A STUDY ON THE SODIUM-POTASSIUM INTERRELATIONSHIP AS AFFECTING THE METABOLISM OF CERTAIN NUTRIENTS IN SHEEP

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By

ADHIR CHANDRA SAHA

M. V. Sc. (Final)

Post-Graduate College of Animal Sciences,
INDIAN VETERINARY RESEARCH INSTITUTE,
IZATNAGAR (U. P.)

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Dr. B. N. Majumdar,
M.Sc., Ph.D.,
Member, New York Academy of Sciences,
Professor of Animal Nutrition.

Post-Graduate College of Animal Sciences,
Indian Veterinary Research Institute,
Izatnagar, U.P.

May 12, 1968.

Certified that the entire research work and results presented in this thesis entitled "A study on the sodium-potassium interrelationship as affecting the metabolism of certain nutrients in sheep" have been authentically carried out by Shri Adhir Chandra Saha, M.V.Sc (Final) himself under my supervision and guidance.

(B.N. MAJUMDAR)

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PREFACE

'All flesh is grass'. This biblical saying has been found true even for milk production. For, it is now agreed that the feeding of grasses alone can not only maintain a dairy animal in good health but also sustain milk production to the extent of 2-3 kg. per day. Feeding of concentrates to dairy animals, particularly to the low yielders, being generally uneconomic, efforts from time to time have been made to replace them by grasses, especially of the leguminous variety. Such green feeds, however, may contain as much as 4 per cent of potassium in the dry ration against a computed requirement of 0.5 per cent for ruminants, either adult or rapidly growing (Ward, 1966). Some of them may also contain much higher amounts of potassium as compared to sodium giving a wide potassium: sodium ratio. In practice, although this high level of potassium is apparently well tolerated by such stock, there is some evidence that this may nevertheless have injurious effect on nutrient metabolism and induce hypomagnesaemia (Carbery et al., 1937; Talapatra et al., 1942; 1948; Ward, 1966). Indeed, Bunge (1873), on the basis rather of meagre data, postulated that an excess of potassium impoverished the organism of sodium and chlorine raising their requirements in the process. That a high ratio of potassium to sodium (10 or 11:1) reduced the assimilation of nitrogen, calcium and phosphorus in young growing pigs has been reported by Richards *et al.* (1927). Orr (1929) has concluded that the effect of a high potassium: sodium ratio was most likely to be manifested when the supply of other nutrients were low and these observations of Richards *et al.* and Orr have found corroboration in the study by Zuntz (cited by Russel and Duncan, 1956) who noted malnutrition and pica in animals fed a ration high in potassium:sodium ratio and low in calcium and phosphorus. The Dutch School led by Brouwer (cited by Russel and Duncan, *loc. cit.*) also suggest that as grazing animals like cattle and sheep normally consume potassium in amounts much larger than their requirements, ill health often leading to hypomagnesaemia grass tetany may result from a deficiency or surplus of the total alkali (potash + soda) and alkali earth metals (calcium and magnesium) or an imbalance of alkali radicals *inter se* (Russel and Duncan, *loc. cit.*). Sodium and potassium, on the other hand, are known to serve the needs of great many rumen organisms during growth (Hungate, 1966), while potassium at certain level, according to many workers, improves cellulose digestion and plays an active role in plants in the synthesis of protein from non-protein nitrogenous sources.

There, thus, seems to be much grounds for thinking that high potassium ingestion or a wide potassium:sodium ratio affects nutrient metabolism. Further study is, therefore, indicated on the level of potassium: sodium ratio vis-a-vis certain nutrient metabolism. Work on ruminants, especially, to study the role of potassium in metabolism does not seem to have been done in any systematic manner so far. This is what has been attempted in this thesis.

The thesis is divided into four Chapters, including one in which relevant literature on the subject has been adequately reviewed. A summary accompanies each chapter followed by bibliography and a general summary and conclusions at the end.

CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Sodium and potassium belong to the group of macro-minerals and are generally considered together along with chlorine because of their certain common metabolic functions, though they each have their own independent roles to play in plant and animal kingdoms.

In plants, sodium strictly is not an essential nutrient, but it nevertheless affects their water relations and helps them to withstand drought conditions and partially conserve or replace potassium, particularly in sodium loving plants such as sugar-beet, mangold, barley etc. (Wallace, 1951). Potassium on the other hand is considered with normal cell division, synthesis of carbohydrates and proteins, reduction of nitrates and development of chlorophyl etc. in them (Robbins et al., 1961).

In animals, the major portion of sodium is present in extra-cellular fluid and that of potassium inside the cells. Their basic functions include maintenance of (a) osmotic pressure, (b) acid-base equilibrium, (c) passage of nutrients to and from the cells and (d) water metabolism in general (Maynard and Loosli, 1962). Both of them are concerned with muscular contraction, have anti-coagulant properties and are present in brain, bone, muscles, teeth, blood, milk, saliva etc. (Oser, 1965). As to their independent roles, sodium is concerned with catalytic effect on enzyme activity, normal appetite, weight increase, storage of fat and its synthesis along with protein, while potassium inside the cells aids in the enzymatic transfer of phosphate from ATP to pyruvic acid and has a role in a number of other basic enzymatic reactions (Oser, loc. cit.).

Sodium and potassium imbalances

There appears to be no specific disease resulting from sodium deficiency. However, its lack can cause retarded growth, lowered utilization of protein and energy and failure of reproduction. In poultry, its deficiency causes a drop in weight and egg production as also the occurrence of cannibalism (Maynard and Loosli, loc. cit.). Cows not getting salt show an abnormal appetite for it and, much later, lustureless eyes and rough body-coat leading to an unthrifty appearance and a decline in body weight and milk yield (Tyler, 1960). Helfferich and Denkeit (1965) observed that cows deprived of sodium appeared to conserve it by a drop in milk yield. On the other hand, poultry are supposed to have a low tolerance for salt, although much more of it can be tolerated in a mash with plenty of fresh water to drink than when salt is given in drinking water (Tyler, loc. cit.).

Potassium deficiency has been reported to have been experimentally produced in several species (Maynard and Loosli, loc. cit.). Besides non-specific symptoms, occurrence of heart lesions, tubular degeneration of kidneys and other pathological changes and a lowering in the potassium content of heart and other organs have been observed. In man, its deficiency causes lack of appetite, muscular weakness and paralysis, as also shallow rapid breathing, heart changes, abdominal distension and mental changes, like lethargy, apathy, delirium etc. (Wright, 1956). On the other hand, large oral doses of potassium administered rapidly have been observed to be fatal to cows. Ward (1966) stated that hypomagnesaemia grass tetany was the only pathological situation related to high potassium intakes in ruminants, and this relationship was not clear. He also reported that potassium might be partially responsible for death of calves suffering from diarrhoea.

Role of sodium and potassium in urine output

The literature available indicates that the water demands for urinary excretion of sodium and potassium may be a factor in the water turnover rate, but this has not been investigated. However, the water intake and urinary volume are directly related to sodium and potassium intake.

Thus, Warth (1923; 1926) observed that increased urination seen under paddy straw feeding was partly due to higher potassium intake. Feeding of paddy straw with Napier grass both of which are rich in potassium has been reported to lead to enhanced urination (cited by Negi, 1965). Ray et al. (1947) and Pandittesekere (1952) observed that diuresis was reduced on water washed paddy straw feeding which contained less potassium.

On the other hand, ingestion of alkali treated paddy straw which contained a very high amount of sodium increased the water intake and urinary volume (Negi, loc.cit.). Wilson (1966) observed that the ingestion of excess sodium increased the water requirements and induced diuresis in sheep.

Sodium and potassium requirements

Babcock and Carlyle (1905) determined sodium requirement to be 15 g. for a cow producing 20 lb. of milk. However, for the growth of heifers, a ration providing only 1.5 g. sodium was considered to be enough (Theiler _et al._, 1927). DuToit _et al._ (1934) arrived at the same requirement for growth but suggested 11 g. for a cow giving 20 lb. of milk, which were later put at 0.02% sodium in the ration for growth and 0.15% or more, according to milk yield, for milk production (DuToit _et al._, 1940). Brouwer (1961), however, observed that cow can subsist on very small amount of sodium, say, less than 0.1% in the dry matter of the feed. Maynard and Loosli (_loc. cit._) recommended sodium requirement during growth of rats, chicks, pigs and calves as ranging from 0.1 to 0.2% of the ration.

Comparatively, potassium requirements seem to be higher. DuToit _et al._ (1934) were the first to report that a ration providing 0.32% potassium in its dry matter was adequate to maintain 2 gallons of milk production over a period of two lactations. Telle _et al._ (1964) found that 0.34% potassium in the ration was the minimum for growing finishing lambs and that the optimum intake was 0.55%. Roberts and St. Omer (1965) found that a potassium level of 0.5 to 0.6% of the ration dry matter was adequate for rapid weight gains in fattening steers. Maynard and Loosli (_loc. cit._) report that the requirement of potassium varies between

0.2 snf 0.3% of the dry matter for rats, pigs and chickens, while Ward (loc. cit.) reports the same to be not more than 0.5% of the ration for ruminants and other herbivores, including rapidly growing sheep or cattle.

