle and 10 percent for sheep as an average for different ratios of concentrate to roughage.

INFLUENCE OF CARBOHYDRATES

The function of CHO in converting NH_3 to microbial protein is to provide energy and carbon skeletons for microbial synthesis (Helmer and Bartley 1971). Rumen microorganisms have a definite energy requirement, and the degree to which this requirement is met influences the utilization of urea (Chalupa 1968), because the amount of fermentable energy available to rumen bacteria influences their growth rate and, consequently, the quantity of NH_3 converted to microbial protein (Roffler and Satter 1975). Johnson(1976) concluded that the conditions under which NPN utilization can be maximized will no doubt relate in large measure to the proportions of CHO of varied solubility. CHO solubility is critical when referring to CHO effect on NPN utilization, since energy must not only be available but must be available when required during periods of maximum NH_3 concentration in the rumen. Johnson reports that of the three major classes of CHO, cellulose is digested slowly over a long period of time, sugars are digested rapidly over a short period of time, and starches are somewhere in between. Helmer and Bartley (1971) report that the least effective CHO for urea utilization seems to be cellulose, and starch is the most effective,being also superior to

molasses and simple sugars.

In the presence of different forms of CHO there is a competition for the available nitrogen sources between the groups of microorganisms utilizing the different forms of CHO. El Shazly et al.(1961) showed that in the presence of both starch and cellulose in purified forms, cellulose digestion was depressed when urea was utilized as a source of nitrogen. In the absence of starch, considerably more cellulose was digested.

McLaren et al.(1965) found that although the dietary level of fermentable CHO significantly influenced the retention of absorbed nitrogen, no influence was noted on the adaptation of animals to utilization of urea.

EFFECT OF PROCESSING ON CARBOHYDRATES

Soluble CHO and CHO solubility are not synonymous when one considers their influence upon fermentation in the rumen. The former refers to a restricted class of CHO of specified solubility whereas the latter portrays a characteristic of any CHO or group of CHO's that often can be modified. Johnson (1976) reports that the processing of starch primarily increases the rate of fermentation, but probably does not drastically change the group of microorganisms which are digesting the starch. According to Hale (1973), proper processing of grain will significantly increase the starch digestion in the entire digestive tract of the ruminant animal. It was further suggested that the major portion of the increase in starch digestion occurs in the rumen.

The effectiveness of starch can be increased by cooking, which makes it more susceptible to microbial breakdown. It then releases energy at a rate more nearly parallel to NH_3 release from

urea, thus permitting rumen microorganisms to use the NH_3 more efficiently (Helmer and Bartley 1971).

Gelatinizing the starch breaks down the starch granules, and this reportedly makes the starch more available to the rumen microorganisms and/or the animal and this change is responsible for improvements in performance noted with fattening cattle (Hale 1973). Adding an amylolytic enzyme to gelatinized starch breaks down the starch into its respective sugars, causes the gelatinized starch to liquify, and provides a more readily available source of energy (Marquardt 1976).

PROTEIN:ENERGY RATIO

Nitrogen metabolism cannot be considered separately from CHO digestion because of the requirements of the rumen microorganisms for both a readily available source of nitrogen and of energy for reproduction. The value of protein supplements is maximized when a CHO that can be fermented at a comparable rate is also present (Webb *et al*.1972). NPN is used most efficiently when small amounts are added to rations low in protein and relatively high in fermentable energy (Roffler and Satter 1975).

The balance between the amounts and availabilities of nitrogen and energy to the rumen microbial population has an important effect on the utilization of both nitrogen and energy. In work on NPN utilization by cattle Roffler and Satter (1975) found that mean ruminal NH_3 concentration was positively related to dietary crude protein concentration and negatively related to total digestible nutrient concentration. They report that the point of NH_3 accumulation

corresponds to a crude protein content of 13.3 percent for rations containing 77.5 percent total digestible nutrients. Roffler et al.(1976) feeding NPN to steers found that ruminal NH_3 began to accumulate at a higher dietary crude protein when a high energy ration was fed than when a low energy ration was fed. Roffler and Satter (1975) fed NPN to cows under a wide variety of feeding programs and found that ration crude protein and total digestible nutrient concentrations accounted for 92 percent of the variation in mean ruminal NH_3 concentration. Thus the net effect of other factors which may have influenced ruminal NH_3 concentration, such as extent of dietary protein degradation, amount of feeding, nitrogen recycling, frequency of feeding and type of CHO was relatively small.

In nitrogen metabolism studies with sheep, McLaren et al.(1965) showed that retention of absorbed nitrogen was significantly improved by approximately two percentage units for each increase in concentration of 100 Kilocalories of readily fermentable CHO in the ration. Bloomfield et al.(1964) reported that 55 grams of CHO were required for each gram of nitrogen fixed by rumen microorganisms. Preston et al.(1965) plotted daily gain of lambs as a function of the ratio of digestible protein to digestible energy content of the ration and found that maximum daily gain resulted when the ratio was 22 grams of digestible protein per 1000 Kilocalories of digestible energy. This is similar to that calculated for cattle, (21 - 27 by Preston - unpublished data, 1964), and these authors suggest that this ratio may well represent the optimal ratio for growing - finishing sheep and cattle.

LIQUID SUPPLEMENTS

Possibly no other development has received more marketing and sales success in this country than the liquid supplement industry. The value is based upon the ability of the liquid supplement to foster rumen microbial synthesis. From the standpoint that their useage is designed for low quality roughage rations,they should be looked upon primarily as sources of nitrogen and energy (Johnson 1976). Factors such as relative cost, ease of application, storage qualities, and how these fit into the operation will help to determine whether to use the liquid supplement mixed with the ration or fed free choice. Addition of a liquid supplement can make the ration essentially a complete feed in terms of energy and protein. Feeding the liquid supplement free choice may result in overconsumption and urea toxicity problems but reduced requirements for labor and equipment may more than compensate.

WHEY LIQUID SUPPLEMENT

In 1973, nearly 14 billion Kilograms of whey was produced in the United States, with only 6.9 billion Kilograms of this whey being processed as animal or human food (Webster and Fife 1975). Most of the remaining 7 billion Kilograms of whey were disposed of as a waste product (Schingoethe 1976). The polluting effect of 100 Kilograms of whey measured by biological oxygen demand is equivalent to the daily waste from 45 people (Milk Industry Foundation 1967). The annual polluting effect of wasted whey is therefore equivalent to the wastes

from 8.4 million people. Thus, the disposal of large quantities of liquid whey represents a serious problem and a great challenge to the dairy industry.

There has been renewed interest in feeding liquid whey in recent years primarily because of pressures to prevent environmental pollution by dumping whey into streams or by other undesireable disposal methods. Selling, or even giving,the liquid whey back to farmers for livestock feeding purposes is generally a favorable option for the dairy plants (Schingoethe 1976).

Liquid whey contains 6 to 7 percent dry matter, composed of 4.9 percent lactose, 0.9 percent nitrogenous matter, 0.6 percent ash and a small amount of minerals and vitamins (Anderson et al.1974). Dried whole whey is approximately 93 percent dry matter, contains about 12 percent protein, 70 percent lactose, 8 percent ash, 0.91 percent calcium and 0.76 percent phosphorus (Schingoethe 1976).

The whey proteins are some of the highest quality natural proteins available. The protein efficiency ratio (PER) determined in rats is approximately 20 percent greater than the PER of casein (Forsum 1974). Schingoethe(1976) reviews work citing the following characteristics of whey. Whey is a source of energy primarily because of its high lactose content, the energy value of dried whole whey being comparable to the energy value of shelled corn and slightly higher than the energy values of most other feed grains. Whey is also a relatively good source of calcium, phosphorus and water soluble vitamins. About 40 percent of the calcium and 43 percent of the phosphorus of the original milk are in the whey from cheddar cheese. Sodium chloride accounts for most of the remaining ash in whey.

The high lactose and mineral content may impose an upper limit on the amount of whey which can be fed to some classes of livestock.

Ruminants can consume up to 30 percent of their dry matter intake as liquid whey without impairing performance (Schingoethe 1976). He reports that at higher liquid whey consumption total dry matter intake often is restricted.

Anderson (1975) fed liquid whey together with alfalfa hay to mature wethers and found that the animals given no access to water consumed 8.7 Kg. of whey daily. Whey consumption of animals on whey and water free choice was reduced to 7.6 Kg. daily as a result of water intake of 1.2 Kg. daily. The total liquid intake of the two groups offered whey was approximately 45 percent higher ($P<0.01$) than for animals receiving only water together with alfalfa hay. When both whey and water were available, the whey accounted for an average of 85 percent of the liquid consumed. Anderson et al(1974) found that dairy cows offered whey and water drank 64.5 percent of the liquid consumed as whey, but found that total consumption of liquid (water plus whey) was the same whether or not water was available. They report that animals do not require water when whey is offered although some animals desire water and drink from puddles or attempt to get to water. Their studies on 6 to 8 month old dairy heifers showed that those animals offered whey instead of 2.3 Kg. of grain daily made gains equal to those receiving a standard ration, while animals receiving both whey and 2.3 Kg. of grain daily made faster gains ($P<0.05$).

Whey consumption significantly reduced consumption of hay or grain. Studies with dairy cattle (Anderson et al.1974) showed hay consumption was reduced 0.7 to 1.0 Kg.per day for each Kg. of whey consumed, which agrees with the one Kg. per day decrease in concentrate consumption for each one Kg. of whey solids consumed in separate studies (Welch and Nilson 1973).

Mavropoulou and Kosikowski (1973)reported that solubility of whey powder in water varied from 91.4 to 99.3 percent with solubility being higher as soluble protein increased.

A few problems have been encountered with feeding whey to ruminants, but none appears to be insurmountable. Whey must be kept fresh. Palatability of whey is lowered as whey acid content rises. Anderson et al.(1974) noted that fresh sweet whey had a pH of approximately 6.1, which dropped to approximately 5.0 in eight hours and to around 4.0 in 24 hours. Although whey 24 hours old was acceptable, whey kept over 36 hours at ambient temperatures was not acceptable. Sweet (cheddar cheese) whey may be more palatable than acid(cottage cheese) whey (Welch and Nilson 1973) although both types have been fed successfully (Anderson et al.1975). Schingoethe(1976) reportedexcess urination at high levels of consumption of whey,and also reportedsome scouring and going off feed if care was not taken in gradually increasing whey feeding. Once adjusted to whey, Anderson et al.(1974) found that fecal consistency was similar to that from pasture feeding.Lynch et al.(1975) observed cases of bloat

initially in experiments feeding acid whey to holstein steers on a grain ration but prevented bloat by feeding hay at 0.4 percent of body weight.

INFLUENCE OF SALT

Chicco et al.(1970) self-fed a protein supplement containing 30 percent sodium chloride to steers on pasture and found significant differences in nitrogen balance data showing that nitrogen retention was depressed by high salt in the ration. However, when the nitrogen balance data were expressed as percent of the nitrogen intake differences among treatments were not significant. Meyer et al.(1955) fed lambs and steers fattening rations with sodium chloride levels of up to 12.8 percent of the diet , which were lower than those consumed by the steers reported by Chicco et al.(1970). No statistically significant influences of level of sodium chloride intake on T.D.N.,digestibility of the protein, or nitrogen retention were found. There was some decrease in daily ration intake by the groups on the high salt intakes, but this did not influence the average daily gain. Dressing percentage was as high for the sheep on the high salt intakes as for those on the basal ration but there was some indication that the higher levels of salt fed to both the sheep and cattle decreased the carcass grades.

