SODIUM, POTASSIUM INTERRELATIONSHIPS

IN WETHER LAMBS

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Thomas John Devlin

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ABSTRACT

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The effect of a low level of potassium, combined with low, medium and high levels of sodium in the rations of wether lambs was studied. Twelve wether lambs were used in the experiment, six in each of two replicate metabolism trials. A nine day pre-experimental period, during which the sheep received equal amounts of a purified ration, was followed by a thirty day experimental period. During the experimental period intake of the purified ration was equalized and levels of sodium consumed were "low" (4.0 mEq per day), "medium" (44.0 mEq per day) and "high" (129.0 mEq per day) with all sheep receiving 30.5 mEq of potassium daily. The following criteria were used to investigate the sodium requirement of sheep when a low level of potassium was fed: sodium, potassium and nitrogen balance; serum and saliva concentrations of sodium and potassium; dry matter and energy digestibility; water consumption and body weight changes.

Data collected indicate that the level of sodium consumed resulted in a significant difference ($P < .01$) in sodium retained among all treatments. The "low" and "medium" treatments were in cumulative negative sodium balance and the "high" treatment was in cumulative positive sodium balance. The sodium requirement for balance appeared to be near 44.0 mEq daily when 30.5 mEq daily of potassium was consumed.

The digestibility of sodium appeared to be affected by the level of sodium consumed. Feces sodium excretion for the three treatments was "low" 6.93; "medium" 14.43; and "high" 27.77 mEq per day. Sodium intake for the "low" treatment sheep was 4.0 mEq per day and as a result a calculated digestibility value would be less than zero.

Difference in potassium balance was significant ($P < .05$), with the "low" treatment sheep being different than the other treatments. There was no significant difference in potassium digestibility due to wide differences obtained with the "low" treatment sheep.

The nitrogen retained over the 30 day experimental period by the "low" treatment sheep was significantly ($P < .01$) less than amounts retained by the "medium" and "high" treatment sheep. Treatment did not significantly affect digestibility of nitrogen.

No significant difference in serum or saliva concentrations of sodium or potassium were noted over the 30 day experimental period.

Dry matter and energy digestibility varied considerably within treatments but there was no significant difference among treatments.

Sheep in all treatments consumed essentially the same daily volume of water but animals receiving the "low" treatment excreted the most urine, followed by the "medium" treatment, with the "high" treatment sheep excreting the least urine.

During the experimental period the "low" treatment sheep lost weight, the "medium" treatment lost just slightly and the "high" treatment maintained their weight. The differences in body weight changes may be associated with differences in digestible energy intake as well as differences in water retention which occurred among treatments.

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INTRODUCTION

In the body sodium and potassium occur largely in the fluids and soft tissues. They function in maintaining osmotic pressure and acid-base equilibrium, in controlling the passage of nutrients into cells, and in water metabolism. There is a regular dietary need for these two ions, mainly because of limited storage. If an excess of either ion is present it is rapidly excreted under normal conditions. On the other hand the body has some ability to conserve its supply through lessened excretion when the intake is limited. General symptoms resulting from a deficiency of either of these elements are a lack of appetite, a growth decline, loss of weight and reduced production of the adult (growth and milk production) and decreased blood concentrations of the two ions.

The body contains about 0.2 per cent of sodium. About one-quarter (35 per cent in man and dogs (27)) of this amount (29) is localized in the skeleton in an insoluble, rather inert form and the balance is found in the extracellular fluids where it undergoes a very active metabolism. Fifty-five per cent of bone sodium is bound chemically in bone matrix (27). The element makes up 93 per cent of the bases of the blood serum. Sodium is found in very small quantities in blood cells, and in considerable quantities in muscle, where it is associated with contraction. A deficiency lowers the utilization of digested protein and energy and prevents reproduction (20). In laying hens a deficiency generally results in lowered production, loss of weight and cannibalism (7). Sodium salts are readily absorbed and circulate throughout the entire body. Excretion takes place predominately through the kidneys as chlorides and phosphates.

Sodium requirements for growth have been reported ranging from approximately 0.1 per cent to 0.2 per cent of the ration from studies with rats, chicks, pigs and calves.

In contrast to sodium, the potassium of the body exists primarily as a cellular constituent. Potassium plays a vital but little understood role in muscle contraction where its content is six times that of sodium. Potassium deficiency has been produced in several species. In addition to non-specific gross symptoms, heart lesions and tubular degeneration of the kidneys have been observed as well as a lowered content of this element in heart muscle and other organs. The potassium requirement appears to exceed that of sodium and ranges from 0.2 per cent to 0.3 per cent of the dry ration. Potassium is readily absorbed and the excess over body needs is excreted mainly in the urine. At inadequate levels of either sodium or potassium the deficiency symptoms seem to be aggravated by a large excess of the other (7).

When sodium and chloride intakes are at a minimum the body makes adjustments so that the output of these two elements in the urine almost ceases. The same is true for potassium. In contrast, large intakes involve a correspondingly large excretion, and water consumption is increased accordingly. The kidney (29) is the regulating organ, which, through its secretory activity, controls the concentration of electrolytes in the blood.

Anderson (2) states that the amounts of sodium and potassium in blood and tissues are controlled by the hormone aldosterone, produced by the adrenal cortex. In Addison's disease, or adrenal insufficiency, there is a loss of sodium and a retention of potassium by the body. This disease has been treated by feeding a diet high in sodium and low in potassium or by supplying the deficient adrenal hormones.

Farm mammals are usually not harmed by consuming considerably larger amounts of sodium chloride than is generally considered to be adequate. The usual livestock feeds (grains and hays) supply ample potassium, thus eliminating any need for supplemental potassium in normal rations. This being the situation, there has been relatively little work done on sodium and potassium interrelationships and how these may effect sodium requirement, particularly in ruminants. This study was initiated to investigate the sodium requirement of sheep when a diet considered low in potassium is fed.

The following criteria were used to investigate the sodium requirement of sheep when a low level of potassium was fed.

1. Sodium, potassium and nitrogen balance.
2. Serum and saliva concentrations of sodium and potassium.
3. Dry matter and energy digestibility.
4. Water consumption.
5. Body weight change.

REVIEW OF LITERATURE

Sodium and Potassium Requirements

Sheep should be supplied with salt either in the ration or free choice. Various investigators have concluded that the sodium requirement of sheep is in excess of 0.06 per cent of the diet or 0.88 grams per day (McClymont et al (30)).

Meyer et al (32) have shown in pigs that the ratio of sodium to chloride retained in animals making optimum growth was 1:1.42 and 1:1.54 respectively, suggesting that salt supplies sodium and chloride in about the right proportions for growing pigs. These workers also showed that a salt deficiency was no more severe than a sodium deficiency, and also with a severe sodium deficiency there was a significant rise in plasma potassium.

Experiments by Burns et al (8) indicated that either sodium or potassium is toxic to chicks if one of the elements is fed in insufficient quantities. As the potassium level in the ration was raised for chicks receiving a high level of sodium, mortality was reduced. Similarly, at the highest level of potassium fed (0.77 per cent) the low level of sodium (0.019 per cent) was insufficient to prevent death. Studies with whole blood and plasma, when various levels of sodium and potassium were fed, showed an increase in sodium level of plasma and whole blood in proportion to increasing dietary sodium. Increasing dietary sodium at any one level of potassium appeared to decrease the level of plasma potassium. At any level of dietary sodium higher than 0.02 per cent, increasing dietary potassium increased the level of plasma sodium. The level of potassium appeared to have no effect on the sodium requirement provided it was not a limiting factor.

Other work by Burns et al (7) on the salt requirement of breeding hens showed there was a greater reduction in egg production resulting from omitting sodium alone from the diet, than from salt omission. These workers suggested an ion imbalance in which a diet deficient in sodium is equivalent to one deficient in salt to which chloride was added, and that chloride exerts a toxic effect when supplied in excess of sodium. When sodium was added to the diet, the effect of the salt deficiency on egg production disappeared. The authors state that since excretion of chloride must be accompanied by cations, and sodium by anions, it is possible that anions other than chloride (e.g. bicarbonate) can be mobilized to accompany the excretion of sodium. However, the excretion of a relatively high amount of chloride may aggravate a sodium deficiency by drawing upon the limited amount of sodium available, if not on other essential cations. The alternative would be a positive chloride balance with the possible consequence of acidosis. The chief effect of salt restriction was lowered egg production and a slight decrease in body weight.

Grunert et al (21) found the sodium requirement of the rat to be 0.05 per cent when 0.25 per cent potassium was present in the diet. They observed an increased requirement for sodium when potassium was increased to 0.5 per cent. The requirement for potassium was not constant and decreased over a six-week period from 0.10 per cent to 0.09 per cent in the presence of 0.1 per cent sodium. The effect of high sodium (1.0 per cent), which was only evident initially, was to lower the requirement for potassium. It appeared that high levels of sodium had a slight sparing action on potassium requirement, but high potassium was antagonistic and tended to increase the sodium requirement. The data of Grunert et al (21) indicated that sodium could replace potassium to a slight extent, at least initially, and that potassium could not replace sodium, but was antagonistic to this ion when the latter was limiting. These results do not agree with those of Miller (37) who found that growth of rats could be greatly retarded by reducing the potassium content below approximately 0.1 per cent. He found that substituting sodium for potassium failed to produce normal growth in rats.

Aines and Smith (1) observed in salt deficient dairy cows that sodium and not chloride ions were of theraputic value. When salt was fed to these deficient cows an increase in milk production, body weight and roughage consumption occurred. When sodium bicarbonate was fed similar results were observed. Feeding magnesium chloride failed to ameliorate the above symptoms. Plasma sodium levels were not significantly affected by the various treatments, although there was some elevation associated with sodium salt therapy and a continual decline in cows given magnesium chloride. Blood and plasma levels of potassium were not significantly affected by any of the treatments.

Effects of High and Low Sodium Levels in the Ration

McClymont et al (30) reported that the addition of 0.25 per cent salt to a fattening ration for sheep resulted in a growth stimulation with responses of 19 to 58 per cent over controls. Basal rations containing from 0.009 to 0.062 per cent of sodium did not seem to affect serum sodium levels. However, with extended periods of low sodium consumption the blood potassium levels tended to increase. A further imbalance in the dietary sodium to potassium ratio was caused by the addition of potassium bicarbonate and created a circulatory deficiency of sodium and severe dehydration. The authors concluded that farm animals require salt to overcome the antagonistic effect on sodium metabolism of high potassium contents of animal feeds.

Nelson et al (38) observed that feeding high salt (6.0 per cent of total ration) rations to steers resulted in a small but significant increase in the retention of sodium and chloride. Similar results were found for wether lambs on a high salt intake (50 grams per day). Of the ingested sodium chloride, 87 per cent of the sodium in steers and 94 per cent in wethers was excreted in the urine along with 98 per cent of the chlorides in both species. The animals on the high salt diets excreted more nitrogen and all the animals were in positive nitrogen balance.

Fattening sheep and cattle have been fed salt ranging from 0.66 to 12.8 per cent of the ration with no detrimental effects (Meyer et al (36)). These levels had no detectable influence on nitrogen digestibility, nitrogen retention or total digestible nutrients of the basal ration. A salt intake of 9.4 per cent or 1.7 pounds daily by steers had no detrimental influence on average daily gains or feed efficiency. Kidney weights increased when the salt level was 9.4 to 12.8 per cent and the authors reported no pathological symptoms.

The effects of sodium chloride added to water, when supplied to heifers, has been observed by Weeth et al (42) and (43). The addition of one per cent salt in the water caused an increase in water consumption up to 52.8 per cent, which otherwise was not harmful over a 30 day period. The safe tolerance appeared near 1.25 per cent. At the 1.50 per cent level the heifers maintained their body weight; but on 1.75 and 2.0 per cent they lost weight and toxic symptoms appeared. Anorexia, anhydremia, depressed rectal temperature and dryness of the skin and feces were the principle symptoms observed. The symptoms of salt water toxicity resembled those of simple dehydration. Blood serum sodium was raised significantly within ten days and serum potassium tended to rise.

