THE USE OF DEHYDRATED GRASS IN RATIONS

FOR EARLY WEANED LAMBS AND SOME PHYSIOLOGICAL

EFFECTS OF A RAPID RATION CHANGEOVER.

by

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ABSTRACT

A study was conducted to evaluate dehydrated grass pellets (Orchard grass — Ladino clover) as a feed for early-weaned lambs. Three groups of 8 Polled-Dorset lambs were weaned at 8 weeks of age and were fed either a) the dehydrated grass, b) a 50-50 mixture of the grass and protein-supplemented barley or c) a protein-supplemented barley ration. All rations were pelleted. Digestibility trials were also conducted and the effect of level of feed intake on nutrient digestibility investigated.

The dehydrated grass resulted in rates of gain comparable to those produced by the pelleted barley ration. Feed conversion efficiency was lowest for the grass and highest for the barley ration. An interaction between the dehydrated grass and barley was observed in nutrient digestibility. Increasing the level of feed intake from approximately maintenance to appetite tended to result in slight depressions in the digestibility of energy and protein of all rations.

It may be concluded from this experiment that dehydrated grass can be used successfully for intensive feeding of early weaned lambs and little nutritional advantage appears to be gained from combining dehydrated grass with barley.

A second study was undertaken to measure the changes occuring in five parameters when the ration of lambs was rapidly changed from all-roughage to all-concentrate. The five parameters were blood plasma glucose, rumen lactate concentration, rumen ammonia level, rumen protozoa population and rumen pH.

The main effect of the change over from roughage to concentrate was the accumulation of lactic acid in the rumen. This accumulation resulted in a lowered

rumen pH and a decrease in protozoa numbers. During the change over an initial increase in rumen ammonia level was followed by a decline in this parameter. It is postulated that this may have been due to the increased nitrogen intake and a subsequent adjustment in the rumen microbe population leading to increased ammonia utilization. An increase in plasma glucose level was observed which was probably due to one of two factors, either the availability of lactate as a carbohydrate source in the rumen or to glucose formed by hydrolysis of starch in the intestine.

From the latter part of the study it may be concluded that when ruminant rations are changed from high roughage to high concentrate the change should be slow enough to prevent a large accumulation of lactic acid. This would mean a period of 3 to 4 weeks under normal circumstances.

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INTRODUCTION

The storage and handling of forage crops has always been a problem for livestock producers. The development of the hay baler, which reduced the bulk density of loose hay, helped to some degree. However, hay bales require a lot of storage space and the handling and feeding is difficult to automate. For these reasons high density forage cubes and pellets have been developed. These products require less storage space and lend themselves well to automated handling and feeding.

Another problem in forage production has been the dependence on weather conditions during harvest. Many million tons of forage are wasted annually due to rain during the field curing process. Experimental work began as early as 1905 (Oehring 1973) on the artificial drying of forages. Today a wide range of crops are artificially dried in drying drums heated with petroleum products.

In the Fraser Valley region of B.C. several dehydration plants produce dried grass pellets. The majority of this product has been used in swine and poultry rations. In Europe there has been an increased interest in feeding dried grass to ruminants. However, very little information is available on the feeding value of dried grass for early. weanedd lambs. Therefore, a study was undertaken to compare the feeding. value of the following rations (1) dried grass, (2) 50% dried grass, 50% barley, plus a protein mineral supplement, (3) barley plus a protein mineral supplement.

When the lambs on the above rations were slaughtered rumen fluid pH's were measured. It was noted that the pH of the rumen fluid of the lambs on the straight dried grass ration was one full pH point higher than that of those on the other two rations. After studying the literature it was decided to undertake a second trial to study the effects of switching a

lamb's ration from straight roughage to straight concentrate. Five parameters were measured during this changeover. The parameters were blood plasma glucose, rumen fluid pH, rumen protozoa population, rumen ammonia concentration and rumen lactic acid levels.

LITERATURE REVIEW

a:– DRIED GRASS FEEDING

Connell (1971) stated that technically the artificial drying of grass is a most efficient route to conserving the high nutritive value of the fresh crop. Patrick (1967) noted that dried green crops can yield 50% more energy and 300% more protein per acre than a two ton crop of barley. Hee further stated that dehydration results in higher yields than other conservation processes because of the low nutrient losses that occur. Christensen (1967) stated that with efficient operation these losses will not exceed 3%, even when losses occuring before the crop enters the dryer are considered. This figure compares very favourably with losses, frequently over 30% of the feeding value, encountered in hay or silage. (Tarrup Unidry 1973).

Smith and Moeller (1973) stated that the trend toward mechanized feeding systems is creating a demand for "roughage" products in a form which can be stored in bulk and can be handled through conventional conveying equipment. Pelleted dehydrated forages would meet these requirements. Therefore, it would appear that from the point of view of quality of feed and ease of handling pelleted dehydrated forages have merit.

From a nutritional point of view dehydrated grass is quite valuable. Forage Drying (Shellstar 1973) listed the average analysis of dehydrated grass as follows:

Crude Protein	—	13-22%
Dry Matter Digestibility	—	62-68%

Similar figures were given by Connell (1971). He stated that the average dry matter digestibility of dehydrated grass was 65% with the range being 60 to 70%.

Dried green crops are rather poor sources of some major and trace minerals and this must always be considered when including dried crops in rations. (Forage Drying - Shellstar 1973)

THE ROLE OF DEHYDRATED FORAGES IN RUMINANT RATIONS

Having outlined that dehydrated grass is a desirable feed for ruminants the next step is to determine how it "fits" into the ration. Raymond (1967) stated that insisting a feed stuff such as dried grass be a complete feed may be impractical. He suggested that perhaps a better use would be to supply certain nutrients to a mixed ration. Raymond (1968) further stated that all livestock enterprises in Britain have access to "fibrous feeds", such as hay, silage or straw. These can provide the basic "fibre" in the rations, dried grass is then used as a partial or complete substitute for the concentrate part of the ration. As well as high digestibility (energy), dried grass can have a high protein content and so can balance the low protein content in "fibrous feeds". It has been claimed that providing the physical form is acceptable, all classes of stock will eat dehydrated grass, high intakes can be achieved with productive animals. Recent research has shown that dried grass may have a higher feeding value than analysis of crude protein and digestibility would suggest. (Forage Drying - Shellstar 1973)

Tayler (1969) stated that the major requirements of dried grass are high digestibility, adequate protein content and a modulus of fineness close to 1. (Appendix 1)

He also felt that a proportion of long forage or roughage was desirable as a means of maintaining good health in animals fed processed dried grass. He stated further that economic considerations indicate that

dried forage should be regarded as a concentrate supplement to grazed or ensiled feeds, which supply nutrients at lower unit costs, rather than as the sole feed. Oehring (1973) suggested that the greatest opportunities for expanding the market for dried green crops was likely to be in direct feeding of ruminants rather than in the production of compound feeds. Blaxter (1973) stated that in assessing the economic worth of dried forages energy value will prove a more important criterion than crude-protein or carotenoid content.

THE USE OF DEHYDRATED FORAGES IN DAIRY CATTLE RATIONS

Connell (1971) reported that 2.27 kg (5 lbs) of dried grass cubes (milled) effectively replaced 1.83 kg (4 lbs) of balanced dairy cubes, as a supplement to hay, during the first twenty weeks of the lactation of Holstein — Friesian cows. He further reported production levels of 32 kg (70 lbs) per day from dairy cattle fed solely on dried grass. Forage Drying (Shellstar 1973) stated that as a concentrate replacer, dried forage can be fed to dairy cattle as a production ration to support milk production up to 23 kg per day. They suggested rates of 2.27 kg of 16% crude protein and 65% digestibility dried grass or 2.04 kg of 20% crude protein and 70% digestibility dried grass per 4.54 kg of milk.

Tayler and Aston (1973) found, that as a supplement fed with grass silage, straight dehydrated grass was equal to a grass-barley mixture or a barley-protein mixture. Khalifa et al (1970) found no difference in production of cows fed three combinations of pelleted dried grass and barley concentrate. The three combinations were 75:25, 50:50 and 25:75.

Gordon and McIlmoyle (1973) reported a replacement value of 1.08:1 for dried grass and concentrates as supplements to silage. In trials where dried grass and grain were compared as a supplement to grass silage they found that dried grass increased silage intake over the intake when grain was fed. Therefore, even though a grass-concentrate pellet was of lower

digestible energy concentration than a straight concentrate pellet the increased silage intake allowed for similar production. In further work Gordon and McIlmoyle (1973) showed that diets of dried grass wafers with low amounts of straw and a mineral supplement were capable of sustaining milk production of about 25 kg per day.

Ostergaard and Neimann-Sorensen (1973) have shown that dried grass can substitute for traditional roughage and for concentrate without any marked changes in milk production.

Waldern (1973) reported that high levels of dehydrated grass (56% of total DM intake), of the quality used (21.2% crude protein), can replace corn silage and grass hay in the diets of lactating cows and satisfactorily maintain high levels (23 to 25 kg FCM) of milk production without altering milk composition.

Body weight changes were recorded in several of the above mentioned trials. It does not appear that these levels of production are accompanied by weight loss when dry grass is fed.

THE USE OF DEHYDRATED FORAGES IN BEEF CATTLE RATIONS

Londsdale et al (1971) compared straight grass wafers with wafers plus 50% rolled barley. They found dry matter intake and live weight gains to be similar on all diets. However, carcass weight gain was significantly higher for animals given wafers containing barley.

It is stated in Forage Drying (Shellstar 1973) that for young calves (dairy or beef) dried forage may be fed free choice. Compared with normal hay and concentrate rations, there appears to be considerable benefit in health and appearance of calves.

For fattening cattle Forage Drying (Shellstar 1973) recommends a 2:3 ratio of high quality dried forage: mineralized rolled cereal, fed in conjunction with a basic roughage.

Tayler (1973) reported that cattle fed pellets of dried grass as a supplement with basal grass (silage in winter and pasture in summer) did as well as cattle fed a barley supplement over an eighteen month feeding period.

However, Coleou (1973) reported that exclusive use of dried grasses, fed alone or in combination with legumes, seldom gives either adequate daily gain or a sufficiently finished animal unless the slaughtering age is postponed.

THE USE OF DEHYDRATED FORAGES IN SHEEP RATIONS

Although little information is available regarding the feeding of dehydrated grass to lambs for fattening Forage Drying (Shellstar 1973) states that dried grass can be fed to in-lamb ewes with quite satisfactory results. They recommend feeding up to 1.35 kg per head per day with up to .68 kg of rolled oats.

THE EFFECTS OF PROCESSING ON THE NUTRITIVE VALUE OF DEHYDRATED FORAGES

Londsdale et al (1971) found that coarse milling compared to chopping reduced the apparent digestibility of dry matter, organic matter, cellulose and energy. Wilkins et al (1972) found that the digestibility of organic matter and cellulose decreased with a decrease in modulus of fineness (more fine particles) and this was associated with more rapid passage of the finely-milled material through the alimentary tract. Milne and Campling (1972) found only small differences in digestibility of organic matter, retention of nitrogen and loss of energy in the urine between alfalfa cobs and alfalfa pellets. However, the digestibility of crude fibre decreased with decreasing particle size.

Thomson (1971) comparing chopped alfalfa with ground and pelleted alfalfa found that the processing significantly depressed the disappearance of apparent digestible energy prior to the small intestine and significantly increased that occuring in the small intestine.

Wainman et al (1972) showed that grass pellets have a greater nutritive value per unit weight than has long unprocessed material. Except for the poorest quality material, pelleting reduced metabolizable energy of the feed, but it markedly increased the net availability of metabolizable energy for production, and the latter effect was of greater magnitude than the former. The net availability of metabolizable energy for production was 52% for pellets and 40% for long material. Blaxter (1973) reported that pelleting depressed the metabolizable energy of high quality dried forages, but tended to increase that of very low quality ones. Van Es and Van der Honing (1973) stated that the higher fecal energy loss of pelleted forages is only slightly compensated for by smaller energy losses in methane or urine. However, a large compensation results from the better utilization of the metabolizable energy of pelleted rations. They conclude that the net energy content of ground and pelleted forage is approximately equal to the net energy content of the original material.

Wilkins (1973) explained the more efficient use of energy in ground roughages compared to long roughages by the following:— reduced expenditure of energy in eating and ruminating, reduced loss of methane and less heat production in the rumen and alteration in the products of rumen fermentation (i.e. acetate levels lower when ground forages fed). The overall effect of the two phenomena (reduced digestibility and increased efficiency) varies among roughages.