Sodium-potassium inter-relationship

The fact that plant products contain very high amounts of potassium as compared to sodium raised the question of the significance of sodium-potassium ratio in the diet. In 1873, Bunge (cited by Brouwer, loc. cit.), on the basis of meagre data, postulated that an excess of potassium impoverished the organism of sodium and chlorine. This theory explains the apparently larger requirements for common salt of the herbivores than of other species, as being due to the greater ingestion of potassium relative to sodium in leafy feed materials. Maynard and Loosli (loc. cit.) also reported that controlled experiments with rats and poultry indicated that there were certain inter-relationship between sodium and potassium in metabolism. For example, at inadequate levels of either, the deficiency symptoms were aggravated by a large excess of the other.

Theiler et al. (1927) observed that growth of heifers from one year to adult weight on rations low in sodium and chlorine but with a $K_2O:Na_2O$ ratio of 12:1 or on ones low in sodium and high in chlorine but with a $K_2O:Na_2O$ ratio of 20:1 or 30:1, or even on ones low in potassium, was not affected when the rations themselves provided 1.5 g. sodium and 5 g. chlorine daily, but calving abnormalities were there. Russel and Duncan (1956) calculated Thomas et al. (1952)'s data and found that the ratios of potassium:sodium for normal pasture grasses and for legumes lay between 15:1 and 30:1 respectively. Glendening et al. (1952) found the ratio to be as wide as 54:1 for prairie grass and hay in Kansas. In experiments on young growing pigs, Richards et al. (1927) found that when the ratio of potassium to sodium was 10 or 11 to 1, assimilation of nitrogen, calcium and phosphorus was reduced. Orr (1929) considered that the effect of a high potassium: sodium ratio was most likely to be manifested when the supply of other constituents was low. These observations of Richards et al. (loc. cit.) and Orr (loc. cit.) find corroboration in the study of Zuntz (cited by Russel and Duncan, 1956) who found malnutrition and pica when the ration contained not only a high potassium-sodium ratio but was also low in calcium and phosphorus.

Objectives of the present investigation

Grasses are by far the best feed for cattle. The feeding of greens alone can not only maintain a dairy animal in good health but also sustain milk production to the extent of 2-3 kg. per day. Feeding of concentrates to dairy animals, particularly the low yielders, being generally uneconomic efforts from time to time have been made to replace them by grasses, especially of the leguminous variety. Such green feeds, however, may contain as much as 4% potassium in the dry ration against a computed requirement of 0.5% for ruminants and other herbivores including rapidly growing sheep or cattle (Ward, loc. cit.). This is a very high level of potassium feeding and although apparently well tolerated by ruminants, it may nevertheless have injurious effects on nutrient metabolism and induce hypomagnesaemia. The injurious effect of paddy straw feeding on mineral metabolism is already well established (Carbery et al., 1937, Talapatra et al., 1942; 1948). In spite of considerable work on the subject, the part which potassium plays in this impaired mineral metabolism has yet to be elucidated.

Another important fodder crop is berseem (*Trifolium alexandrinum*) which during the winter months often forms the sole feed for dairy cattle in certain parts of the country and contains almost double the amount of potassium present in paddy straw, which is the principal roughage in rice growing areas. Whether such a feeding regimen adversely affects the mineral metabolism and health of the animals is not yet known. On the other hand, that potassium plays an essential role in plants in the synthesis of proteins from non-protein nitrogeneous sources is well known. Potassium also seems to effect cellulose digestion (Hubbert et al., 1958; Knox et al., 1965; Leitch and Thomson, 1944;Ward, loc. cit.).

Further work is needed on the relation of the potassium level in the gastro-intestinal tract to the absorption of calcium and magnesium, as dietary potassium is stated to take part in the etiology of grass tetany (Ward, loc. cit.). Work on ruminants, specifically to study the role of potassium on all these aspects does not seem to have been attempted so far, which prompted us to undertake the present investigation.

Again, the Dutch School hold that ill health in grazing animals may arise from or may be promoted by a deficiency or surplus of the total alkali (sodium and potassium) and alkali earth metals (calcium and magnesium) or an imbalance of alkali radicals inter-se (Russel and Duncan, loc. cit.). As grazing animals like cattle and sheep normally consume potassium in high amounts as compared to their requirements, it is logical to assume that an imbalance of alkali radicals can exist under grazing conditions. So, one of the objectives of the present investigation was to study the effect of varying ratios of potassium:sodium, by supplementing potassium to the basal ration, on the metabolism of minerals in adult sheep, keeping the levels, particularly of calcium and phosphorus, as far as practicable at their requirement. Potassium supplement was offered in the form of potassium chloride.

Secondly, it is known that sodium and potassium serve the needs of great many rumen organisms during growth (Hungate, 1966) and they along with bicarbonate provide the necessary optimum condition for bacterial fermentation and digestion. Thus, the effect of varying the ratio of potassium:sodium on the digestibilities of proximate principles and metabolism of nitrogen was also made the subject of study.

Thirdly, as very little work has been done on the water requirement and water turn over rate as affected by high potassium diets (Ward, loc. cit.), the water metabolism studies were also undertaken at the same time.

SUMMARY

The relevent literature available on the subject has been adequately reviewed and the object of the study delineated.

The available information on the essential roles of sodium and potassium, their requirements in the body, their deficiency and toxicity and the importance of the ratio between sodium and potassium in animal nutrition has been fully discussed and the lacunae in our knowledge on the subject stated.

From the literature it appears that very little work has been done on the subject and, particularly, in India no work of this type has been undertaken so far.

CHAPTER II

MATERIALS AND METHODS

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CHAPTER II

MATERIALS AND METHODS

A brief account of the experimental techniques and the methods of analysis adopted during the course of two experiments conducted in the present investigation is given below:

I. Experimental techniques

A successful evaluation of the results in any experiment depends upon the sensitivity and accuracy of the experimental techniques employed. Keeping this fact in view, best efforts have been made in every aspect of this investigation.

(a) Selection of animals and their grouping

The nature of the investigation undertaken demanded that the work should be carried out on ruminants. The experiment was, however, designed to be conducted in sheep as per the availability of animals and economy in feeding and management practices.

Twelve healthy adult sheep (male) of local breed, aged between 2 and 2½ years and weighing from 20 to 30 kg., were selected for the experiments. The animals were kept under observation for a fortnight and during this period daily rectal temperature, pulse and respiration rates were noted which were found normal. Their faecal samples were also examined for intestinal parasites. As some of the samples showed positive tests for strongyles (nematodes), all the animals were dewormed by doses of Phenothiazine (15 g. each), which is a specific antihelminthic drug drug against a number of common nematode parasites occurring in these animals. Only when the faecal examination revealed negative results, the animals were put to pre-experimental feeding. These precautions were taken to ensure a healthy stock to start with.

The animals were divided at random into three groups of four animals after forming 4 blocks of 3 animals each. One of the groups served as control and the other two for different treatments, i.e., different levels of potassium feeding. The treatments also were randomized. For the purpose of the second experiment that was conducted, the animals were regrouped exactly on the pattern as outlined before. The initial live weights of the animals recorded in the beginning of the two experiments and detail of their grouping have been given in Table I.

Table I

Initial live weights and grouping of animals in Experiments I and II

EXPERIMENT I			EXPERIMENT II		
Group specification	Animal No.	Live weight (kg.)	Group specification	Animal No.	Live weight (kg.)
Group I (Control)	58	30.5	Group I (Control)	58	31.0
	53	28.5		53	29.0
	62	24.5		62	27.0
	78	22.5		72	22.0
Average		26.5	Average		27.3
Group II (ca 2% K level)	50	30.5	Group II (ca 3% K level)	61	31.0
	60	28.5		56	27.5
	54	24.5		59	27.0
	72	20.5		54	24.0
Average		26.0	Average		27.4
Group III (ca 4% K level)	61	30.5	Group III (ca 4% K level)	50	31.5
	56	25.5		60	28.5
	59	25.0		71	25.5
	71	22.5		78	24.0
Average		25.9	Average		27.4

(b) Selection and computation of basal diet

Experiment I

The nature of the present investigation demanded that the basal ration fed should be as low in potassium as possible. Sheep generally prefer soft leafy fodders. It was, therefore, decided that the animals should be maintained partly on a green feed which is available throughout the year and at the same time highly palatable. Cultivated fodders like green jowar, maize, etc. were eliminated, because most of them become so stemmy after 3 or 4 months that sheep can neither consume them sufficiently nor utilise them properly. Pakar (*Ficus infectoria*) leaves, a tree-leaf fodder, which are available green practically throughout the major part of the year were used as a part of the basal ration, especially because of their comparatively low potash content and high palatability for sheep.

To ensure a balanced maintenance ration it was considered advisable to meet up at least 50% of the protein requirement of the individual animals in the form of a concentrate mixture composed of 2 parts of crushed maize, 1 part of maize starch and 1 part of decorticated groundnut cake. Wheat *bhoosa* was fed *ad libitum* to all the animals to meet their 'dry matter' and 'total-digestible-nutrients' requirements. As, however, wheat bhoosa contained relatively high amounts of potassium, it was soaked in water for 24 hours, washed thoroughly and then dried in the snu. This washing treatment was done to remove, as far as possible, the soluble salts of potassium (viz. potassium oxalates, etc.) present. The ration was so devised as to make the sodium:potassium ratio in the experimental rations progressively wide between the groups. Their ratios in the three groups were approximately 1:3, 1:10 and 1:19 respectively.