The previous authors have examined the effects of high and low sodium levels in the ration whereas Hubbert et al (25) utilized washed suspensions of rumen microorganisms in studying the requirement of rumen microflora for sodium and potassium. They found the presence of potassium in the fermentation medium was essential for in vitro cellulose digestion whereas sodium had no effect on cellulose digestion when potassium was absent. Interrelationships of varying concentrations showed that the addition of sodium to a fermentation medium containing 50 micrograms or less of potassium per milliliter either depressed or had no influence on cellulose digestion. However, when the potassium concentration was from 100 to 400 micrograms per milliliter, the addition of sodium increased cellulose digestion. Chloride was not found to be a limiting factor in these studies. Cardon (10) using artificial rumen techniques observed that increased salt concentration in the rumen, caused by feeding high salt rations, did not cause a decrease in rumen microbial activity. Digestible cellulose as well as digestible energy was not altered by the increased consumption of salt.

Effects of High and Low Potassium Levels in the Ration

Daniel et al (14) fed high levels of potassium (4.2 per cent added potassium chloride) to ewes and observed no significant effect on the number of lambs dropped, weight of lambs at birth and at sixty days, and physiological state of the ewes as indicated by plasma levels of potassium, sodium, calcium, magnesium and phosphorus. Kunkel et al (27) reported that sodium, potassium, calcium and total protein content of the serum of sheep were not markedly altered by the ingestion of potassium bicarbonate at 5.0 per cent level. However, the inclusion of potassium decreased feed intake and weight gains. Deprivation of salt or limited water appeared to accentuate the decrease in rate of gain.

Curme et al (13) fed "high" and "normal" potassium hays, (2.73 and 1.31 per cent potassium, respectively) both with and without added potassium chloride to make the potassium intake equivalent to 4.0 per cent of the ration to sheep. Balance studies resulted in statistically significant increases in the actual and per cent retention of potassium due to feeding high potassium hay, and also to feeding supplementary potassium chloride over normal hay alone.

Fontenot et al (20) reported the effect of high protein, high potassium levels on 70 pound wether lambs. The normal ration contained 12.8 per cent protein and 1.44 per cent potassium, and the high ration 34.4 per cent protein and 4.7 per cent potassium. They observed no difference in concentration of either sodium or potassium in the plasma as a result of feeding large amounts of protein and potassium.

Black and Milne (5) have examined the effect of a potassium deficiency in man. A diet containing less than 10 mEq of potassium per day was fed to two normal men for six and seven days after control periods. Potassium deficits during this potassium depletion period totalled 268 and 289 mEq. In addition, serum potassium levels fell and there was a parallel rise in serum bicarbonate. A retention of sodium occurred during potassium depletion and there was an increase in volume of extracellular fluids at the expense of intracellular fluids.

Blahd and Basset (6) conducted a prolonged metabolic study (17 five day periods) on a healthy 35 year old man. For two periods of five days each he consumed a normal diet containing 91 mEq of potassium and 138 mEq of sodium. He was then changed to a diet containing 14 mEq of potassium and 92 mEq of sodium, for 11 five day periods. Then, for two five day periods potassium intake was increased to 86 mEq daily by supplementing with potassium citrate. The study terminated after two five day periods on normal potassium diets. Following the start of the low potassium diet a negative potassium balance developed. Over the first 15 days, urinary potassium fell to a level which continued unchanged throughout the rest of the low potassium period. Despite maximum renal conservation a negative potassium balance of from one to thirteen mEq per day continued during periods four to eleven. Cumulative potassium loss for 55 days was 278 mEq. Serum potassium fell from four to three mEq per liter. During the period of potassium loss there was a net retention of sodium and chloride totalling 1102 and 64 mEq, respectively. When potassium was restored to normal levels a retention of 273 mEq occurred. No clinical alterations were observed, body weight was maintained and from nitrogen balance studies there was no evidence of aberrant protein metabolism. The authors state that although no clinical symptoms occurred during potassium deprivation, certain significant changes occurred in the distribution of body fluid. The actual amount of potassium lost before the supplement was administered would correspond to the release of two to three liters of intracellular water. However, no significant loss of weight was observed. There was, instead, a considerable retention of salt, suggesting that intracellular fluid was moving into the extracellular compartment. In conformity with this redistribution of body fluid, a 12 per cent decline in the hematocrit occurred. With potassium supplementation readjustment of electrolytes and fluids were observed for several days. The authors propose that the potassium reentered the depleted body cells, threatening the isotonicity of the extracellular fluid and as a consequence the sodium and chloride previously retained were excreted. After potassium supplementation storage occurred. However, these potassium stores were dissipated within a subsequent five day period. Consequently, a compensatory sodium, chloride and water retention developed to counteract the mild dehydration following the saline diuresis. The authors (Blahd and Bassett (6)) interpret these data as evidence of a definite loss of potassium from the body cells without reason to suspect it was replaced by sodium.

Effects of High Water Intakes

DeWardener and Hexheimer (16) observed the effect of high water intake on salt consumption and salivary secretion in man. The authors experimented with men over a 22 day period. During the first five day period water intake was normal. Water intake during the next 12 days (second period) was 10 to 12 liters per 24 hours. During the third or post experimental period the patients were deprived of water for 26 hours and then allowed normal water consumption for four days. One man was in sodium equilibrium during the control period but during the second period developed a substantial negative sodium balance which persisted to the end of the third period. The second man was in slight negative sodium balance during the control period and during the second period the cumulative sodium balance gradually reached equilibrium. In the third period the balance was slightly negative. Subject one had a salivary Na:K ratio always below 1.1 and it fell to its lowest level when sodium equilibrium was being restored. The concentration of sodium in the saliva was quite different in the two subjects but both were within the normal range. The potassium concentrations differed less and were also considered normal. The salivary Na:K ratio was higher in subject one when allowances were made for different rates of flow. The Na:K ratio increased with rate of flow. This paper indicates the Na:K ratio continues to increase at higher rates (over three milliliters per minute) of flow. The authors conclude that the difference in Na:K ratios may be due to differences in aldosterone secretion--if it is related to sodium balance.

Starvation and water deprivation in sheep have been examined by

Meyer et al (35). Four crossbred wethers were used in an experiment, two were fed a basal ration (0.5 per cent NaCl) and two were fed the basal plus 11.0 per cent sodium chloride. During a preliminary period of 35 days the sheep were fed their respective rations. After 36 hours of shrink, ad libitum water consumption returned to normal only after feed was offered. The amount of urine excreted by the high salt sheep during the preliminary period was much greater than was excreted by sheep on the basal ration. During the shrink period the rate of urine excretion of the high salt sheep decreased rapidly and at 36 hours was reduced to the excretion rate of the sheep receiving the basal ration. The excretion rate remained the same during the nine hour period when the sheep were offered water only. When both groups were offered food and water the amount of urine excreted by the high salt sheep rose to a very high level. Urinary chloride excretion followed very closely to that of the total urine excreted. After shrinking for 36 hours the amount of chloride excreted by the high salt sheep decreased to about the same as that excreted by sheep on the basal ration. The pattern of sodium excretion was similar to chloride excretion. Potassium excretion in urine dropped to a very low level as shrink progressed. There were no differences in patterns of potassium excretion by sheep receiving the two rations, however, a larger amount of potassium was excreted by sheep on the high salt ration during the preliminary and recovery periods than sheep receiving the basal diet. Nitrogen excretion dropped in the low salt sheep during the shrink period but it did not drop to the same extent as in the high salt sheep. The sheep on the basal ration retained a larger amount of potassium during the pre-shrink and post shrink period than the high salt sheep. The greatest weight loss occurred with the high salt sheep and the largest nitrogen loss occurred with the basal ration sheep due to the large nitrogen urinary loss (tissue breakdown). The authors stated that when sheep fed a high salt ration are shrunk a large part of the weight loss is probably loss of extracellular fluid. In the case of sheep receiving the basal diet the weight loss during shrink is probably loss of intracellular fluid. Negative potassium balances were observed with both groups during shrink.

Hix et al (23) reported experiments with sheep dealing with extracellular water and dehydration. Extracellular water consists of water of the blood plasma and the interstitial fluid, including the lymph. The great speed of exchange between plasma and extravascular fluid is indicated by the fact that as measured with D_2O, 73 per cent of the water (Flexner et al (19)) and 60 per cent of the sodium (Merrell et al (31)) is exchanged with extravascular fluid every minute. In one experiment 50 lambs were divided into four lots and received a ration of corn and alfalfa hay for 96 days. Lot one also received 32.3 grams of potassium bicarbonate adjusting the Na:K ratio to 1:82. Lot two received 30.3 grams of sodium bicarbonate adjusting the Na:K ratio to 1:2. Lot three received salt ad libitum (average daily consumption of 21 grams), adjusting the Na:K ratio to 1:2. Lot four received the basal ration only and showed a Na:K ratio of 1:45. After the feeding period three wethers from each lot were placed in metabolism cages for 21 days to determine mineral balances and ration digestibility. On the last day of the balance study the Na:K ratios in lots two and four were changed to 1:82 (formerly 1:2) and 1:2 (formerly 1:45), respectively, for antagonism and sodium retention studies and continued for seven days. In a second experiment one lot received a basal ration plus salt ad libitum and a second lot received the basal only for 94 days. Three lambs from each group were selected and continued on their respective diets with the exception that lambs from lot one then received 20 grams of sodium chloride per head daily. Sodium retention studies (Experiment I, Lot 4) showed that on administering 21 grams of sodium chloride (equal to 8.34 grams of sodium) daily for seven days to lambs that previously received a diet deficient in sodium, only 37 per cent of the sodium intake was excreted within 12 hours; 39 per cent of the sodium intake within 24 hours and after 36 hours 112 per cent of the sodium intake was excreted. Between the second and seventh day there was a steadily decreasing retention of sodium. This general trend of exceptionally high sodium retention followed by a negative sodium balance 36 to 48 hours after continuous administration of sodium chloride had been observed repeatedly. This phenomenon was explained by a rapid expansion of extracellular fluid volume in the early sodium retention stage due to rapid transfer of intracellular water to the extracellular compartment, which was followed by an abrupt check in expansion as demonstrated by a negative sodium balance. The renal excretion of sodium was increased in an endeavor to establish a normal balance in body fluids. As long as sodium chloride administration continued the sheep remained mildly hydrated. The authors state that it is tempting on this and other evidence to suggest that sodium chloride intoxication is enhanced when the dehydrated sodium deficient lambs are fed salt. Already dehydrated the ingested salt may result in further cellular dehydration and rapid expansion of extracellular fluid volume, creating a thirst drive which could not be immediately satisfied because of the loss of all sense of physiologic balance. The deprivation of supplementary salt (Experiment II, Lot 2) to lambs on a fattening ration results in a loss of body fluids. More obvious was the higher degree of dehydration caused by feeding potassium bicarbonate to lambs with very little or no reserve sodium (Experiment II, Lot 2) as compared to those with an apparent store of sodium (Experiment II, Lot 1). The administration of sodium chloride to a lamb (Experiment II, Lot 2) deprived of supplemental salt for approximately seven months hydrated the animal with an increase in extracellular water of about 14 per cent. The quantitative extent of the negative sodium balance (Experiment I, Lot 2) for the seven day period for three lambs was quite similar (approximately 1.4 grams of sodium). However, the initial response of these lambs was quite different to the potassium bicarbonate as evidenced by the excretion of 874 per cent of the dietary sodium intake within twelve hours by one animal; 592 per cent by a second and 267 per cent by a third. Sodium chloride and sodium bicarbonate are hydrating while potassium bicarbonate is dehydrating to lambs. Hix et al (23) conclude that dehydration due to high dietary potassium intake is produced by a resulting sodium diuresis which may be continuous or transitory. Administration of sodium chloride to lambs deficient in sodium expands the extracellular fluid volume rapidly and provides for the storage of sodium, much of which is exchangeable, and may in metabolic emergencies contribute to maintenance of the normal extracellular fluid volume. Sodium chloride supplementation to lambs (20 grams daily) hydrates the extracellular fluids to increase body weight by 3 per cent as compared with unsupplemented lambs. The superior gains of salt supplemented lambs appears to be due to retention of water as a result of hydration.