Tayler (1969) found that milling of dried grass increased liveweight gains over the same grass fed in a long form. This increased gain was associated with increases in voluntary intake of processed grass.

Wallenius et al (1966) disagreed with many of the above authors. They felt that the reduced cellulose digestibility of finely ground pelleted dehydrated alfalfa made it an undesirable feed for ruminants. They reported cellulose digestibility values of 52.6% in one experiment and 37.2% in another when ground pelleted dehydrated alfalfa was fed. This was compared with 70.5% cellulose digestibility when long alfalfa hay was fed.

THE EFFECT OF DRYING PROCESS ON NUTRITIVE VALUE OF GRASS

Thomson (1971) found that when fresh and dried grass were compared the overall digestion of energy did not differ but the site of digestion was different. When dried grass was fed less of the apparently digested energy disappeared prior to the duodenum and significantly more in the passage through the small intestine. He also found that although overall nitrogen digestibilities did not differ the amount of nitrogen entering the small intestine was markedly higher in the dried compared to the wet grass.

Ekern et al (1965) reported that the metabolizable energy of fresh grass was 4% greater than that of the same grass dried (60.92 kcal/100 kcal ingested vs 58.22 kcal/100 kcal ingested). However, the heat production from the metabolizable energy of fresh grass was on average 16% greater than that of the same grass when artificially dried. The overall result was that the energy retention observed when dried grass was given was greater than when grass was given in the fresh state.

These authors also reported a greater nitrogen absorption when fresh grass was fed. They felt the low absorption of nitrogen from dried grass was probably related to denaturation of the grass protein by heat and to lowered absorption of nitrogen as ammonia. Sheep given fresh grass excreted 15% less nitrogen in the feces and 11% more in the urine than those given dried grass. No differences occured in nitrogen retention.

Ekern et al (1965) stated that their experiments provided evidence that the bacterial and digestive processes in ruminants given fresh grass and dried grass differ. The energy of fresh herbage was digested better than that of the dried, and more nitrogen was apparently absorbed, to be excreted in the urine. These and other observations indicated a more active and rapid fermentation process in the sheep given fresh grass.

Blaxter (1973) reported that several experiments have shown that dehydration increases the nutritive value of a crop slightly. Both apparent digestibility and metabolizable energy are depressed by drying the crop, but the efficiency with which the metabolizable energy of the dried crop is used is enhanced, the animals producing slightly less heat when fed the dried rather than fresh material. The net effect is a very small 3-4% increase in the value of the material as an energy source to the animal.

THE EFFECT OF TEMPERATURE OF DRYING ON NUTRITIVE VALUE OF GRASS

Jarrige et al (1973) reported that high temperature dehydration resulted in a slight decrease in apparent digestibility of organic matter and a 5-10 unit decrease in crude protein digestibility. (inlet temperature 700-900°C outlet temperature 90-115°C) Israelsen (1973) reported that excessive drying may reduce the net protein utilization to nearly zero.

THE EFFECT OF PHYSICAL FORM OF DRIED FORAGE ON ITS UTILIZATION

Raymond (1968) stated that present evidence suggests that the optimum package for utilization by ruminants may be a fairly large pellet, produced directly from unmilled dried grass, but containing a portion of small particles.

Tayler and Aston (1973) reported that when dried grass was offered to dairy cattle as wafers, cobs or pellets (Appendix 2) with grass silage, the cattle receiving pellets ate 6% more silage and produced 19% more milk than those receiving cobs or wafers. These authors concluded that when dried grass is given as a concentrate supplement to silage fed ad libitum the dried grass should be in pellets of low modulus of fineness.

Tayler (1969) found that the intake of dried grass increased as the proportion of fine particles in the feed increased. He also reported that the hardness of pellets was an important consideration. If pellets were too hard (unit density in excess of 1.1g/cc), young cattle ate even less than the same material in chopped form. He also found that if the package was too easily broken and was dusty, the full potential intake was not achieved. He reported that when dried grass was fed ad libitum as a sole feed, and excessive hardness or dustiness were avoided the highest intake by ruminants was obtained when the grass had been ground in a hammer-mill with screens of about 2 to 4 mm.

THE EFFECT OF COMBINING OTHER FEEDS WITH DRIED GRASS

German workers in the late 19th century demonstrated that added starch decreased the digestibility of other nutrients of hay. Armsby (1917) termed this phenomenon "depression of digestibility" since potential digestible matter escaped digestion. This "depression" was particularly manifested by feeds containing large amounts of soluble carbohydrate. He reported that the dry matter digestibility of hay may be reduced by as much as 12%

when these feeds are included in the ration.

Forbes (1933) stated "an individual foodstuff expresses its normal and most characteristic nutritive value, for a given kind of animal, under specified conditions governing nutritive requirements, only as it is a part of a ration which is qualitatively complete and quantitatively sufficient, for conditions existing." He further emphasized that feedstuffs cannot be properly evaluated individually as the net energy values of individual foodstuffs are fundamentally variable when in different combinations in a ration.

Kromann (1973) reported that the associative effects of feeds may be manifested at any one or all levels of metabolism (digestion, absorption and cellular metabolism) and stated: "The interactional effect at the digestive level is well known and this was thought to be the only level of metabolism influenced by interaction of feeds within a ration. The decreased utilization of fibre as influenced by soluble carbohydrates in ruminants is perhaps relatively simple to explain since the micro-organisms use the most readily available carbohydrate as an energy source. These soluble carbohydrates are not available per se to the microorganisms but are hydrolyzed by enzymes secreted by them. Hydrolysis releases the simple sugars which the microorganisms utilize as an energy source. Similarly, there are hydrolytic enzymes in the digestive tract. These enzymes hydrolyze the soluble carbohydrates, proteins and fats to their respective simple units which can then be absorbed. As explained by the Law of Mass Action the less complex substrates are more likely to come in contact with hydrolytic enzymes than the complex substrates. Sucrose would have more reacting material than an equal weight of starch. Thus, more monosaccharide would be hydrolyzed from sucrose than starch per unit time; subsequently absorption as well as metabolism would be influenced."

Londsdale et al (1971) found that the inclusion of 50% barley with chopped or coarsely ground grass increased the overall digestibility of organic matter but reduced the digestibility of cellulose.

Tayler (1969) reported that the inclusion of 50% barley in wafers increased the rate of gain by only 8% compared to a response to milling alone of 5%. In view of the difference in the estimated net energy values of dried grass and barley this indicated a nutritional interaction between the two components of the wafer.

Londsdale et al (1971) stated that the reduction in gut fill, when barley grain was added to a roughage feed, masks any increased rate of gain which may occur in body tissues. Therefore, when doing feeding trials to compare dried grass with barley-dried grass mixtures carcass weight gain should be measured, as differences in gut fill may mask differences in weight gain.

Forbes et al (1967) reported that supplementing grass intake with barley increased total dry matter intake. Greenhalgh (1973) stated that concentrates increased total intake of long grass but reduced total intake when included in pellets.

McCullough (1972) reported that the supplementation of grass silage with dehydrated grass was superior to supplementation with barley. As the metabolizable energy concentration of rolled barley appears to be higher than that of dried grass this author concludes that the apparent higher nutritive value of dried grass in this experiment is probably due to the better associative effect between the silage and dried grass than between the silage and rolled barley. His results suggested that 1.12 kg of dried grass was equivalent to 1.80 kg

of rolled barley as a supplement for silage. This underlines the point made earlier that the feeding value of a feedstuff obtained by feeding it alone to ruminants is of little use in practical nutrition.

THE EFFECT OF FORAGE PROCESSING ON RUMEN pH

Ground roughages lead to lower rumen pH than long roughages. Wilkins (1973) stated that rapid feed consumption coupled with the low level of rumination when ground diets are fed tends to reduce the quantity of saliva secreted. He also noted that rumen VFA levels increase more quickly after feeding when ground roughage is fed, due to rapid consumption resulting in larger quantities of feed arriving in the rumen in a short period of time. These two factors combine to yield reduced rumen pH levels when ground roughage is fed.

b:— RATION CHANGEOVER EXPERIMENT

LACTIC ACIDOSIS

Ruminants not accustomed to a grain diet often suffer acute digestive disturbances and in many cases death, within twenty-four hours after consumption of a large quantity of grain (Hungate et al 1952; Gilchrist and Clark 1957; Ahrens 1967; Brawner et al 1969). Rumen atony and loss of appetite are symptoms of this disorder. In many cases reported in the literature these symptoms have been induced by rather unnatural methods (ie. not likely to occur in practical feeding situations). For example, the animals are held without feed for twenty-four hours and are then allowed to engorge themselves with grain (Ahrens 1967) or the carbohydrate source is added directly to the rumen by way of a rumen fistula (Hungate et al 1952). These drastic methods usually cause acute acidosis and death. In commercial animal feeding this very sudden intake of grain is not likely to occur. It may occur accidentally but it is not a major problem.

Lactic acidosis may be a problem during the change from a high roughage to a high concentrate ration as could take place when animals enter a feedlot, if the change was too rapid. The ingestion of excessive amounts of carbohydrate allows for rapid fementation within the rumen. The main product of the fermentation is lactic acid. The normal pH of animals on roughage rations is approximately within the range 6.5 - 7.5 (Gilchrist and Clark 1957; Thomson 1967; Ahrens 1967; Browner 1969). As lactic acid accumulates, the pH drops from these normal levels to 3.5 - 5.0 in severe cases.

Tremere et al (1967) have reported an experiment where concentrates were introduced at two different rates to cattle on a hay ration. They found that in both cases lactic acid levels increased and that the highest level of lactic acid (75 mM/litre) corresponded to the lowest pH.

The results of this increased acidity were as follows:
(1) chemical rumenitis due to the acidity;
(2) a massive flow of fluids into the rumen from the body circulation caused by the increased osmotic pressure;
(3) destruction of the protozoan and bacterial flora of the rumen with the exception of the Streptococci and Lactobacilli which are the organisms carrying out the fermentation of the grain. (Thomson 1967).

The increased lactic acid concentration is due to a sudden bloom of Streptococcus bovis. Hungate et al (1952) reported that the numbers of Streptococcus bovis diminished almost immediately after the maximum of several billion per millilitre was reached and lactobacilli then predominate. Streptococcus bovis readily ferments soluble carbohydrates to lactic acid. Its predominance in the rumen would cause lactic acid to be relatively more abundant than

other products.

Under favourable conditions of pH, lactic acid may be fermented to propionic acid (Phillipson and McAnally 1942; Elsden 1945). However, the build up of lactic acid depresses the pH to such an extent that propionic acid bacteria (for example, Peptostreptococcus elsdenii) cannot grow.

An abundance of lactobacilli in the rumen of animals suffering from acidosis has in some instances been interpreted as implicating lactobacilli in the development of the acidity, but these examinations may have been made after the initial increase of streptococci has taken place (Perry et al 1957). Streptococcus bovis occurs in larger numbers in hayfed ruminants than do the lactobacilli and have an extremely rapid potential growth rate. In most cases these factors permit Streptococcus bovis to outgrow the lactobacilli initially, but Streptococcus bovis is inhibited at the high acidities it causes, whereas the lactobacilli are not. Therefore, the initial increase of Streptococcus bovis which occurs when grain is fed is followed by a great reduction of streptococci and the development of a very abundant population of lactobacilli. Hungate (1966) reported that lactobacilli are quite numerous in animals with chronic high rumen acidity.

The concensus of opinion is that the inclusion of soluble carbohydrate in ruminant rations lowers the rumen pH. This lowered pH is caused by increased levels of lactic acid in the rumen. The degree of this increase appears to be related to the changeover period and the levels of grain which are fed. (Tremere et al 1967). Annison (1959) showed very similar lactic acid accumulations when ruminant diets were changed from hay to lush pasture.

The fate of lactic acid in the rumen appears to be open to some discussion. Jayasuriya and Hungate (1959), using isotopes, demonstrated that

most of the lactate gave rise to acetate in hay fed animals. This implies conversion of lactate to pyruvate and decarboxylation of pyruvate to acetate. Lactic acid is apparently an unimportant intermediate in the rumen fermentation of hay-fed steers and is not a precursor of the propionate formed. If lactate were an essential intermediate in the production of rumen propionate, little propionate would be expected in rumen contents of hay-fed animals. A considerable amount is usually found, arising via pathways in which lactate is not involved.

However, in the grain fed animal lactate becomes an important intermediate and gives rise to propionate. Phillipson (1952) noted that in corn fed lambs the fermentation of starch in the rumen involved two stages. The first stage leading to the formation of lactic acid and the second being a further fermentation of the lactic acid with the production of volatile fatty acids, particularly propionic acid. (Figure 1).