Experiment II

In the second experiment, the concentrate mixture and pakar leaves were replaced by green berseem (Trifolium alexandrinum), which formed the only source of protein meeting the requirement of this nutrient of each animal. Wheat bhoosa was fed as such (i.e., unwashed) in order to have a different set of ratios of sodium:potassium ingestion in between the groups of animals, the major part of potassium in which coming from the feeds. The ratios are approximately 1:4, 1:8 and 1:11 respectively. The average chemical composition of ingredients of the basal ration throughout the feeding period of each experiment is set out in Table II.

Table II

Average percentage chemical composition of feeds throughout the feeding period of each experiment (on dry matter basis)

Feeds used	ORGANIC MATTER (%)					MINERAL MATTER (%)					
	Crude protein	Ether extract	Crude fibre	Nitrogen free-extract	Total	Total ash	Calcium	Phosphorus	Magnesium	Sodium	Potassium
EXPERIMENT I											
Concentrate mixture	19.10	2.19	3.53	71.84	96.66	3.34	0.061	0.308	0.215	0.231	0.972
Green pakar leaves	10.71	2.15	22.24	54.55	89.65	10.35	2.210	0.227	0.550	0.271	1.188
Wheat bhoosa (water washed)	2.69	0.82	43.22	48.83	95.56	4.44	0.242	0.108	0.098	0.189	0.453
EXPERIMENT II											
Green berseem	21.56	2.57	25.72	40.24	90.09	9.91	1.981	0.219	0.382	0.820	2.917
Wheat bhoosa (unwashed)	2.65	0.85	39.48	50.55	93.53	6.47	0.215	0.102	0.154	0.191	1.249

In order to avoid, as far as practicable, the variation in the chemical composition of the basal rations, the concentrate mixture was prepared in amounts to last for the whole experimental period, and so was wheat bhoosa stored. All the ingredients that made up the ration were chemically analysed before starting each of the experiments, and the basal ration was computed on this basis. Graded doses of potassium in the form of of potassium chloride were fed as supplement to raise the potassium intake upto the desired levels. Feeding was done according to the schedule given in the N.R.C. report 'Nutrient requirements of sheep' - Revised, 1957, at just above the maintenance level.

(c) Housing and management of animals

(i) Housing:

The animals were housed under hygienic conditions and necessary precautions taken during winter to prevent the animals from exposure to cold. Throughout the preliminary feeding period, the animals were let loose every morning for exercise in the open air, with muzzles on, so that the animals were unable to take any feed outside. While feeding in the shed, the animals were tied properly from both sides in order to prevent them from getting access to the feeding troughs of their neighbours.

(ii) Feeding and watering

In the first experiment the animals were fed thrice a day, while in the second twice a day. This was due to the nature of the two rations fed. Potassium is known to have a diuretic effect and as excessive accumulation of potassium in the body may cause toxicity, ad lib. watering of animals at least thrice a day was considered essential in these experiments, under high levels of potassium feeding.

Experiment I

The concentrate quota of the ration for each animal was weighed and offered daily at 9.30 A.M. individually in galvanized iron troughs assigned to each animal separately. When the concentrate mixture offered was completely eaten away, clean wholesome drinking water was offered liberally in measured quantities to each of the animals in order to study their water metabolism. The animals were then let out for exercise, with muzzles on, under the care of an attendant. Pakar leaves were offered in the afternoon followed by wheat bhoosa, which only was supplied ad lib. Every time water was offered the amount drunk was recorded. The quantities of wheat bhoosa allotted to each animal was so adjusted, during the first few days of the preliminary feeding periods of both the trials, that there was little residue left over in each case.

Experiment II

Here, the basal ration comprised of green berseem and unwashed wheat bhoosa only. Berseem is rich in potassium and wheat bhoosa also constitutes a good source of this mineral. The central idea of choosing this feeding regimen is (a) to limit potassium ingestion, as far as possible, from natural feeds alone and also (b) to study the effect on metabolism of ratios of sodium:potassium other than the ones used in the first experiment. Weighed quantities of green berseem allotted to each animal were offered at 9.30 A.M. daily in the individual mangers assigned to each animal. It was usual for the animals to consume the whole of the berseem offered in an hour or so. They were then watered and let out for exercise as usual. Wheat bhoosa was offered in the afternoon and its quantity consumed recorded.

(iii) Live weight records

The animals were initially weighed on three consecutive days to eliminate variability. Thereafter, weekly weighments were carried out and the adequacy of nutrients checked out. The weighings were usually done early in the morning before any feed or water was offered. The animals were also weighed both at the start and at the end of collection period in each trial.

(iv) Potassium supplementation

Potassium chloride (KCl), B.P. quality of S. Merck make, which contained 52.3% of potassium on raw basis formed the mineral supplement. It was added to the concentrate and pakar leaves quota of the basal ration of the first experiment and in berseem in the second at two graded levels so that the total potassium ingestion in the first experiment came approximately to 2 per cent and 4 per cent of the dry ration and around 3 and 4 per cent in the second. The control groups in the two experiments consumed about 0.7 and 1.8 per cent potassium respectively from the rations alone. The supplemental feeding of the salt (KCl) was initiated at a low level and then raised slowly to bring it to the levels desired in about a week's time. When the full quota of potassium chloride was fed, then only the preliminary feeding started.

These high levels of potassium feeding were adopted on the basis of considerations discussed in Chapter I.

(d) Conducting the metabolism trial

(i) Preliminary feeding and collection period

Two metabolism trials were conducted during the course of the present investigation. Each trial was preceded by a preliminary feeding period of 15 days, followed by a 7 day collection period on the basis of the following considerations.

In all metabolic studies, a preliminary feeding period varying from 2 to 4 weeks is usually considered necessary to eliminate the effect of the previous feed, although Hamilton *et al.* (1927-28) by using different indicators found that a three day preliminary feeding period in the case of ruminants was sufficient to eliminate the residual effect of the previous feed. According to Mitchell *et al.* (1932) also, longer preliminary feeding is un-necessary. The length of collection period in digestibility trials is likewise a matter of controversy. While longer collection period may secure more accuracy, it increases the labour, expense, and even the risk of animal sickness etc., which may affect the results adversely. Staples and Dinusson (1951) by comparing the relative accuracies between a 7 day and a 10 day collection periods concluded that a 7 day collection period could replace a 10 day period within reasonable limits of accuracy.

In the present investigation, therefore, a 15 day preliminary feeding period was followed by a 7 day collection period.

(ii) Sampling and preservation of feeds and feed residues

A regular routine as described before was followed in feeding and watering the animals during both the experimental and pre-experimental feeding periods. For the purposes of sampling, the concentrate mixture was thoroughly mixed before offering to the animals and a representative sample (about ½ kg.) was taken daily during the trial period for dry matter determination, and subsequently the dried material of each day was pooled and preserved in a well stoppered bottle for chemical analysis. Similarly, a representative sample of wheat bhoosa (about ½ kg.) was taken daily and after dry matter determination was pooled and preserved for analysis after milling.

In the case of green berseem or pakar leaves, a representative sample (about ½ kg.) was taken out daily from the lot at the time of feeding. After chopping well, two representative samples were taken for dry matter and crude protein estimations. The dried material of each day, after moisture determination, was pooled and preserved for further analysis after milling.

The wheat bhoosa residues left over daily were quantitatively collected for each animal, weighed and preserved. Necessary corrections in the consumption were later introduced. The total residues of all the animals were thoroughly mixed together in a lot and then a truly representative sample was taken to the laboratory for analysis. After dry matter determination, the wheat bhoosa residue was preserved in well stoppered bottles for further analysis after milling.

(iii) Collection, preservation and sampling of faeces and urine in the metabolism stall

As the usual conventional method was followed for the metabolism trials, the animals were shifted from the shed to the metabolism stall fitted with the usual conveniences and the collections were taken in the usual manner. The animals were harnessed with faecal and urine collection bags three days before the start of actual collection in order to acclimatise them to the harness condition as well as new environment. During these days the collections of faeces and urine, although taken, were rejected after weighing and measuring.

During the actual collection period of 7 days, the faeces and urine voided in 24 hours were collected and preserved in separate containers (plastic buckets for faeces and three litre glass bottles for urine) for each animal with the help of trained attendants keeping constant vigilance. The daily faecal excretions (24 hours' collections) were accurately weighed at a particular hour in the morning. Next, the faeces of each animal was mixed thoroughly and a representative sample obtained in a wide mouthed bakelite stoppered glass bottle bearing the brand number of the animal.

Simultaneously, the 24 hourly collections of urine from each animal also were accurately measured and after stirring well a representative sample of about half a litre was taken in a rubber stoppered glass bottle assigned to each animal separately. All the samplings were completed by 9.30 A.M. daily before offering feeds to the animals. The samples of faeces and urine were then brought to the laboratory for further aliquoting before analysis.

It may be mentioned here that 5 ml. of toluene was placed as a preservative in each collection bottle before each collection to avoid bacterial fermentations during each succeeding 24 hours.