Denton (15) has studied saliva levels in sheep using a parotid fistula. The sheep secreted three liters of alkaline saliva per day. The sodium concentration was approximately 180 mEq per liter and the potassium concentration 10 mEq per liter, (Na:K ratio 18). With a normal diet and adequate replacement of sodium, the sheep remained in good condition indefinitely. If sodium replacement was withheld the animal became grossly depleted of sodium, and the saliva volume decreased by approximately one liter per day. In addition, the saliva sodium concentration decreased to 60 mEq per liter and potassium concentrations increased to 120 mEq per liter, (Na:K ratio 0.5). There was a commensurate relationship between the amount of sodium depletion and the Na:K ratio of the parotid saliva. During very large intakes of sodium, the Na:K ratio of the saliva rose again.

<u>Sodium and Potassium in Abnormal Individuals</u>

Cannon <u>et al</u> (9) have shown that manifestations of the potassium deficiency syndrome are related to the presence of relatively large amounts of sodium as much as they are to potassium deficits. Experiments have shown that myocardial lesions in rats will develop in the presence of potassium depletion. These, however, may be insignificant if sodium is also depleted, but in the presence of added sodium in potassium deficient animals, such lesions become more severe and possibly even lethal. It has also been noted that the severity of myocardial fibre necrosis in potassium deficient animals is influenced by acid-base balance and adrenocortical hormones as well as by sodium intake.

Laragh (28) has experimented with potassium administrations to patients having low blood sodium levels. It is believed that patients with edema and hyponatremia (low blood serum sodium levels) may have exchanged some potassium for sodium in their cells thus reducing extracellular sodium. The author has studied the oral administration of potassium chloride to six patients with hyponatremia. This treatment did not induce either water or sodium diuresis. Serum sodium increases were often striking and serum potassium levels also rose. Some of the potassium administered may have been exchanged for sodium in the cells, releasing sodium which was not excreted but served to increase the serum sodium concentration and correct the hyponatremia.

EXPERIMENTAL PROCEDURE

Twelve wether lambs were used in the experiment, six in each of two replicate metabolism trials. They ranged in weight from 62 to 75 pounds and were maintained in metabolism cages for the duration of each trial. There were two sheep per treatment in each trial or a total of four sheep per treatment. Prior to receiving the various experimental rations the animals were adjusted to the metabolism cages and fed a purified diet over a 14 day period. The adjustment period was followed by a nine day pre-experimental period during which all animals were offered the same quantity of purified ration. The daily sodium and potassium intakes of each animal were 142 and 122 mEq, respectively, during this period. A 30 day experimental period followed, during which all animals in each trial received the same basal ration, but the sodium and potassium intakes were changed. As difficulty was encountered during the first trial in maintaining feed consumption of some sheep, the level of cellulose in the second trial was reduced from 175 to 150 grams per feeding. The potassium intake of each sheep during the 30 day trials was 30.5 mEq daily, and the different levels of sodium fed were 4.0, 44.0 and 129.0 mEq daily. These levels of sodium are designated for future reference in the text as "low", "medium" and "high", respectively.

The basal ration used in this experiment is shown in Table I. Because of the tendency of ration ingredients to separate, the sucrose, corn starch and casein were mixed together and weighed out at each feeding. Likewise, the cellulose and mineral mixture were weighed separately and fed. This enabled closer control of nutrient intake and where an animal appeared to be reducing its feed intake the level of cellulose was reduced in order to ensure a constant intake of nitrogen, sodium and potassium. During the pre-experimental period the sodium was supplied as sodium chloride (eight grams daily) and the potassium as potassium carbonate. During the experimental period the various quantities of sodium were supplied as sodium carbonate and potassium supplied in the same form as before. The chloride intake during the experimental period was 3.4 mEq per day and determined by the gravimetric method as described by the A.O.A.C. (3).

TABLE I

BASAL RATION

INGREDIENT	PER CENT OF RATION
Solka-floc (cellulose)	35.0
Corn Starch	25.0
Sucrose	25.0
Casein	10.0
Mineral Mix*	5.0

*The mineral mix contained the following (expressed in grams per pound): $CaCO_3$, 177.06; $CaHPO_4$, 222.75; $MgSO_4$, 49.0; $FeSO_4$, 4.13; $MnSO_4$, 0.45; $CuSO_4$, 0.09; KI, 0.14; $ZnSO_4$, 0.32; $CoCl_2$, 0.0014; MoO_3, 0.0036; and vitamins A and D to supply 2000 I.U. and 500 I. U., respectively, per day. In addition, potassium as K_2CO_3 and sodium as Na_2CO_3 were added at levels to supply 30.5 mEq per day of potassium and 4.0, 44.0 and 129.0 mEq daily of sodium during the experimental period.

During the pre-experimental and experimental periods feed and water consumption, urine and feces excretions and change in body weight were recorded. In addition, saliva and blood samples were collected at various times (0 and 9 days of the pre-experimental period for both trials, and 0, 15 and 30 and 0, 25 and 30, respectively, for the first and second trials of the experimental period).

The feed was weighed into the feeders each morning and evening. Where consumption was a problem, as mentioned earlier, the quantity of cellulose was reduced in order to maintain a constant intake of the other nutrients. Water was available at all times and daily consumption was recorded.

The feces excreted were collected seperately from the urine and weighed daily. Three consecutive daily fecal samples were combined, and retained for analysis. Urine was collected by means of a rubber urinal which drained into a glass collection jar. These urinals were constructed of rubber inner tubes with a 5/16 inch rubber hose leading from the urinal to a glass jar located under the metabolism crate. The urinals were attached by tying them to a harness which had been fitted to each sheep. The urine was collected under toluene and the total quantity excreted during each three day period was recorded and a sample was retained and frozen for later analysis.

Saliva samples were taken twice during the pre-experimental and three times during the experimental period. The samples were obtained by allowing the sheep to chew on a weighed piece of sponge until it became thoroughly moistened. The sponge was then removed and reweighed, and the quantity of saliva calculated by difference. The sponge and saliva samples were put into polyethylene bags and frozen for later analysis.

Blood was collected twice during the pre-experimental and three times during the experimental period. The samples were centrifuged at 2000 r.p.m. for 20 minutes and the serum retained for analysis.

Individual animal body weights were recorded at the beginning and end of the experimental period.

<u>Analytical Methods</u>

Total nitrogen was determined in feed, feces and urine samples using the Kjeldahl method described by the A.O.A.C. (3).

For determination of nitrogen in the urine, 10 milliliters were diluted with water to a volume of 50 milliliters, and nitrogen determined on 10 milliliters of the resulting solution. The specific gravity of urine was taken as 1.030.

Fecal nitrogen was determined by homogenizing 50 grams of fresh feces in a Waring Blender with 500 milliliters of an acid-water solution (20 mls. of concentrated HCl and 480 mls. of distilled water). Twenty-five milliliters of the homogenate were used for the nitrogen determination. A further sample of the homogenized feces was retained for sodium and potassium determinations.

The feed, feces, urine, serum and saliva samples were analyzed for sodium and potassium by flame photometry, using an internal standard method as described by Berry <u>et al</u> (4). An "Advanced Flame Photometer" was used in which lithium at a concentration of 300 ppm. was utilized as the internal standard.

For sodium and potassium analyses the homogenized feces was digested in micro Kjeldahl flasks. The volume of homogenate digested depended on treatment, but generally, 20 milliliters were required for the "high" and "medium" levels of sodium and 40 milliliters were required for the "low" sodium level. The organic matter was partially digested using nitric acid and then, six milliliters of perchloric acid was added and the heat increased to complete the oxidation of organic matter and drive off the nitric acid. Fifteen milliliters of deionized water was then added to the Kjeldahl flasks and the digest filtered through Whatman #40 filter paper and made to volume, generally, 100 milliliters for the "high" sodium treatment, 50 milliliters for the "medium" sodium treatment and 25 milliliters for the "low" sodium treatment. If a reading could not be obtained with these dilutions a further dilution was made.

It was found with the "low" sodium samples that duplicate flame photometer readings would vary considerably. It was thought that the concentration of acid in the final dilution was too high and this was partially responsible for the variation in readings. Subsequently, the "low" sodium digestions were done using 1.5 milliliters of perchloric acid and little trouble was experienced thereafter.

For sodium and potassium analyses of urine and blood serum, the samples were diluted, according to the approximate concentration of the two ions, with deionized water and analyzed directly in the flame photometer. The saliva was analyzed in a similar manner. However, prior to analysis, the saliva was extracted from the sponge by placing it in a polyethylene bag with 25 milliliters of deionized water. The sponge was kneaded for two minutes to obtain equilibrium between the water and saliva and an aliquot of the equilibrated solution was diluted and analyzed.

Dry matter of feed and feces was determined by the oven drying method described by the A.O.A.C. (3). Dry matter digestibility of the rations was determined by the total collection method for two separate periods (one seven day and one six day), in each of the two trials. A wide range in digestibility was obtained in the first seven day period (days 16 to 22) and a subsequent six day period (days 23 to 28) was investigated. The two values were pooled and an average value is presented for each sheep. In addition, the dried feed and feces samples were combusted in a Parr Adiabatic Oxygen Bomb Calorimeter according to the method of Parr Manual No. 130, and the digestible energy of each ration was determined.

Statistical methods used were analysis of variance as described by Snedecor, (41), and Duncan's multiple range test (Federer (18)).

RESULTS AND DISCUSSION

Some feed was wasted through spillage during the adjustment period. To prevent this wooden stanchions were installed between the metabolism cage and removeable feeders. This restricted the animals movement in the cages while feeding and corrected the problem to a large degree.

During the pre-experimental period of the first trial the sheep received 200 grams of the sugar, starch and casein mixture plus 175 grams of cellulose per feeding. A feed consumption problem was encountered with one sheep, and as a result the concentrate was reduced to 170 grams per feeding during the subsequent experimental period. A consumption problem was still encountered during the experimental period with five sheep (sheep numbers 1, 3, 4, 5 and 6). Consequently, during both the pre-experimental and experimental periods of the second trial the cellulose was reduced to 150 grams per feeding. A feed consumption problem was also encountered in the second trial, but to a lesser degree. Sheep numbers one and six, ("low" treatment), sheep number two ("high" treatment), and sheep number three ("medium" treatment) all required reductions in the level of cellulose fed in order to maintain concentrate consumption over the 30 day experimental period.

Pre-experimental Period

Original data for the pre-experimental and experimental periods are presented in the Appendix I, Tables XIV, XV and XVI. Sodium, potassium and nitrogen balances for the pre-experimental period are presented in Table V. During this period eight sheep were in positive nitrogen balance, three were in positive sodium balance and twelve were in positive potassium balance. The remaining sheep showed negative balances for nitrogen and sodium. The average daily balances ranged from -1.29 to +2.14 grams per day for nitrogen, -48.41 to +28.10 mEq per day for sodium and +9.83 to +47.91 mEq per day for potassium.

As all twelve sheep were receiving relatively high levels of sodium (142 mEq per day) and potassium (122 mEq per day) during this period the reason for negative balances is somewhat obscure. The length of time of adjustment period, coupled with initiation of feeding a purified ration, and the added stress of being placed in metabolism cages are possible explanations. The level of feed intake prior to the pre-experimental period was extremely variable, and in most cases quite low, which meant that the intake of sodium, potassium and nitrogen during this period was also variable. There was no information as to physiological condition of the sheep prior to being used for this experiment, which may have contributed to the negative balances observed with sodium and nitrogen. Some hay, which was fed during the adjustment period to promote eating, might be the reason for the positive potassium balances in all sheep. Hay, being relatively high in potassium, would have enabled the animals to be in positive potassium balance at the initiation of the pre-experimental period. At the same time some of the sheep may have been in negative nitrogen and sodium balance at the beginning of the pre-experimental period. This negative sodium balance could also have been the result of sodium-potassium antagonism resulting from a wide sodium-potassium ratio, which may have increased potassium retention and at the same time increased sodium excretion with the sheep unable to overcome this negative balance during the nine day period. This is partially substantiated by the work of Grunert et al (21) with rats and Hix et al (23) with sheep. They found that high potassium levels (wide sodium-potassium ratio) were antagonistic, and tended to increase the sodium requirement.