NITROGEN-BALANCE DETERMINATION

In contrast to other methods which might be used to study nitrogen metabolism in the rumen, the results obtained from nitrogen balance determination reflect changes in rumen metabolism as they relate to the metabolism of the whole animal (Helmer and Bartley 1971). However, care must be taken in interpretation of the results of such studies. Price et al.(1972) conducted growth and metabolism studies on lambs and found that even though feed was provided ad. lib.in the metabolism studies, the observed feed intakes of lambs in metabolism crates were less than those observed in the growth studies. Similar effects were observed by Streeter et al.(1973) who reported that feed consumption of the lambs confined in metabolism crates was approximately 60 percent of that which could be expected under practical conditions. These authors suggest that these low consumptions could have resulted in a condition in which the limitation on energy consumption prevented the expression of differences between nitrogen sources in their work.

The adequacy of a protein concentrate for supporting acceptable performance in ruminants is an end-point measurement of a number of simultaneously acting physiological processes.

The following parameters are important in formulating a meaningful interpretation of the performance of the lambs on the various feeding regimes in this study.

RUMEN NH_3

Most of the dietary nitrogen is metabolized to NH_3 by the microbial fermentation in the rumen. Also, NH_3 is the major nitrogen source used for microbial protein synthesis. Therefore the concentration of NH_3 in rumen fluid is important in determining the efficiency of nitrogen utilization in ruminants.

NH_3 in the rumen is either utilized by the microorganisms or, in amounts directly proportional to its concentration, is absorbed from the rumen into the blood and/or passed out of the rumen down the gastrointestinal tract. Therefore, maintenance of ruminal NH_3 concentrations in excess of the bacterial requirement results in wastage of nitrogen.

Recent work by Satter and Slyter(1974), Roffler and Satter (1975), and Roffler et al.(1976) has shown that maintenance of ruminal NH_3 at 5 mg.NH_3/100 ml.of rumen fluid is adequate to support maximal growth rates of rumen microorganisms, that there is zero utilization of NPN under conditions in the rumen where NH_3 concentration exceeds this level, and that total uptake of NH_3 by rumen microorganisms remains static and is unaffected by an increase in NH_3 concentration over this level.

As reported by Wholt et al.(1976b)several workers have observed an increase in the concentration of rumen fluid NH_3 shortly before feeding. They suggest that this increase in rumen NH_3 may be due to endogenous metabolism of non-growing microbes when soluble CHO is deficient, to cytolytic bacteria digesting other rumen organisms with

the subsequent release of NH_3, to decreased NH_3 utilization as a result of a deficiency of energy for microbial protein synthesis, or to urea recycling via saliva.

Factors affecting the concentrations of NH_3 in rumen fluid are location of sampling, time of sampling, method of sampling,type of diet and rumen fluid volume (Wohlt et al.1976). These authors showed that the amount of nitrogen in the rumen may be either under- or overestimated, depending on the location from which the sample is obtained and whether it is taken via stomach tube or via rumen cannula. In their study,samples taken by stomach tube, and those taken from the midpoint and ventral parts of the rumen, underestimated the total NH_3 in the rumen by 27, 10 and 13 percent respectively.In contrast, the sample from the dorsal part of the rumen overestimated total NH_3 by 17 percent.

BLOOD NH_3

In ruminant animals, nitrogen is absorbed from the alimentary tract as amino acids and as NH_3. The greatest proportion of amino acids is absorbed from the small intestine, while the majority of NH_3 is absorbed from the rumen, with minor amounts of NH_3 being absorbed from other parts of the gastrointestinal tract including the omasum, small intestine and cecum.

Absorption of NH_3 from the rumen is directly related to conditions within the rumen. Webb et al(1972) have shown significant ($P < 0.01$) positive correlations between rumen and blood ammonia nitrogen (BAN) concentrations. They also showed significant positive correlations ($P < 0.01$) between rumen pH and BAN concentration. Bloomfield et al.

(1963) stated that the increased absorption of NH_3 at a higher pH is probably the result of an increase in the proportion of NH_3, in relation to ammonium ion, which may more readily penetrate the lipid layers of the rumen mucosa.

Lewis et al.(1957) observed that NH_3 concentration in peripheral blood increased only when rumen NH_3 exceeded the concentration of 1000 mg /liter. However, Bhattacharya and Pervez (1973) found much lower levels of rumen NH_3 reflected in BAN in sheep, which is in agreement with the observations of Salem and Devlin (1972) on cattle. Preston et al.(1965) suggested that NH3-N accounts for no more than 4 percent of blood urea nitrogen.

It is the opinion of most workers (Austin 1967) that NH_3, either directly or indirectly, is the toxin involved in urea poisoning. An elevation of rumen pH generally occurs during urea feeding, resulting in conditions in the rumen conducive to increased absorption of NH_3. Inability of the liver to convert all absorbed NH_3 to urea is responsible for increases in NH_3 in peripheral blood. Urea toxicity is characterized by elevated concentrations of rumen NH_3 and subsequent high concentrations of NH_3 in peripheral blood. Webb et al.(1972) working with cattle found severe toxicity occurred when BAN concentrations exceeded 0.7 to 0.8 mg /100 ml.. Numerous other workers have indicated that toxic symptoms appear when BAN levels reach a critical value of approximately 1 to 4 mg per 100 ml..

Recently investigators have begun to report studies on the effect of subacute NH_3 absorption. Prior et al.(1970) reported changes

in metabolites in plasma and liver tissue resulting from prolonged high-level NH_3 detoxification in the liver and suggested a performance depressing effect.

BLOOD UREA

The NH_3 lost from the rumen via the portal system is converted to urea in the liver,and this blood urea nitrogen (BUN) is either excreted in the urine or recycled through the rumen via saliva or direct transfer through the rumen wall. Goshtasbpour-Parsi et al. (1974) have found evidence indicating that there is secretion of endogenous nitrogen into the digestive tract between the omasum and abomasum on low nitrogen diets.

Hogan (1975) reported that within the range of dietary protein content normally encountered in dairy and beef feedlot rations, an amount of nitrogen equivalent to only 10 - 15 percent of dietary nitrogen is recycled to the reticulorumen. However, Chalupa (1968) suggested that re-entry of urea into the rumen is undoubtedly important in the efficient utilization of dietary urea nitrogen, especially when dietary sources are low and an additional supply of nitrogen to the rumen would benefit cellulolytic and other bacteria.

Houpt (1959) investigated the transfer of urea from the blood to the rumen and found that urea passing directly from the blood to the rumen represents the major pathway of nitrogen return to the rumen. In the same experiment, he found that 52 percent of intravenously injected urea (5 mmole urea-nitrogen per Kg. body weight) was not recovered in urine nor did it remain in body fluids; presumably the urea was recycled and utilized for rumen protein synthesis.

Varner and Woods (1975) suggested that the majority of BUN is excreted from the body via the urine resulting in considerable loss to the nitrogen economy of the animal. Thornton and Wilson (1972) working with cattle found that urinary urea nitrogen was linearly related to the BUN concentration (r=.97). McIntyre (1970) reported an increased rate of urea and water excretion via the kidneys prevented plasma urea nitrogen (PUN) from exceeding a limit of 30-35 mg./100 ml. plasma in sheep. This loss of water may affect thirst and produce an increased water intake. This may explain the higher ($P< 0.01$) levels of water intake and urine volume with certain high solubility diets such as shown by Wohlt et al.(1976a).

Pfander et al.(1975) suggested that PUN can be used as an indicator of the level of metabolism in growing lambs.This was based on the assumption that if insufficient protein is being delivered to the cells, PUN will be at a minimum, and if excess protein is available, PUN will be elevated. However, Streeter et al.(1973) working with lambs, suggested that measurement of PUN levels of ruminants may not provide easily interpretable data for studying nitrogen metabolism except to indicate extreme differences in ration formulation.

Torell et al.(1974) showed that with grazing sheep neither age nor sampling time had any significant effect on BUN, but variation between animals within age class was significant ($P< 0.01$).

Pfander et al.(1975) found large variations in individual PUN concentrations of growing finishing lambs fed the same diet free choice. However, for individual lambs they found significant segregation of PUN's was obtained within one week after changes in rations and that these were generally maintained.

Numerous factors are known to modify BUN. Preston et al. (1961) showed that BUN in lambs was altered by feeding various CHO and protein sources. Lewis et al. (1957) found rumen NH_3 levels to be associated with BUN levels. Webb et al. (1972) working with cattle found significant ($P < 0.01$) correlations between rumen and blood NH_3 concentrations, indicating that NH_3 absorption is related to rumen NH_3 concentration. However, no significant ($P < 0.05$) correlations were found between blood NH_3 and BUN concentrations, when the NH_3 absorbed exceeded the capacity of the liver to synthesize urea.

Wohlt et al. (1976) working with wethers found that PUN concentrations increased with increasing dietary protein solubility. They also found that plasma urea was affected by a significant interaction ($p < 0.05$) between solubility and amino acid profile of the dietary protein. Plasma urea concentration increased with biological value as diet solubility increased.

Preston et al. (1965) obtained excellent correlations between the level of dietary protein and PUN. They also found, in agreement with work done on cattle by Salem and Devlin (1972), that BUN concentration is significantly higher for urea fed lambs than for those fed soy protein. Freitag et al. (1968) found no difference in BUN levels in steers fed diets containing 30 percent and 70 percent of the total nitrogen supplied by urea.

Preston et al. (1965) observed BUN concentration to be a good indication of adequacy of dietary protein in growing lambs, provided a certain protein to energy ratio was maintained. They suggested a ratio of 22 gm. digestible protein/1000 Kilocalories of digestible energy for maximum growth. They associated low BUN with a low protein to energy ratio in the diet and with retarded growth of the lambs. If the ratio was increased above that suggested , BUN increased

rapidly and was not associated with increases in growth rate. They showed normal minimum and maximum levels in lambs of 2.7 and 32.9 mg. urea nitrogen/100 ml. of blood respectively.

Pfander et al.(1975) found that average daily gain favored those lambs which were maintained at a PUN of 20 mg./100 ml.. Their average daily gains were not significantly greater than those whose PUN's were maintained at 15 mg./100ml., but both were superior to the 10 mg./100 ml. level($P < 0.05$).

Roffler and Satter (1975) suggested that high tissue demand for amino acids at high production may reduce hepatic deamination of amino acids, thereby reducing PUN concentration.

Combs et al.(1968) showed a marked difference in BUN levels between breeds and sexes of lambs during a growing - fattening period, indicating that there might be a nutritional level x growth stage interaction. Pfander et al.(1975) found that PUN tended to increase with age in animals maintained on the same dietary level of protein.

Weeth et al.(1960) found that BUN was decreased when heifers on a roughage diet were drinking either 1 or 2 percent salt water, with the effect being more pronounced on 2 percent salt water. They suggested that lowered BUN on the 1 percent salt water diet was due to increased water consumption, and that decreased BUN on 2 percent salt water treatment may have been caused by low feed intake on this treatment.

URINE AND FECES

Amounts and composition of urine and feces can be important indicators of bodily nitrogen metabolism.McIntyre (1970) , and Pang (1971) reported that an increased rate of urea and water excretion via the kidneys prevented plasma urea levels from exceeding an upper limit in sheep. This loss of water may affect thirst and produce an increased water intake. This may explain the higher ($P< 0.01$) levels of water intake and urine volume with high solubility diets as reported by Wohlt et al.(1976) when comparing diets of 13 and 35 percent solubility. Further, they reported that the amount of urinary nitrogen excreted increased with increasing dietary protein solubility, but there was no significant change in fecal nitrogen losses with variations in solubility. Schingoethe (1976) reported excess urination associated with high whey consumption. Chicco et al.(1970) self-fed a 30 percent sodium chloride protein supplement to steers on pasture and reported that nitrogen balance data showed significantly greater intake($P <0.05$) and urinary losses ($P< 0.01$) of nitrogen for the supplemented groups. Nitrogen retention was significantly ($P< 0.01$) depressed by the high salt ration due to increased ($P< 0.01$) urinary losses.