Baldwin et al (1963) reported that when soluble carbohydrates were fed, the main pathway of conversion of lactic acid to propionic acid was the acrylate pathway.

The very low rate of lactate fermentation when hay fed cattle receive soluble carbohydrates indicates a scarcity of lactate fermenters. The result of this scarcity is the accumulation of lactic acid. By the time enough lactate has accumulated to favour lactic acid fermenters, the lactic acid production so exceeds its fermentation that the rumen becomes acid and microfloral growth stops before an adequate population of lactacidioves develope. With a gradual change to grain there is no excess acidity, and a balanced flora adapted to continuous fermentation of the new ration evolves.

The physiological basis for the accumulation of lactate depends on a shift in the position of the rate limiting step in the fermentation from the hydrolysis of a polysaccharide to the dissimilation of a 3-carbon compound. According to information gained by the use of radioactive isotopes, lactate is not involved to any significant extent as an intermediate in the fermentation of roughage rations, (Eusebio et al 1959; Baldwin et al 1963), so that when lactate does accumulate the limiting step is probably the fermentation of a compound which may act as a precursor of lactic acid but is usually converted to other products. In all probability it is the dissimilation of pyruvate which is greatly slowed down. Instead of being converted to volatile fatty acids, pyruvate acts as a hydrogen acceptor in the re-oxidization of the reduced pyridine nucleotide coenzymes generated by the breakdown of carbo-hydrates. (Walker 1968).

A number of factors may be responsible for the slowing of the conversion of pyruvic acid to volatile fatty acids and of these pH may be most important. A fall in pH within the rumen accompanying the fermentation of readily fermented carbohydrate is presumably the result of an increased production of acid materials at a rate which cannot be balanced by absorption through the rumen wall and neutralization by bicarbonate entering the rumen in saliva. Enzymes dissimilating pyruvic acid may be adversely affected by the lower pH and it is known that the rates of production of acetic, propionic and higher acids decline with decreasing pH below 6.0. (Bruno and Moore 1962). In addition, below pH 5.5 bicarbonate would be in the form of carbonic acid, which in turn means the conversion of pyruvate to propionate would be blocked because that pathway requires the fixation of carbon dioxide. The reducing power normally used in the conversion of pyruvate to propionate is then available for the reduction of pyruvate to lactate. Walker (1968) has demonstrated this phenomenon in his work. Hopgood (1965) demon-strated that the rumen cellulolytic bacteria, Ruminococcus flavefaciens produced

OUTLINE OF VOLATILE FATTY ACID FORMATION FROM LACTATE

FIGURE 1

CO_2 H_2

Acetyl-CoA ←   Pyruvate —————→ Oxaloacetate

$2H$

ATP

Acetate

Acetoacetyl-CoA

Lactate $2H$

$2H$ Malate

$2H$

B-Hydroxybutyryl-CoA

H_2O

H_2O

Acrylate   Fumarate

Crotonyl-CoA

H_2O

$2H$

$2H$?ATP

ATP

$2H$

Propionate ————————— Succinate

Butyryl-CoA

ATP

Butyrate

SLATTER AND ESDALE   (1968)

PATHWAYS

HAY FED ANIMALS   LACTATE→PYRUVATE→ACETATE

GRAIN FED ANIMALS   LACTATE→ACRYLATE→PROPIONATE

large quantities of succinic acid when supplied with glucose and bicarbonate, but almost entirely lactic acid if an exogenous source of carbon dioxide was not provided.

RUMEN AMMONIA LEVELS

Another parameter which may be affected by changes in rations is rumen ammonia. Several workers have noted that rumen ammonia levels increase as the nitrogen level in the diet increases. (Annison et al 1959; McIntyre 1970). This can occur when the ration is changed from poor grass hay to grain, or from grass hay to pasture. The general explanation for this is that there is an excess of nitrogen available in the form of protein and non-protein nitrogen which is readily fermented to yield ammonia. Adaptation of the microbial population to the diet causes a return to normal levels.

Reis and Reid (1959), showed that pH affected ammonia production in the rumen. The effect of pH was most probably the result of an effect on the enzymes concerned in deamination of amino acids. The most favourable pH for ammonia accumulation is 6.5 - 7.0. The lowered levels at low pH, in the presence of soluble carbohydrate, is due largely to increased utilization for the synthesis of microbial protein. Therefore, during a change from a poor quality hay to a grain ration there is an initial increase in rumen ammonia levels due to an excess of nitrogen which cannot be utilized. However, as the rumen organisms adapt to the higher nitrogen levels the rumen ammonia levels drop. After the ration has been changed to a grain ration the rumen ammonia levels may decline below the levels in hay fed animals due to the increased synthesis of microbial protein. Annison et al (1954) showed that the amount of ammonia accumulating reduced as the level of starch was increased when high protein supplements were fed.

Ammonia accumulation levels in general are the result of a balance between rate of formation within the rumen, rate of passage to the omasum, rate of absorption from the rumen, and rate of uptake by microbial populations.

Purser and Moir (1966) stated that greater protozoal populations are associated with higher ammonia levels. Protozoa probably produce ammonia as a by-product of endogenous metabolism (Warner 1956) but the significance has yet to be determined.

Calculations based on the net protein utilization values for protozoal and bacterial protein reported by McNaught et al (1954) indicated that, in converting bacterial protein to protozoal protein, protozoa could release as ammonia nitrogen, 18% of the protein nitrogen involved in the conversion before the host animal would suffer a loss of available amino acid nitrogen. This was due to the higher digestibility of the protozoal protein (74% for bacterial protein as compared to 90% for protozoal protein) and higher biological value.

The relationship between rumen ammonia levels and protozoa numbers is open to some discussion. Purser and Moir (1966) reported that protozoa numbers reflect rather than cause variations in the accumulation levels of ammonia. However Christiansen et al (1965) and Klopfenstein et al (1966) considered that higher ammonia levels in faunated sheep, as compared to defaunated sheep, were the result of the protozoa present in the former. Christiansen et al (1965) found significantly higher ammonia concentrations in faunated lambs (12.2 mg % versus 6.4 mg %) as compared to defaunated lambs.

Klopfenstein et al (1966) stated that protein degradation in the rumen was greater in the presence of protozoa, resulting in elevated rumen ammonia concentrations.

There is considerable diurnal variation in rumen ammonia levels. The level is lowest immediately before feeding and reaches a maximum from 1.5 to 3.0 hours after feeding. (Davis and Stallcup, 1967).

Leibolz (1969) stated that the increase in concentration of ammonia in the rumen liquor after feeding was dependent on the solubility of the dietary protein and the dietary energy intake. The more soluble the protein the higher the ammonia concentration.

Pearson and Smith (1943) reported that starch stimulated synthesis of protein in rations containing urea. Annison (1956) showed that the rates of disappearance of ammonia and amino acids from the sheep rumen after the feeding of casein were increased in the presence of carbohydrate. It is likely that there is a stimulation of synthetic reactions that involve an increased utilization of ammonia when carbohydrate is present.

One of the most interesting problems in rumen ecology is the extent to which ammonia serves as the nitrogenous material for the synthesis of microbial cells. Many of the rumen bacteria assimilate ammonia in preference to amino acids and for some it is essential (Bryant and Robinson 1963).

Ammonia is probably relatively more important for the nutrition of the fibre digesting bacteria than for those utilizing starch or soluble sugars. Immediately after forage is ingested, both soluble carbohydrate and soluble proteins are present. Digestion of the proteins is rapid, with release of at least small concentrations of amino acids which may be assimilated directly, and ammonia which may also be assimilated with the available carbohydrate. By the time the fibre-digesting bacteria have started growth and during the extended period in which they attack the more resistant components of the forage, amino acids will be scarce. It is thus not surprising that fibre-digesting bacteria

have the capacity to use ammonia as a source of nitrogen. (Hungate 1952)

The formation of ammonia in the rumen leads to two opposing nutritional actions. First, substances such as urea, which are nutritionally valueless to the host, can be converted to ammonia and utilized for growth of bacteria, that is for the synthesis of protein, which may be subsequently digested and used by the host. By contrast, the degradation of protein to ammonia, which can be directly absorbed from the rumen, implies a source of loss of nitrogen to the host animal. The interaction of these opposing actions is probably a major factor leading to the relative constancy of biological value of food nitrogen (crude protein) for ruminants (McDonald 1952).

RUMEN PROTOZOA

One effect of acidosis in the ruminant is the elimination or severe reduction in protozoa numbers as the pH drops. This is rather a complex area as the numerous species of protozoa have very different nutritional requirements. It has been suggested that below pH 5 protozoa numbers are greatly reduced or totally eliminated. (Mackenzie 1967; Thomson 1967). However, in the intermediary period, after grain is first fed, protozoa numbers may remain constant or even increase. Certain protozoa, notably Entodinium caudatum, thrive on starch so that when grain is first fed to animals on a hay diet their numbers increase. Nakamura and Kanegasaki (1960) reported higher protozoa numbers in cattle fed a mixed diet of hay and grain than in cattle fed straight hay. Species present were different between the hay fed and mixed diet fed cattle. Part of the difference may be due to differences in protein level between rations.

The role of protozoa in ruminant nutrition appears to be very complex. There seems to be some disagreement as to their role in metabolism. Christiansen et al (1965) suggested that the major influence of protozoa was on volatile

fatty acid metabolism. However, Klopfenstein et al (1969) considered that the effect upon nitrogen metabolism was of equal if not greater importance than the effect of volatile fatty acid metabolism.

Christiansen et al (1965) found that within the rumen of faunated sheep there were:

(1) larger amounts of volatile fatty acids produced,

(2) altered ratios of volatile fatty acid production,

(3) greater degradation of proteinaceous material as compared to defaunated sheep.

The acetate to propionate ratio was narrower in faunated sheep than in defaunated sheep. These authors also found that faunated lambs performed better in the feedlot than defaunated lambs, but were unable to determine which one of the three differences mentioned accounted for the improved performance. Klopfenstein et al (1966) reported that faunation resulted in greater dry matter digestion.

Purser and Moir (1959) stated that the extent of pH depression and the period during which low pH prevails appear to be the major factors in determining the concentration of ciliate protozoa in the rumen when grain is fed.

RUMEN pH

As mentioned in the section on lactic acidosis, the pH of the rumen contents drops when soluble carbohydrates are fed. Balch and Rowland (1957), showed that pH was inversely related to total volatile fatty acids present in the rumen. Briggs et al (1957), reported that rumen pH rarely falls outside the range of 5.0 to 7.5 on diets that do not lead to lactic acid accumulation.

There are numerous reports in the literature of lowered pH values induced by lactic acid accumulation. Hungate et al (1952) noted a drop of 1.7 pH units twenty-two hours after placing soluble carbohydrate into the rumen of sheep. Briggs et al (1957) reported that lactic acid levels above 20 mM/L were always associated with pH levels below 5.0, although values higher than 80mM/L were often recorded, rumen pH levels never fell below 4.35. Brawner et al (1969) reported a drop of 3.05 pH units when cattle were given a ration high in soluble carbohydrates. This drop in pH was associated with an increase in rumen lactic acid from 0.33 mM/L to 99.4 mM/L.

Jensen et al (1954) reported that in animals fed barley the rumen epithelium was necrotic and vesicated. The vesicles contained serum, erythrocytes, leukocytes and colonies of bacteria including Scherophorus necrophorus. These authors considered that parakeratosis was due to the build up of acid in the rumen. They also found that the association of gastric lesions and liver abscesses showed statistical significance.

Harris (1962) also suggested a relationship between lowered rumen pH and liver abscesses and liver necrosis. He suggested that very acid conditions within the rumen could result in damage to the mucosa, possibly allowing release of ruminal bacteria into the bloodstream and thus to the liver.

Simon and Stovell (1969) indicated that Scherophorus necrophorus was the organism causing liver abscesses. In further work Simon and Stovell (1971) examined four hundred and thirty liver abscesses and found Scherophorus necrophorus in ninety-seven percent of the abscesses.

From the work of the above authors it would appear that high grain rations, which cause the rumen pH to drop can lead to the development

of parakeratosis. This parakeratosis then enables Scherophorus necrophorus to enter the bloodstream and cause liver abscesses. Obviously anything which will lessen the build up of acid in the rumen will help to prevent parakeratosis and liver abscesses. Changing gradually from roughage to concentrate rations will help to lessen the build up of acid in the rumen. This may be an important consideration when bringing cattle or sheep into a feedlot.