Digestibility values (Table IV) calculated for sodium were 88.1, 85.6 and 79.0 per cent; for potassium 80.3, 88.7 and 85.7 per cent and for nitrogen 55.2, 56.2 and 54.4 per cent, respectively, for the "low", "medium" and "high" treatments. There were no statistical differences in treatment effect for digestibility of sodium, potassium or nitrogen. However, a period effect was noted with potassium digestibility which was significant at the five per cent level. This probably resulted from age differences of the wethers. These values for sodium and potassium are not quantitative since no values were known for the quantity of these ions supplied from saliva or by constant ion exchange through the rumen. They do, however, give an indication of the amount of sodium and potassium digested by sheep relative to the amounts fed. Likewise, the digestibility values presented for nitrogen are apparent and not true values.

The excretion of sodium, potassium and nitrogen in urine and feces on an average daily basis during the pre-experimental period is shown in Table V. The sheep designated "low" excreted slightly more sodium in the urine and less in the feces than the "medium" and "high" sheep. Values obtained for sodium were 151.71, 133.37 and 134.43 mEq per day in urine for the "low", "medium" and "high" sheep, respectively, and 16.87, 20.64

and 29.77 mEq per day in feces for the same three treatments. Total average daily excretions for the "low", "medium" and "high" treatments were 168.58, 154.01 and 164.20 mEq of sodium, respectively. Sodium intake during the nine day pre-experimental period was 142 mEq per day, and consequently, the sheep showed overall negative sodium balance. The possible reasons for these negative balances have been mentioned previously. Values obtained for potassium excretion via urine reveal a similarity in output for all sheep. The feces potassium excretion by sheep to be designated "low" was slightly higher than the "medium" and "high" treatment. Urinary potassium excretion for the "low", "medium" and "high" treatments was 72.33, 72.92 and 67.89 mEq per day, respectively, while feces values were 23.68, 13.77 and 17.42 mEq per day, respectively, for the same three treatments. Total daily output was 96.01, 85.79 and 85.31 mEq, respectively, for the "low", "medium" and "high" treatments.

Average daily nitrogen excretions for the "low", "medium" and "high" treatments were 4.06, 4.62 and 5.09 grams, respectively, for urine, and 4.23, 4.08 and 4.37 grams, respectively, for feces. The totals were 8.29, 8.70 and 9.46 grams, respectively.

Average serum values during this period for the "low", "medium" and "high" designated sheep were 140.2, 141.7 and 139.2 mEq per liter for sodium and for potassium 4.62, 4.93 and 5.04 mEq per liter, respectively.

The variation in saliva concentration of sodium and potassium among sheep during the pre-experimental period was relatively large. However, average values for the "low", "medium" and "high" sheep were 103.36, 110.14 and 121.40 mEq per liter for sodium and 18.21, 16.44 and 26.14 mEq per liter, respectively, for potassium.

Average total water consumption in each of the three groups was quite similar over the nine day period, being 13.71, 12.65 and 12.65 liters, respectively, for the "low", "medium" and "high" designated sheep. Likewise, average total urine excretion was similar (6.57, 5.72 and 5.02 liters, respectively, for the three treatments).

Experimental Period

The average daily excretion of sodium, potassium and nitrogen during the experimental period is presented in Table V. Since there was a wide variation in average three day balance values the data are also reported as cumulative three day values throughout the 30 day period (Figure 1). It was felt cumulative balances would give a clearer indication of the balance state of the animal over a time period and trends could be more clearly delineated. Cumulative balances were calculated by adding or subtracting, as the case may be, progressive average three day balances. The value obtained at any period throughout the trial is total balance (total intake-total output) up to that period.

Sodium Balance

Both cumulative and three day sodium balances are shown in Figure 1. The "low" treatment sheep were in negative cumulative balance which showed decreasing sodium retention throughout the 30 day period. The "medium" treatment sheep were in slight negative cumulative balance, which became less negative as the period progressed. Sheep receiving the "high" treatment were in positive cumulative balance which increased throughout the 30 days.

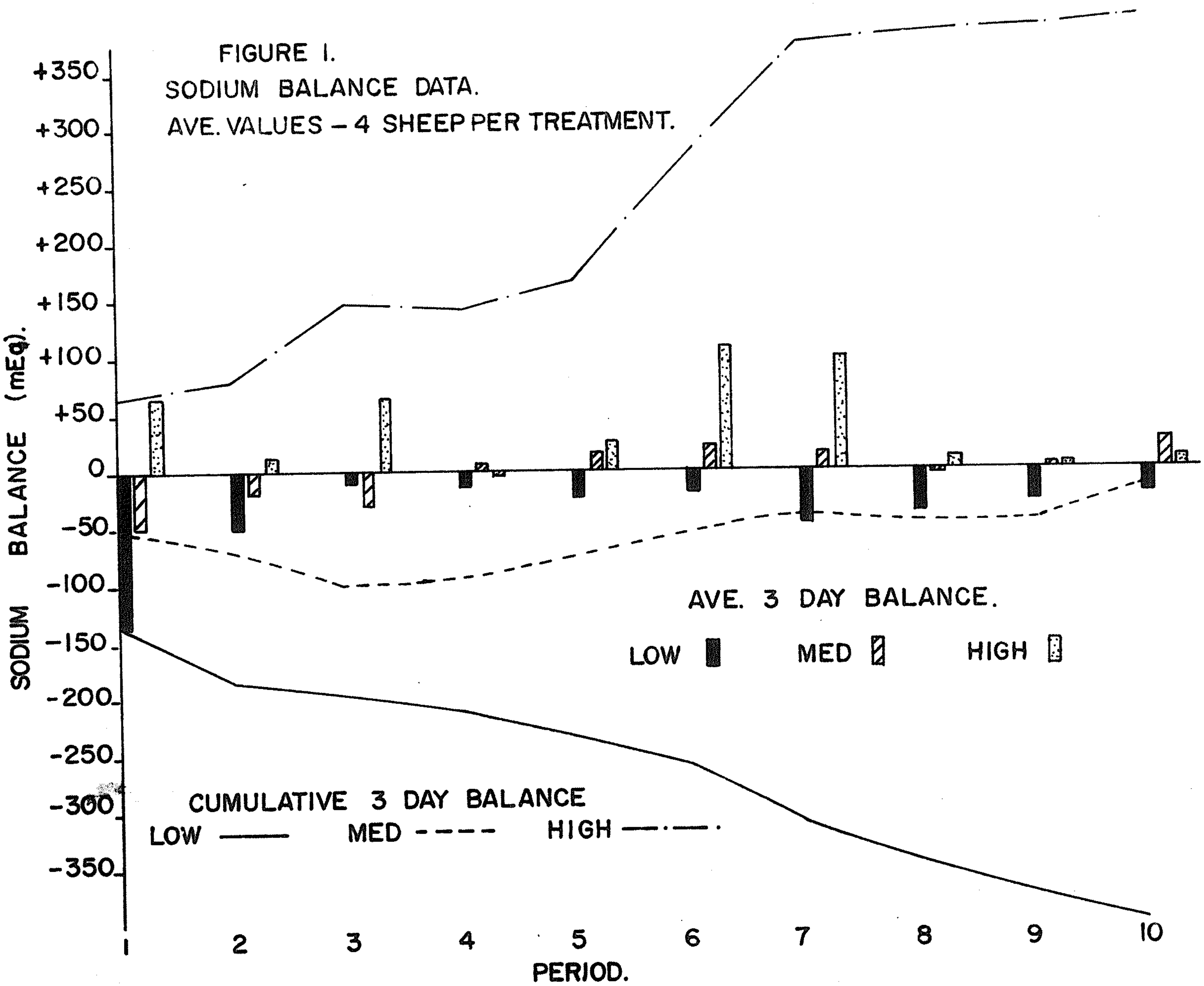

FIGURE I.
SODIUM BALANCE DATA.
AVE. VALUES – 4 SHEEP PER TREATMENT.

Statistical analysis of sodium balance is presented in Table II. Difference between treatments was significant ($P < .01$) and a comparison of treatment means (Table III) showed a significant difference ($P < .01$) between all three treatments. There was also a significant ($P < .01$) interaction (the interacting being period times level) indicating that treatment effect varied among sheep between periods.

Using total cumulative balance values for individual sheep and calculating average daily balance, all four sheep on the "low" treatment were in negative sodium balance; two of four sheep on the "medium" treatment were in positive sodium balance and all sheep on the "high treatment were in positive sodium balance. The range in average daily balance was as follows: "low" -19.87 to -6.75 mEq per day; "medium" -3.90 to +3.17 mEq per day; and "high" + 1.19 to +24.22 mEq per day.

Digestibility of sodium (Table IV) was calculated using the average excretion for four sheep on each treatment. The "low" treatment group excreted more sodium via the feces than they consumed so no value could be obtained. For the "medium" treatment the value was 67.2 per cent and the "high" treatment value was 78.5 per cent. Thus, feces sodium excretion appeared to be affected by the level of sodium fed.

The average daily sodium excretion (Table V) in both urine and feces was lowest in the "low" treatment sheep and then increased as sodium consumption increased. Urine values for the "low", "medium" and "high" treatments were 10.95, 30.86 and 88.97 mEq per day, respectively. Feces excretion for the three treatments were "low" 6.93; "medium" 14.43; and "high" 27.77 mEq per day. The total daily excretion in both urine

TABLE II

ANALYSIS OF VARIANCE FOR SODIUM BALANCE

Source of Variation	d/f	Sum of Squares	Mean Square	Calculated F Value
Levels	2	1258050.53	629025.26	50.64**
Periods	1	2519.52	2519.52	0.20
L x P	2	329612.71	164806.35	13.27**
Error	6	74522.70	12420.45	
Total	11	1664705.46		

**($P < .01$)

TABLE III

DUNCAN'S COMPARISON OF MEANS FOR SODIUM BALANCE (1% LEVEL)

Treatment	"Low"	"Medium"	"High"
Average Sodium Balance	-394.77	-18.38	+397.99

TABLE IV

DIGESTIBILITY OF SODIUM, POTASSIUM AND NITROGEN DURING PRE-EXPERIMENTAL AND EXPERIMENTAL PERIODS

	TREATMENT "LOW"	"MEDIUM"	"HIGH"
PRE-EXPERIMENTAL			
Sodium (%)	88.1	85.6	79.0
Potassium (%)	80.3	88.7	85.7
Nitrogen (%)	55.2	56.2	54.4
EXPERIMENTAL			
Sodium (%)	0.0*	67.2	78.5
Potassium (%)	48.9	71.9	73.7
Nitrogen (%)	59.2	58.1	56.8

*More sodium was excreted in the feces than was consumed and consequently, if a digestibility value was calculated it would be less than zero.