Clifford and Tillman (1968) fed purified diets to lambs in order to compare different ratios of urea to soybean meal and reported that fecal and urinary nitrogen excretions were not affected by diet. Fecal nitrogen losses were not affected by time; however, urinary nitrogen excretion was higher during the first 10 day period on the diet and there was no further change. The authors suggest that these data may indicate that 'adaptation' took place in the body rather than in

the contents of the digestive system.

VOLATILE FATTY ACIDS

Fermentation in the rumen makes a large proportion of the substrate of structural components of plants available in forms which are directly useable by the tissues of the animal. Carbohydrates, proteins, and all other fermentable substrates are converted simultaneously into volatile fatty acids (VFA's) , methane, carbon dioxide,NH_3 and microbial cells (Leng 1970).

VFA's are absorbed, to a large extent, directly from the rumen, whereas glucose, amino acids, VFA's and other metabolites are absorbed from the small intestine. The absolute amount of each of these specific metabolites absorbed determines the actual energy value of a feedstuff (Moe and Tyrrell 1973). VFA's are the most important byproducts of ruminal fermentation and are the major source of energy to the animal. Annison and Armstrong (1970) reported that VFA's contribute 60 - 80 percent of the metabolizable energy of the ruminant. The production of a mixture of acetic and propionic acids, a butyric isomer and traces of a valeric isomer are characteristic of fermentation in the rumen.

Annison and Lewis (1959) reported that acetic acid predominates in the mixtures of VFA's found in the rumen under all dietary conditions, and that acetate is the major end-product of the fermentation of CHO's and the principle VFA produced by the degradation of protein. Foodstuffs fermented rapidly such as starches and sugars tend to promote an increase in percentages of propionic and butyric acids. Branched - chain VFA's arise chiefly as an end - product of

protein degradation. Clifford and Tillman (1968) reported the carbon structures of branched chain VFA's are derived mostly from proteins. They reported, as did Ludwick et al.(1972) consistent reduction in the branched - chain VFA's when urea was fed compared to soy protein as the sole source of nitrogen, thus indicating the importance of the carbon skeletons supplied by soy protein.

Leng (1970) reported that there is a reversible flow of carbon between the acetate and butyrate pools in the rumen,but little or no interconversion of propionate with acetate or butyrate. He found that the addition of lactate to rumen fluid increased the conversion of acetate to butyrate, probably because a slightly lower pH favors production of butyrate over acetate.

The quantitative contribution of protein to the production of VFA's and their pathways of production from amino acids in the rumen are little known, but at least on high protein diets protein contributes significantly to VFA production (Leng 1970).

Clifford and Tillman (1968) found a tendency, though not significant, for reduced acetic and increased propionic and higher straight and branched chain fatty acid concentration as urea was replaced by soy protein in purified diets fed to sheep. As urea was replaced by soy protein, valeric acid showed a significant increase. These results are in agreement with the findings of Freitag et al. (1968) feeding high roughage non - purified rations to cattle, who also observed no significant difference in total ruminal concentrations of VFA's due to dietary source of nitrogen. However,

Oltjen and Davis (1965) reported that urea in high concentrate diets resulted in lower total rumen VFA concentration. Freitag et al.(1968) feeding levels of 7 and 11 percent crude protein found that regardless of nitrogen source the concentration of acetate ($P< 0.05$) and total VFA's ($P< 0.10$) were increased on the higher level of dietary nitrogen. A higher level of butyrate was found with the soybean meal diets ($P< 0.10$) compared to the corn plus urea diets. The ruminal concentrations of isovalerate were significantly ($P< 0.05$) reduced by the substitution of corn and urea for soybean meal and by the lower level of dietary nitrogen. Ruminal valerate was also significantly ($P< 0.05$) reduced when urea and corn were substituted for soybean meal. Annison and Lewis (1959)reported that high protein diets resulted in increased concentrations of total VFA's with the relative proportions of acetic acid decreased and of butyric acid increased. They also reported in vitro studies in which casein was incubated with rumen microorganisms resulting in considerably higher proportions of C_4 and C_5 acids than are normally found in rumen contents.

Anderson (1975) feeding sheep alfalfa hay and whey reported increased rumen concentrations ($P< 0.01$) of butyric and decreased concentration of acetic and valeric acids with whey feeding, whereas total propionic acid, acetate:propionate ratio, and total VFA concentrations were not affected by whey feeding. He suggested that the decreased concentrations of acetic acid from whey feeding were accounted for primarily by the increase in butyric acid, because the lactose in whey was serving as a substrate for rumen bacteria

for the production of butyric acid. Schingoethe (1976) in his review on whey feeding reported that molar percentage of propionate usually is reduced slightly with whey in the ration but acetate is little affected and butyrate is increased consistently. He assumed most of the response to be attributable to lactose since the responses were similar whether the source was dried whey, partially delactosed whey, demineralized whey or lactose. He also reported that the degree of response in rumen VFA changes was essentially the same at both low and high lactose intakes.

Franks et al.(1972) feeding cattle, found that VFA concentration was not significantly ($P< 0.05$) affected by type of grain, when the test grain comprised 80 percent of the ration. Hale (1973) cites work showing that processing of grain tends to shift the VFA concentration in favor of propionic acid, thus reducing the acetate: propionate ratio. The grain most affected by processing was milo, and that which was affected the least was barley. Hale reported also that comparisons of processed and non - processed grain in vitro indicated that greater amounts of VFA's may be produced per unit of dry matter digested by rumen microorganisms on processed grain. He also reported that sheep appear to be unique in their ability to digest and utilize grain and as a result processing methods and grain species may not be as important as with cattle.

Frequency of feeding can alter feed consumption and VFA ratios. Theurer et al.(1976) offered feed for either 3 or 24 hours a day and found those fed ad libitum consumed 65 to 100 percent

more feed and had lower molar percent of acetic and increased molar percent of propionic and butyric acids in ruminal vein and jugular vein plasma. Molar proportions of valeric and isovaleric acids were not altered by feeding frequency.

Present evidence indicates that the absorption of VFA's from the rumen into blood can be explained by diffusion alone. However, the rate of diffusion is greatly modified by concentration, metabolism within the rumen epithelium, and by ruminal pH (Stevens 1970). This author reported that the rate of absorption of VFA's increased with chain length, but that the respective concentrations in the venous return from the rumen were found to be in the reverse order. He also cited in vitro studies showing that when the lumen bath contained 30 mmoles/liter of a given VFA buffered to pH 7.4, the differences in the relative rates of absorption and transport to the blood of the various VFA's could be attributed to differences in the rate at which each was metabolized by the rumen epithelium. Metabolism accounted for 45 percent of the acetate, 65 percent of the propionate, and 85 percent of the butyrate absorbed from the lumen bath. Decreasing the pH or increasing the VFA concentration from these conditions increased rate of absorption and greatly increased rate of transfer with increasing chain length.

Leng (1970) reported that in many studies of individual VFA production, using isotope dilution techniques, the proportion of VFA production appeared to be equal to the proportion of VFA concentration in the rumen. In vitro work reviewed by Annison and

Lewis (1959) suggests that butyric acid is produced at the same rate as propionic acid, with the lower concentration of butyric acid in the rumen being attributed to its more rapid absorption.

The production rates of valerate, isovalerate, and isobutyrate have not been examined as extensively as those of the major VFA's. A knowledge of the production of these acids may be important because the higher acids appear to be essential for the growth of cellulolytic organisms, and because the isobutyrate and valerate are potentially glucogenic. The production of these VFA's has been assumed to be low because of their low concentrations in the rumen. However, since they are utilized by rumen microrganisms as well as being absorbed, the relationship between production and concentration may be different from those of other VFA's (Leng 1970). The author also reported that since almost all the research has been done on ruminants fed roughage rations, the relationship between production and concentration may not necessarily follow in ruminants given grain diets.

Acetate and butyrate are incorporated, in the intermediary metabolic system of the animal, into long - chain fatty acids. Propionate contributes little to fatty acid synthesis, but is the only VFA which makes a net contribution to glucose synthesis and is quantitatively the most important single precursor of glucose (Annison and Armstrong 1970).

Armstrong and Blaxter (1957) first reported that acetate is

utilized less efficiently than propionate and butyrate, and since then efforts have been made to alter VFA production to decrease the acetate:propionate ratio. Balch and Rowland (1957) reported that the proportions of acetic and propionic acids varied inversely, and that decreasing the ratio of fibrous to starchy carbohydrates in the diet caused a decrease in the ratio of acetie to propionic acid.

It has been recognized for some time that the ratio of VFA's influence the efficiency with which metabolizable energy is used for gain much more than the efficiency with which it is used for maintenance (Blaxter 1967).

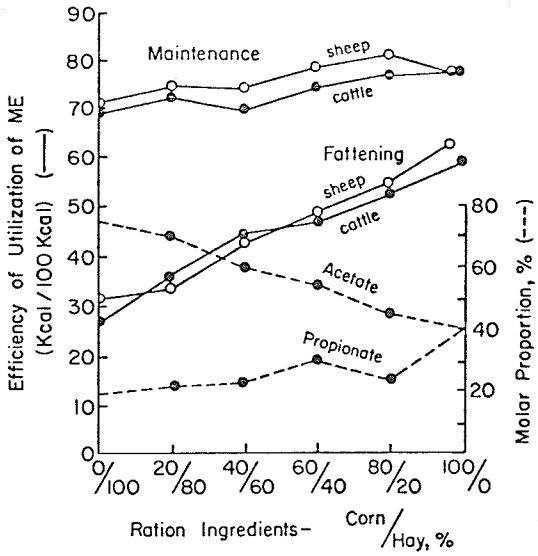

Figure 4. Interrelationships among the efficiency of utilization of ME for fattening and for maintenance (———) the molar proportion of acetate and propionate (– – –) and the ration composition (Blaxter and Wainman, 1964).

As reviewed by Kromann (1973) the efficiency of lipogenesis is greater for high grain rations yielding high concentrations of

propionate. In sheep, heat increment of acetate is much higher than for propionate and butyrate. As acetate increases, heat increment increases and less net energy is available for production.

MATERIALS AND METHODS

EXPERIMENTAL OBJECTIVE

Two experiments were undertaken to evaluate mixtures of urea with whey or processed fababean starch for use as liquid protein supplements for ruminant animals. The first experiment was a feeding trial with lambs to determine consumption, growth rate and feed efficiency under practical feeding conditions. The second experiment was designed to determine metabolic effects as indicated by nitrogen balance, rumen ammonia, blood ammonia and urea, and rumen volatile fatty acids.

EXPERIMENT I - FEEDING TRIAL

Experimental Animals

Forty male and forty female crossbred lambs with mean body weights of 30.4 and 28.1 Kg. respectively were randomly alloted to eight groups of ten (five male and five female) animals. Groups of lambs and treatments were randomly assigned to pens.

Management

Lambs were dewormed and treated for coccidiosis during adjustment to the diet treatment. The University of Manitoba sheep barn was used for the feeding trial. The building is enclosed on three sides with the pens being exposed to the south. Each pen measured approximately three by twenty-two meters, with approximately fifty percent of each pen being under a roof. Approximately two and one-half meters of feed bunk space was provided at the

sheltered end of each pen. Water was provided free choice from float-regulated water bowls situated in the feeding area. The whey liquid protein supplements (WLPS) were offered in galvanized iron pails situated in the feeding area. Eight consecutive pens comprising the west wing of the barn were used.