(iv) Aliquoting and preservation of faeces and urine in the laboratory

All precautions were taken to avoid contamination of the samples from extraneous sources right from the time of collection to the time of final estimation. To prevent any decomposition and subsequent loss of ammonia, the urine samples were aliquoted first and the faeces samples later as described below.

Urine

Before aliquoting, the specific gravity of each urine sample was determined by means of a urinometer. There were large variations in the urinary output of different groups of animals in each trial and, therefore, the urine samples were aliquoted groupwise. Different aliquots were taken for nitrogen and mineral estimations.

For nitrogen estimation, the calculated quantity of urine aliquot for each animal was accurately pipetted out into the respective Kjeldahl flask (500 ml. capacity) assigned to each sample, in duplicate, containing 40 ml. of concentrated sulphuric acid. The flasks were, then properly covered and kept in place for the next day's aliquoting. Thus, the aliquots for 7 consecutive days for each animal were pooled together in the same flask for digestion.

Similarly, for mineral estimations, the calculated quantities of urine aliquot for individual animals were pipetted out into the respective weighed vitreosil basins, in duplicates. The samples in the basins were daily dried over hot water bath and the next day's fresh aliquots were added into the same basins. When all the seven days' pooled samples were completely dried, the basins were weighed again to determine the total solids and then kept for ashing for mineral estimations.

Faeces

After discarding the top layers of faeces from each collected sample, the calculated aliquot (1/20th of the total excretion per day) for dry matter determination was accurately weighed and taken up in a clean weighed petridish. The sample in the petri-dish was evenly spread out with the help of a horn spatula and dried in a hot air oven at 100°-105°C for 24 hours. The dry matter in the faeces for each animal was thus estimated daily during the trial period, and the dried material was pooled and preserved separately for each animal. At the end of the collection period, the dried faecal samples were milled in a milling machine and then preserved in well stoppered bottles bearing the brand numbers of the animals for chemical analysis.

Simultaneously, separate aliquots (1/50th of the total fresh faeces voided per animal per day) for nitrogen estimations were accurately weighed, taken up in a porcelain mortar, mixed up thoroughly with about 10 ml. of 25% sulphuric acid for fixation of nitrogen and then preserved in wide mouthed well stoppered weighed bottles assigned to each animal separately. After the collection period of 7 days, the bottles were weighed again and the pooled samples in each bottle were thoroughly mixed up. A suitable aliquot (ca 10 g. each) was then taken in a Kjeldahl flask, in duplicate, containing 30 ml. of concentrated sulphuric acid for digestion. Since, considerable loss of nitrogen takes place during drying (Kleiber et al., 1936), the nitrogen in faeces was estimated from the fresh sample only.

II. Methods of Chemical analysis

In the course of the present investigation, the methods of chemical analysis recommended by the A.O.A.C. (1960) were generally followed for the estimations of dry matter and proximate principles, while for the mineral estimations the methods adopted were the A.O.A.C. methods as modified by Talapatra, Ray and Sen (1940).

Feeds, feed residues, and faecal samples were analysed for dry matter, organic matter, crude protein, ether extract, crude fibre, nitrogen-free extract, mineral matter, total ash, calcium, phosphorus, magnesium, sodium and potassium. Nitrogen-free extract and total organic matter were, of course, found by difference. The results have been reported on per cent dry matter basis.

Urine samples, on the other hand, were analysed for total solids, total ash, nitrogen, calcium, phosphorus, magnesium, sodium and potassium; and the results have been reported as 'total excretion in urine per day'.

In all the estimations, the averages of duplicate results have been reported. A brief outline of the analytical methods employed in this work is given below:

(a) Dry matter determination

On proper sampling, a weighed quantity (8-10 g.) was taken in a clean and dry weighed moisture cup. The material was dried in the hot air oven at 100°-105°C for 24 hours and weighed again. The dry matter percentage of the samples was separately determined each time so that the results could be expressed uniformly on moisture free basis.

(b) Estimation of nitrogen and crude protein

This was carried out by the well known semi-micro Kjeldahl method. After the usual digestion with concentrated sulphuric acid in the presence of a catalyst (1 g. copper sulphate + 10 g. anhydrous sodium sulphate) the distillation was carried out with excess of 40% sodium hydroxide solution added to liberate ammonia, the distillate being collected in a known volume of standard sulphuric acid containing methyl red as an indicator. The figures of nitrogen found were, as usual, multiplied by 6.25 to obtain the protein content. For accuracy, a blank was run with all the reagents used, every time a batch of distillation was performed.

(c) Estimation of ether extract

Ether extract was estimated by the usual Soxhlet method of extraction as per recommendations of the A.O.A.C. (*loc. cit.*). After complete removal of the petroleum ether, the oil flask was weighed to a constant weight to get the weight of the ether extract.

(d) Estimation of crude fibre

The usual Weende method of crude fibre estimation was followed, utmost care being exercised in regard to the period of boiling, filtration, washing etc. The washed residue was quantitatively transferred in a weighed crucible and dried at 100°C to a constant weight. The dried residue was then ashed, cooled and weighed again. The loss in weight on ignition gave the weight of crude fibre content.

(e) Estimation of nitrogen-free extract

The percentage of nitrogen-free extract was found by the method of difference by subtracting the sum total of the percentages on dry basis of crude protein, ether extract, crude fibre and total ash from hundred.

(f) Estimation of total ash and organic matter

A weighed quantity of the powdered sample taken in a vitreosil basin was ignited, first on a low flame to char the material and then in an electric muffle furnace to ash it at 550°C for about 2 hours. It was cooled and weighed again to get the total ash content. The total organic matter percentage was then obtained by subtracting the percentage of total ash from hundred.

(g) Estimation of calcium

Calcium was estimated in the hydrochloric acid extract of the ash by the method of McCrudden as modified by Talapatra, Ray and Sen (1940).

Calcium was precipitated as calcium oxalate at a pH of 4.0 to 5.5. The washed precipitate of calcium oxalate was then titrated hot against a standard N/10 potassium permanganate solution, using concentrated sulphuric acid to liberate the nascent oxygen from the oxidation of oxalic acid. The result was calculated as elemental calcium on per cent dry matter basis.

(h) Estimation of phosphorus

Phosphorus was estimated by the method of Neumann as modified by Talapatra _et al._ (_loc. cit._), which is based on the principle that when a solution of phosphorus in an excess of dilute nitric acid is treated with ammonium molybdate, a canary yellow precipitate of ammonium phosphomolybdate [$(NH_4)_3PO_4 12MoO_3 6H_2O$] is obtained.

The washed precipitate of ammonium phosphomolybdate was dissolved in a known volume of standard sodium hydroxide solution and the excess of alkali was back titrated against a standard nitric acid solution, using phenolphthalein as indicator. The percentage of phosphorus was calculated on the elemental basis.

(i) Estimation of magnesium

Magnesium was estimated in the combined filtrate and washings from calcium determination by the A.O.A.C. method as modified by Talapatra _et al._ (_loc. cit._), which is based on the principle that the magnesium pyrophosphate formed by the addition of 10% ammonium phosphate and sodium citrate in a strongly ammoniated solution can be determined gravimetrically.

The washed precipitate of magnesium pyrophosphate along with the filter paper was dried and ignited in an electric muffle furnace at 600°C when a greyish-white ash was obtained. The weight of the ash gave the content of magnesium pyrophosphate which was then calculated as elemental magnesium.

(j) Estimation of sodium and potassium

Sodium and potassium were estimated by the A.O.A.C. method as modified by Talapatra et al. (loc. cit.), a brief outline of which is given below.

A suitable aliquot of the prepared hydrochloric extract, after evaporation to dryness, was moistened with a drop of HCl and little distilled water, boiled for a few minutes with clear baryta water until alkaline and then filtered hot to remove iron, aluminium, sulphates etc. The dried residue of the filtrate, after cooling, was taken up with 35 ml. of alcoholic ammonium-carbonate solution and stirred thoroughly for 5 minutes. It was then transferred quantitatively into a 100 ml. volumetric flask and the volume made upto the mark with the same alcoholic ammonium-carbonate solution. The contents were thoroughly shaken, allowed to stand overnight and then filtered to remove calcium, barium etc. An aliquot of the filtrate was pipetted out into a weighed vitreosil basin and evaporated to dryness. The dry residue was taken up with 1 ml. of concentrated hydrochloric acid and a little distilled water and again evaporated to dryness. The latter was carefully heated on a low flame until dense white fumes of ammonium salts no longer appeared. The mixed chlorides of sodium and potassium, after cooling in a dessicator, were weighed and dissolved in a little hot distilled water and then transferred quantitatively into a beaker.

The mixed chlorides were then treated with perchloric acid (sp. gr. 1.125) to transform the potassium chloride into potassium perchlorate which was later separated out in presence of 95% alcohol and filtered. The washed solid potassium perchlorate on the filter paper was dissolved in hot distilled water by washing the filter paper thoroughly and the solution was received in a weighed vitreosil basin and evaporated to dryness. The dry residue was heated on a low naked flame taking care that the solid potassium perchlorate did not melt. It was cooled in a desiccator and weighed again to get the weight of potassium perchlorate formed. The amount of potassium chloride was calculated and by deducting it from the mixed chlorides, the weight of sodium chloride was obtained. The elemental sodium and potassium were calculated from the weights of sodium chloride and potassium perchlorate respectively.