PLASMA GLUCOSE

Annison et al (1959) reported that sheep previously housed indoors and fed hay had increased blood glucose levels when they were placed on pasture. Throughout the period of grazing the blood sugar level was significantly greater than when the animals were indo ors. The maximum level was six to ten days after turning out to grass (approximately 65 mg%) and then fell slightly toward the end of the experiment. These authors stated that the increased availability of propionate may account for the rise in blood sugar, but the supplies of lactate may be equally or more important as a source of carbohydrate.

Jorgenson and Schultz (1963) reported increased blood glucose levels when pelleted roughages were fed. They also reported higher total volatile fatty acids and higher propionate levels. Schmidt and Schultz (1959) reported no difference in blood blucose levels in dairy cattle fed three levels of grain.

Roy (1970) reported that much higher blood glucose levels are maintained by the ruminant calf fed all-concentrate diets than by those given all-hay diets. At sixteen weeks of age, calves on all-concentrate diets had mean plasma glucose values of 93 mg% compared with 68 mg% for calves on all hay diets. He stated that how far these high plasma glucose levels are the result of the glucogenic effect of propionate or to glucose formed by

hydrolysis of starch in the intestine is uncertain. Little is known of the extent to which concentrates can escape digestion in the rumen by rapid passage into the abomasum.

Abou Akkada and el-Shazly (1964) noted higher blood blucose levels in defaunated lambs than in faunated lambs. Church (1969) stated that blood glucose levels tend to rise to very high values under conditions of acidosis. It would seem logical that any ration that increase propionic acid production in the rumen could lead to increased plasma glucose levels.

MATERIALS AND METHODS

a:— **DRIED GRASS FEEDING**

Twenty-four Polled Dorset lambs were used in the feeding trial. These lambs were weaned at eight weeks of age and assigned to three rations. The mean initial weight of the lambs was 19.2 ± 0.6 kg. The rations fed were (1) dried grass, (2) 50% dried grass, 50% barley plus a protein mineral supplement, (3) barley plus a protein mineral supplement. All rations were pelleted. Details of ration composition are given in Table 1. The lambs were given vitamins A, D and E, by intramuscular injection at the beginning of the experiment and again six weeks later. Cobalt iodized salt and water were freely available. All animals were fed to appetite twice daily and weighed, prior to the afternoon feeding at weekly intervals.

The dried grass used for this experiment was produced by Springbank Dehydration, Chilliwack, B.C., from Orchard grass — Ladino clover mixed stands. The forage was artificially dired prior to fine grinding and pelleting.

Digestibility data were obtained by means of the total collection technique, using six lambs on each ration with a ten day preliminary adjustment period, followed by a ten day collection period. Daily fecal outputs were weighed and representative samples taken for analysis. Digestibility values were determined at two levels of feed intake to assess the effect of level of feeding on nutrient digestibility. The levels used for these determinations were 600 g and 1000 g (air-dry weight) daily, fed to 45 kg male lambs. These two levels of feed approximately represented maintenance and appetite respectively.

Chemical analyses for crude protein, energy and ash were conducted according to Association of Official Agricultural Chemists procedures (AOAC 1965).

The acid detergent fibres (ADF), were determined by the micro Van Soest method of Waldern (1972). The data were subjected to analysis of variance and Duncan's multiple range test. (Steel and Torrie 1960).

At the end of the feeding period (45 kg) the animals were slaughtered and rumen wall and rumen content samples were taken.

b:—   RATION CHANGEOVER EXPERIMENT

Two trials were conducted to measure the changes occuring in rumen lactate, rumen ammonia, rumen protozoa, rumen pH and plasma glucose when the diet of lambs was changed from 100% roughage to 100% concentrate. In the first trial the diet of four sheep was changed, over a period of seven days, from poor quality chopped hay to rolled barley. In the second trial the change was from the chopped hay to pelleted barley. Daily rumen and blood samples were taken. Four sheep (approximately 40kg) were individually penned and fed twice daily at 8:30 AM and 3:30 PM. The sheep were fed 681 g per day of poor quality chopped hay for four weeks to allow them to adjust completely to this ration. Their ration was then changed to 454 g per day of barley. The changeover period was six days. (Table 2) Daily rumen and blood samples were taken at 11:30 AM. A period of four weeks was allowed to allow the sheep to adjust completely to the barley ration. Rumen and blood samples were then taken to represent adjusted values.

SAMPLING PROCEDURES

All sampling was done at 11:30 AM, three hours after the morning feeding .

Blood samples were collected in heparinized vacutainer tubes by venous puncture of the jugular vein. The samples were centrifuged at 2000 r.p.m. for

TABLE 1

RATION COMPOSITION

	RATION 1 (Dried grass)	RATION 2 (50/50)	RATION 3 (Barley)
Dried grass %	100	50	—
Barley %	—	40	80
Supplement %	—	10	20
Chemical Analysis (DM)			
CP%	22.7	18.7	16.9
ADF%	27.0	17.8	6.3
ASH%	13.8	8.9	4.0

Supplement:— Protein-mineral supplement containing 32% CP, 2.3% Ca, 1.0% P.

TABLE 2

CHANGEOVER DESIGN

Day 1   681 g of hay

Day 2   567 g of hay plus 114 g of barley

Day 3   454 g of hay plus 227 g of barley

Day 4   340 g of hay plus 340 g of barley

Day 5   227 g of hay plus 454 g of barley

Day 6   114 g of hay plus 454 g of barley

Day 7   454 g of barley

30 minutes. The plasma was then drawn off with a Pasteur pipette and placed in a test tube. The test tubes were stoppered and stored in a freezer at —5 C.

Rumen samples were obtained by means of a stomach tube. The tube was made of hard plastic (Tygon). 6.36 mm inside diameter. A series of holes were drilled at the end of the tube to prevent blocking with fibrous material. A plastic speculum was used to facilitate the passage of the stomach tube through the mouth and down the throat of the sheep. A suction pump was used to draw the samples. The rumen samples were collected in plastic containers which were sealed as soon as the sampling was completed.

The rumen samples were strained through two thicknesses of cheese cloth. Ammonia concentrations were measured on the fresh samples. The remainder of the sample was frozen for further analyses.

ANALYTICAL PROCEDURES

BLOOD PLASMA GLUCOSE

Glucose was determined using the enzymatic "Glucostat" kit (Worthington Chemicals). Plasma was frozen after collection and glucose determinations were carried out in batches at the end of the changeover period.

The plasma was deproteinized with 5.1% zinc sulphate and 0.36N sodium hydroxide. A 0.2 ml sample was used for the determination, which was diluted 10:1 with distilled water before deproteinizing. The colour development was measured using a Spectronic 20 at a wavelength of 400 mμ.

LACTIC ACID

Rumen samples were frozen after collection. Rumen lactic acid concentration was determined using the colourimetric method of Barker and Summerson

(1941) with the suggested modifications of Pennington and Sutherland (1956). The rumen content samples were deproteinized with 5.1% zinc sulphate and 0.36N sodium hydroxide. A 1.0 ml sample of this diluted solution was used for the determination. In this method the lactic acid is converted into acetaldehyde by treatment with concentrated reagent grade sulphuric acid, and the acetaldehyde determined by its colour reaction with p-hydroxydiphenyl (p-phenylphenol, Eastman Kodak Company) in the presence of cupric ions.

The colour development was read on a Spectronic 20 at a wavelength of 560 mμ. The procedure was as follows:— A 1 ml sample, after deproteinization and copper-lime treatment, was added dropwise with shaking to 9 ml of ice cold concentrated reagent grade sulphuric acid. The tube was then covered with parafilm and placed in a boiling water bath for five minutes. After cooling, four drops of 4% copper sulphate and seven drops of the p-hydroxyphenyl reagent was added. The tube was then allowed to stand in ice for one hour with occasional shaking. The tube was then placed in the boiling water bath for ninety seconds and returned to the ice-bath for five minutes. The sample was allowed to return to room termperature before the colour development was read.

RUMEN pH

The pH was determined on the fresh rumen samples immediately after filtration. (pH meter 28 - Radiometer Copenhagen).

RUMEN AMMONIA CONCENTRATION

Ammonia determinations were carried out on fresh rumen liquor immediately after filtering, using the microdiffusion technique of Conway & O'Malley (1942). A 2.0 ml sample of rumen liquor was used for the determination.

The procedure was as follows: By means of a small brush, a thin coat of gum arabic fixative was applied to the outer rim of the microdiffusion unit. (Figure 2). A 2.0 ml aliquat whole rumen fluid was added to the outer chamber of the unit and 1.0 ml of boric acid indicator-solution was added to the inner chamber. Approximately 3 ml of magnesium oxide suspension were added to the outer chamber of the unit and the lid was immediately replaced. After the lid was sealed the contents of the outer chamber were mixed thoroughly. The unit was then placed in a cupboard for twenty-four hours.

At the end of the twenty-four hours the lid was removed from the unit and 1.0 ml of water added to the central chamber. The boric acid indicator was then back titrated with 0.005N sulphuric acid.

PROTOZOA COUNTS

Protozoa counts were carried out on a 15:1 dilution of rumen fluid. The protozoa were counted, using a McMaster Fecal Counting Chamber. The rumen fluid was diluted with Sheather's sugar solution so that the protozoa would rise to the top of the counting chamber.

Some problems were encountered when the sheep were receiving barley as the presence of starch granules made the counting more difficult.

STATISTICAL ANALYSIS

The results were subjected to correlation and regression analysis. The significance of the correlations were measured at the five and ten percent level, using the t-table. (Huntsberger, 1967).
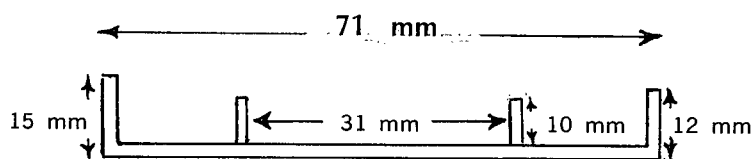
Two trials were conducted. In Trial 1, rolled barley was introduced into the diet of hay fed lambs following the schedule in Table 1. In Trial 2, pelleted barley was used. The results of the two trials were very similar and therefore were pooled for analysis and discussion.

FIGURE 2

CONWAY MICRODIFFUSION UNIT
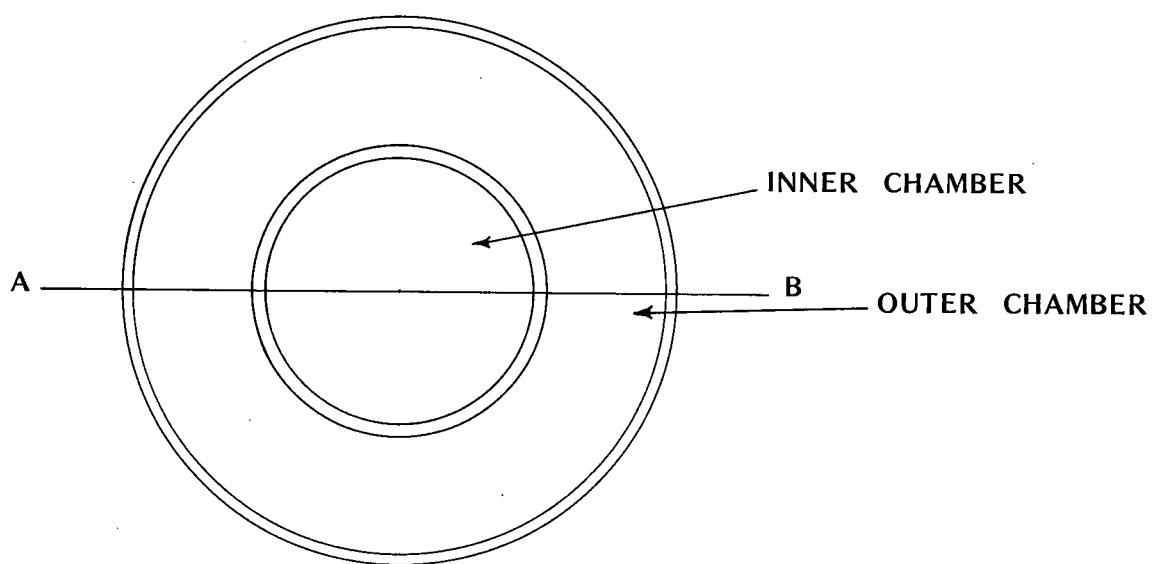
PLAN

VERTICAL SECTION ON LINE A—B

CONWAY AND O'MALLY
1941

RESULTS

a:—   DRIED GRASS FEEDING

Average daily gain (ADG) over a fourteen week feeding period from
approximately 20 to 40 kg liveweight did not differ significantly ($P > 0.05$)
for the three rations fed (Figure 3). The values were 213, 211 and 216 g for
treatments 1, 2 and 3 respectively (Table 3). The ADG of entire male
lambs was significantly ($P < 0.05$) greater than that of females on all rations.
The mean daily gain was 236 g for males compared to 191 g for females
with no interaction between sex and ration.