Diets

Four experimental diets were prepared (Table 1). Straw and grain ingredients were employed, with a mechanical limitation to ration formulation being dictated by the University of Manitoba feed mill, through which a maximum of forty percent straw can be incorporated into pelleted diets.

Diet 1 was formulated to provide approximately 8 percent protein. Soybean meal or urea replaced the barley in Diet 1 to formulate the other three diets. Diets 2,3, and 4 were formulated to provide approximately 10.5, 14 and 14 percent crude protein respectively. All diets were pelleted.

Eight treatments were employed (Table 2).

Preparation of Liquid Protein Supplements

The 32 percent fababean starch liquid protein supplement (FSLPS) was prepared as follows, using fababean starch fractionated by the Prairie Regional Laboratory of the N.R.C. located at Saskatoon.

To prepare one liter of 32 percent protein supplement:

1. 200 g of fababean starch were added to approximately 600 ml. of water and mixed well.
2. the starch-water solution was heated to approximately 90 degrees celsius until gelatinization occurred. This was done by infusing steam into the mixture via a rubber hose,

Table 1. Composition and nitrogen content of experimental diets fed to lambs.

Ingredient	Percent Composition			
	Diet 1	Diet 2	Diet 3	Diet 4
Oats	30.0	30.0	30.0	30.0
Barley	25.5	19.5	8.5	23.5
Barley straw	40.0	40.0	40.0	40.0
Beet molasses	3.0	3.0	3.0	3.0
Soybean meal	-	6.0	17.0	-
Urea	-	-	-	2.0
Trace mineralized salt	0.5	0.5	0.5	0.5
Calcium phosphorus supp.[a]	1.0	1.0	1.0	1.0
Vitamin A [b]	+	+	+	+
Vitamin D[c]	+	+	+	+
Nitrogen[d]	1.3	1.6	2.2	2.1

[a] Calcium phosphorus supplement 15.5 - 18.5 Ca:20.5 P

[b] Vitamin A added to supply 275 I.U./kg of diet.

[c] Vitamin D added to supply 88 I.U./kg of diet.

[d] Nitrogen values are an average of three analyses and reported on an air dry basis.

which also served to stir the mixture while heating.

3. the mixture was cooled and 113.5 g of feed grade urea and 5 g of HT 1000 enzyme (Miles Laboratories Inc.) were added and thoroughly stirred.
4. the volume was adjusted to 1000 ml. by adding water and then mixing thoroughly to provide the final liquid supplement.

The supplement was kept refrigerated and prior to feeding was thoroughly stirred.

The WLPS was prepared in the following manner, using spray dried non-hygroscopic sweet whey. Supplements with two levels of dry matter were prepared - 6 percent DM, which is that normally found, and 25 percent DM which could be economical under conditions where maximum DM would be advantageous for transport.

Supplements were prepared by weighing the water, weighing the whey as if it were one hundred percent dry matter, and adding the urea to the mixture. Thorough mixing was accomplished using a one-half inch size electric drill fitted with a T-shaped steel paddle.

Procedure

The lambs were adjusted for 21 days on their respective diet treatments. Lambs were weighed the first day of the trial and weekly at the same time during the approximately 58 day feeding trial. Immediately prior to weighing, the feed troughs were thoroughly cleaned out and the remaining feed weighed and samples obtained.

Before feeding on weigh day, diet consumption for the

Table 2. Composition of individual treatments as formulated.

Trt.	Pen	Diet	DM in WLPS % Wt.	Crude Protein from WLPS (%)	Crude Protein from FSLPS (%)
1	5	3	-	-	-
2	3	4	-	-	-
3	2	1	-	-	40
4	7	2	-	-	25
5	1	1	25	40	-
6	4	1	6	40	-
7	6	2	25	25	-
8	8	2	6	25	-

previous week was calculated and the amount of protein supplement required to raise the protein level of that amount of diet to 14 percent was determined. On this weekly basis the amount of FSLPS added to the diet and the amount of urea added to the whey mix was adjusted. The protein in the whey powder was not taken into account when calculating the amount of urea required.

Fresh FSLPS was prepared approximately bi-weekly and kept refrigerated. The FSLPS was poured over the diet at the time of feeding and mixed until uniformly distributed. It was assumed for the purposes of calculation that the FSLPS was 32 percent protein. Samples were taken from each preparation, frozen and subsequently analysed for crude protein.

The WLPS was weighed and offered on a daily basis. The liquid was offered in galvanized steel pails which were scrubbed with a brush daily.

The lambs were fed free choice with WLPS also being available at all times.

Water was available free choice and pen consumption measured daily using water meters* (PSM 190) fitted into the water lines.

Lambs were shipped for slaughter when they reached a weight of approximately 41 Kg.

* Kent Meters Ltd., England

EXPERIMENT II - METABOLISM STUDY

Experimental Design

Sixteen male crossbred lambs with a mean body weight of 34.6 Kg. were obtained from the University flock and each lamb randomly allotted to four of the eight treatments in a completely randomized design.

Diets

The four basic diets (Table 1) were the same formulation as those used in the feeding trial, with the exception that wheat straw was substituted for barley straw. Prior to commencing the experiment, sufficient amounts of diet were prepared to last the duration of the experiment. Each diet was sampled by sampling each bag with a probe, mixing, and taking a subsample, which was analysed for nitrogen prior to feeding.

The FSLPS was prepared as described in Experiment I. Sufficient FSLPS was added as a 32 percent protein supplement to raise the crude protein content of treatments 3 and 4 to 14 percent based on air dry weight of diet.

The WLPS was prepared as described in Experiment I. In this experiment, a constant amount and concentration of WLPS was fed (Table 3). Sufficient supplement was offered to increase to 14 percent the crude protein content of the diet in treatments 5,6,7and 8. These values were based on consumption of 1.8 Kg. of diet and all the WLPS offered, which were levels of consumption derived from results of Experiment I.

Table 3. Composition and amounts of whey liquid protein supplement offered on a daily basis.

Trt.	Whey Powder (% Wt.)	Water (% Wt.)	Weight of Supplement Kg.	Grams of Urea Added
5	25	75	4.5	34.0
6	6	94	6.8	34.0
7	25	75	4.5	21.0
8	6	94	6.8	21.0

Treatments were the same as in the feeding trial (Table 2).

Lambs were fed free choice, with feed, water, and WLPS available at all times.

Procedure

Lambs were dewormed and treated for coccidiosis prior to commencing the experiment. Lambs were tied in individual stalls and adjusted for 15 days to their respective treatments.They were then put in metabolism crates to facilitate collection of urine and feces.

Measurements were begun the second day the lambs were in the collection crates. Fresh feed, WLPS and water were weighed and offered daily, and daily samples of diet and WLPS and FSLPS were taken.

Samples of diet and WLPS which had not been consumed were also taken. All samples of WLPS and FSLPS were immediately frozen.

Daily fecal collections were weighed and 10 percent aliquots were kept frozen until the end of the collection period. At that time the aliquot samples were composited and held for chemical analysis after drying and grinding.

Daily urine volumes were measured and aliquot samples were refrigerated, composited at the end of each collection period and a subsample frozen for subsequent analysis. Sulphuric acid was used to prevent loss of ammonia during the collection of urine.

Diet, feces, FSLPS and WLPS dry matter were determined by drying the samples in a forced air oven at 70 degrees celsius

until a constant weight was attained.

Urine was filtered prior to nitrogen determination. Diet, feces, urine, WLPS and FSLPS were analysed for total nitrogen using the Kjeldahl method as described by the A.O.A.C. (1970).

The collection period was of 5 days duration. On day 6, the lambs were removed from the collection crates and returned to their respective stalls with the same dietary treatment provided. Also on day 6, blood and rumen samples were taken 1 hour before feeding and at ½, 1,2,4,6,8,12, and 24 hours postfeeding.

Blood samples were taken from the jugular vein with a standard plasma vacutube and refrigerated immediately, centrifuged for 20 minutes at 10,000 revolutions per minute and the serum removed, sealed and frozen for subsequent ammonia and urea analysis.

Rumen samples were obtained by inserting a metal strainer on the end of a plastic tube into the rumen via the oesophagus and drawing out a sample with a syringe. Twenty-five ml. samples of rumen fluid were added to one ml. of concentrated sulphuric acid, mixed and frozen for subsequent ammonia and volatile fatty acid analysis.

Following the last blood and rumen collection, the lambs were adjusted to the next dietary treatment for fifteen days prior to the next collection period.

By using sixteen lambs, eight were adjusting to a new treatment while the other eight were in the collection crates, thus enabling eight replications of the eight treatments with

a minimum of weight change.

Blood ammonia and urea and rumen ammonia concentrations were determined on a Technicon autoanalyser II (model 7 - 70 - 140A).

Rumen samples for volatile fatty acid determination were prepared as outlined by Erwin et al. (1961). The samples were analysed for VFA's using a Tracor model 550 gas chromatograph. The analyser was equipped with a flame ionization detector. The injection port temperature was 220 degrees celsius. The 1.83 meter by 0.63 centimeter stainless steel column was packed with 20 percent NPGS (Neo-Pentyl Glycol Succinate),2 percent H_3PO_4 on Gas-Chrom R (C 22 firebrick, 60-80 mesh).

The column was conditioned by passing 50 ml. of helium per minute through the column for 24 hours at a column temperature of 170 degrees celsius. For VFA analysis, a column temperature of 130 degrees celsius was used with helium as the carrier gas with a flow rate of 50 ml. per minute. The hydrogen flow to the flame jet was 50 ml. per minute while the air flow to the detector chamber was 280 ml. per minute.

The output of the ionization detector amplifier was transmitted to a Sargent-Welch recorder model SRC. The free fatty acids and isomers were eluted as symmetrical peaks at twelve minutes. The amounts of short chain acids were obtained by determining peak areas of the acid eluted from a standard solution and comparing them to the rumen sample peaks.

Gross energy determinations were done on a Parr Oxygen Bomb calorimeter.

Statistical analyses were made according to procedures outlined in Snedecor and Cochran (1967). Of the eight repetitions of the treatments, only the latter seven repetitions were used for statistical analysis since the feeding of restricted amounts of pelleted feed in the first repetition proved impractical. The SNK test was employed to test for significant differences among means.

Standard Error of treatment means was calculated using the formula $S.E.= \sqrt{\frac{EMS}{n'}}$ where $n'= \frac{K}{\frac{1}{n_1} + \frac{1}{n_2} + \cdots \frac{1}{n_K}}$ and K = number of treatments.

RESULTS AND DISCUSSION

EXPERIMENT I - FEEDING TRIAL

Growth performance data for lambs are shown in Table 4.

Average daily weight gains for treatments 3, 4, and 5 were significantly ($P<0.05$) superior to the urea control (treatment 2) as were treatments 1,6,7 and 8 ($P<0.01$).

The total dry matter intake and feed efficiency tended to be lower for the urea control group, as compared to the other treatments.

There was no consistent relationship between rate of gain and level of protein consumption, protein consumption as percentage of dry matter consumed, or percent of protein consumed derived from urea.

Total liquid consumption was higher and total actual water consumed from water and WLPS tended to increase as the percent of total dry matter consumed as whey increased.

WLPS consumed as a percentage of total liquid consumed, and percentage of total dry matter consumed as whey dry matter was lower for the groups of lambs receiving WLPS containing 6 percent dry matter than for those receiving WLPS containing 25 percent dry matter.