(k) Statistical interpretation of data

The relevant data concerning each trial was subjected to 'Analysis of variance' individually according to Snedecor (1961). The characters in which the 'F' ratio between treatments came out to be significant, and their group means were subsequently compared with the help of 'Critical difference' and the results discussed.

SUMMARY

The basis for the selection of animals for the two experiments, their ration schedule and supplements, plan of the experiments, feeding and management of animals, aliquoting and preservation of biological materials, estimation of various nutrients and the methods of analysis including the statistical interpretation of the data employed during the course of the present investigation have been discussed in brief in this Chapter.

CHAPTER III

STUDIES ON SODIUM:POTASSIUM RATIO AS AFFECTING THE NUTRIENT METABOLISM IN ADULT SHEEP- PART I

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CHAPTER III

STUDIES ON SODIUM:POTASSIUM RATIO AS AFFECTING THE NUTRIENT METABOLISM IN ADULT SHEEP

PART I

Recent investigations on the mineral requirements of the growing animal make it increasingly evident that the adjustment of the proportions of the inorganic constituents of a ration requires as much consideration as the absolute amounts of these elements in the diet. Even though a mineral is present in a ration in sufficient amount for the animal's requirements, the presence of other minerals in unsuitable proportions may lead to insufficient assimilation and retention. The importance in animal nutrition of this balancing of the ration has been frequently emphasised by Orr (1924), who quotes various instances of the interdependence of the different mineral elements. Of special interest in this connection are sodium and potassium. The importance of the ratio of these to each other in the diet was discussed by Bunge as long ago as 1873, and since then the ratio has received more attention than the absolute requirements of each.

A perusal of the review of literature in Chapter I would indicate that high potassium intake or wide sodium:potassium ratio can disturb mineral metabolism by the animals. Richards _et al._ (1927) observed that when the ratio of sodium:potassium was 1:10 or 11, even nitrogen assimilation was reduced in growing pigs. Water intake and urinary volume are also directly related to sodium and potassium intake. Ward (1966) observed that water demands for urinary excretion of potassium may be a factor in water turn over rate, but this has not been investigated. No systematic work on these aspects has been conducted in ruminants, which prompted us to undertake the present investigation. The results obtained are presented in this Chapter.

RESULTS AND DISCUSSION

As already indicated in Chapter II, twelve adult sheep were employed in the present study. Their grouping, mode of feeding and other experimental details have been outlined earlier. After 15 days of preliminary feeding a metabolism trial extending over a 7 day period was conducted. During the trial period the levels of sodium and potassium feeding were as shown in Table III.

It will be seen from Table III that the percentage of sodium in the basal ration on dry matter basis (0.22%) was adequate as per the requirement suggested by Maynard and Loosli (1962) and the percentage of potassium progressively increased from 0.77 to 4.38 as per the planning of the experiment from the first group to the last. Likewise, sodium:potassium ratio as well as sodium + potassium ingestion also systematically increased from group to group.

Feed consumption, dry matter digestibility and live weight records

The data regarding dry matter consumption and its digestibility are presented in Tables IV and V and the live weight records of the whole feeding period in Table VI.

It will be seen from Table IV that the animals ingested on an average 31.81 g., 30.31 g. and 29.91 g. of dry matter per kg. body weight in groups I, II and III respectively, which appeared to be higher than the N.R.C. (1957) recommendations, i.e., 2.6% of the live weight or

Table III

Levels of sodium and potassium ingestion during the trial period

Trial I

Animal No.	% Na in the ration	% K in the ration	Na ingested (g.)	K ingested (g.)	Na:K ratio of ingestion	Na + K ingested (g.)
			Group I (Control)			
58	0.22	0.75	1.92	6.53	1:3.4	8.45
53	0.22	0.76	1.88	6.45	1:3.4	8.33
62	0.22	0.79	1.77	6.21	1:3.5	7.98
78	0.22	0.77	1.84	6.35	1:3.5	8.19
Average	0.22	0.77	1.85	6.39	1:3.5	8.24
			Group II (ca 2% K level)			
50	0.23	2.50	1.74	19.21	1:11.0	20.95
60	0.22	2.34	1.75	18.19	1:10.4	19.94
54	0.23	2.44	1.60	16.81	1:10.5	18.41
72	0.24	2.31	1.54	15.11	1: 9.8	16.65
Average	0.23	2.40	1.66	17.34	1:10.4	18.99
			Group III (ca 4% K level)			
61	0.22	4.45	1.77	34.97	1:19.8	36.74
56	0.23	4.41	1.67	32.13	1:19.2	33.80
59	0.23	4.43	1.66	32.12	1:19.3	33.78
71	0.23	4.22	1.61	29.40	1:18.3	31.01
Average	0.23	4.38	1.68	32.16	1:19.2	33.83

Table IV

Average live weights and dry matter consumption of individual animals per day

Trial I

Animal No.	Live weight (kg.)			Dry matter consumption (g.)				
	At the start of collection period	At the end of collection period	Average during collection period	From concentrate mixture	From pakar leaves	From wheat bhoosa (water washed)	Total	Per kg. live weight
				Group I (Control)				
58	30.00	30.50	30.25	202.50	195.00	476.68	874.18	28.90
53	28.00	29.00	28.50	202.50	195.00	454.63	852.13	29.90
62	24.00	24.00	24.00	202.50	195.00	391.17	788.67	32.86
78	23.00	23.50	23.25	202.50	195.00	429.65	827.15	35.58
Average	26.25	26.75	26.50	202.50	195.00	438.03	835.53	31.81
				Group II (ca 2% K level)				
50	28.50	29.00	28.75	202.50	195.00	371.80	769.30	26.76
60	27.00	28.00	27.50	202.50	195.00	379.82	777.32	28.27
54	22.00	22.00	22.00	202.50	195.00	291.64	689.14	31.32
72	19.50	18.00	18.75	202.50	195.00	256.90	654.40	34.90
Average	24.25	24.25	24.25	202.50	195.00	325.04	722.54	30.31
				Group III (ca 4% K level)				
61	28.50	29.00	28.75	202.50	195.00	389.17	786.68	27.36
56	24.50	25.00	24.75	202.50	195.00	331.45	728.95	29.45
59	23.50	22.50	23.00	202.50	195.00	327.22	724.72	31.51
71	22.50	22.00	22.25	202.50	195.00	299.66	697.16	31.33
Average	24.75	24.63	24.69	202.50	195.00	336.88	734.38	29.91

Table V

Trial I

Dry matter digestibility data

Animal No.	Total intake (g.)	Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
Group I (Control)				
58	874.2	429.5	444.7	50.87
53	852.1	424.6	427.5	50.17
62	788.7	390.6	398.1	50.48
78	827.2	406.6	420.6	50.85
Average	835.5	412.8	422.7	50.59
Group II (ca 2% K level)				
50	769.3	374.9	394.4	51.27
60	777.3	362.9	414.4	53.31
54	689.1	306.7	382.4	55.49
72	654.4	311.6	342.8	52.38
Average	722.5	339.0	383.5	53.11
Group III (ca 4% K level)				
61	786.7	375.4	411.3	52.28
56	729.0	345.4	383.6	52.62
59	724.7	299.2	425.5	58.71
71	697.2	351.5	345.7	49.58
Average	734.4	342.9	391.5	53.30

Table VI

Live weights of animals during the whole feeding period

Trial I

Animal No.	0 day	8th day	16th day (before expt.)	25th day (after expt.)	Weight gain or loss
			Group I (Control)		
58	30.5	30.5	30.0	30.5	Nil
53	28.5	28.0	28.0	29.0	+ 0.5
62	24.5	24.0	24.0	24.0	- 0.5
78	22.5	23.0	23.0	23.5	+ 1.0
Average	26.5	26.4	26.3	26.8	+ 0.3
			Group II (ca 2% K level)		
50	30.5	30.0	28.5	29.0	- 1.5
60	28.5	28.0	27.0	28.0	- 0.5
54	24.5	23.0	22.0	22.0	- 2.5
72	20.5	20.0	19.5	18.0	- 2.5
Average	26.0	25.3	24.3	24.3	- 1.8
			Group III (ca 4% K level)		
61	30.5	30.0	28.5	29.0	- 1.5
56	25.5	25.0	24.5	25.0	- 0.5
59	25.0	24.0	23.5	22.5	- 2.5
71	22.5	23.0	22.5	22.0	- 0.5
Average	25.9	25.5	24.8	24.6	- 1.3

26 g. per kg. live weight on a ration containing 90% dry matter. The ration fed was evidently palatable. The live weight records given in Table VI, however, indicate that the animals maintained their live weights during the short period of 25 days with difficulty and indeed in the potassium supplemented groups there was a small depression. This seems to be in harmony with the observations of Meyer and Cohn (1911) who stated that potassium salts, as a rule, caused a loss of weight (cited by Richards _et al._, _loc. cit._).