TABLE V

AVERAGE DAILY EXCRETION OF SODIUM, POTASSIUM AND NITROGEN IN FECES AND URINE DURING PRE-EXPERIMENTAL AND EXPERIMENTAL PERIODS

	TREATMENT "LOW"	"MEDIUM"	"HIGH"
PRE-EXPERIMENTAL			
Sodium (mEq per day)			
Feces	16.87	20.64	29.77
Urine	151.71	133.37	134.43
Total	168.58	154.01	164.20
Potassium (mEq per day)			
Feces	23.68	13.77	17.42
Urine	72.33	72.02	67.89
Total	96.01	85.79	85.31
Nitrogen (gms per day)			
Feces	4.23	4.08	4.37
Urine	4.06	4.62	5.09
Total	8.29	8.70	9.46
EXPERIMENTAL			
Sodium (mEq per day)			
Feces	6.93	14.43	27.77
Urine	10.95	30.86	88.97
Total	17.88	45.29	116.74
Potassium (mEq per day)			
Feces	15.59	8.56	8.05
Urine	14.05	14.16	13.57
Total	29.64	22.72	21.62
Nitrogen (gms per day)			
Feces	3.38	3.67	3.76
Urine	4.76	3.87	3.82
Total	8.14	7.54	7.58

and feces was "low" 17.88; "medium" 45.29; and "high" 116.74 mEq per day. Thus, while the "medium" sodium sheep were in negative cumulative balance the average daily balance was only slightly negative (1.29 mEq per day). This would indicate that consumption of 44.0 mEq of sodium and 30.5 mEq of potassium daily is very near the amount required for sodium balance in sheep, under the conditions of this experiment. The reason for the "medium" treatment sheep showing a slight negative cumulative balance, was that, initially (first three periods) they were in relatively high negative balance. However, during five of the remaining six periods they showed a positive balance (Figure 1). Considering the level of sodium excreted in urine (10.95 mEq per day) and feces (6.93 mEq per day) by the "low" treatment sheep it appears that there is a minimum amount of sodium that can be excreted by sheep regardless of intake. The quantities excreted among sheep on the "low" treatment varied considerably. The range for urine was 6.83 to 16.80 mEq per day with three sheep being under 12.3 mEq per day; and feces 4.38 to 11.21 mEq per day with three sheep being under 7.6 mEq per day. This minimum daily sodium excretion via urine and feces appears to fall somewhere between 11.21 and 24.49 mEq per day when 4.0 mEq is fed. Horrocks (24) noted that the minimum amount of sodium which could be excreted per day by steers in the urine and feces appeared to be approximately 0.5 grams (21.7 mEq) when fed a maintenance ration and supplying 8.69 mEq daily of sodium.

Potassium Balance

Potassium balance data is reported in Figure 2. On initiation of feeding the experimental levels of sodium and the reduced level of

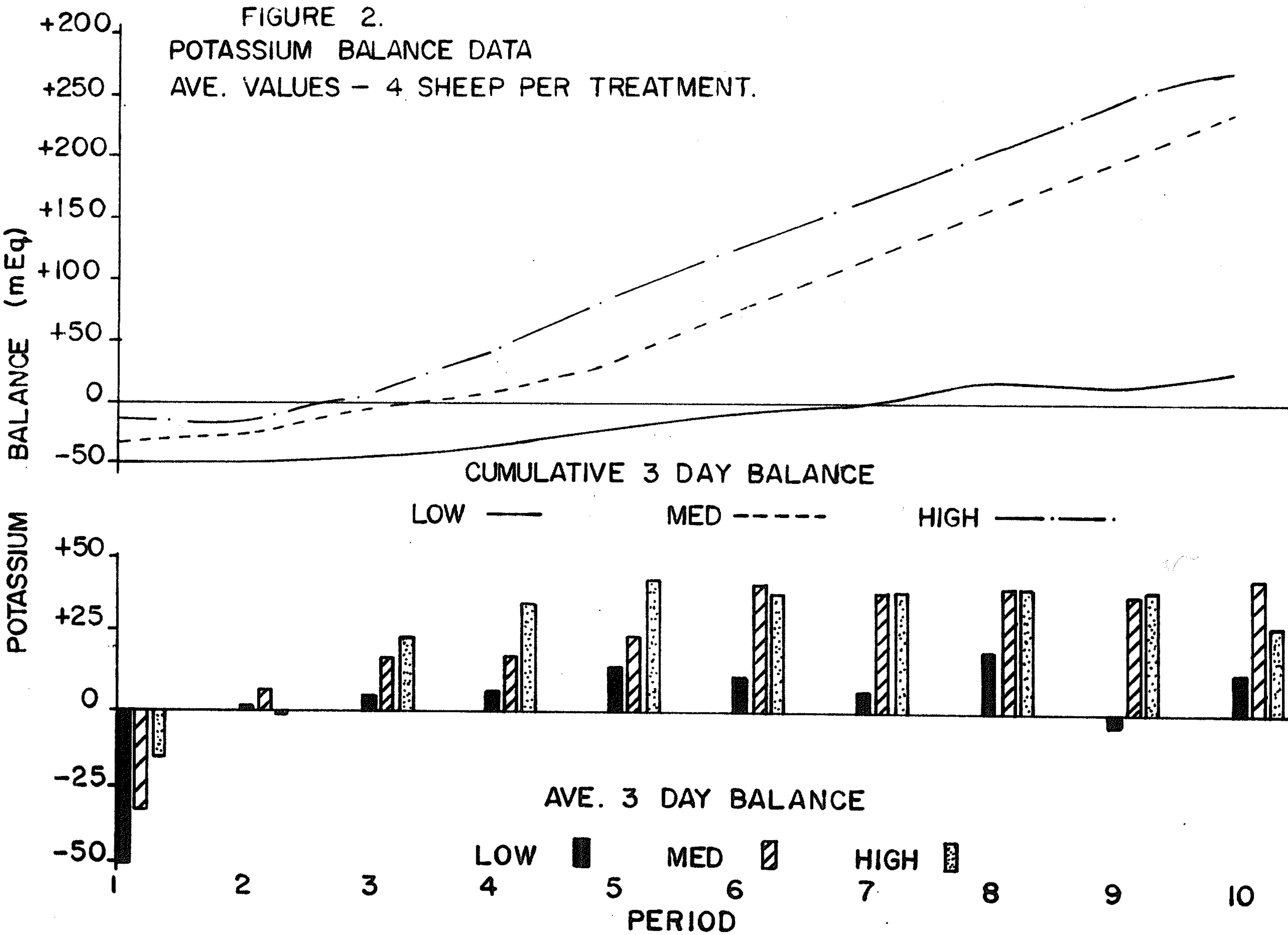

FIGURE 2.
POTASSIUM BALANCE DATA
AVE. VALUES – 4 SHEEP PER TREATMENT.

potassium, the sheep all showed a negative potassium balance at the first collection period. This indicates that at least three days are required for sheep to physiologically adjust, or to regain potassium balance, when sodium and potassium intakes are abruptly changed. The largest negative balance occurred with the "low" treatment, followed by the "medium" and the least negative balance was observed in the "high" treatment. It would appear from this data that after reducing potassium consumption, the excretion of potassium, for a short period at least, remains similar to when a higher level was fed. In addition, the level of sodium consumed may influence potassium excretion, at least temporarily. The lowest level of sodium consumed appeared to increase potassium excretion. It should be noted, however, that by the second three day period, the sheep had adjusted for this imbalance and were again nearly at balance. The fact that level of sodium affects potassium balance is further substantiated when the trend in the average three day balance values is considered. Although all sheep were in positive balance, the "low" sheep retained considerably less potassium than either the "medium" or "high" sheep. This appears to be associated with digestibility of potassium, possibly caused by an antagonistic effect due to the sodium-potassium ratio. Potassium digestibility values of 48.9, 71.9 and 73.7 per cent were observed for the "low", "medium" and "high" treatments, respectively, (Table IV). Statistical analysis, however, revealed no differences in digestibility of potassium which could be explained by the extremely wide variation in digestibility which occurred among sheep on the "low" treatment. Values obtained were 6.27, 54.6, 56.4 and 78.2 per cent for the "low" treatment sheep. In the case of one sheep (number three) in the first trial, fecal potassium excretion during the initial part of the experimental period remained at the same level as during the pre-experimental period. On the other hand, sheep number six in the second trial excreted considerably less potassium in the feces than any of the other "low" treatment sheep, and consequently, had a relatively high digestibility value. The reason for these wide differences is not known but they occurred only with sheep on the "low" treatment. The other two sheep, (numbers four and one) on the "low" treatment had similar digestibility values (average 55 per cent) and were considerably lower than values obtained for the "medium" and "high" treatments. Thus, when potassium consumption is 30.5 mEq per day the quantity of sodium required for maximum potassium digestibility appears to be greater than 4.0 mEq and nearer 44.0 mEq daily.

Analysis of variance (Table VI) revealed a significant difference ($P < .05$) in potassium balance as affected by the level of sodium fed. Duncan's comparison of treatment means (Table VII), showed that the "low" treatment was significantly less ($P < .05$) than the other treatments. Urinary potassium excretion was approximately the same for all treatments, being 14.05, 14.16 and 13.57 mEq per day for the "low", "medium" and "high" levels, respectively (Table V). Thus, any marked differences in potassium balance must be associated with fecal potassium excretion, which was 15.59, 8.56 and 8.05 mEq per day for the "low", "medium" and "high" treatments, respectively (Table V). These generally higher levels of

TABLE VI

ANALYSIS OF VARIANCE FOR POTASSIUM BALANCE

Source of Variation	d/f	Sum of Squares	Mean Square	Calculated F Value
Levels	2	154302.35	77151.17	7.32 *
Periods	1	63.02	63.02	0.005
L x P	2	22640.04	11320.02	1.08
Error	6	63277.08	10546.18	
Total	11	240282.84		

*($P < .05$)

TABLE VII

DUNCAN'S COMPARISON OF MEANS FOR POTASSIUM BALANCE (5% LEVEL)

Treatment	"Low"	"Medium"	"High"
Average Potassium Balance	14.89	238.49	269.40

potassium excreted in the feces of sheep on the "low" treatment account for the lower positive balances. This, however, is not associated with dry matter digestibility since no significant treatment differences were observed for dry matter digestibility. Therefore, it would appear that the level of sodium fed was the factor affecting potassium digestibility.

Nitrogen Balance

Data concerning nitrogen balance is presented in Figure 3. All three treatments showed positive cumulative balances. The cumulative balances for the "medium" and "high" treatments were very similar and increased steadily throughout the 30 day trial. On the other hand, the cumulative balance for the "low" treatment remained fairly constant (between 2.0 and 7.0 grams nitrogen) throughout the 30 days and during the last four periods the average balances were negative. There was a significant ($P < .01$) treatment effect on cumulative nitrogen balance (Table VIII). Sheep receiving the "low" treatment retained significantly less nitrogen than animals receiving either the "medium" or "high" treatments (Table IX). Further, there was a significant difference ($P < .05$) between trials in nitrogen balance, with animals showing greater positive balance during the second trial. This may have been due to age differences of the wethers, as the sheep used in the second trial were approximately 90 days older than the sheep used in the first trial.

Nitrogen digestibility (Table IV) was similar for all treatments, being "low" 59.2, "medium" 58.1 and "high" 56.8 per cent. Fecal nitrogen excretion (Table V) for the "low", "medium" and "high" treatments was 3.38, 3.67 and 3.76 grams per day, respectively. This would

FIGURE 3.
NITROGEN BALANCE DATA.
AVE. VALUES - 4 SHEEP PER TREATMENT.