Feces were noticeably softer from lambs on treatments 7 and 8, consuming 40.44 and 85.14 percent respectively of their total liquid from WLPS.

Table 4. Mean growth, feed consumption and feed efficiency of lambs during the 58 day feeding trial. Experiment 1.

Item	Treatment 1	2	3	4	5	6	7	8	S.E. of Means
No. Lambs / Pen	10	10	10*	10*	10	10	10	10	
Ave. Daily Gain Kg	0.257^{A}	0.180^{abzABCD}	0.251^{a}	0.226^{b}	0.241^{z}	0.292^{B}	0.280^{C}	0.284^{D}	±0.04
D.M. cons. Kg/day	1.618	1.386	1.645	1.669	1.564	1.474	1.884	1.794	
% D.M. from supp.	-	-	5.39	3.39	3.13	5.36	27.07	16.44	
Kg feed/Kg gain	6.31	7.72	6.57	7.39	6.50	5.05	6.73	6.32	
Whey cons./day Kg	-	-	-	-	0.28	1.02	2.75	5.27	
Water cons./day.L	4.6	3.33	3.77	3.82	4.07	2.60	4.05	0.92	
Prot. cons. % NRC req.	155	125	152	151	102	112	170	163	
% Prot. cons. as urea	0.0	40.8	39.1	24.3	17.0	27.56	22.6	24.2	
Urea-% of total D.M.	0.0	2.13	2.09	1.27	0.64	1.21	1.18	1.27	

'a - z' Treatment means showing the same superscript are significantly different ($P<0.05$)

'A - Z' Treatment means showing the same superscript are significantly different ($P<0.01$)

* Means of pens with superscript * are result of 9 observations/trt. All other means are the result of 10 observations/trt.

DISCUSSION

The significantly lower rate of gain of the lambs on treatment 2 can be attributed in part to a lower D.M. consumption. This could have been caused by the high percentage of urea in the diet resulting in lower palatability. This would agree with findings by Bhattacharya and Pervez (1973) who fed pelleted rations containing 45 percent wheat straw to growing-fattening lambs and found a slight depression in feed intake but equal rate of gain and feed efficiency with supplemental urea at the 1.5 percent level, but lower feed intake and rate of gain with supplemental urea at the 2 percent level. That there was no depression in feed intake of lambs on treatment 3 with a urea level of over 2 percent of D.M. consumed could have been because the fababean starch masked the taste of the urea. However, it was observed that towards the end of the week , prior to the feed bunks being cleaned, there was a marked odor of ammonia over the feed bunk for treatment 3, and to a lesser extent for treatment 4. This may or may not have discouraged feed consumption to some extent.

The results for treatments 5 and 6 must be examined with care. The urea levels in the supplement were adjusted each week to bring the protein consumption of the total diet up to 14 percent based on the previous week's level of consumption. This resulted in increasing levels of urea as whey consumption dropped, until eventually at week 5 , virtually no WLPS was being consumed. At

this point, low levels of urea were added to the WLPS with the objective being to increase consumption. This had the net effect, over the whole feeding period, of reducing the level of protein consumption on these two treatments to very close to N.R.C. standards. That average daily gain was not significantly different suggests that N.R.C. levels of 163 gms. of crude protein/day are adequate.

There is no apparent explanation for the noticeable improvement in feed efficiency of lambs on treatment 6. It is unlikely that this efficiency advantage could be repeated since very little whey D.M. was consumed, a very low proportion of the protein in the diet was from urea, and the diet as consumed was basically an unsupplemented diet containing 112 percent of the N.R.C. recommended requirements for crude protein.

EXPERIMENT II NITROGEN BALANCE STUDY

Nitrogen balance and diet consumption data for the 8 treatments are shown in Table 6.

Lambs on treatment 2 (urea) had significantly ($P<0.05$) lower nitrogen retention, as percent of intake, than lambs on treatment 5 and also all other dietary treatments ($P<0.01$).

There were no significant differences ($P<0.05$) among treatments in total nitrogen consumed (Table 5&6). Percentage of total protein consumed as urea had no effect on percent N retention.

Protein digestibility was significantly greater ($P<0.05$) for treatment 1 than for the treatments (5,7) supplemented with WLPS containing 25 percent D.M. (Table 6). There was no significant difference ($P<0.05$) among other treatments but there was a tendency for treatments supplemented with WLPS containing 6 percent D.M. to be nearly as low in protein digestibility as those supplemented with WLPS containing 25 percent D.M.. Values for those treatments supplemented with FSLPS fell between the SBM control and the urea control.

There were no significant differences ($P<0.05$) in mean total daily D.M. intakes, but there were differences in composition of the D.M. consumed. Approximately 33 percent of the D.M. consumed in the treatments incorporating 25 percent D.M. WLPS was from whey D.M., and approximately 18 percent of the D.M. consumed in the treatments incorporating 6 percent D.M. WLPS was from whey D.M..

D.M. digestibility was greater on all treatments incorporating WLPS (Table 6). Treatment 7 (25 percent whey) showed greater D.M. digestibility ($P<0.05$) than both treatments incorporating FSLPS and greater D.M. digestibility ($P<0.01$) than both the SBM control and urea control treatments. Treatment 6 (6 percent whey) had higher D.M. digestibility values than the SBM control($P<0.05$), and urea control ($P<0.01$), and D.M. digestibility values for treatment 8 were greater ($P<0.05$) than both the SBM and urea control treatments. D.M. digestibility values for treatment 5 were greater ($P<0.01$) than the SBM and urea control treatments and both treatments incorporating FSLPS.

Amounts of water consumed tended to be lower and the total liquid consumed to be higher for those lambs being fed WLPS.Consumption by weight of WLPS containing 6 percent D.M. (treatments 6 and 8) was approximately double that of the WLPS containing 25 percent D.M. (treatments 5 and 7) when calculated as actual WLPS consumed or as a percentage of total liquid consumed.When compared on the basis of actual total liquid (water and whey) consumed(Kg.)as a percentage of D.M. consumed, there is very little difference among treatments, with values for treatments incorporating WLPS being slightly greater. Diets containing whey tended to show a slight but nonsignificant ($P<0.05$) increase in fecal N as a percent of intake and an increase in urine volume.

Table 5. Actual protein composition of treatments.Experiment II

Trt.	% Crude Protein of DM as Consumed	% Crude Prot.in Ration-No Liq. Supp.	Type of Prot. Supp.
1	16.08	16.08	SBM
2	14.85	9.41	UREA
3	15.13	9.41	FSLPS
4	14.77	11.74	FSLPS
5	13.80	9.41	WLPS
6	14.30	9.41	WLPS
7	13.84	11.74	WLPS
8	14.57	11.74	WLPS

Table 6. Effect of control diets, FSLPS diets, or WLPS diets on nitrogen balance and consumption parameters of lambs.

Item	Treatment 1	2	3	4	5	6	7	8	Std. Error
N cons. g/day	32.04	29.58	34.55*	32.58	30.09	36.19	30.85	35.18*	±2.09
Fecal N g/day	7.12	7.61	8.71	7.95	8.14	9.79	8.59	9.58	
Urine N g/day	11.63	15.28	10.21	11.31	12.08	10.97	10.63	10.49	
Apparent N dig. %	77.78^{ab}	74.27	74.79*	75.60	72.95^{a}	72.95	74.52^{b}	72.77*	±1.28
N retained g/day	13.29	6.69	15.63	13.32	9.87	15.43	11.63	15.11	
N retained, % intake	41.76^{B}	22.62^{aABCDEF}	45.24^{E}*	40.88^{C}	32.80^{a}	42.64^{D}	37.70^{A}	42.95^{E}*	±3.42
N ret. as % of that dig.	53.33	30.45	60.49	54.08	44.97	58.45	52.25	59.02	
Fecal N, % intake	22.22	25.73	25.21	24.40	27.05	27.05	27.84	27.23	
Urine N, % intake	36.30	51.66	29.55	34.72	40.15	30.31	34.46	29.82	
Prot. cons. % NRC req.	123.0	113.0	133.0	125.0	115.0	139.0	118.0	135.0	
Prot. cons. % as urea	0.0	36.63	34.62	20.31	25.52	31.83	14.52	19.56	
Urea, % of total DM	0.0	1.93	1.86	1.06	1.25	1.61	0.71	1.01	
% prot. cons. from supp.	0.0	0.0	39.61	23.44	56.36	47.31	43.05	35.47	
Prot. cons. as % tot. DM	16.08	14.85	15.13	14.77	13.80	14.30	13.84	14.57	
DM intake, Kg	1.245	1.245	1.427*	1.379	1.363	1.582	1.393	1.509*	±0.09
% DM from supp.	0.0	0.0	5.35	3.29	35.36	19.22	32.88	19.55	
% DM from supp. no urea	0.0	0.0	3.43	2.10	34.12	17.57	32.16	18.56	
DM dig. %	51.65^{bcCE}	51.03^{dBDF}	54.77^{eE}*	56.27^{aA}	66.76^{AEFG}	61.07^{bB}	63.96^{deCD}	59.96^{cd}*	±2.00
Whey cons. Kg	0.0	0.0	0.0	0.0	2.268	5.114	2.108	4.948	
Water cons. L.	4.89	4.35	4.81	4.95	3.63	1.81	4.02	2.31	
Actual water cons. Kg	4.89	4.35	4.99	5.06	5.42	6.62	5.67	6.96	
Liquid:DM ratio, Kg	3.93	2.86	3.50	3.67	3.98	4.18	4.07	4.61	

'a-z' Treatment means showing the same superscript are significantly different (P 0.05).

'A-Z' Treatment means showing the same superscript are significantly different (P 0.01).

Treatment means are the result of 7 obs./trt. except where postscript '*' denotes 6 obs/trt.

NH_3 - N concentrations in the rumen showed no concentration pattern over time so mean values were used.

Rumen concentration of NH_3 (Table 7) was higher ($P<0.05$) for the urea control treatment than for treatment 3. Values among the other treatments did not differ significantly ($P<0.05$); however, there was a tendency for those treatments (3,5,6) with low initial dietary protein supplemented with higher levels of urea mixed with WLPS or FSLPS to have lower levels of rumen NH_3 than the other treatments.

Serum NH_3 - N showed no significant ($P<0.05$) differences among treatments (Table 7), or in time after feeding patterns.

Serum urea - N concentrations showed a tendency to parallel the rumen NH_3 levels, with those treatments (3,5,6)with low initial dietary pr tein supplemented with higher levels of urea mixed with WLPS (Trts.5,6) or FSLPS (Trt.3) tending to have lower levels of serum urea (Table 7). Both the SBM (Trt.1) and urea control (Trt.2) treatments had higher serum urea values ($P<0.01$) than treatments 3,5 and6. Treatment 7 also had higher serum urea - N concentrations ($P<0.05$) than treatment 3.

There were no significant ($P<0.05$) differences among treatments in total rumen VFA levels, but there were differences in the percentage proportions of the individual acids (Table 7).