The data concerning the total dry matter ingested and its digestibility coefficients presented in Table V were subjected to analysis of variance. The 'F' ratio within treatments was found to be significant at 5% level in the case of total dry matter intake only. The results of analysis of variance has been set out in Table VII.

In the case of total dry matter intake, it will be seen from Tables IV and VII that the means of experimental groups were not statistically different from one another, though both were significantly different from the control. This shows that a change of average sodium: potassium ratio from 1:3.5 to 1:10.4 tends to depress the dry matter consumption significantly and is not further

Table VII

Analysis of varience data for dry matter ingested, digested and and per cent digestibility

Trial I

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
Total dry matter ingested				
Between blocks	3	14778.6135	4926.2045	
Between treatments	2	30850.5207	15425.2604	9.80*
Error	6	9448.7374	1574.7896	
Total dry matter digested				
Between blocks	3	3789.72	1263.24	
Between treatments	2	3435.26	1717.630	2.74 N.S.
Error	6	3766.29	627.715	
Per cent dry matter digestibility				
Between blocks	3	28.0016	9.3339	
Between treatments	2	18.2689	9.1345	2.06 N.S.
Error	6	26.5650	4.4275	

* Significant at 5% level.
Critical difference (C.D.) = 68.80
N.S. denotes not statistically significant.

affected when the ratio becomes as wide as 1:19.2.

Digestibility of proximate principles

The digestibility data of crude protein, ether extract, crude fibre and nitrogen-free extract are presented in Tables VIII, IX, X and XI respectively. In addition, actual T.D.N. ingestion during the metabolism trial as compared with the N.R.C. (loc. cit.) recommendations for identical weights has been calculated and incorporated in Table XII.

It will be seen from Table XII that the animals had been ingesting more T.D.N. than their stipulated requirements; C.P. ingestion likewise as shown in Table VIII had been more than adequate as per the N.R.C. (loc. cit.) calculated allowances, which are 2 g. per kg. live weight.

The average digestibility figures of crude protein given in Table VIII indicate an increase from 33.32 in the control group to 38.83 and to 42.38% respectively in the two potassium supplemented groups, those of ether extract increased from 45.22 to 54.12 and to 56.41% (Table IX) and of nitrogen-free extract (Table XI) from 55.92 to 59.79 and to 60.46% from group I to II

Table VIII

Crude protein digestibility data

Trial I

Animal No.	Intake (g.)				Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
	From concentrate mixture	From pakar leaves	From wheat Bhoosa (washed)	Total			
Group I (Control)							
58	38.68	21.27	13.01	72.96	44.63	28.33	38.83
53	38.68	21.27	12.48	72.43	51.31	21.12	29.16
62	38.68	21.27	10.93	70.88	49.94	20.94	29.54
78	38.68	21.27	11.86	71.81	46.13	25.68	35.76
Average	38.68	21.27	12.07	72.02	48.00	24.02	33.32
Group II (ca 2% K level)							
50	38.68	21.27	10.46	70.41	44.75	25.66	36.44
60	38.66	21.27	10.65	70.60	46.13	24.47	34.66
54	38.66	21.27	8.51	68.46	41.50	26.96	39.38
72	38.65	21.27	7.67	67.62	37.31	30.31	44.82
Average	38.68	21.27	9.32	69.27	42.42	26.85	38.83
Group III (ca 4% K level)							
61	38.66	21.27	10.88	70.83	44.25	26.58	37.53
56	38.68	21.27	9.48	69.43	40.44	28.99	41.75
59	38.68	21.27	9.38	69.33	34.13	35.20	50.77
71	38.68	21.27	8.71	68.66	41.56	27.10	39.47
Average	38.68	21.27	9.61	69.56	40.10	29.47	42.38

Table IX

Trial I

Ether extract digestibility data

Animal No.	Intake (g.) From concentrate mixture	From Pakar leaves	From wheat bhoosa (washed)	Total	Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
			Group I (Control)				
58	4.43	4.19	3.63	12.25	7.56	4.69	38.29
53	4.43	4.19	3.54	12.16	6.75	5.41	44.49
62	4.43	4.19	3.26	11.88	6.17	5.71	48.06
78	4.43	4.19	3.43	12.05	6.02	6.03	50.04
Average	4.43	4.19	3.47	12.09	6.63	5.46	45.22
			Group II (ca 2% K level)				
50	4.43	4.19	3.17	11.79	5.44	6.35	53.86
60	4.43	4.19	3.21	11.83	5.77	6.06	51.23
54	4.43	4.19	2.82	11.44	4.08	7.36	64.24
72	4.43	4.19	2.67	11.29	5.98	5.31	47.03
Average	4.43	4.19	2.97	11.59	5.32	6.27	54.12
			Group III (ca 4% K level)				
61	4.43	4.19	3.25	11.87	6.49	5.38	45.32
56	4.43	4.19	2.99	11.61	3.80	7.81	67.27
59	4.43	4.19	2.97	11.59	5.21	6.38	55.05
71	4.43	4.19	2.85	11.47	4.82	6.65	57.98
Average	4.43	4.19	3.02	11.64	5.08	6.56	56.41

Table X

Crude fibre digestibility data

Trial I

Animal No.	Intake (g.) From concentrate mixture	Intake (g.) From Pakar leaves	Intake (g.) From wheat bhoosa (washed)	Intake (g.) Total	Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
Group I (Control)							
58	6.74	43.37	214.62	264.73	112.14	152.59	57.64
53	6.74	43.37	204.36	254.47	109.63	144.84	56.92
62	6.74	43.37	174.84	224.95	100.15	124.80	55.48
78	6.74	43.37	192.74	242.85	107.95	134.90	55.55
Average	6.74	43.37	196.64	246.75	107.47	139.28	56.40
Group II (ca 2% K level)							
50	6.74	43.37	165.83	215.94	98.64	117.30	54.32
60	6.74	43.37	169.56	219.67	96.68	122.99	55.99
54	6.74	43.37	128.54	178.65	68.76	109.89	61.51
72	6.74	43.37	112.38	162.49	78.77	83.72	51.52
Average	6.74	43.37	144.08	194.19	85.71	108.48	55.84
Group III (ca 4% K level)							
61	6.74	43.37	173.91	224.02	107.55	116.47	51.99
56	6.74	43.37	147.06	197.17	95.61	101.56	51.51
59	6.74	43.37	145.09	195.20	82.37	112.83	57.80
71	6.74	43.37	132.27	182.38	94.83	87.55	48.00
Average	6.74	43.37	149.58	199.69	95.09	104.60	50.33

Table XI

Nitrogen-free extract digestibility data

Trial I

Animal No.	Intake (g.) From concentrate mixture	Intake (g.) From pakar leaves	Intake (g.) From wheat bhoosa (washed)	Intake (g.) Total	Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
			Group I (Control)				
58	145.88	100.13	223.42	469.43	214.11	255.32	54.39
53	145.88	100.13	212.99	459.00	204.53	254.47	55.44
62	145.88	100.13	182.96	428.97	182.53	246.44	57.45
78	145.88	100.13	201.17	447.18	195.05	252.13	56.38
Average	145.88	100.13	205.14	451.15	199.06	252.09	55.92
			Group II (ca 2% K level)				
50	145.88	100.13	173.79	419.80	176.84	242.96	57.88
60	145.88	100.13	177.59	423.60	168.02	255.58	60.34
54	145.88	100.13	135.86	381.87	147.86	234.01	61.28
72	145.88	100.13	119.42	365.43	147.36	218.07	59.67
Average	145.88	100.13	151.67	397.68	160.02	237.66	59.79
			Group III (ca 4% K level)				
61	145.88	100.13	182.01	428.02	169.16	258.86	60.48
56	145.88	100.13	154.70	400.71	161.99	238.72	59.57
59	145.88	100.13	152.70	398.71	138.86	259.85	65.17
71	145.88	100.13	139.66	385.67	167.31	218.36	56.62
Average	145.88	100.13	157.27	403.28	159.33	243.95	60.46

Table XII

Actual T.D.N. ingestion per day as compared to the stipulated requirements (N.R.C., loc. cit.) on the basis of average live weights during the trial period

Trial I

Animal No.	Actual ingestion	Stipulated requirement
	Group I (Control)	
58	446.79	393.25
53	432.60	370.50
62	405.03	312.00
78	426.28	302.25
Average	427.68	344.50
	Group II (ca 2% K level)	
50	400.21	373.75
60	416.68	357.50
54	387.42	286.00
72	344.05	243.75
Average	387.09	315.25
	Group III (ca 4% K level)	
61	414.02	373.75
56	386.84	321.75
59	422.24	299.00
71	347.97	289.25
Average	392.77	320.94

and to III respectively. In the case of crude fibre, however, the average digestibility figures shown in Table X, show a decreasing trend from 56.40 to 55.84 and to 52.33 in groups I, II and III respectively.

When the digestibility data of each nutrient was subjected to analysis of variance, the 'F' ratio between treatments came out to be significant at 5% level in the case of nitrogen-free extract only. In all other cases, it was not significant even at this level. The results of analysis of variance are given in Table XIII.