The feed conversion ratio (FCR) decreased as the level of barley in
the ration increased and was 5.37, 4.84 and 3.98 for treatments 1, 2 and
3 respectively.

The dressing percentages were 48.7, 50.5 and 53.2% for rations 1,
2 and 3 respectively. However, gut contents were not weighed so it was not
possible to compare carcass growth.

On a group basis feed intake was higher in Group 1 (dried grass)
and lowest for Group 3 (pelleted barley) but digestible energy intakes were
similar due to differences in DE levels of the rations. The digestible energy
intakes were 3.16, 2.86 and 2.84 Mcals for treatments 1, 2 and 3 respectively.

Rumen pH was higher in lambs fed dried grass. The rumen pH in
those sheep was 6.74 compared with 5.78 and 5.74 for treatments 2 and
3 respectively.

Digestibilities of DM, OM, gross energy, CP and ADF were measured.
The DDM, DOM and DE values followed similar trends and percentage DE was
significantly ($P < 0.05$) different for the three treatments. The mean DE values

FIGURE 3

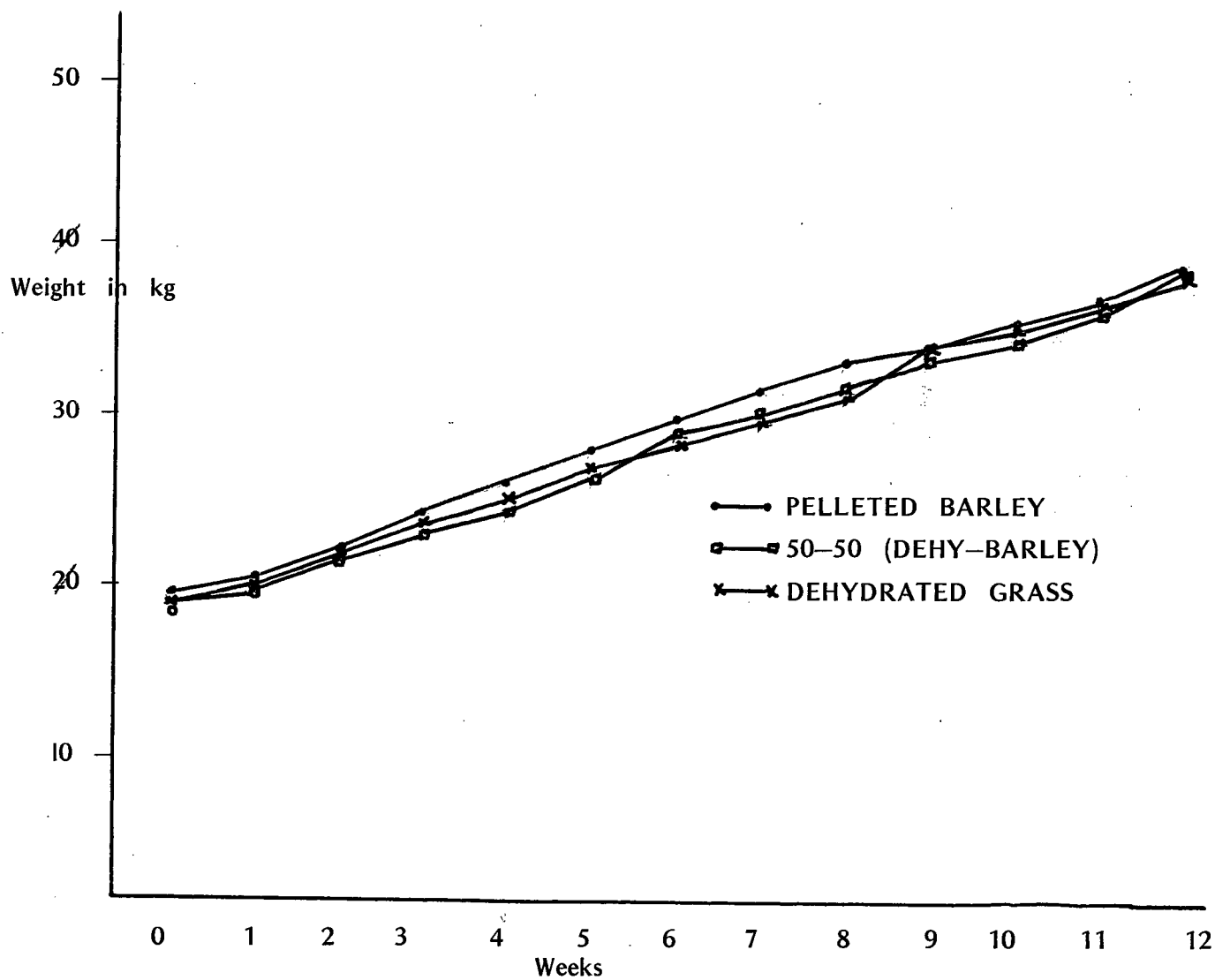WEIGHT CHANGE OF LAMBS (kg)

VS

TIME (weeks)

TABLE 3

ANIMAL PERFORMANCE DATA

	RATION 1	RATION 2	RATION 3
Average daily gain (ADG)			
All animals g	213	211	216
Males g	237	239	233
Females g	189	183	200
Food conversion ratio (FCR)	5.37	4.84	3.98
Dressing percentage	48.7	50.5	53.2
Rumen pH	6.74	5.78	5.74
Feed intake:			
DM/day kg	1.04	0.95	0.76
DE/day Mcals	3.16	2.86	2.84

were 66.1, 69.1 and 82.0% for rations 1, 2 and 3 respectively. Digestibility of CP declined as the level of barley decreased, the means being 67.4, 70.0 and 79.0% for treatments 1, 2 and 3 respectively. Differences between the means were significantly different (P<0.05). Digestibility values for ADF indicated that this was highest for the dried grass and lowest for the pelleted barley. The means were 50.0, 45.8 and 24.2% for groups 1, 2 and 3 respectively. The digestibility data are summarized in Table 4.

The effect of level of feed intake on the digestibility of the energy of the feed was studied. With the dried grass ration the increase in intake from 600 to 1000 g resulted in a significant (P>0.05) decrease in digestibility. The digestibility of energy also tended to be lower at the higher levels of intake for the other two rations but the differences were not significant (P>0.05). The mean values at an intake of 600 g were 67.7, 69.8 and 82.2% and at 1000 g, 64.4, 68.3 and 81.7% for treatments 1, 2 and 3 respectively.

There was no significant (P>0.05) effect of level of feed intake on protein digestibility, but there was a tendency for digestibility of protein to be lower at the higher level of intake for the dried grass and 50-50 rations. The mean protein digestibilities at an intake of 600 g were 68.4, 71.2 and 78.9% and at 1000 g, 66.5, 68.7 and 79.2% for treatments 1, 2 and 3 respectively.

The appearance of the rumen contents were quite different for the three rations. (Appendix 3) The rumen contents from the sheep on pelleted barley were watery with the solid portion having a "porridge" like appearance. The contents of the rumen of the sheep on dehydrated grass contained large amounts of trapped gas and had a frothy appearance. They were dark green colour and had an odor very similar to that of the feces of cattle on lush grass. The rumen contents of the sheep on the 50-50 ration were very similar to those on the dehydrated grass, however, there was less trapped gas and the contents were thicker.

TABLE 4

DIGESTIBILITY DATA (%)

	RATION 1	RATION 2	RATION 3
Gross energy	66.1a	69.1b	82.0c
DM	63.1	70.6	82.3
OM	66.2	72.3	83.2
CP	67.4a	70.0b	79.0c
ADF	50.0a	45.8b	24.2c

Values on the same line followed by different letters are significantly different. (P<0.05)

RUMEN WALL CHARACTERISTICS

On the barley ration the papillae were short, clumped and appeared keratinized. On the 50-50 ration the papillae were clumped, dark in colour, closely packed and short. On the dehydrated grass ration, the papillae were extremely variable, some were long and flakey, with others very undeveloped. (Appendix 4)

b:— RATION CHANGEOVER EXPERIMENT

LACTIC ACID

The tabulated data are presented in Appendix 5.

Rumen lactate levels increased over the period of the trail (Figure 4). The increase in lactic acid concentration from day 1 (100% hay) to day 8 (100% barley) was 321.2 mg %. The most marked increase occured between day 7 and day 8.

The rumen lactate concentration was positively correlated ($P < 0.10$) with the level of barley in the ration and negatively correlated with the level of hay ($P < 0.10$) (Table 5). Rumen lactate and rumen pH were negatively correlated ($P < 0.10$). There was a negative correlation ($P < 0.05$) between lactic acid levels and protozoa numbers.

As stated above, lactic acid levels rose markedly during the changeover period. The correlation between rumen lactate levels and rumen pH was significant ($P < 0.10$) suggesting that the "build-up" of lactic acid was responsible for the drop in rumen pH. The symptoms of indigestion (scouring, refusal of feed, drooping of the head), also appeared to be related to the increases in rumen lactate. In all sheep the onset of symptoms of "indigestion" corresponded to the build-up of rumen lactate.

TABLE 5

* Significance at 5% level.
** Significance at 10% level.

	BARLEY FED	HAY FED	RUMEN pH	RUMEN LACTATE	RUMEN PROTOZOA NUMBERS	RUMEN AMMONIA	PLASMA GLUCOSE
BARLEY FED			-0.64**	0.29**	-0.08	-0.37**	0.34**
HAY FED			0.72**	-0.36**	0.20*	0.43**	-0.38**
RUMEN pH	-0.64**	0.72**		-0.70**	0.37**	0.38**	-0.23**
RUMEN LACTATE	0.29**	-0.36**	-0.70**		-0.23*	-0.06	0.14
RUMEN PROTO-ZOA NUMBERS	-0.08	0.20*	0.37**	-0.23*		0.44**	-0.17
RUMEN AMMONIA	-0.37**	0.43**	0.38**	-0.06	0.44**		
PLASMA GLUCOSE	0.34**	-0.38**	-0.23**	0.14	-0.17		

Correlations between ration fed, rumen pH, rumen lactate, rumen protozoa numbers, rumen ammonia, and plasma glucose when the ration of lambs is changed from roughage to concentrate over an eight day period.

FIGURE 4

RUMEN LACTIC ACID CONCENTRATION
(mg%) VS TIME (days) (Study 2)

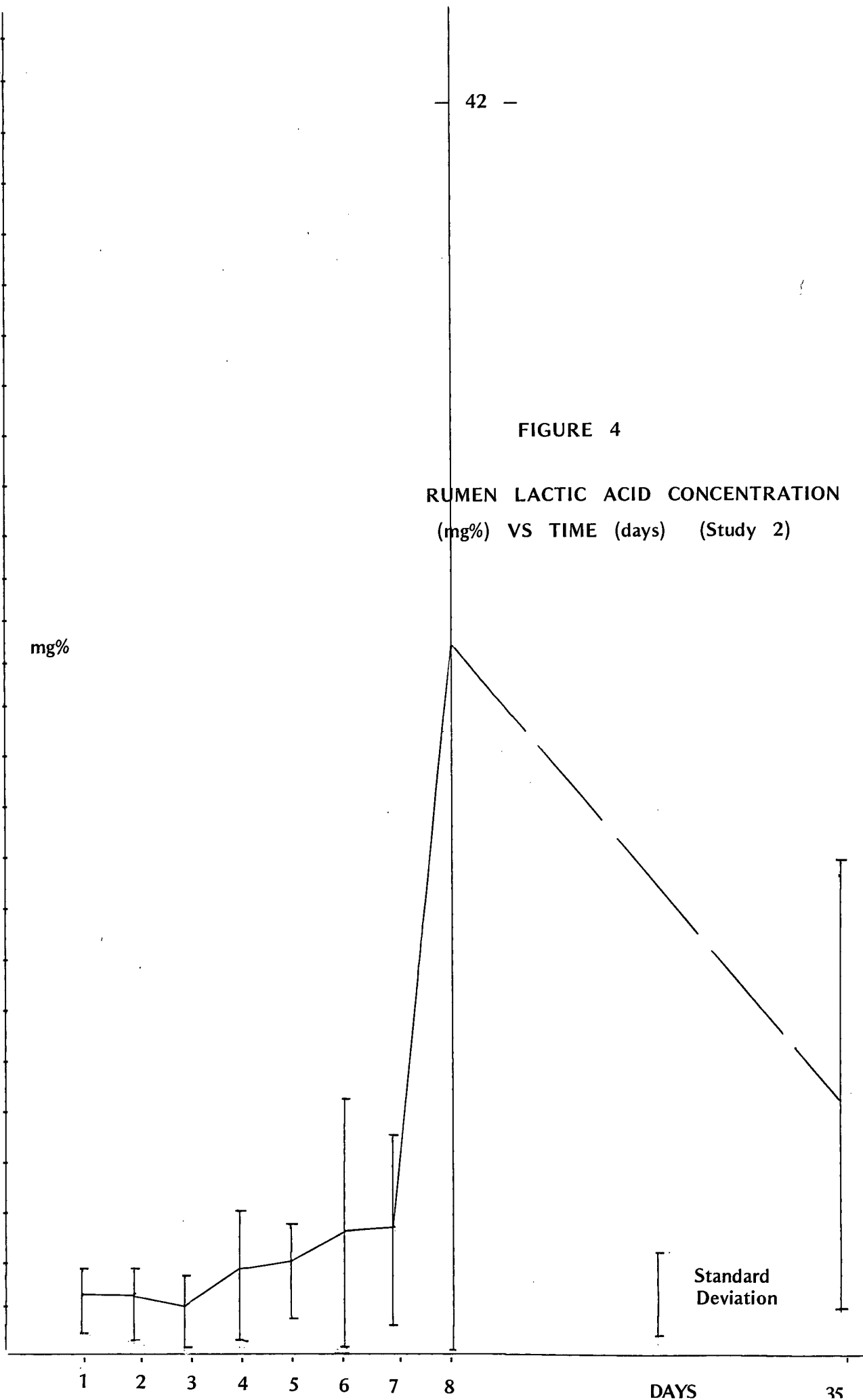## RUMEN AMMONIA CONCENTRATION

Tabulated results are presented in Appendix 6.