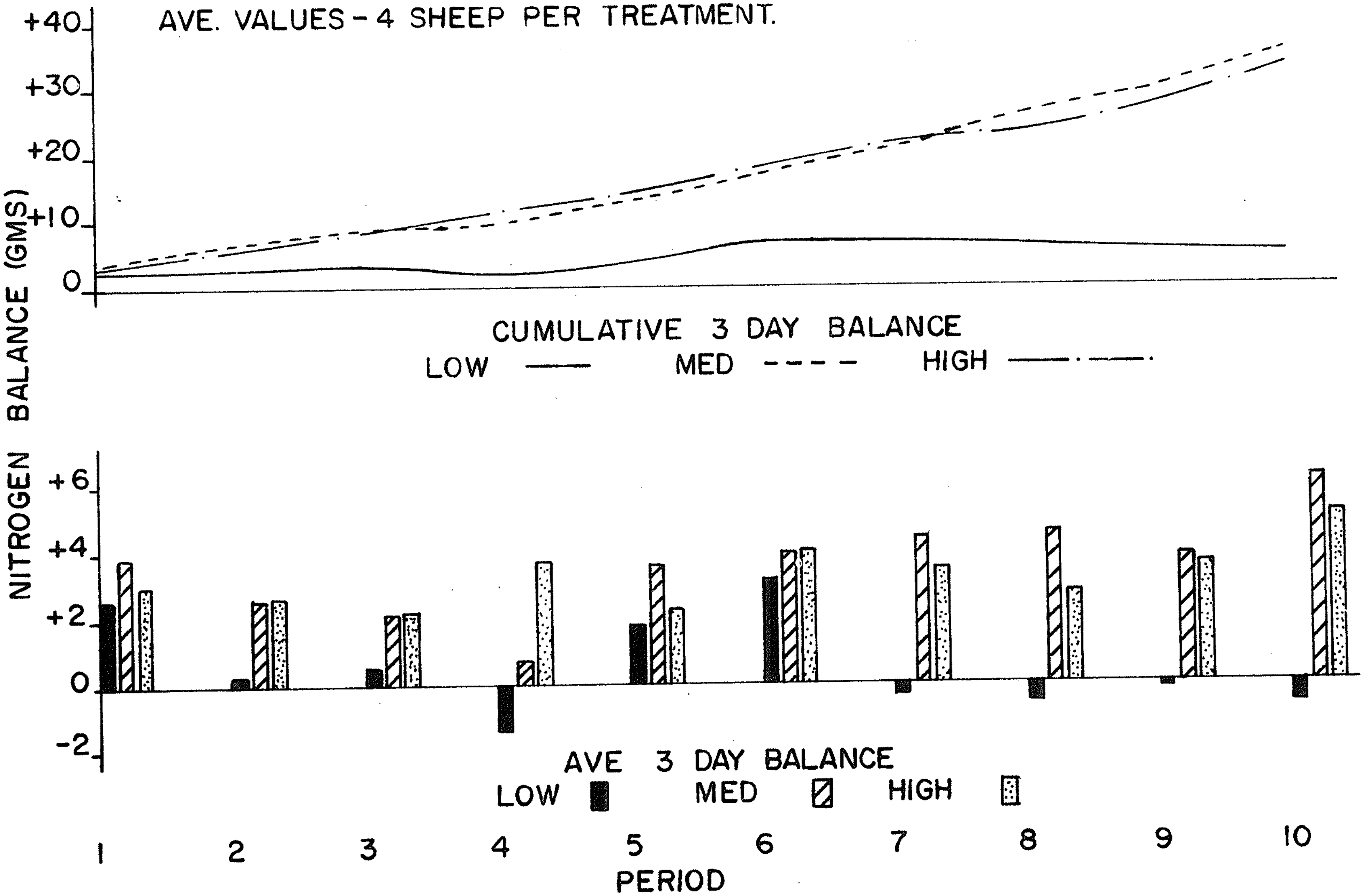

TABLE VIII

ANALYSIS OF VARIANCE FOR NITROGEN BALANCE

Source of Variation	d/f	Sum of Squares	Mean Squares	Calculated F Value
Levels	2	2284.13	1142.07	12.27**
Periods	1	1095.07	1095.07	11.77*
L x P	2	227.12	113.56	1.22
Error	6	558.39	93.07	
Total	11	4164.71		

**$(P < .01)$
*$(P < .05)$

TABLE IX

DUNCAN'S COMPARISON OF MEANS FOR NITROGEN BALANCE (1% LEVEL)

Treatment	"Low"	"High"	"Medium"
Average Nitrogen Balance	5.67	33.38	36.29

account for the slight differences in digestibility since nitrogen intake among treatments was the same. Urinary nitrogen excretion (Table V) was 4.76, 3.87 and 3.82 grams per day, respectively, for the "low", "medium" and "high" treatments. As the "low" treatment sheep had the highest nitrogen digestibility, yet retained the least nitrogen over 30 days, the larger urinary loss suggests lowered cellular utilization. Further verification of this phenomenon is shown by the fact that the "low" treatment sheep all lost weight during the experimental period (Table X), whereas, the "medium" treatment lost slightly and the "high" treatment gained slightly in weight. The level of sodium fed may have affected utilization of the absorbed nitrogen, thus resulting in weight losses to the animals. This would seem to coincide with a general statement by Maynard and Loosli (29). They indicate that a lack of sodium lowers the utilization of digested protein and energy.

Sodium and Potassium in Serum

Serum sodium and potassium levels are shown in Table XI. There was no statistical treatment difference in serum concentrations of either sodium or potassium. The serum collected after 30 days on test showed a lower sodium concentration than previous values for the "low" treatment sheep. However, this was probably due to a within animal variation and not a decline which would continue had the experiment been of longer duration.

Sodium and Potassium in Saliva

Sodium and potassium concentrations in saliva are presented in

TABLE X

BODY WEIGHT CHANGES OF SHEEP DURING EXPERIMENTAL PERIOD (LBS.)

Treatment	Sheep No.	Initial Weight	Final Weight	Weight Change
"Low"	3	74	64	-10
	4	68	60	- 8
	1	68	64	- 4
	6	66	63	- 3
	Average	69.0	62.7	- 6.2
"Medium"	1	75	73	- 2
	6	67	61	- 6
	3	68	67	- 1
	4	69	70	+ 1
	Average	69.7	67.7	- 2.0
"High"	2	73	73	0
	5	68	68	0
	2	70	72	+ 2
	5	62	63	+ 1
	Average	68.2	69.0	+ 0.7

TABLE XI

SERUM SODIUM AND POTASSIUM CONCENTRATION (mEq per LITER)

TREATMENT	SHEEP NO.	PRE-EXPERIMENTAL PERIOD 1 Na	PRE-EXPERIMENTAL PERIOD 1 K	PRE-EXPERIMENTAL PERIOD 2 Na	PRE-EXPERIMENTAL PERIOD 2 K	EXPERIMENTAL PERIOD 1 Na	EXPERIMENTAL PERIOD 1 K	EXPERIMENTAL PERIOD 2 Na	EXPERIMENTAL PERIOD 2 K	EXPERIMENTAL PERIOD 3 Na	EXPERIMENTAL PERIOD 3 K
"LOW"	3	140	5.20	142	5.28	140	4.38	135	4.00	140	4.28
	4	139	5.04	139	4.28	141	3.76	137	3.72	137	3.68
	1	143	4.08	142	4.16	142	2.62	146	3.40	125	4.60
	6	122	11.20	154	4.48	138	2.92	142	4.08	133	3.26
	Average	136	6.38	144	4.55	140	3.42	140	3.80	134	3.96
"MEDIUM"	1	142	5.44	140	5.48	139	4.14	145	4.24	143	4.44
	6	137	5.00	145	4.20	142	3.68	136	3.44	142	3.56
	3	142	4.80	145	4.72	160	4.24	155	4.24	146	4.08
	4	140	5.26	142	4.40	139	5.16	144	4.64	171	5.20
	Average	140	5.13	143	4.70	145	4.31	145	4.14	151	4.32
"HIGH"	2	141	4.59	125	4.76	136	3.74	132	4.26	134	4.20
	5	133	8.56	139	3.16	142	3.84	130	3.68	135	5.44
	2	143	4.52	144	4.60	174	5.00	136	4.32	152	4.58
	5	142	5.48	145	4.82	161	5.08	140	4.32	149	4.44
	Average	140	5.79	138	4.34	153	4.42	135	4.15	143	4.67

Table XII. The concentration of these ions varied considerably among sheep within treatments. At the conclusion of the 30 day experimental period there was no significant difference between treatments in either sodium or potassium saliva levels.

Water Consumption

Water intake and urine excretion are reported in the Appendix I tables. Average daily water intake during the experimental period was similar for all treatments being 1066, 1085 and 1072 milliliters for the "low", "medium" and "high" sheep, respectively. Urine output varied considerably and values obtained were 527, 336 and 319 milliliters, respectively, for the three treatments. The "low" treatment sheep excreted more urine indicating some dehydration due to the "low" sodium intake. This could partially account for the greater loss of weight observed with these sheep.

Ration Digestibility

Feces dry matter data is presented in the Appendix II, Table XVII. Dry matter and energy digestibility data are presented in Table XIII. The values for the two different periods investigated with the same sheep show a fairly large variation in both dry matter and energy digestibility. In addition, the variation among sheep within treatments was also considerable. There was, however, no significant difference between treatments in dry matter or energy digestibility. The average daily energy intake was highest for the "high" treatment (1.59 therms digestible energy) and slightly less for the "medium" (1.45 therms digestible

TABLE XII

SALIVA SODIUM AND POTASSIUM CONCENTRATION (mEq per LITER)

TREATMENT	SHEEP NO.	PRE-EXPERIMENTAL PERIOD				EXPERIMENTAL PERIOD					
		1		2		1		2		3	
		Na	K	Na	K	Na	K	Na	K	Na	K
"LOW"	3	143.3	18.8	112.6	20.3	93.1	25.2	119.3	11.2	126.2	24.0
	4	71.7	13.8	113.3	27.2	107.1	33.6	138.5	12.2	125.6	18.1
	1	114.5	21.9	87.5	18.6	97.0	26.6	106.7	24.8	114.5	17.9
	6	91.8	10.5	92.3	14.7	73.6	9.0	95.4	14.8	79.8	29.6
	Average	105.3	16.3	101.4	20.2	92.7	23.6	114.9	15.7	111.5	22.4
"MEDIUM"	1	127.9	19.2	111.8	32.5	105.1	20.9	130.2	17.8	134.8	16.8
	6	106.7	11.6	114.9	21.8	125.4	11.9	139.4	13.1	103.5	18.5
	3	120.1	9.6	108.5	22.2	133.1	19.3	128.1	14.4	107.1	14.2
	4	81.2	14.1	110.1	10.5	123.8	15.3	103.4	23.0	145.0	14.0
	Average	108.9	13.6	111.3	21.8	121.9	16.9	125.3	17.1	122.6	15.9
"HIGH"	2	193.3	137.8	83.4	34.5	82.6	16.7	141.8	7.7	127.9	15.7
	5	135.1	14.5	181.1	27.2	140.1	26.1	142.2	11.9	148.5	12.1
	2	103.1	25.7	112.2	13.4	121.7	9.6	135.3	10.9	124.7	6.6
	5	74.1	32.0	103.3	27.9	90.6	34.7	93.9	24.3	101.1	26.5
	Average	126.4	52.5	120.0	25.6	108.8	21.8	128.3	13.7	125.6	15.2

TABLE XIII

DRY MATTER AND ENERGY DIGESTIBILITY AND DIGESTIBLE ENERGY INTAKE

TREATMENT	SHEEP NO.	PERIOD*	DRY MATTER DIGESTIBILITY (PER CENT)	DIGESTIBLE ENERGY (PER CENT)	DAILY DIGESTIBLE ENERGY CONSUMED (THERMS)
"LOW"	3	1	51.78	52.01	1.38
		2	53.02	54.89	1.00
	4	1	64.67	65.47	1.73
		2	58.84	59.48	.95
	1	1	63.91	64.21	1.58
		2	70.81	72.23	1.65
	6	1	65.57	66.39	1.64
		2	60.46	61.52	1.39
		Average	61.13	62.02	1.40
"MEDIUM"	1	1	62.02	61.51	1.63
		2	62.64	65.44	1.73
	6	1	51.01	51.55	1.28
		2	64.21	66.76	1.36
	3	1	69.45	69.87	1.72
		2	51.51	53.82	1.25
	4	1	55.52	55.66	1.37
		2	59.98	59.79	1.48
		Average	59.54	60.42	1.45
"HIGH"	2	1	66.92	67.51	1.79
		2	63.92	64.74	1.72
	5	1	62.22	62.68	1.64
		2	57.10	57.52	1.41
	2	1	72.12	73.07	1.80
		2	68.21	68.56	1.69
	5	1	46.16	47.17	1.16
		2	60.39	61.14	1.51
		Average	62.13	62.79	1.59

*Period--1 refers to first 7 day trial and 2 refers to second 6 day trial.

energy) and "low" treatments (1.40 therms digestible energy). This difference in digestible energy consumption by the "low" and "medium" treatments when compared to the "high" treatment was due to a reduction in the level of cellulose fed. As mentioned earlier an appetite problem was encountered and in order to maintain constant intake of protein and minerals the cellulose was reduced. This problem was not encountered to the same extent with the "high" treatment sheep and as a result the daily energy intake was higher over the 30 day period. These differences in energy intake along with differences in water retention would account for the variations in body weight change which occurred among treatments.