Percent acetic acid was greater for treatment 8 and the urea control ($P<0.05$) and for the SBM control ($P<0.01$) than for

Table 7. Serum ammonia, urea, rumen ammonia and rumen VFA's of lambs. Experiment II

Item	Treatment 1	2	3	4	5	6	7	8	S.E. of Means
Serum Ammonia, mgN/L	7.21	7.51	7.84	7.70	8.70	7.35	7.36	7.22	±1.12
Serum urea, mg/100 ml	25.59^{ABE}	25.92^{CDF}	17.81^{cdEF}	22.20	18.65^{bBD}	19.05^{aAC}	22.90^{c}	24.38^{abd}	±1.23
Rumen Ammonia, mgN/L	118.42	154.42^{d}	83.42^{a}	138.85	98.85	95.42	131.00	126.16	±15.20
Rumen VFA, mmole/100ml	7.25	8.11	7.28	7.60	6.07	8.09	7.47	7.35	±0.47
Acetic Acid, %	66.02^{AG}	64.97^{bE}	50.40^{BCDEFG}	60.13^{B}	61.39^{F}	55.84^{abA}	61.33^{c}	63.76^{aD}	±1.80
Propionic Acid, %	18.27^{A}	18.62^{d}	32.79^{abcdeAB}	19.97^{B}	18.25^{a}	21.84^{b}	20.22^{c}	15.36^{e}	±2.75
Isobutyric Acid, %	1.00	0.94	0.92	1.23	1.33	1.04	0.94	0.98	±0.13
Butyric Acid, %	14.68	14.08	11.77	16.15	15.82	18.79	15.82	15.43	±1.67
Isovaleric Acid, %	0.75	0.53	0.71	0.91	0.99	0.55	0.71	0.63	±0.19
Valeric Acid, %	0.76^{AH}	0.86^{cB}	3.42^{ABCDEFG}	1.23^{c}	2.23^{abcDH}	1.94^{E}	1.25^{aF}	0.93^{bG}	±0.29
% Acetic:% Propionic Ratio	4.06	3.93	1.71	3.35	3.97	2.89	3.18	3.83	±0.52

'a-z' Treatment means showing the same superscript are significantly different ($P<0.05$).

'A-Z' Treatment means showing the same superscript are significantly different ($P<0.01$).

Treatment means are the result of 7 obs/trt except as follows:
- for VFA values - trts. 2,6,7,and 8 - 6obs/trt
  - trt. 3 - 5 obs/trt.
- for serum ammonia and urea, and rumen ammonia - trts. 3 and 8 - 6obs/trt.

treatment 6. With the exception of treatment 6, all the other treatments showed greater percentage concentrations ($P<0.01$) of acetic acid than treatment 3.

Percent propionic acid was greater for treatment 3 than for treatments 1 and 4 ($P<0.01$) and all other treatments ($P<0.05$).

Percent valeric acid was greater ($P<0.05$) for treatment 5 than for treatments 2, 7 and 8 and greater ($P<0.01$) for treatment 5 than for treatment 1. Percentage values for valeric acid for treatment 3 were greater ($P<0.01$) than for all other treatments.

There were no significant differences ($P<0.05$) among treatments in percentages of isobutyric, butyric and isovaleric acids or in the acetic : propionic ratios, although treatment 3 tended to have a much narrower acetic : propionic ratio.

DISCUSSION

Nitrogen Retention

The significantly higher N retention for all other treatments compared with the urea control (Trt.2) indicate that some or all of the ingested N was utilized with greater efficiency by the body in these treatments.

There were no significant differences among treatments in total N consumed. Lambs on treatment 1 (SBM control) retained a significantly greater percentage of the N consumed than those on treatment 2, the diets were isocaloric and there was no significant difference in total D.M. consumption.From this it is suggested that the point of NH_3 accumulation had been reached in treatment 2, and that some of the preformed amino acids from the SBM in

treatment 1 which were not degraded in the rumen were absorbed by the lower gut and utilized by the body, thus improving N retention.

Otherwise it would be reasonable to expect the percentage N retention for the two treatments to be similar. There is no way of knowing under the terms of this study exactly how much, or whether in fact any of the urea was synthesized to microbial protein in treatment 2. There is reason to suspect that some part of the urea was utilized by the rumen microorganisms since the basal diet in treatment 2 contained only 9.41 percent preformed protein, or 89 percent of the N.R.C. requirement for crude protein of 10.6 percent. However, Roffler and Satter (1975) reported that for typical feedlot rations ruminal NH_3 exceeds the needs of bacteria at approximately 10.0 percent crude protein for lambs.

Two basic explanations are feasible for the superior N retention in the remainder of the treatments. The urea could be utilized to a greater extent, or whey D.M. or fababean starch undegraded in the rumen could have contributed to the amino acid pool via the lower gut.

The latter reasoning may be feasible for the whey supplemented diets since approximately 33 gms and 54 gms, or 15 and 30 percent of the total protein in the diet from the 6 percent and 25 percent D.M. WLPS diets respectively came from whey D.M.. Although very little of this whey protein would have escaped from the rumen undegraded, some could have been absorbed from the small intestine. In treatments supplemented with FSLPS

the actual protein contribution from the fababean starch was only 1.5 to 2.5 g, or approximately 1 percent of the total protein consumed. Considering that this was probably degraded to a considerable extent in the rumen, the preformed protein from fababean starch can be assumed to make no significant contribution to the amino acid pool via the lower gut.

The more probable explanation for the increased N retention is that there was increased utilization of NH_3 in the rumen by providing rumen microorganisms with readily utilizable energy at the time of NH_3 release. This could have maximized utilization of NH_3 by rumen microorganisms and caused an increase in the point of NH_3 accumulation in the rumen.

NH_3 begins to accumulate in the rumen at a higher dietary crude protein when a high energy rather than a low energy diet is fed (Roffler et al. 1976). All basal diets in this test were formulated to be isocaloric and had approximately equal digestible energy contents. Whey D.M. and fababean starch have a gross energy approximately equal to the prepared diets but have a somewhat higher digestible energy. In the case of the treatments supplemented with FSLPS little change would have occurred in total digestible energy intake via the supplement since only 2.1 percent and 3.4 percent of the total D.M. consumed consisted of fababean starch. However, the treatments supplemented with 6 percent D.M. and 25 percent D.M.WLPS had approximately 18 percent and 32 percent of the D.M. of the total diet consumed as whey D.M., and at this level it is possible that the digestible energy of the total diet could have been increased sufficiently to cause an increase in the point of NH_3 accumulation.

The major cause of increased N retention on those treatments supplemented with WLPS or FSLPS is undoubtedly associated with provision of energy during periods of peak NH_3 production in the rumen.

Both whey,and fababean starch in its gelatinized and partially digested state, are readily available sources of energy in the rumen. Urea is hydrolysed very rapidly in the rumen (Johnson 1976) , and the peak energy release from both these sources would tend to approximate the peaks of NH_3 production to a much greater degree than the basal diet, especially if consumed at the same time. Thus, even though the fababean starch would not necessarily have contributed large quantities of energy compared to the basal diets, it could have provided energy at times of critical need. The whey D.M. probably contributed more total available energy and it would appear that this energy could have ensured maximum use of rumen NH_3 when large amounts of whey D.M. are present.However, degradation of whey protein in the rumen produces NH_3 and this would tend to increase NH_3 concentrations. Thus, a high level of whey D.M. may not necessarily promote higher N retention, especially when fed with urea. This may explain why the two treatments in which 33 percent of the D.M. consumed consisted of whey had relatively low N retention levels. These levels of whey D.M. could possibly have promoted an increase in N retention if no urea was fed by

providing energy to rumen microorganisms, especially when the crude protein levels in the basal ration were relatively high.

Under conditions of self feeding, small amounts of diet are being consumed over an extended period and this would tend to reduce the peaks of NH_3 production in the rumen.This would tend to reduce losses of NH_3 from the rumen and it would be reasonable to expect that the differences in N retention would be greater if animals were fed less frequently.

Rumen Ammonia

Individual observations were averaged over 24 hours to give an average rumen NH_3 value for each replication.This was done because no trends were noted in rumen NH_3 concentration related to time after feeding. There were minor peaks of NH_3 concentration but these were not consistent as would be expected with continuous feeding of lambs.

There was no discernible pattern relating treatment and rumen NH_3 concentration with the exception that the three treatments having the highest level of urea supplementation fed with WLPS or FSLPS had noticeably low rumen NH_3 concentrations. The reason for this occurrence is not known. The whey D.M. may have been providing energy at periods of peak NH_3 production thus making for greater NH_3 utilization. However, since both the low and high urea 25 percent D.M. WLPS provided equal amounts and percentages of whey D.M. to the diet, then the treatment providing less urea should have tended to keep lower NH_3 levels in the rumen - not the opposite, even though the differences

were not statistically significant. Since the treatment supplemented with the higher level of FSLPS provided more D.M. as well as urea, a decrease in the rumen fluid concentration of NH_3 because of the energy provided from the fababean starch is a possibility, although the higher level of supplementation with FSLPS provided more urea and only approximately 1 percent more of the total D.M. as starch. The notion that the D.M. from whey and fababean starch provided enough energy to utilize all the extra NH_3 provided by the urea, and that there was less production of NH_3 from the basal diet because of a lower level of preformed protein, is credulous but requires further investigation to lend tenability to it.

Ruminal levels of NH_3 for all treaments were above the 50 mg NH_3/L. stated to be adequate (Roffler et al. 1976) to support maximal growth rates of rumen microorganisms.

Blood Ammonia

The lack of any significant differences in blood NH_3 concentrations or trends reflecting the rumen NH_3 concentrations agree with work by Lewis (1957) who reported that substantially higher concentrations of rumen NH_3 than those observed in the present experiment are necessary before changes in rumen NH_3 are reflected in blood NH_3-N (BAN) concentrations in peripheral blood. The present results do not seem to agree with observations by Webb et al. (1972) working with cattle, who observed that severe NH_3 toxicity occurred when BAN concentration exceeded 0.7 to 0.8 mg BAN /100 ml.. The level of 10 to 40 mg BAN/L (as reviewed by Chalupa (1968)) would seem to more closely agree

with results from this experiment.

Blood Urea Nitrogen

Since NH_3 absorbed by the portal blood is synthesized to urea in the liver, changes in rumen NH_3 concentrations should be reflected in BUN concentrations in peripheral blood,such as was observed in this experiment, with the exception of treatment 1 - supplemented with SBM.

Since dietary protein level was higher in treatment 1, the high BUN level even with low rumen NH_3 may be explained by hepatic deamination of amino acids which could have produced a level of BUN not directly related to rumen NH_3 concentration.This agrees with Pfander et al.(1975) who suggested that BUN can be used as an indicator of the level of metabolism in growing lambs. Their reasoning was based on the assumption that if insufficient protein is being delivered to the cells, BUN will be at a minimum, and if excess protein is available, BUN will be elevated. At the BUN levels attained in this experiment there was no apparent correlation between BUN and either concentration of N in the urine or total N excreted in the urine.

Volatile Fatty Acids

There were no significant differences in total rumen VFA's among treatments, which is in agreement with work by Freitag et al.(1968). They found no difference in

total VFA concentration due to dietary source of N. Anderson (1975) found no change in total rumen VFA concentration due to whey feeding. With the exception of treatment 3 - supplemented with a high level of FSLPS - there was no evidence of treatment effect on individual VFA's. The higher propionic acid level in treatment 3 lambs was associated with a reduction in levels of acetic and butyric acid. Annison and Lewis (1959) observed that rapidly fermented foodstuffs such as starches and sugars tend to promote an increase in percentages of propionic and butyric acids. The decrease in acetic : propionic ratio, combined with the slightly lower percentage of butyric acid and the significantly ($P<0.01$) greater percentage of valeric acid (Trt.3) was not to be expected and cannot be explained with the information available from this experiment.