Rumen ammonia levels increased initially and then dropped below day 1 values. The highest level (6.0 mg%) occured on day 3 (Figure 5).

The rumen ammonia concentration was negatively correlated ($P < 0.10$) with barley intake and positively correlated ($P < 0.10$) with hay intake. Ammonia levels were positively correlated ($P < 0.10$) with protozoa numbers (Table 5).

RUMEN PROTOZOA NUMBERS

Tabulated results are presented in Appendix 7.

Rumen protozoa numbers increased during the changeover period to day 7 and then declined sharply (Figure 6). There was a further reduction in numbers over the adjustment period.

Protozoa numbers were positively correlated ($P < 0.05$) with hay intake. Protozoa numbers and pH were positively correlated ($P < 0.10$). Rumen protozoa numbers and the rumen lactate levels were negatively correlated ($P < 0.05$). (Table 5).

Protozoa numbers increased when barley was added to the ration. This initial increase was followed by a decline in numbers as the level of barley increased. The sharpest decline in numbers occured on day 8, which corresponded with the largest increase in lactic acid.

FIGURE 5

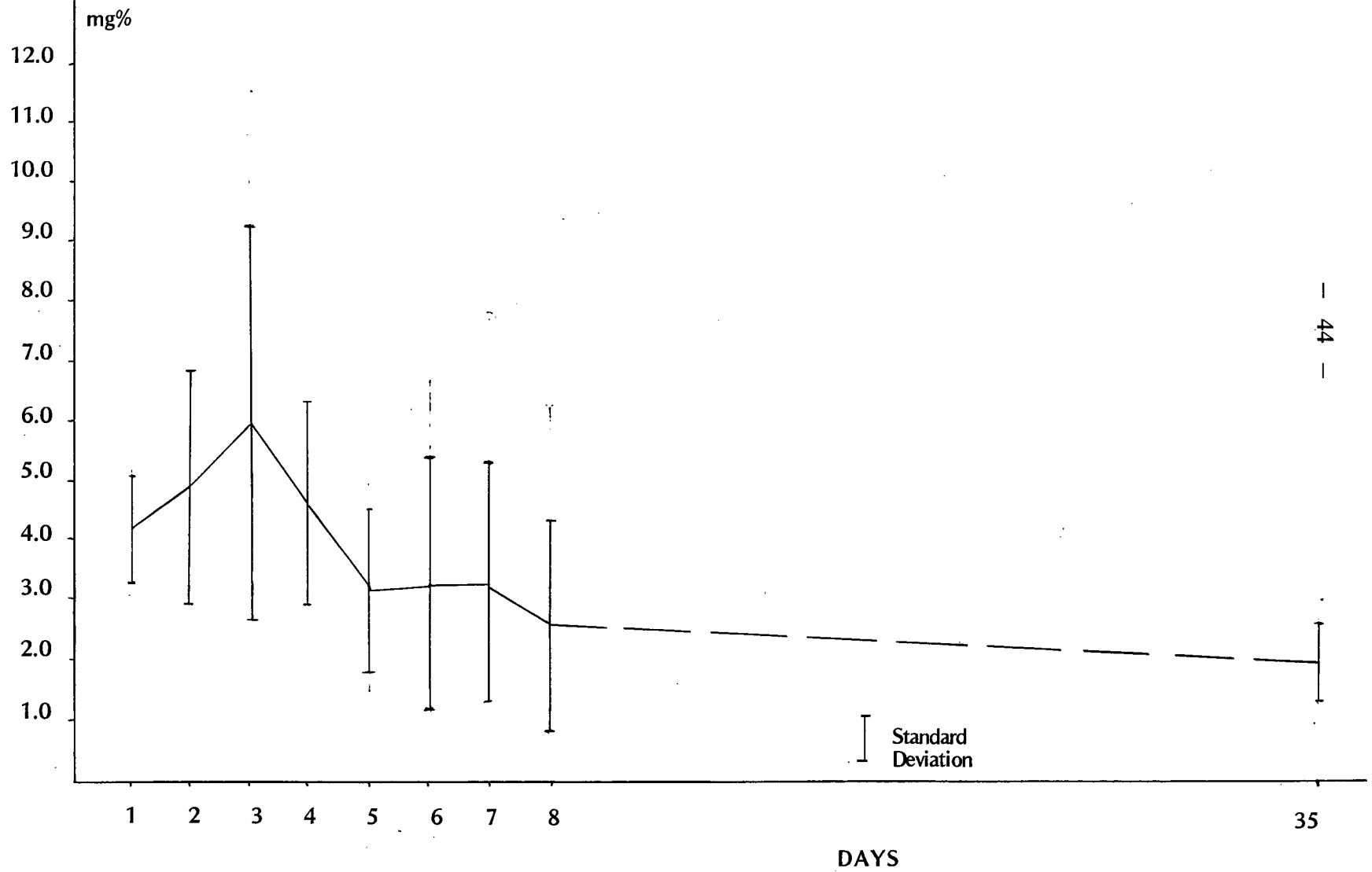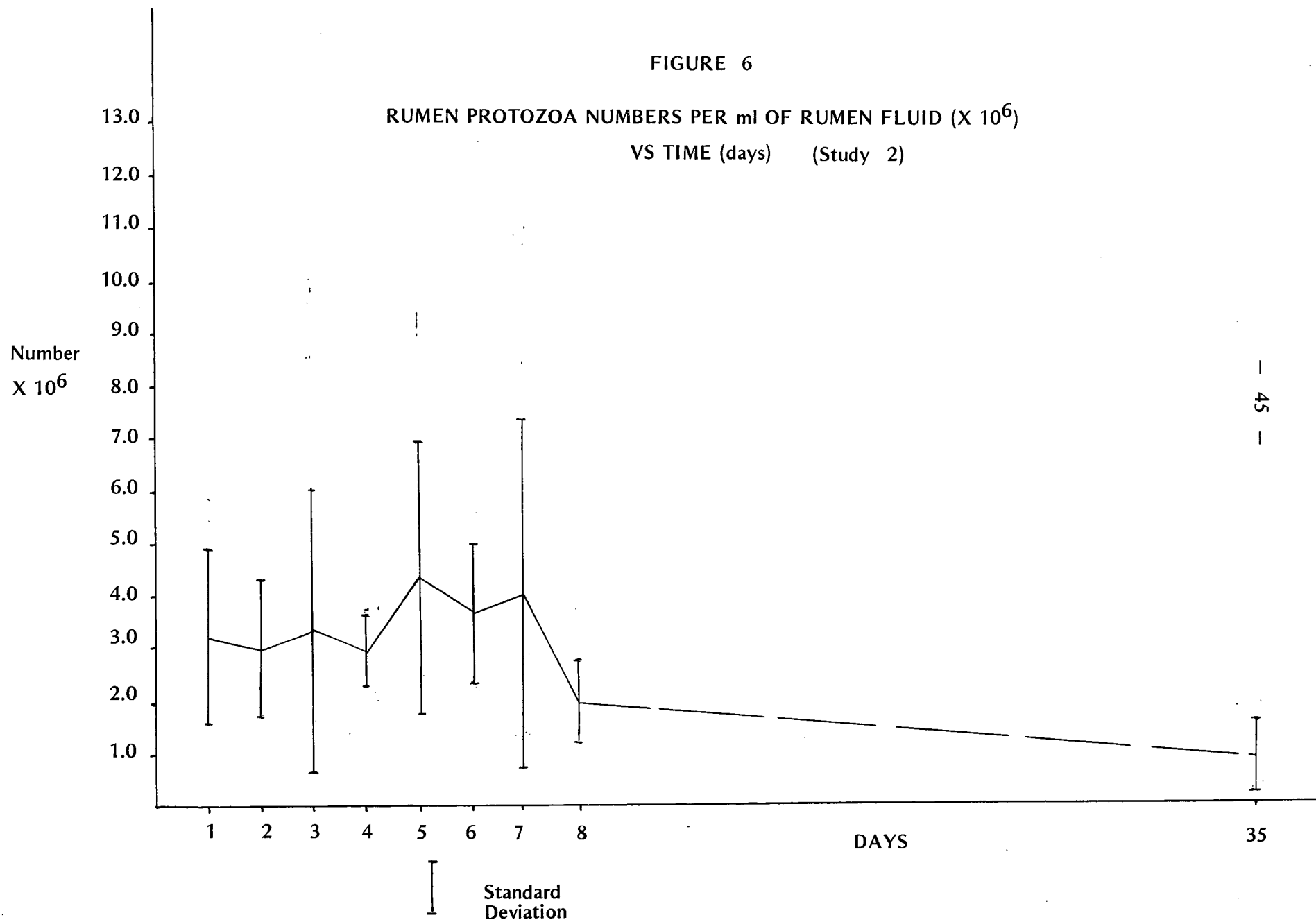RUMEN AMMONIA CONCENTRATION (mg%) VS TIME (days) (Study 2)

FIGURE 6

RUMEN PROTOZOA NUMBERS PER ml OF RUMEN FLUID (X 10^6)

VS TIME (days)   (Study 2)

RUMEN pH

Tabulated results are presented in Appendix 8.

The rumen pH dropped during the changeover period and continued a slight decline over the adjustment period (Figure 7).

Rumen pH was negatively correlated (P < 0.10) with barley intake and positively correlated (P < 0.10) with hay intake. Rumen ammonia and rumen protozoa numbers were positively correlated with rumen pH (P < 0.10). Blood glucose and rumen lactate were negatively correlated with rumen pH (P < 0.10). (Table 5) The relationship between rumen pH and rumen lactate is demonstrated in Figure 8.

The molar concentration of lactic acid reached in this study was 76.3 mM/L.