So far as the digestibility of crude fibre is concerned, our results do not tally with the following observations:

Hubert et al. (1958) observed that potassium was essential for cellulose digestion in an in vitro system. Balch and Johnson (1950) showed that a higher moisture content in the rumen, as a result of potassium feeding, favoured cellulose digestion by the cow. Increases in potassium intake were related among others to increases in crude fibre intake (Knox et al., 1965, Leitch and Thomson, 1944). Simultaneously, a number of trials with cattle and sheep fed high grain rations or

Table XIII

Analysis of variance data for various nutrient digestibility and actual "Total digestible nutrients" ingested

Trial I

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
		Crude protein digestibility (%)		
Between blocks	3	46.7902	15.5967	
Between treatments	2	166.6051	83.3025	2.73 N.S.
Error	6	183.1806	30.5301	
		Ether extract digestibility (%)		
Between blocks	3	174.6519	58.2173	
Between treatments	2	279.2925	139.6463	2.67 N.S.
Error	6	313.5821	52.2637	
		Crude fibre digestibility (%)		
Between blocks	3	65.0349	21.6783	
Between treatments	2	38.9623	19.4812	2.90 N.S.
Error	6	40.9438	6.8240	

N.S. denotes not statistically significant.

Table XIII (contd.)

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
		Nitrogen-free extract digestibility (%)		
Between blocks	3	28.1239	9.3746	
Between treatments	2	48.1834	24.0917	6.90*
Error	6	20.9071	3.4845	
		Actual T.D.N. ingested		
Between blocks	3	3897.2756	1299.0919	
Between treatments	2	3863.8797	1931.9399	5.11 N.S.
Error	6	2269.6066	378.2678	

* Significant at 5% level

Critical difference (C.D.) = 3.23

N.S. denotes not statistically significant.

rations containing corn cobs as roughage have shown that improvements in digestibility and weight gains could be produced by adding alfalfa or alfalfa ash to the rations, which contained much higher concentration of potassium than the basal ration supplemented with a mineral mixture supplying all the known requirements of sheep (Chappel et al., 1955; Ward, loc. cit.). The results of certain experiments conducted by Gupta (1967) have indicated that the digestibility of wheat bhoosa nitrogen was improved when buffalo bullocks were offered rations consisting of urea, wheat bhoosa and molasses, the latter two being rich in potassium.

Balances of Nitrogen and Minerals

The balance data of nitrogen, calcium, phosphorus, magnesium, sodium and potassium have been set out in Tables XIV, XV, XVI, XVII, XVIII and XIX respectively.

Nitrogen balance data

From Table XIV, it will be seen that the total amount of nitrogen ingested was about the same in all the groups and the ingestion was higher than that recommended by N.R.C. of the U.S.A. (loc. cit.) for animals of similar body weight. The balances of nitrogen were also positive

Table XIV

Nitrogen balance data

Trial I

Animal No.	Intake (g.)				Outgo (g.)			Balance
	From concentrate mixture	From pakar leaves	From wheat bhoosa (washed)	Total	in faeces	in urine	Total	
Group I (Control)								
58	6.19	3.40	2.08	11.67	7.14	3.89	11.03	+ 0.64
53	6.19	3.40	2.00	11.59	8.21	2.92	11.13	+ 0.46
62	6.19	3.40	1.75	11.34	7.99	3.05	11.04	+ 0.30
78	6.19	3.40	1.90	11.49	7.38	3.33	10.71	+ 0.78
Average	6.19	3.40	1.93	11.52	7.68	3.30	10.98	+ 0.55
Group II (ca 2% K level)								
50	6.19	3.40	1.67	11.26	7.16	4.16	11.32	- 0.06
60	6.19	3.40	1.70	11.29	7.38	3.89	11.27	+ 0.02
54	6.19	3.40	1.36	10.95	6.64	4.33	10.97	- 0.02
72	6.19	3.40	1.23	10.82	5.97	4.48	10.45	+ 0.37
Average	6.19	3.40	1.49	11.08	6.79	4.22	11.00	+ 0.08
Group III (ca 4% K level)								
61	6.19	3.40	1.74	11.33	7.08	5.18	12.26	- 0.93
56	6.19	3.40	1.52	11.11	6.47	3.43	9.90	+ 1.21
59	6.19	3.40	1.50	11.09	5.46	6.08	11.54	- 0.45
71	6.19	3.40	1.39	10.98	6.65	4.07	10.72	+ 0.26
Average	6.19	3.40	1.54	11.13	6.42	4.69	11.11	+ 0.02

Trial I

Table XV

Calcium balance data

Animal No.	Intake (g.)				(Outgo (g.)			Balance
	From concentrate mixture	From pakar leaves	From wheat bhoosa (washed)	Total	In faeces	In urine	Total	
Group I (Control)								
58	1.24	4.31	1.22	6.77	4.98	0.33	5.31	+ 1.46
53	1.24	4.31	1.22	6.77	5.52	0.17	5.69	+ 0.98
62	1.24	4.31	1.02	6.57	5.31	0.18	5.49	+ 1.08
78	1.24	4.31	1.12	6.67	4.72	0.20	4.92	+ 1.75
Average	1.24	4.31	1.12	6.67	5.13	0.22	5.35	+ 1.32
Group II (ca 2% K level)								
50	1.24	4.31	0.92	6.47	5.70	0.27	5.97	+ 0.50
60	1.24	4.31	1.02	6.57	5.01	0.36	5.37	+ 1.20
54	1.24	4.31	0.82	6.37	5.24	0.18	5.42	+ 0.95
72	1.24	4.31	0.72	6.27	4.52	0.38	4.90	+ 1.37
Average	1.24	4.31	0.87	6.42	5.12	0.30	5.42	+ 1.00
Group III (ca 4% K level)								
61	1.24	4.31	1.02	6.57	4.73	0.51	5.24	+ 1.33
56	1.24	4.31	0.92	6.47	4.49	0.61	5.10	+ 1.37
59	1.24	4.31	0.88	6.43	4.22	0.34	4.56	+ 1.87
71	1.24	4.31	0.82	6.37	4.57	0.49	5.06	+ 1.31
Average	1.24	4.31	0.91	6.46	4.50	0.49	4.99	+ 1.47

Table XVI

Phosphorus balance data

Trial I

Animal No.	Intake (g.)				Outgo (g.)			Balance
	From concentrate mixture	From pakar leaves	From wheat bhoosa (washed)	Total	In faeces	In urine	Total	
Group I (Control)								
58	0.608	0.429	0.534	1.571	0.863	0.013	0.876	+ 0.695
53	0.608	0.429	0.516	1.553	0.692	0.007	0.699	+ 0.854
62	0.608	0.429	0.464	1.501	0.633	0.009	0.642	+ 0.859
78	0.608	0.429	0.495	1.532	0.886	0.007	0.893	+ 0.639
Average	0.608	0.429	0.502	1.539	0.769	0.009	0.778	+ 0.762
Group II (ca 2% K level)								
50	0.608	0.429	0.443	1.425	1.342	0.005	1.347	+ 0.138
60	0.608	0.429	0.454	1.491	1.310	0.009	1.319	+ 0.172
54	0.608	0.429	0.382	1.419	1.037	0.100	1.137	+ 0.282
72	0.608	0.429	0.354	1.391	0.981	0.005	0.986	+ 0.405
Average	0.608	0.429	0.410	1.447	1.168	0.030	1.197	+ 0.249
Group III (ca 4% K level)								
61	0.608	0.429	0.462	1.499	1.558	0.004	1.562	+ 0.063
56	0.608	0.429	0.415	1.452	1.351	0.003	1.354	+ 0.098
59	0.608	0.429	0.411	1.448	1.188	0.035	1.223	+ 0.225
71	0.608	0.429	0.389	1.426	1.121	0.004	1.125	+ 0.301
Average	0.608	0.429	0.419	1.456	1.305	0.012	1.316	+ 0.172

Table XVII

Magnesium balance data

Trial I

Animal No.	Intake (g.)				Outgo (g.)			Balance
	From concentrate mixture	From pakar leaves	From wheat bhoosa (washed)	Total	In faeces	In urine	Total	
Group I (Control)								
58	0.435	1.073	0.473	1.981	1.250	0.550	1.800	+ 0.181
53	0.435	1.073	0.453	1.961	1.230	0.310	1.540	+ 0.421
62	0.535	1.073	0.396	1.904	1.090	0.520	1.610	+ 0.294
78	0.435	1.073	0.431	1.939	1.180	0.460	1.640	+ 0.299
Average	0.435	1.073	0.438	1.946	1.190	0.460	1.650	+ 0.299
Group II (ca 2% K level)								
50	0.435	1.073	0.379	1.887	1.460	0.390	1.850	+ 0.037
60	0.435	1.073	0.386	1.894	1.160	0.400	1.560	+ 0.334
54	0.435	1.073	0.307	1.815	1.470	0.280	1.750	+ 0.065
72	0.435	1.073	0.275	1.783	1.220	0.470	1.690	+ 0.093
Average	0.435	1.073	0.337	1.845	1.330	0.390	1.713	+ 0.132
Group III (ca 4% K level)								
61	0.435	1.073	0.394	1.902	1.200	0.370	1.570	+ 0.332
56	0.435	1.073	0.342	1.850	1.310	0.380	1.690	+ 0.160
59	0.435	1.073	0.339	1.847	0.960	0.540	1.500	+ 0.347
71	0.435	1.073	0.314	1.822	1.510	0.360	1.870	- 0.048
Average	0.435	1.073	0.347	1.855	1.250	0.410	1.658	+ 0.198