Percent Protein Digestibility

The protein digestibilities(Table 6) in the whey treatments were similar to one another, ranging between 71.70 and 72.79, and these were also similar to all the other treatments with the exception of treatment 1. These results agree with those of Anderson (1975) who found that whey treatment failed to change the digestibility of protein in the total ration, and that when whey solids made up approximately 29 percent of the ration the protein digestibility of the total ration of whey and alfalfa hay was 72.3 to 74.0

percent.

The increased protein digestibility($P<0.05$) shown in treatment 1 over the two 25 percent D.M. WLPS treatments may have been due to the high level of readily digestible soybean protein in the diet and not to something attributable to the whey.

As concluded by Wohlt et al. (1976a) apparent digestion of various dietary fractions, especially protein, can be misleading when there are, depending on protein source, differential amounts of protein degradation and microbial production in the rumen.

Percent Dry Matter Digestibility

Whey powder is very soluble and is rapidly degraded in the rumen. Anderson (1975) reported a whey D.M. digestibility calculated by difference, of approximately 87 percent when whey solids constituted 29 percent of the D.M. of the ration. This would explain the 12 to 15 percent and 8 to 10 percent increase in total D.M. digestibility over the SBM control when whey D.M. comprised 33 percent and 18 percent respectively of the D.M. of the diet.

Urine And Feces

The higher fluid intakes on the whey supplemented diets may have been partly a result of the salt content of the whey. The lambs on the 6 percent WLPS diets consumed

more liquid but only one-half to two-thirds of the actual whey D.M. consumed by the lambs on the 25 percent WLPS diets. Thus, the increased salt consumption does not itself govern the level of fluid intake at these levels of whey consumption. Diets with high protein solubility have been shown to increase fluid intake but here again this explanation does not fully explain the increase in fluid intake in this case since protein solubility on the 25 percent D.M. WLPS diets was higher but the fluid intake lower. A combination of the two factors in the whey supplemented diets may have been the factors which caused an increase in fluid consumption, and thus a tendency towards increased urine volume.

SUMMARY AND CONCLUSIONS

1. These studies have indicated that a diet of approximately 9.0 percent protein, when supplemented with 2 percent urea, resulted in lower A.D.G. and N retention than the same ration supplemented with urea incorporated into liquid protein supplements based on whey or fababean starch.

2. A diet containing 2 percent urea may or may not affect D.M. consumption of lambs as compared to a pelleted SBM control diet. Feed consumption was reduced by 15 percent for lambs on the urea control diet in the feeding trial, but no reduction was noted for lambs on the urea control diet in the N-balance trial. This could be due either to a slightly higher level of urea in the feeding trial or to decreased D.M. consumption in the N-balance trial. A combination of the two factors was probably responsible, since every increase in urea concentration in the area of 2 percent would tend to render the ration less palatable. Since average D.M. consumption of all diets on the N-balance trial was only 85 percent of that on the feeding trial, the lambs on the SBM supplemented diets would tend to decrease consumption while the lambs on the urea supplemented diets may or may not decrease consumption to the same extent. Consumption by lambs on the urea control were lower on the feeding trial, and on the

N-balance trial showed a much lower percentage decrease in consumption compared to lambs on the SBM control diet.

3. As indicated by D.M. consumption, urea, when fed in either liquid whey or liquid fababean starch tends to be equally as palatable as a diet supplemented with SBM. In addition, these studies showed that where urea is incorporated into a liquid protein supplement with whey or fababean starch, it is utilized by the ruminant animal with an efficiency equal to the SBM supplemented diets at these levels of urea supplementation.

4. When whey liquid protein supplement and water are fed free choice to growing-finishing lambs, total liquid consumption and urine volume tend to increase, with the extent of increase not necessarily having any direct relationship to the actual amount of whey D.M. consumed. At the higher levels of urea incorporation the supplement was rendered less palatable in comparison to the lower levels in both the 25 percent D.M. and 6 percent D.M. WLPS.

5. When whey and water are fed free choice to lambs, liquid whey containing 6 percent D.M. can be expected to comprise 70 to 85 percent of the total liquid consumed,and liquid whey containing 25 percent D.M. can be expected to comprise approximately 40 percent of the total liquid consumed.

6. The N-balance data for treatment 3 - supplemented with a high level of FSLPS - suggesting an increase in efficiency of feed utilization was not reflected by results of the feeding trial. Regardless, sufficient important and independent parameters in the N-balance study suggest changes in metabolism to warrant further study.

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Table 1A. Amounts and urea concentrations of WLPS offered and consumed in feeding trial.

Feeding period	Trt.	Whey mix offered kg	Urea added g	Ave. daily cons. kg/lamb	No. lambs
July					
8 - 15	5	18.18	386	0.73	10
	6	36.36	384	2.55	10
	7	18.18	258	1.33	10
	8	45.46	258	3.40	10
16-22	5	13.64	540	0.40	10
	6	36.36	408	1.95	10
	7	18.18	264	1.73	10
	8	45.46	242	4.25	10
23-29	5	4.55	675	0.12	10
	6	27.27	393	1.87	10
	7	27.27	279	2.35	10
	8	54.55	240	5.20	10
30-Aug5	5	4.55	300	0.09	10
	6	27.27	473	1.08	10
	7	27.27	228	2.70	9
	8	63.64	255	5.52	10
6-14	5	4.55	382	0.05	10
	6	9.09	302	0.24	7
	7	36.36	208	3.68	8
	8	40.91	170	5.99	6
15-21	5	4.55	250	0.05	6
	6	4.55	350	0.00	5
	7	13.64	53	3.41	2
	8	34.09	143	5.76	4
22-28	5	4.55	160	0.35	4
	6	4.55	139	0.13	4
	7	-	-	-	0
	8	22.73	96	5.84	3
28-Sept4	5	4.55	153	0.46	3
	6	4.55	91	0.39	3
	7	-	-	-	0
	8	14.55	63	6.21	2

Table 2A. Average dry matter and nitrogen consumption on control treatments and treatments supplemented with FSLPS. Experiment II

Trt.	Rep.	Total feed D.M. g	Total FSLPS D.M. g *	N from feed g	N from supp. g
1	1	1466		37.74	
	2	1652		42.53	
	3	1405		36.17	
	4	999		25.71	
	5	1102		28.38	
	6	1009		25.97	
	7	1082		27.84	
2	1	1420		33.73	
	2	1288		30.60	
	3	1224		29.08	
	4	1264		30.04	
	5	1042		24.76	
	6	1113		26.44	
	7	1365		32.43	
3	1	--	--	--	--
	2	1206	68	17.36	13.48
	3	1743	98	26.14	18.44
	4	1637	92	24.55	17.31
	5	1349	76	20.23	14.27
	6	1083	61	16.24	11.46
	7	1088	62	16.32	11.52
4	1	1459	50	27.28	8.40
	2	1505	51	28.14	8.64
	3	1309	45	24.47	7.53
	4	1097	37	20.51	6.29
	5	1843	63	34.46	10.59
	6	834	28	15.59	4.79
	7	1285	44	24.02	7.39

*includes urea D.M.

Table 3A. D.M. and nitrogen from feed and supplement in treatments supplemented with WLPS. Experiment II

Trt.	Rep.	Feed D.M. g	Supp.* D.M. g	N from feed g	N from supp. g
5	1	956	622	14.30	21.76
	2	525	637	7.86	21.92
	3	726	583	10.86	20.16
	4	1203	299	18.00	11.04
	5	888	497	13.28	17.28
	6	926	496	13.85	17.12
	7	941	241	14.08	9.12
6	1	1321	285	19.75	16.00
	2	1251	411	18.71	22.40
	3	1229	341	18.38	19.20
	4	1040	339	15.55	18.88
	5	1183	273	17.70	15.36
	6	1514	267	22.64	16.16
	7	1410	209	21.10	11.52
7	1	756	432	14.20	12.48
	2	1230	268	23.11	8.00
	3	1208	553	22.70	15.84
	4	811	823	15.25	23.52
	5	950	407	17.86	11.84
	6	879	468	16.51	13.60
	7	714	253	13.41	7.68
8	1	1237	343	23.25	14.40
	2	--	--	--	--
	3	1342	239	25.22	9.76
	4	1268	247	23.81	10.56
	5	1074	291	20.17	12.32
	6	1069	380	20.09	15.84
	7	1296	267	24.34	11.36

*Includes urea - assumed urea remains evenly distributed through supplement regardless of % consumption.

Table4A . Nitrogen consumption, excretion and retention. Experiment 2.

Trt.	Rep.	N cons. g	N in feces g	N in urine g	% N ret. (of N dig)	% N ret. (of N cons)
1	1	37.74	7.36	10.88	63.87	50.95
	2	42.53	10.77	21.65	31.83	23.77
	3	36.17	8.24	8.74	68.71	53.06
	4	25.71	5.32	6.95	65.92	52.28
	5	28.38	5.31	7.96	65.50	53.24
	6	25.97	6.45	13.43	31.20	23.45
	7	27.84	6.11	11.82	45.61	35.60
2	1	33.73	10.31	13.51	42.31	29.38
	2	30.60	8.46	16.80	24.12	17.45
	3	29.08	7.67	15.63	26.99	19.88
	4	30.04	7.42	14.23	37.08	27.93
	5	24.76	5.97	12.10	35.60	27.02
	6	26.44	6.41	15.46	22.82	17.28
	7	32.43	7.06	19.20	24.32	19.03
3	1	-	-	-	-	-
	2	30.84	7.17	10.86	54.12	41.54
	3	44.58	12.14	13.48	58.45	42.53
	4	41.86	10.27	11.16	64.67	48.81
	5	34.50	9.13	9.79	61.41	45.16
	6	27.70	7.22	9.94	51.47	38.05
	7	27.84	6.33	6.05	71.87	55.53
4	1	35.68	8.12	11.89	56.86	43.92
	2	36.78	11.16	9.23	63.97	44.56
	3	32.00	8.77	11.95	48.56	35.25
	4	26.80	5.15	8.62	60.19	48.62
	5	45.05	9.36	17.78	50.18	39.76
	6	20.38	4.97	8.33	45.94	34.74
	7	31.41	8.12	11.34	51.31	38.05
5	1	36.06	9.10	11.70	56.60	42.32
	2	29.78	6.66	9.53	58.78	45.63
	3	31.02	9.22	11.52	47.16	33.17
	4	29.04	8.26	8.73	57.99	41.49
	5	30.56	8.44	17.13	22.56	16.33
	6	30.97	8.66	16.06	28.01	20.18
	7	23.20	6.72	9.81	40.47	28.75

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Table 4A. Nitrogen consumption, excretion and retention. Experiment 2.