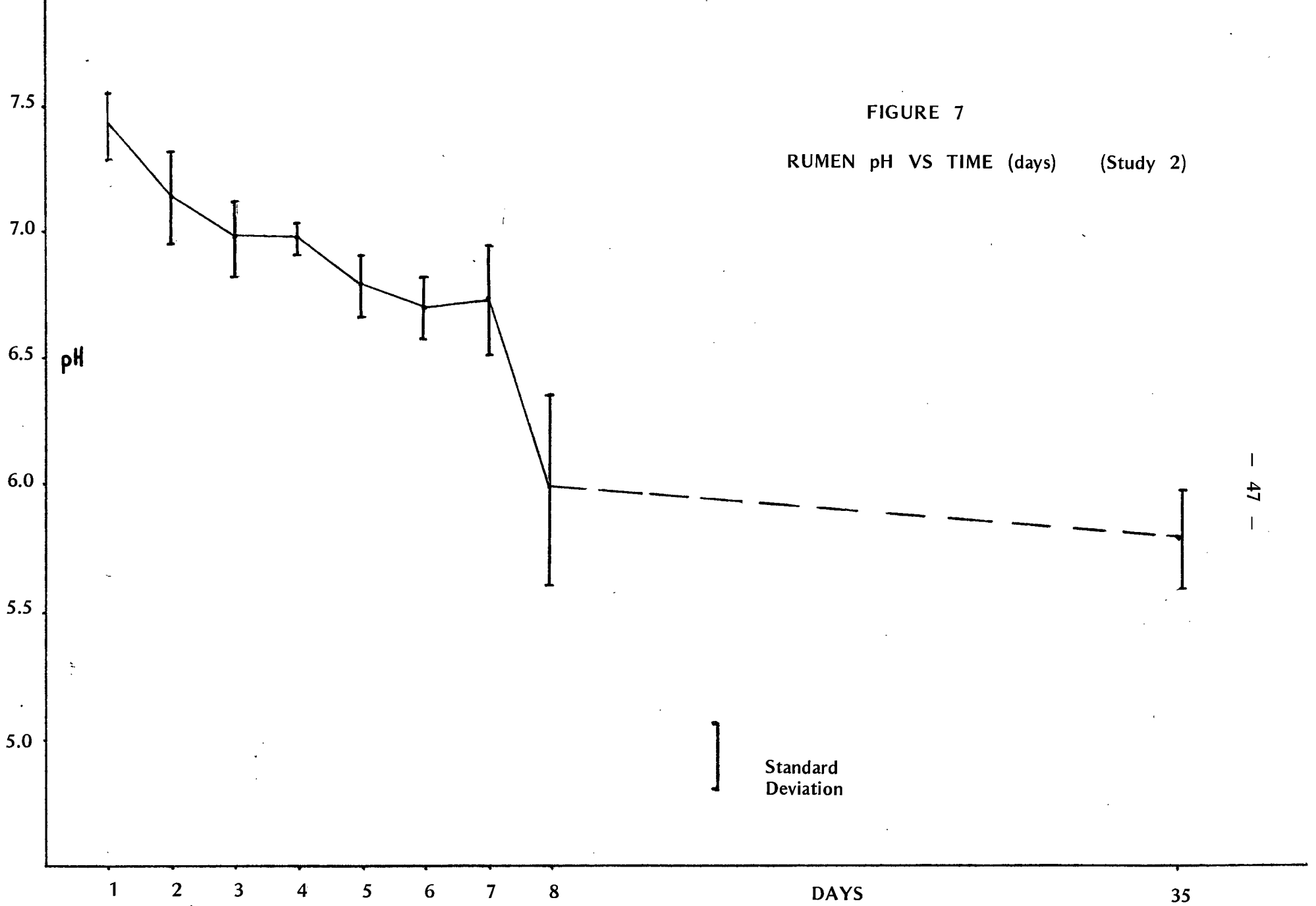## BLOOD GLUCOSE CONCENTRATION

The tabulated results are presented in Appendix 9.

Plasma glucose increased during the changeover period. There was a slight drop in plasma glucose levels during the adjustment period but levels were still above initial values. (Figure 9)

Blood glucose levels were positively correlated (P < 0.10) with barley intake and negatively correlated (P < 0.10) with hay intake. Blood glucose and rumen pH were negatively correlated (P < 0.10). (Table 5)

FIGURE 7

RUMEN pH VS TIME (days)   (Study 2)

Standard
Deviation

— 47 —

RUMEN LACTATE CONCENTRATION VS RUMEN pH (Study 2)
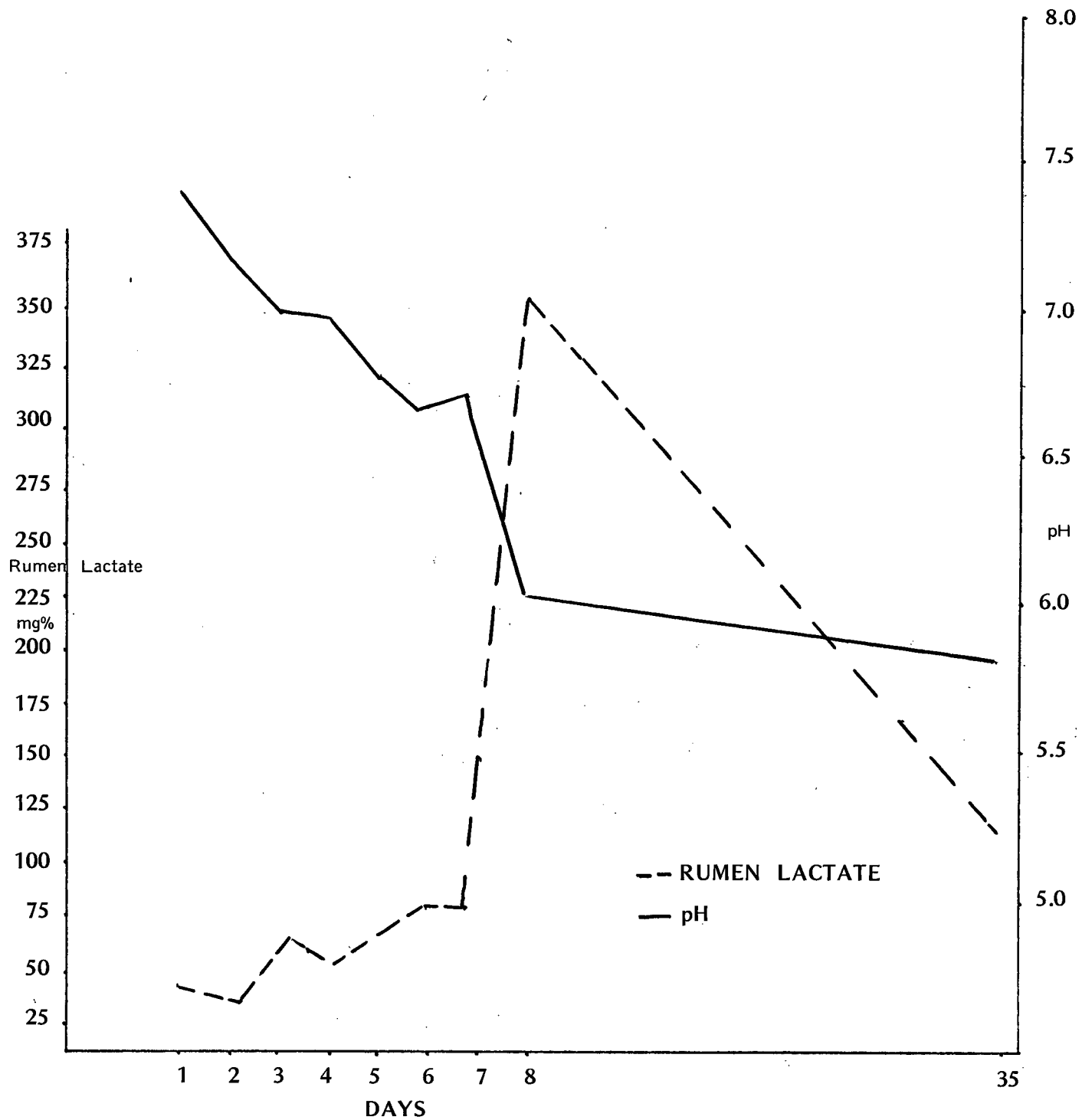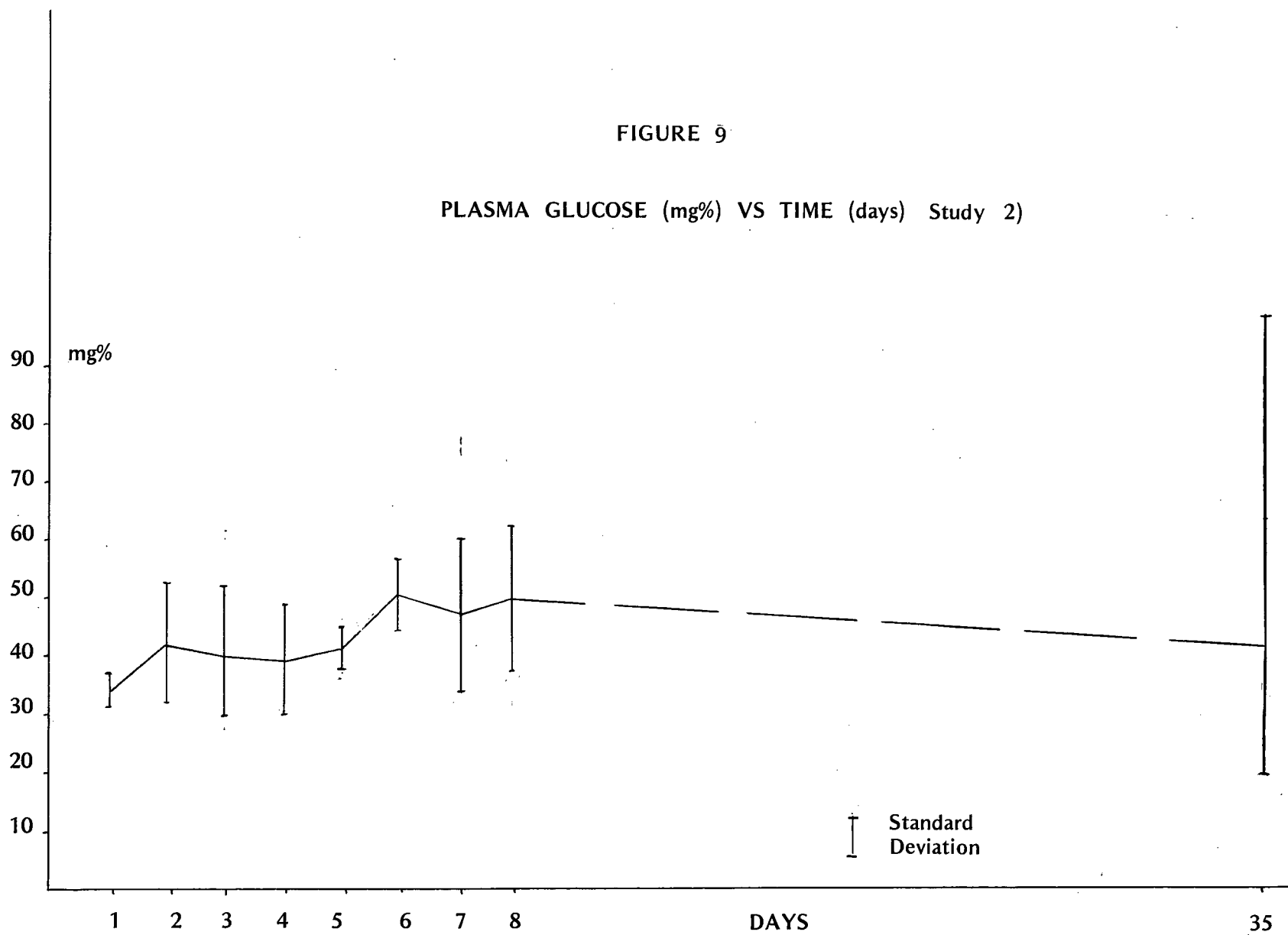
FIGURE 8

FIGURE 9

PLASMA GLUCOSE (mg%) VS TIME (days) Study 2)

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DISCUSSION AND CONCLUSIONS

The dressing percentage figures obtained in the first trial agree with those of Lonsdale et al (1971) who found that dressing percentage increased when barley was added to grass wafers for cattle. Although weight gains for the trial were similar for the three rations, the dressing percentage was 4.5 percentage units higher for lambs fed straight barley compared to straight grass. The difference between straight grass and 50-50 grass-barley was 1.8 percentage units in favour of the 50-50 ration. Therefore, although the three rations appear to give equal liveweight gains, the carcass gain would probably be higher for the barley fed animals. Unfortunately no sample lambs were slaughtered at the start of the trial so that the actual differences in carcass gain between rations could not be measured. Using the dressing percentages obtained it would appear that a 50 kg lamb would yield 24.3, 25.3 and 26.6 kg carcass respectively for rations 1, 2 and 3. This represents an approximate difference of 9.2% in carcass yield between rations 1 and 3.

Coleou (1973) reported difficulties in obtaining the degree of finish wanted on calves fed straight grass. This was not observed in this experiment. All lambs were adequately finished at approximately 45 kg.

The replacement value of dried grass for barley in this experiment was 1.35:1. This compares favourably with the 1.25:1 replacement ratio reported by Connell (1973) in work with dairy cattle.