SUMMARY AND CONCLUSIONS

Twelve wether lambs were used in the experiment, six in each of two replicate metabolism trials. A nine day pre-experimental period, during which the sheep received equal amounts of a purified ration, was followed by a 30 day experimental period. During the experimental period intake of the purified ration was equalized and levels of sodium consumed were "low" (4.0 mEq per day), "medium" (44.0 mEq per day) and "high" (129.0 mEq per day) with all sheep receiving 30.5 mEq of potassium daily.

Data collected indicate the following:

(1) The level of sodium consumed resulted in a significant difference ($P < .01$) in sodium retained among all treatments. The "low" and "medium" treatments were in cumulative negative sodium balance and the "high" treatments were in cumulative positive sodium balance. The sodium requirement for balance appeared to be near 44.0 mEq daily when 30.5 mEq daily of potassium was consumed.

(2) The digestibility of sodium appeared to be affected by the level of sodium consumed. Feces sodium excretion for the three treatments was "low" 6.93; "medium" 14.43; and "high" 27.77 mEq per day. Sodium intake for the "low" treatment sheep was 4.0 mEq per day and as a result a calculated digestibility value would be less than zero.

(3) Difference in potassium balance was significant ($P < .05$), with the "low" treatment sheep being different than the other treatments. All treatments, however, showed cumulative positive potassium balance.

(4) There was no significant difference in potassium digesti-

bility due to wide differences obtained with the "low" treatment sheep.

(5) The nitrogen retained over the 30 day experimental period by the "low" treatment sheep was significantly ($P < .01$) less than amounts retained by the "medium" and "high" treatment sheep.

(6) Treatment did not significantly affect digestibility of nitrogen.

(7) No significant difference in serum or saliva concentrations of sodium or potassium were noted over the 30 day experimental period.

(8) Dry matter and energy digestibility varied considerably within treatments but there was no significant difference among treatments.

(9) Sheep in all treatments consumed essentially the same daily volume of water but animals receiving the "low" treatment excreted the most urine, followed by the "medium" treatment, with the "high" treatment animals excreting the least urine.

(10) Over the experimental period the "low" treatment sheep lost weight, the "medium" treatment lost just slightly and the "high" treatment maintained their weight. The differences in body weight changes may be associated with differences in digestible energy intake as well as differences in water retention which occurred among treatments.

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APPENDIX I

TABLE XIV

FEED CONSUMPTION, SODIUM INTAKE[1], SODIUM IN FECES, SODIUM IN URINE, POTASSIUM INTAKE[2], POTASSIUM IN FECES, POTASSIUM IN URINE, NITROGEN INTAKE, NITROGEN IN FECES, NITROGEN IN URINE, WATER INTAKE, URINE OUTPUT AND FECES OUTPUT OF SHEEP ON LOW SODIUM CONSUMPTION

	PRE EXPERIMENTAL PERIOD			EXPERIMENTAL PERIOD									
SHEEP NO.	1	2	3	1	2	3	4	5	6	7	8	9	10
				FEED CONSUMPTION (gms. per 3 days)									
3	2250	2250	2250	2070	2070	2070	1465	1720	1890	2000	1670	1825	925
4	2250	2250	2250	2070	2070	2055	1815	1490	1460	1550	1540	1380	1380
1	1920	1920	1920	1920	1920	1920	1920	1920	1920	1770	1420	1745	1770
6	1920	1920	1920	1920	1920	1920	1920	1920	1230	1470	1720	1845	1745
				SODIUM IN FECES (mEq. per 3 days)									
3	45.6	32.2	28.1	81.7	22.0	9.1	10.7	12.4	15.0	42.9	13.7	15.3	7.4
4	70.0	43.8	23.7	77.6	22.9	19.9	23.3	25.6	27.3	25.1	31.6	27.2	55.2
1	102.3	58.5	66.0	20.1	20.1	12.9	9.2	7.7	18.6	11.5	10.5	8.9	11.4
6	58.8	47.7	30.1	26.8	16.8	14.5	9.1	7.0	9.2	19.3	7.9	13.0	9.2
				SODIUM IN URINE (mEq. per 3 days)									
3	533.9	340.0	506.2	103.8	110.2	25.1	9.3	52.0	39.2	62.3	47.0	32.0	22.8
4	173.0	433.2	377.1	166.4	31.5	9.4	38.9	33.7	21.0	13.1	25.7	16.0	13.9
1	448.8	476.2	407.3	30.2	8.9	9.2	8.7	10.0	11.4	14.3	29.9	33.3	48.5
6	591.3	513.2	555.0	83.3	21.8	1.7	2.0	2.8	1.4	62.1	25.6	21.0	12.9

[1]Pre experimental period 411.0 mEq. per 3 days.
Experimental period 12.0 mEq. per 3 days.

[2]Pre experimental period 367.5 mEq. per 3 days.
Experimental period 91.5 mEq. per 3 days.

TABLE XIV (continued)

SHEEP NO.	PRE EXPERIMENTAL PERIOD 1	2	3	EXPERIMENTAL PERIOD 1	2	3	4	5	6	7	8	9	10
POTASSIUM IN FECES (mEq. per 3 days)													
3	162.1	140.6	119.6	133.4	85.2	118.6	105.3	78.6	64.7	67.4	71.8	65.1	67.0
4	64.2	69.6	34.1	70.5	34.3	32.6	31.3	27.3	54.5	48.2	27.7	51.2	20.8
1	86.3	76.6	33.4	27.4	49.1	55.0	40.3	67.2	75.9	41.0	23.6	19.0	16.0
6	33.6	26.9	20.8	19.6	17.5	19.2	12.1	8.5	19.2	50.8	18.6	23.9	9.9
POTASSIUM IN URINE (mEq. per 3 days)													
3	317.2	74.2	195.5	43.1	15.8	7.9	17.1	5.2	4.8	4.9	4.8	30.7	27.3
4	210.0	230.4	225.4	79.8	36.9	36.6	54.2	29.6	50.1	40.0	25.3	46.5	58.1
1	147.4	228.8	260.5	73.6	42.4	32.6	39.8	57.6	40.8	32.6	61.2	50.0	64.1
6	194.9	210.0	228.2	113.6	83.7	42.5	36.8	34.9	9.6	52.2	53.8	96.1	48.9
NITROGEN INTAKE (gms. per 3 days)													
3	31.1	31.1	31.1	26.4	26.4	26.4	19.8	22.7	24.7	25.8	23.7	25.3	12.3
4	31.1	31.1	31.1	26.4	26.4	26.4	24.0	22.7	24.0	25.9	23.2	20.1	20.1
1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
6	26.1	26.1	26.1	26.1	26.1	26.1	26.1	23.0	26.1	26.1	26.1	26.1	26.1
NITROGEN IN FECES (gms. per 3 days)													
3	13.4	11.2	11.5	10.9	8.2	10.0	10.1	10.1	8.4	12.4	10.2	7.8	8.4
4	12.0	15.8	13.3	10.6	10.6	10.7	9.4	6.7	8.6	9.9	8.7	11.4	8.5
1	11.4	14.5	10.7	8.7	11.8	12.2	12.4	11.6	10.3	12.7	11.4	9.0	7.6
6	14.5	12.1	12.2	11.9	11.1	11.2	11.8	8.2	6.5	13.3	10.7	13.5	8.3

TABLE XIV (continued)

SHEEP NO.	PRE EXPERIMENTAL PERIOD 1	2	3	EXPERIMENTAL PERIOD 1	2	3	4	5	6	7	8	9	10
						NITROGEN IN URINE (gms. per 3 days)							
3	18.0	9.2	11.7	13.7	19.3	18.1	16.8	11.4	13.1	13.2	10.7	17.4	12.6
4	18.4	8.3	6.7	11.7	16.2	15.5	17.0	10.4	17.2	12.9	14.7	12.1	10.7
1	10.9	12.6	9.2	15.1	12.5	13.1	12.4	11.1	12.6	12.9	20.6	13.2	13.1
6	20.4	9.9	11.0	11.1	14.9	12.9	12.8	18.6	12.3	18.7	15.4	14.3	18.4
						WATER INTAKE (mls. per 3 days)							
3	6575	6525	6430	3840	4940	4780	2945	4630	4340	5660	4765	3875	3070
4	5025	3175	3560	2690	2930	4080	1975	2620	3770	2610	3375	1890	1890
1	3250	5430	3720	3745	3850	2440	2835	3240	3505	2990	2695	2660	2785
6	2470	4000	3680	3075	2720	2180	2815	3910	1060	1500	3175	3775	2710
						URINE OUTPUT (mls. per 3 days)							
3	4700	2350	4170	1100	2885	2025	2325	2500	2440	3500	3485	2225	1635
4	875	1500	980	970	945	1050	1130	655	1000	820	990	890	775
1	1575	2025	2540	2050	1475	1465	1575	1185	1595	1160	1775	1685	1925
6	1725	2100	2565	1515	1315	1080	1340	1910	835	1475	1115	1950	1440
						FECES OUTPUT (gms. per 3 days)							
3	1826	1953	1507	3296	1870	1380	1178	1233	1170	1498	1283	1076	998
4	1361	1930	1207	1742	1320	1269	1312	936	878	1025	948	1018	919
1	1783	1931	1358	1059	1257	1249	1191	1126	1391	1274	1014	833	1012
6	1298	1116	895	1079	1117	1063	1039	737	667	1171	908	1193	876

TABLE XV

FEED CONSUMPTION, SODIUM INTAKE[1], SODIUM IN FECES, SODIUM IN URINE, POTASSIUM INTAKE[2], POTASSIUM IN FECES, POTASSIUM IN URINE, NITROGEN INTAKE, NITROGEN IN FECES, NITROGEN IN URINE, WATER INTAKE, URINE OUTPUT AND FECES OUTPUT OF SHEEP ON MEDIUM SODIUM CONSUMPTION

	PRE EXPERIMENTAL PERIOD			EXPERIMENTAL PERIOD									
SHEEP NO.	1	2	3	1	2	3	4	5	6	7	8	9	10
				FEED CONSUMPTION (gms. per 3 days)									
1	2250	2250	2250	2070	2070	2070	1945	1920	1970	2070	2070	2070	2070
6	2250	2250	2250	2070	2070	1766	1780	1845	1970	1815	1620	1545	1595
3	1920	1920	1920	1920	1920	1920	1920	1920	1920	1745	1920	1920	1770
4	1350	1445	1820	1920	1920	1920	1920	1920	1920	1920	1920	1920	1920
				SODIUM IN FECES (mEq. per 3 days)									
1	118.6	52.3	41.5	142.1	60.8	57.6	31.3	38.9	42.1	40.6	62.5	59.4	42.9
6	81.9	97.1	127.7	138.9	137.5	76.0	67.8	44.3	33.8	52.6	36.0	35.2	28.6
3	38.7	37.3	34.4	36.4	28.6	25.6	23.8	15.8	26.7	22.2	25.6	31.0	18.5
4	38.9	36.2	29.1	13.7	20.7	31.2	30.6	26.1	20.9	14.8	25.9	32.3	32.6
				SODIUM IN URINE (mEq. per 3 days)									
1	234.9	349.9	332.0	128.8	84.3	86.7	69.0	89.5	85.2	69.3	115.0	81.7	82.2
6	267.9	225.9	280.8	46.4	36.8	60.7	67.4	66.8	43.3	99.3	132.4	119.0	96.6
3	494.6	435.6	520.5	136.6	127.2	108.8	100.1	78.6	121.5	122.0	102.1	83.8	65.0
4	646.8	524.3	487.8	94.4	115.5	213.8	123.6	103.9	77.8	53.7	62.4	91.1	59.5

[1]Pre experimental period 411.0 mEq. per 3 days.
Experimental period 132.0 mEq. per 3 days.