Trt.	Rep.	N cons. g	N in feces g	N in urine g	% N ret. (of N dig)	% N ret. (of N cons)
6	1	35.75	10.08	8.56	62.29	47.86
	2	41.11	9.73	17.11	45.48	34.71
	3	37.58	9.98	12.41	55.04	40.42
	4	34.43	8.13	7.84	70.19	53.62
	5	33.06	8.65	14.76	39.53	29.22
	6	38.80	10.56	11.33	59.88	43.58
	7	32.62	11.43	4.77	77.49	50.34
7	1	26.68	8.75	9.68	46.01	30.92
	2	31.11	8.81	9.52	57.31	41.05
	3	38.54	12.75	14.13	45.21	30.25
	4	38.77	7.77	10.86	64.97	51.97
	5	29.70	7.30	12.70	43.30	32.66
	6	30.11	7.58	10.13	55.04	41.18
	7	21.09	7.19	7.34	47.19	31.10
8	1	37.65	10.05	13.20	52.17	38.22
	2	-	-	-	-	-
	3	34.98	10.65	6.69	72.50	50.43
	4	34.37	8.59	13.98	45.77	34.33
	5	32.49	8.55	12.65	47.16	34.75
	6	35.93	9.76	9.01	65.57	47.79
	7	35.70	9.86	7.46	71.13	51.51

Table 5A. Rumen ammonia levels(mg N/L)*

Trt.	Rep.	NH_3	Trt.	Rep.	NH_3
1	1	112.87	5	1	53.11
	2	86.22		2	74.44
	3	113.11		3	52.22
	4	152.16		4	156.85
	5	135.62		5	132.22
	6	76.28		6	127.50
	7	153.50		7	96.85
2	1	211.25	6	1	92.25
	2	142.87		2	64.00
	3	67.11		3	103.75
	4	178.00		4	75.42
	5	239.22		5	100.00
	6	112.62		6	102.50
	7	129.60		7	115.57
3	1	-	7	1	116.37
	2	70.33		2	104.87
	3	161.11		3	95.50
	4	30.57		4	148.12
	5	98.87		5	174.85
	6	94.00		6	119.85
	7	67.25		7	124.50
4	1	70.88	8	1	125.11
	2	170.77		2	-
	3	148.50		3	151.00
	4	208.28		4	126.71
	5	109.33		5	112.85
	6	146.62		6	142.00
	7	127.00		7	99.42

*Each value is the mean of 9 samples.

Table 6A . Blood ammonia and urea levels.*

Trt.	Rep.	NH_3 mg N/L	Urea mg/100ml	Trt.	Rep.	NH_3 mg N/L	Urea mg/100ml
1	1	6.39	27.06	5	1	5.31	22.22
	2	4.10	34.06		2	4.26	19.00
	3	6.00	22.83		3	6.47	14.67
	4	9.41	21.21		4	9.97	17.58
	5	4.59	23.94		5	5.64	21.28
	6	9.09	22.31		6	10.60	17.38
	7	10.89	27.69		7	11.07	18.43
2	1	4.97	32.67	6	1	6.13	13.94
	2	4.63	28.72		2	4.01	22.00
	3	7.81	18.56		3	6.10	18.56
	4	10.16	24.29		4	10.47	19.17
	5	4.83	24.50		5	6.31	16.22
	6	10.45	23.69		6	9.40	22.38
	7	9.70	29.00		7	10.39	21.13
3	1	-	-	7	1	6.69	23.56
	2	4.41	18.17		2	4.68	22.94
	3	6.19	17.17		3	7.34	24.83
	4	12.41	14.36		4	11.56	20.93
	5	5.17	21.11		5	5.14	25.06
	6	11.10	19.50		6	11.46	21.81
	7	12.89	16.56		7	10.43	21.19
4	1	5.52	19.06	8	1	5.51	27.78
	2	4.09	24.89		2	-	-
	3	5.63	22.44		3	6.98	21.78
	4	10.56	22.00		4	10.97	20.08
	5	5.53	25.44		5	6.03	23.78
	6	10.19	22.14		6	11.89	27.06
	7	9.94	19.43		7	11.05	23.75

* Each value is the mean of 9 samples.

Table 7A . Rumen volatile fatty acid concentrations *

Trt.	Rep.	Total VFA mmole/100ml	Acetic %	Prop. %	I-But. %	Butyric %	I-Val. %	Valeric %
1	1	6.802	61.60	17.35	1.04	18.09	1.09	0.84
	2	6.589	68.44	20.33	0.64	9.86	0.40	0.32
	3	6.195	67.74	16.13	0.52	14.68	0.37	0.48
	4	8.724	63.42	20.99	1.22	12.50	1.25	0.67
	5	8.971	67.89	14.05	0.55	15.94	0.62	0.96
	6	5.029	65.61	16.30	1.40	14.71	0.70	1.25
	7	8.413	67.42	12.37	1.63	17.00	0.84	0.77
2	1	6.549	68.55	12.82	0.94	16.18	0.76	0.73
	2	8.460	57.57	33.33	0.59	6.74	0.37	1.41
	3	-	-	-	-	-	-	-
	4	9.480	65.30	16.14	0.61	16.56	0.55	0.84
	5	8.569	65.23	18.90	1.08	13.42	0.54	0.83
	6	7.377	65.85	17.62	1.46	13.82	0.57	0.63
	7	8.228	67.31	12.88	0.97	17.74	0.36	0.71
3	1	-	-	-	-	-	-	-
	2	6.818	50.00	33.72	0.63	10.56	0.80	4.26
	3	-	-	-	-	-	-	-
	4	9.294	47.15	45.32	0.66	3.55	0.62	2.75
	5	7.573	54.82	18.36	0.89	22.19	0.75	3.03
	6	6.896	47.97	36.67	1.15	8.99	0.72	4.45
	7	5.822	52.06	29.90	1.28	13.57	0.64	2.59
4	1	6.325	63.98	16.27	0.78	17.06	0.47	1.37
	2	7.807	59.54	19.85	1.34	17.29	0.38	1.57
	3	7.378	63.55	10.43	1.18	23.17	0.88	0.76
	4	9.646	49.74	31.71	0.93	15.86	0.50	1.22
	5	7.070	64.50	17.54	1.20	14.85	0.73	1.18
	6	7.191	59.53	23.78	1.58	11.40	2.70	1.01
	7	7.757	60.05	22.68	1.60	13.40	0.74	1.48

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Table 7A . Rumen volatile fatty acid concentrations *

Trt.	Rep.	Total VFA mmole/100ml	Acetic %	Prop. %	I-But. %	Butyric %	I-Val. %	Valeric %
5	1	6.860	55.83	26.38	0.86	11.08	0.95	4.94
	2	6.951	52.37	26.91	0.88	16.69	0.57	2.60
	3	5.702	58.42	18.60	1.95	18.60	0.42	2.06
	4	3.030	62.05	17.82	1.37	13.20	2.91	2.64
	5	7.514	67.64	8.79	1.70	20.24	0.74	0.94
	6	6.749	66.96	12.15	1.02	17.93	0.68	1.25
	7	5.670	66.49	17.11	1.51	13.05	0.64	1.20
6	1	8.761	55.25	18.95	0.95	21.46	0.53	2.86
	2	7.591	65.48	16.47	0.98	15.68	0.62	0.79
	3	-	-	-	-	-	-	-
	4	7.541	46.02	35.68	0.57	13.79	0.72	3.23
	5	8.351	53.77	27.55	1.39	15.09	0.44	1.77
	6	8.528	54.98	18.17	1.25	23.21	0.52	1.84
	7	7.738	59.56	14.21	1.09	23.51	0.47	1.14
7	1	6.042	56.13	21.52	1.06	18.71	0.82	1.79
	2	6.544	61.01	22.94	0.87	13.30	0.78	1.17
	3	6.660	62.46	14.86	0.80	19.67	0.65	1.55
	4	8.830	59.57	24.80	0.59	13.25	0.91	0.88
	5	9.187	63.22	17.95	1.03	16.21	0.54	1.02
	6	7.563	65.61	17.72	1.31	13.76	0.53	1.11
	7	-	-	-	-	-	-	-
8	1	7.973	65.25	12.92	0.88	19.57	0.47	0.95
	2	-	-	-	-	-	-	-
	3	8.229	66.10	11.91	1.05	19.68	0.45	0.80
	4	7.604	67.37	18.29	0.69	12.24	0.82	0.65
	5	6.556	59.15	27.74	1.34	9.76	0.62	1.34
	6	6.859	60.93	16.33	1.07	20.12	0.52	1.02
	7	6.865	63.76	22.42	0.85	11.21	0.87	0.83

* Each value is the mean of 5 samples.

Table 8A. Average daily urine and feces. Experiment II

Trt.	Rep.	Urine ml	Feces g D.M.	Trt.	Rep.	Urine ml	Feces g D.M.
1	1	818	714	5	1	1112	431
	2	1425	703		2	1355	256
	3	528	729		3	1675	406
	4	496	469		4	1025	605
	5	514	505		5	2146	487
	6	940	576		6	1336	530
	7	534	492		7	1280	468
2	1	492	818	6	1	464	617
	2	1323	594		2	2607	617
	3	2580	562		3	1198	549
	4	1412	642		4	1795	526
	5	376	507		5	1484	599
	6	663	578		6	1440	708
	7	862	570		7	420	696
3	1	--	--	7	1	1230	400
	2	968	526		2	1088	563
	3	2096	767		3	2248	716
	4	805	741		4	2542	423
	5	568	705		5	826	455
	6	1660	572		6	1066	432
	7	232	528		7	1000	473
4	1	742	569	8	1	1534	581
	2	1000	755		2	--	--
	3	670	646		3	328	688
	4	642	417		4	1408	644
	5	1536	787		5	3162	524
	6	228	447		6	2364	576
	7	1490	561		7	736	614

Table 9A. Average daily whey and water consumption*. Experiment II

Trt.	Rep.	Water kg	Trt.	Rep.	Water kg	Whey kg
1	1	5.73	5	1	3.64	2.85
	2	5.48		2	2.41	2.90
	3	5.48		3	3.21	2.67
	4	4.02		4	4.42	1.55
	5	4.18		5	4.22	2.30
	6	4.42		6	3.66	2.30
	7	4.02		7	3.85	1.32
2	1	3.96	6	1	0.58	4.85
	2	4.33		2	1.50	6.61
	3	5.98		3	0.59	5.74
	4	5.33		4	3.56	5.71
	5	3.46		5	1.21	4.63
	6	3.55		6	2.33	4.85
	7	3.85		7	1.67	3.41
3	1	--	7	1	3.37	1.99
	2	4.11		2	4.68	1.37
	3	6.87		3	5.06	2.46
	4	5.47		4	5.49	3.60
	5	4.12		5	3.40	1.90
	6	4.80		6	3.26	2.13
	7	3.50		7	2.88	1.30
4	1	4.31	8	1	0.54	5.79
	2	5.66		2	--	--
	3	4.36		3	1.70	3.90
	4	4.90		4	1.90	4.22
	5	6.99		5	3.35	4.91
	6	3.08		6	1.63	6.28
	7	5.38		7	1.06	4.58

*Average room temperature 26°C.

Table 10A Actual volume of FSLPS added to feed by actual measurement

ml supp. measured	ml supp. on feed	ml supp. remaining on measuring device
180	173	7
225	217	8
300	289	11
375	362	13
450	434	16

Ave. wt. fababean liquid supplement 1 ml - 1.1144 gm

Ave. % D.M. fababean liquid supplement - 29.35

Ave. % prot. fababean liquid supplement - 36.67

Table 11A Effect of percent of consumption* of WLPS on percent DM in rejected WLPS. Experiment II

25% D.M. as Fed		6% D.M. as Fed	
% Rejected	% D.M. in reject	% Rejected	% D.M. in reject
10	30.0	1.5	13.0
15	29.5	2.5	10.0
20	29.0	5	10.0
25	28.5	10	9.0
30	28.0	15	8.5
35	27.0	20	7.5
40	26.5	25	7.3
45	26.0	30	7.3
50	26.0	35	7.0
|		40	6.8
70	26.0	45	6.5
|		50	6.5
100	23.7	|	
		85	6.5
		90	6.3
		100	6.3

*As measured by weight.

Table 12A. Randomization of lambs on treatments. Experiment II.

	Lambs #							
	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16
Period	Treatment #							
1	1	2	3	4	5	6	7	8
2	7	1	4	6	2	5	8	3
3	8	7	5	2	6	3	4	1
4	5	4	1	7	3	8	6	2

Table 13A. The following is the analysis of variance table used to analyse response criteria in Experiment II.

	df
Total	55
Treatment	7
Between lambs within treatments	48