The digestible energy percentage of treatment 2 was not as high as would have been expected from the values for dried grass and barley separately. A similar effect when dried grass and barley were combined has been reported by Tayler and Lonsdale (1970). These workers have concluded that with un-

processed dried grass the digestibility of a mixed diet of grass and barley was greater than that of grass alone at low digestibilities but the difference between diets declines with increasing digestibility of the grass. When the grass has an organic matter digestibility exceeding 75% the addition of barley tends to depress the digestibility of the mixture below that of grass alone. Similarly, Wainman et al (1970) reported metabolizable energy to remain almost constant with rations ranging from all dried grass to all barley, but they found net energy almost doubled over this range. The digestibility of OM of the grass used by Wainman et al (1970) was slightly in excess of 70%.

In the present experiment digestibility of OM was 66.2% for the dried grass. Tayler and Lonsdale (1970) have proposed the following equation to predict digestibility of mixed diet when the value for the dried grass is known:

$$Y = 39.0 + 0.48 \quad X$$

where:

Y = the OM digestibility of the mixed diet.

X = the OM digestibility of the dried grass.

The OM digestibility of the mixed ration in this experiment was 72.3% compared to a value of 70.8% predicted by the equation of Tayler and Lonsdale (1970). This would appear to be a reasonable approximation considering that the equation was derived with unprocessed dried grass while the material used in this study was ground and pelleted. The value which would have been predicted from the digestibilities of grass and barley was 75%.

Tayler and Lonsdale (1970), Kromann (1973), Londale et al (1971) have suggested this associative effect may be due to a reduction in fibre digesion. In this study ADF digestibility data did not indicate that the digestibility of this fraction was less in the mixed ration than that which would

have been prediced from the values for the components. It would appear some other associative effect accounts for the reduced digestibility.

Blaxter (1962) has suggested that the decline in digestibility with increased level of feed intake may be due to the increased rate of passage and a decrease in fibre digestion. While depressions in digestibility at the higher levels of feed intake were observed in this study, it was not possible from the results to identify reduced fibre digestion as the cause. The use of only 3 animals per treatment for the digestibility determinations may have con- tributed to the lack of significant differences. Rate of passage was not measured in this study and therefore its effect is not known.

Very little can be concluded on the effect of these rations on rumen papillae. Comparing papillae development becomes difficult because the location of the rumen wall samples was not noted. Therefore some differences may be due to differences in location of sample. The papillaè appeared to be developed more in sheep fed straight dehydrated grass than in the other groups.

No health problems were encountered with the lambs during this experiment and the results suggest that dried grass could be used successfully in the intensive rearing of early weaned lambs. The decision would be primarily dependent on the relative costs of dried grass and protein supplemented cereal grain rations.

In the second trial the introduction of barley into the ration of sheep receiving hay led to changes in the blood and rumen fluid, the most notable of these being the "build-up" of lactic acid in the rumen. This one factor appears to be the dominant result as it in turn affects several other parameters. This "build-up" of the lactic acid leads to lowered pH levels. Protozoa numbers which increase initially due to the availability of starch are then inhibited by

the lowered pH. The introduction of soluble carbohydrates, in the form of grain, into the ration of ruminants, normally results in a drop in rumen pH. The depression of 1.64 pH units observed in this study was very similar to the values of 1.70 pH units reported by Hungate et al (1952).

The drop in rumen pH corresponded closely with the increase in lactic acid concentration in the rumen. This agrees with the work of Brawner et al (1969) and Briggs et al (1957). The molar concentration of lactic acid reached in this study is very similar to that reported by Briggs et al (1957).

Saliva contamination was difficult to avoid when obtaining rumen samples. This may have increased the pH of the rumen fluid. However, the initial pH values correspond to those reported by Gilchrist and Clark (1957), Thomson (1967), Ahrens (1967) and Brawner (1969).

Rumen ammonia increased somewhat when barley was first fed. This was due in part to increased nitrogen intake which was not utilized. As the rumen microbes adapt they are able to utilize the increased levels of available carbohydrate as an energy source for microbial synthesis. Therefore, rumen ammonia levels drop after the initial rise. This trend was evident in this trial and agrees with the work of Annison (1959) and McIntyre (1970).

Rumen pH and the rumen ammonia appear to be related (P < 0.10). This agrees with the work of Reis and Reid (1959), who suggested the effect of pH is probably an effect on the enzymes concerned in the deamination of amino acids.

Plasma glucose increased as the level of grain in the ration increased. This increase was probably due to one of two factors, the availability of lactate as a carbohydrate source in the rumen or to glucose formed by hydrolysis of

starch in the intestine. As Roy (1970) stated, little is known of the extent to which concentrates can escape digestion in the rumen by rapid passage into the abomassum. When the animal is adjusted to a grain diet, the higher glucose values are probably due to the increased propionate production. However, during the changeover period propionate production is impeded and therefore it is not likely it is the source of increased glucose levels.

Protozoa numbers increased when barley was added to the ration. This initial increase was followed by a decline in numbers as the level of barley increased. These data agree with the work of Mackenzie (1967), Thomson (1967) and Nakamara and Kanagesaki (1969). The initial increase in protozoa numbers may be due to the increased availability of starch causing an increase in numbers of the protozoa capable of using starch. As the pH declines protozoa numbers drop.

The correlation between protozoa numbers and rumen ammonia levels was positive. There is some disagreement as to which is the governing variable. Purser and Moir (1966) stated protozoa numbers reflect, rather than cause, variations in the accumulation levels of ammonia. However, Klopfenstein et al (1966) stated that protein degradation in the rumen was greater in the presence of protozoa, resulting in elevated rumen ammonia concentrations. Warner (1956) and Christiansen et al (1965) tend to support this latter view. The data from this study does not aid in this controversy.

Rumen and blood fatty acid levels would have aided in interpretation of results. Blood lactate levels should also have been measured. These figures may have explained differences between lambs and given more insight into the effects of the changeover.

The importance of a gradual changeover from hay to grain is emphasized in the second trial as the high rumen lactate levels reached and the accompanying

symptoms would be most undesireable in a commercial feeding situation. No attempt was made to ascertain a suitable time interval for this changeover. Hironaka (1970) has suggested a period of 4 weeks under normal conditions or 8 days when starter rations such as those he has developed are used.

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APPENDIX 1

DEFINITION OF MODULUS OF FINENESS

:— Percentage of a 250 gram sample of ground feed remaining on each of seven screens. (3/8, 4, 8, 14, 28, 48, and 100 mesh) and in the pan following a 5 minute test.

eg.

SCREEN MESH	PERCENT OF MATERIAL ON EACH SCREEN		
3/8	1.0 x 7	=	7.0
4	2.5 x 6	=	15.0
8	7.0 x 5	=	35.0
14	24.0 x 4	=	96.0
28	35.5 x 3	=	106.5
48	22.5 x 2	=	45.0
100	7.5 x 1	=	7.5
PAN	0.0 x 0	=	0.0
TOTALS	100.0		312.0

THEREFORE MODULUS OF FINENESS IS

312/100 = 3.12

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APPENDIX 2

DEFINITIONS

1. wafers — made by compressing chopped forage in a piston-type press.

2. cobs — made by compressing chopped forage in a roller-die press.

3. pellets — made by compressing ground forage (hammer mill) in a roller-die press.

APPENDIX 3

PHOTOGRAPH OF RUMEN CONTENTS

APPENDIX 4

PHOTOGRAPHS OF RUMEN WALL SAMPLES

APPENDIX 4
(continued)

RATION 1   100% GRASS

RATION 1

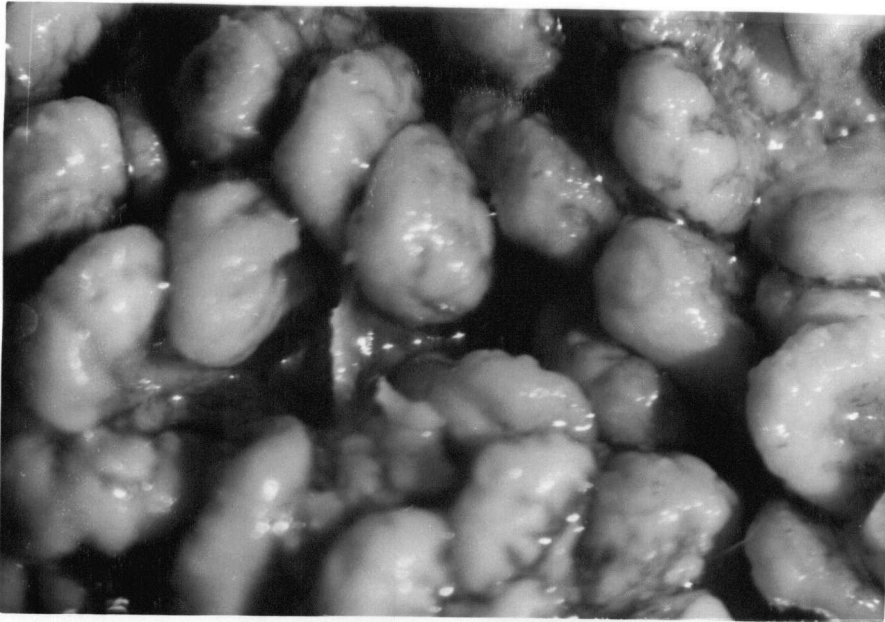# APPENDIX 4

(continued)

RATION 2   50% GRASS

RATION 2

APPENDIX 4

(continued)

RATION 3   BARLEY
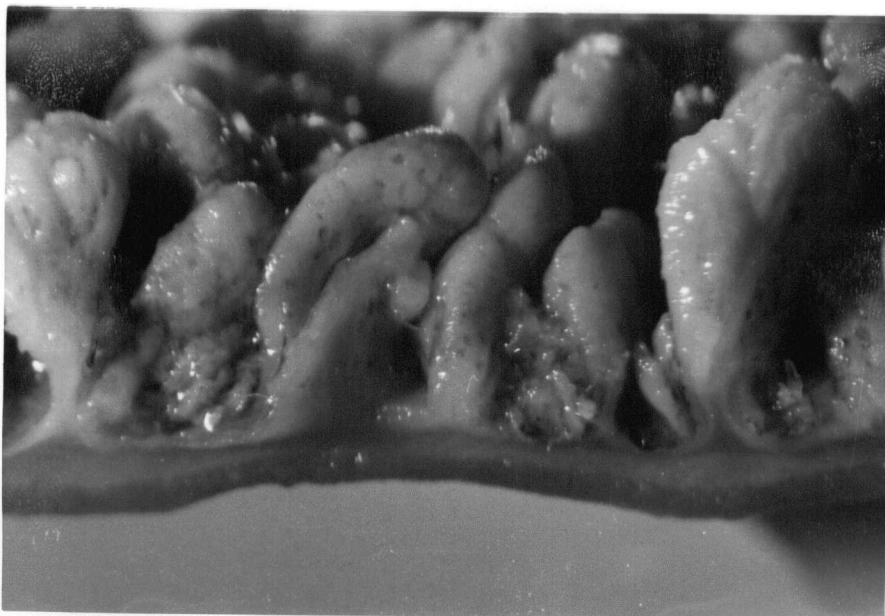
RATION 3

APPENDIX 5

RUMEN LACTIC ACID CONCENTRATIONS

DAY	LACTIC ACID mg%
1	31.7
2	31.8
3	23.1
4	39.7
5	47.1
6	59.6
7	65.2
8	352.9
35	127.6

CONCENTRATIONS ARE THE AVERAGE OF EIGHT SHEEP

APPENDIX 6

RUMEN AMMONIA CONCENTRATIONS

DAY	RUMEN AMMONIA mg%
1	4.2
2	4.9
3	6.0
4	4.5
5	3.2
6	3.3
7	3.3
8	2.6
35	2.0

CONCENTRATIONS ARE THE AVERAGE OF EIGHT SHEEP

APPENDIX 7

RUMEN PROTOZOA NUMBERS

DAY	PROTOZOA NUMBERS/ ml X10^6
1	3.2
2	3.0
3	3.4
4	2.9
5	4.4
6	3.6
7	4.1
8	2.0
35	0.8

CONCENTRATIONS ARE THE AVERAGE OF EIGHT SHEEP

APPENDIX 8

RUMEN pH

DAY	pH
1	7.44
2	7.14
3	6.99
4	6.98
5	6.80
6	6.71
7	6.75
8	6.01
35	5.80

CONCENTRATIONS ARE THE AVERAGE OF EIGHT SHEEP

APPENDIX 9

PLASMA GLUCOSE CONCENTRATIONS

DAY	GLUCOSE mg%
1	37.3
2	42.8
3	41.5
4	41.1
5	42.2
6	53.1
7	49.7
8	52.4
35	43.5

CONCENTRATIONS ARE THE AVERAGE OF EIGHT SHEEP