[2]Pre experimental period 367.5 mEq. per 3 days.
Experimental period 91.5 mEq. per 3 days.

TABLE XV (continued)

SHEEP NO.	PRE EXPERIMENTAL PERIOD 1	2	3	EXPERIMENTAL PERIOD 1	2	3	4	5	6	7	8	9	10
POTASSIUM IN FECES (mEq. per 3 days)													
1	39.4	37.6	33.0	70.2	25.1	26.8	17.3	19.6	21.9	23.6	18.8	17.2	13.9
6	59.3	96.9	104.1	109.3	56.1	48.3	47.3	40.0	31.7	40.9	18.1	18.1	15.2
3	16.5	16.6	26.9	27.7	16.5	14.2	12.3	14.3	22.6	24.2	18.8	20.6	12.6
4	17.3	14.8	33.2	19.8	16.4	17.3	16.8	14.7	12.3	13.1	18.9	16.9	16.0
POTASSIUM IN URINE (mEq. per 3 days)													
1	167.7	258.3	251.5	62.1	40.3	31.4	28.4	35.2	21.7	23.1	24.8	18.4	21.9
6	154.1	172.2	216.3	29.4	25.0	53.2	57.9	27.0	34.9	35.1	27.3	48.9	51.6
3	187.7	180.7	246.0	86.0	79.2	38.3	40.5	42.2	23.1	28.7	37.6	34.1	26.6
4	204.9	261.0	291.8	94.1	80.6	64.5	79.6	75.6	32.3	23.9	34.9	43.2	34.8
NITROGEN INTAKE (gms. per 3 days)													
1	31.1	31.1	31.1	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4
6	31.1	31.1	31.1	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4
3	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
4	23.0	23.5	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
NITROGEN IN FECES (gms. per 3 days)													
1	15.3	12.2	11.8	11.3	12.2	14.5	12.1	12.6	13.1	11.4	12.1	13.7	9.3
6	11.5	17.5	12.9	10.3	11.1	9.8	11.2	11.3	8.4	12.1	8.3	9.3	8.7
3	8.9	9.1	11.6	12.1	10.4	8.1	10.3	8.9	10.9	12.3	10.8	11.5	8.5
4	10.0	9.8	16.6	10.9	12.9	11.2	12.1	9.9	10.3	11.1	11.3	11.7	12.3

TABLE XV (continued)

SHEEP NO.	PRE EXPERIMENTAL PERIOD 1	2	3	EXPERIMENTAL PERIOD 1	2	3	4	5	6	7	8	9	10
NITROGEN IN URINE (gms. per 3 days)													
1	14.2	15.1	14.9	10.4	11.9	11.9	13.6	12.9	12.7	10.8	12.9	10.0	9.3
6	9.5	12.7	13.6	8.4	11.3	16.5	16.3	15.6	16.9	15.5	15.3	16.0	15.5
3	18.9	9.8	10.5	11.2	11.9	10.5	11.1	11.5	8.2	9.7	10.4	9.1	9.1
4	15.7	14.8	16.9	14.9	13.3	13.8	15.4	7.8	8.3	4.4	5.5	8.0	6.9
WATER INTAKE (mls. per 3 days)													
1	6075	6090	7190	4085	5555	5195	5025	5510	5195	5440	4605	4410	3240
6	3975	6350	5375	3335	4470	4405	2805	2665	3355	3690	4150	2250	2375
3	2710	3530	2600	2705	2405	2085	2740	2950	1800	2375	1940	3085	3520
4	1210	3465	2010	2370	2550	1675	2135	3275	1700	2515	2435	1975	2325
URINE OUTPUT (mls. per 3 days)													
1	2150	3075	3470	1285	1895	1665	1935	2025	1955	1880	2675	1440	1370
6	1840	2100	2600	545	815	1215	1025	1040	975	990	860	960	825
3	1325	1100	1230	510	600	675	630	620	570	620	625	615	600
4	1225	1450	1330	610	735	1270	895	845	620	415	515	530	450
FECES OUTPUT (gms. per 3 days)													
1	1457	1373	1196	1585	1428	1610	1213	1348	1374	1426	1448	1435	1355
6	1244	2112	2074	3123	2443	1790	1692	1566	1478	1601	1150	1078	857
3	900	989	1263	1115	1038	801	784	867	1056	997	914	1037	714
4	809	752	1471	1262	1206	1414	1356	1172	1134	1090	1170	1253	1361

TABLE XVI

FEED CONSUMPTION, SODIUM INTAKE[1], SODIUM IN FECES, SODIUM IN URINE, POTASSIUM INTAKE[2], POTASSIUM IN FECES, POTASSIUM IN URINE, NITROGEN INTAKE, NITROGEN IN FECES, NITROGEN IN URINE, WATER INTAKE, URINE OUTPUT AND FECES OUTPUT OF SHEEP ON HIGH SODIUM CONSUMPTION

	PRE EXPERIMENTAL PERIOD			EXPERIMENTAL PERIOD									
SHEEP NO.	1	2	3	1	2	3	4	5	6	7	8	9	10
FEED CONSUMPTION (gms. per 3 days)													
2	2250	2250	2250	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
5	2250	2250	1982	1965	2055	2070	2070	1835	1760	1695	1920	2070	1745
2	1920	1920	1920	1920	1920	1920	1920	1485	1720	1920	1920	1920	1920
5	1920	1920	1360	1775	1920	1920	1920	1920	1920	1920	1920	1920	1920
SODIUM IN FECES (mEq. per 3 days)													
2	100.6	191.0	181.7	132.1	69.6	118.7	121.53	81.5	95.5	76.2	76.1	114.8	129.5
5	112.2	102.4	43.0	104.4	146.2	81.6	66.3	38.3	59.4	88.1	72.1	96.9	98.7
2	61.2	91.5	55.1	47.6	64.8	60.2	46.8	93.1	85.6	57.7	52.2	62.4	60.1
5	45.1	45.2	41.4	32.4	93.8	106.5	264.6	76.6	46.2	79.2	63.1	37.2	36.1
SODIUM IN URINE (mEq. per 3 days)													
2	305.7	280.8	271.2	113.4	191.2	231.0	269.0	196.4	195.9	216.6	215.4	311.2	222.0
5	409.9	342.5	375.7	201.6	246.4	231.4	253.6	277.1	231.4	124.6	313.2	346.8	316.5
2	724.8	387.0	465.4	366.7	384.8	160.3	283.0	379.2	190.4	228.0	326.9	274.4	329.4
5	622.9	433.2	220.0	298.2	306.2	291.7	274.4	315.0	218.8	287.0	397.7	296.0	332.7

[1]Pre experimental period 411.0 mEq. per 3 days.
Experimental period 387.0 mEq. per 3 days.

[2]Pre experimental period 367.5 mEq. per 3 days.
Experimental period 91.5 mEq. per 3 days.

TABLE XVI (continued)

SHEEP NO.	PRE EXPERIMENTAL PERIOD			EXPERIMENTAL PERIOD									
	1	2	3	1	2	3	4	5	6	7	8	9	10
POTASSIUM IN FECES (mEq. per 3 days)													
2	66.9	60.3	66.7	22.0	16.6	25.7	19.8	21.4	18.7	25.4	19.2	22.6	29.3
5	95.3	114.5	69.7	58.2	60.0	37.3	15.4	16.5	29.1	34.4	16.5	23.1	29.7
2	21.4	29.9	24.1	18.4	13.8	18.8	19.7	26.9	21.3	18.2	19.4	21.3	21.2
5	18.9	25.6	33.5	28.3	24.4	24.3	31.7	31.9	19.3	20.1	14.7	17.5	13.0
POTASSIUM IN URINE (mEq. per 3 days)													
2	239.2	225.6	238.5	60.1	35.8	76.6	31.3	24.6	37.4	37.12	22.2	20.3	25.3
5	211.2	81.7	182.2	63.9	50.5	16.2	15.7	10.7	15.1	7.9	25.5	22.2	36.8
2	188.7	170.6	319.4	101.3	104.0	16.8	49.2	27.4	21.8	22.5	40.1	38.1	43.9
5	168.1	209.4	211.0	76.8	67.0	57.7	42.7	33.8	51.8	46.8	49.4	46.4	54.5
NITROGEN INTAKE (gms. per 3 days)													
2	31.1	31.1	31.1	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4
5	31.1	31.1	31.1	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4
2	26.1	26.1	26.1	26.1	26.1	26.1	26.1	21.7	26.1	26.1	26.1	26.1	26.1
5	26.1	26.1	20.7	25.6	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1	26.1
NITROGEN IN FECES (gms. per 3 days)													
2	16.3	15.4	11.9	10.2	9.6	11.0	11.0	10.7	13.0	14.9	9.2	12.1	11.6
5	17.3	15.8	9.1	8.9	11.8	14.2	8.4	15.5	10.9	19.4	8.6	12.2	10.5
2	17.2	15.0	12.5	10.2	11.4	10.2	11.9	13.4	9.9	12.1	11.0	10.3	10.3
5	10.6	9.5	5.9	13.2	10.0	11.5	9.6	9.1	9.4	10.3	11.5	11.8	10.7

TABLE XVI (continued)

SHEEP NO.	PRE EXPERIMENTAL PERIOD 1	2	3	EXPERIMENTAL PERIOD 1	2	3	4	5	6	7	8	9	10
NITROGEN IN URINE (gms. per 3 days)													
2	19.2	15.9	12.1	10.7	11.2	15.7	11.3	8.9	11.6	11.0	9.4	9.4	7.9
5	14.7	16.2	12.8	16.6	12.8	12.5	14.4	11.4	12.2	3.9	16.4	13.2	14.6
2	13.5	7.5	13.2	11.3	15.8	9.8	12.0	9.9	7.9	7.6	11.8	10.5	8.7
5	14.1	23.6	20.8	11.3	11.8	11.5	11.3	12.3	14.4	11.5	12.7	10.8	9.9
WATER INTAKE (mls. per 3 days)													
2	4025	4250	4810	2840	4080	3705	1980	3840	3120	4925	3025	2375	2805
5	3845	6355	3245	4790	4590	4745	3715	4175	4490	4270	3775	3255	2630
2	2005	6355	5115	3890	4195	2915	3165	1605	2680	3050	2090	2845	2415
5	2320	4475	3790	2110	3255	1600	3475	3300	2555	2225	2845	2515	2810
URINE OUTPUT (mls. per 3 days)													
2	1300	1200	1500	530	975	830	775	670	690	540	845	790	610
5	1200	1675	850	900	815	750	1045	845	1050	365	1160	865	1055
2	1510	2570	3175	1920	2525	2240	700	1145	855	750	1040	845	990
5	1195	2175	1730	710	1025	660	700	1050	1050	1015	1075	925	995
FECES OUTPUT (gms. per 3 days)													
2	1505	2164	2292	1555	1094	1397	1452	1430	1644	1687	1490	1595	1629
5	1994	2061	1207	2110	2209	1604	1025	1380	1049	1588	1154	1605	1671
2	1011	1460	1129	964	969	986	979	1412	961	998	994	1066	1009
5	1038	1304	1214	1314	1707	2015	2908	1474	1381	1422	1221	1374	1288

APPENDIX II

TABLE XVII

FECES DRY MATTER (PER CENT)

TREATMENT	SHEEP NO.	PERIOD 1*	PERIOD 2**	AVERAGE
"LOW"	3	54.13	64.10	59.12
	4	57.00	55.03	56.02
	1	56.62	56.70	56.66
	6	60.80	67.63	64.22
	Average	57.13	60.86	59.00
"MEDIUM"	1	50.79	55.50	53.15
	6	42.35	59.43	50.89
	3	70.30	64.43	67.37
	4	62.82	59.16	60.99
	Average	56.56	59.63	58.10
"HIGH"	2	54.17	45.67	49.92
	5	41.75	49.83	45.79
	2	56.06	59.16	57.61
	5	45.11	57.46	51.29
	Average	49.27	53.03	51.15

*Refers to first 7 day period.
**Refers to second 6 day period.