Table XVIII

Trial I

Sodium balance data

Animal No.	Intake (g.)				Outgo (g.)			Balance
	From concentrate mixture	From pakar leaves	From wheat bhoosa (washed)	Total	In faeces	In urine	Total	
Group I (Control)								
58	0.47	0.53	0.92	1.92	0.52	0.08	0.60	+ 1.32
53	0.47	0.53	0.88	1.88	0.13	0.12	0.25	+ 1.63
62	0.47	0.53	0.77	1.77	0.51	0.05	0.56	+ 1.21
78	0.47	0.53	0.84	1.84	0.61	0.00	0.61	+ 1.23
Average	0.47	0.53	0.85	1.85	0.44	0.06	0.50	+ 1.35
Group II (ca 2% K level)								
50	0.47	0.53	0.74	1.74	0.22	2.44	2.66	- 0.92
60	0.47	0.53	0.75	1.75	0.18	0.49	0.67	+ 1.08
54	0.47	0.53	0.60	1.60	0.06	0.03	0.09	+ 1.51
72	0.47	0.53	0.54	1.54	0.12	0.35	0.47	+ 1.07
Average	0.47	0.53	0.66	1.66	0.15	0.83	0.97	+ 0.69
Group III (ca 4% K level)								
61	0.47	0.53	0.77	1.77	0.04	0.28	0.32	+ 1.45
56	0.47	0.53	0.67	1.67	0.21	2.26	2.47	- 0.80
59	0.47	0.53	0.66	1.66	0.51	0.04	0.55	+ 1.11
71	0.47	0.53	0.61	1.61	0.28	0.12	0.40	+ 1.21
Average	0.47	0.53	0.68	1.68	0.26	0.68	0.94	+ 0.74

Table XIX

Potassium balance data

Trial I

Animal No.	Intake (g.)					Outgo (g.)			Balance
	From concentrate mixture	From pakar leaves	From wheat bhoosa (washed)	From potassium chloride supplement	Total intake	In faeces	In urine	Total	
Group I (Control)									
58	1.97	2.32	2.24	-	6.53	2.02	1.97	3.99	+ 2.54
53	1.97	2.32	2.16	-	6.45	2.97	0.95	3.92	+ 2.53
62	1.97	2.32	1.92	-	6.21	2.11	1.20	3.31	+ 2.90
78	1.97	2.32	2.06	-	6.35	2.31	1.22	3.53	+ 2.82
Average	1.97	2.32	2.10	-	6.39	2.35	1.34	3.69	+ 2.70
Group II (ca 2% K level)									
50	1.97	2.32	1.84	13.08	19.21	2.66	10.70	13.36	+ 5.85
60	1.97	2.32	1.87	12.03	18.19	1.23	13.80	15.03	+ 3.16
54	1.97	2.32	1.54	10.98	16.81	2.64	9.47	11.11	+ 4.70
72	1.97	2.32	1.41	9.41	15.11	1.31	13.40	14.71	+ 0.40
Average	1.97	2.32	1.67	11.38	17.34	1.96	11.84	13.80	+ 3.53
Group III (ca 4% K level)									
61	1.97	2.32	1.91	28.77	34.97	1.73	25.89	27.62	+ 7.35
56	1.97	2.32	1.69	26.15	32.13	1.62	21.20	22.82	+ 9.31
59	1.97	2.32	1.68	26.15	32.12	1.91	11.88	13.79	+18.33
71	1.97	2.32	1.57	23.54	29.40	1.93	23.50	25.43	+ 3.97
Average	1.97	2.32	1.71	26.15	32.16	1.80	20.62	22.42	+ 9.74

in all the groups. But while in the control group the intake and outgo of the nutrient were almost balanced leaving a small positive retention of + 0.55 g. on the average, in the potassium supplemented groups the retention progressively declined so that in the 4 per cent potassium supplemented group the intake and outgo just balanced. Thus, although the decline was in consonance with similar decline in ingestion, it seems obvious that large potassium ingestion does not help nitrogen retention and, if at all, it depresses it.

That water washing of paddy straw improves nitrogen retention because of the removal of the large amount of potassium present in it has been shown by Ray et al. (1947). Similar improvement in nitrogen retention when alkali treated paddy straw is fed has also been reported (Sen et al., 1942; Negi, 1955). The latter contains more of sodium than of potassium and it seems that potassium rather than sodium is involved in this improved retention of nitrogen. In the present experiment also water-washed wheat straw was used and a low potassium ration was fed to the control animals, so that the higher nitrogen retention may be the direct result of it. But the statistical treatment of the data shown in Table XX does not support such a conclusion.

Table XX

Analysis of variance data for nitrogen and mineral balances

Trial I

Sources of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio 'F'
		Nitrogen balances		
Between blocks	3	1.1105	0.3702	
Between treatments	2	0.6595	0.32975	1.14 N.S.
Error	6	1.7353	0.2892	
		Calcium balances		
Between blocks	3	0.2431	0.0810	
Between treatments	2	0.4495	0.2248	1.73 N.S.
Error	6	0.7791	0.12985	
		Phosphorus balances		
Between blocks	3	0.048527	0.016176	
Between treatments	2	0.822350	0.411175	35.50**
Error	6	0.069445	0.011574	

** Highly significant at 1% level.
Critical difference (C.D.) = 0.186
N.S. denotes not statistically significant.

Table XX (contd.)

Sources of Variation	Degrees of freedom	Sum of squares	Mean square	Variance
		Magnesium balances		
Between blocks	3	0.058397	0.019466	
Between treatments	2	0.056285	0.028143	1.30 N.S.
Error	6	0.128391	0.021399	
		Sodium balances		
Between blocks	3	1.0857	0.3619	
Between treatments	2	1.07765	0.538825	0.56 N.S.
Error	6	5.8219	0.9703	
		Potassium balances		
Between blocks	3	59.0946	19.6982	
Between treatments	2	118.5079	59.2540	5.03 N.S.
Error	6	70.6773	11.7796	

N.S. denotes not statistically significant.

Calcium and phosphorus balance data

Looking at the calcium balance data shown in Table XV, it is found that calcium ingestion from the ration was also similar in all the groups and the level of its feeding was much higher than the recommended allowance, according to the N.R.C. (loc. cit.). The balances too were positive in all the groups and of almost similar order. It is also seen that the retention was comparatively low against an ingestion level which is regarded to be much higher than the recommended allowance (1.8 g. calcium/25 kg. body weight).

It, therefore, seems that potassium ingestion as such had no influence on calcium retention and the statistical analysis shown in Table XX supports it.

The phosphorus ingestion figures set out in Table XVI are within limits of the recommended allowance (1.4 g.P/25 kg. body weight). Even so, there was a slight positive balance in the potassium supplemented groups and this increased many times when the level of potassium feeding was at its lowest, i.e., 0.8% compared to 2 and 4% in the supplemented groups. Here also it would seem that removal of potassium from the ration was, as in the case of nitrogen, helpful in the retention of phosphorus in the body and what is more, this is fully supported by the analysis of variance conducted on the phosphorus balance data as shown in Table XX, the level of significance being 1 per cent. Critical difference test also shows that the mean of the control group was significantly different from both the experimental ones, although the two means within the experimental groups were not much different. The conclusion, therefore, seems justified that the effect of wide sodium: potassium ratio was highly depressing on the retention of phosphorus under the condition of feeding where phosphorus requirement was only marginally met.

Reference has already been made of the studies on pigs by Richards _et al._ (_loc. cit._) or the observation of Orr (_loc. cit._) that high potassium ingestion, especially when associated with a wide sodium:potassium ratio like 1:10 or 1:11, reduced the assimilation of nitrogen, calcium and phosphorus, particularly when the supply of these nutrients in the ration was low. Zuntz (1912) (cited by Russel and Duncan, 1956) also has observed that malnutrition and pica resulted when the ration contained not only a wide sodium:potassium ratio but also was low in calcium and phosphorus.

The ration fed to our animals was marginal in respect of phosphorus only but not to calcium or protein. This was, rather unfortunate, for initially this was intended to be. Nevertheless, from what has been shown above, it seems th.t high level of potassium ingestion with a sodium:potassium ratio as wide as 1:10.4 detrimentally affected phosphorus metabolism, although a still wider ratio of 1:19.2 h.d no greater harmful effect. It is possible, had the level of phosphorus feeding been still less, the effect would have been more pronounced.

Reference may also be made in this connection to the work of Negi (*loc. cit.*), who did not find any appreciable effect of supplementing a rape cake plus wheat *bhoosa* ration with potassium oxalate to simulate the conditions of paddy straw feeding on calcium and phosphorus retention. This worker as also sen *et al.* (*loc. cit.*) reported lower retention of phosphorus from untreated paddy straw (containing high potassium) than from alkali treated straw. On the other hand, Ray et al. (*loc. cit.*) did not find any improvement in phosphorus retention on feeding water washed paddy straw. The level of phosphorus feeding in their case, however, was 28 per cent lower than the comparable group.

Magnesium balance data

Magnesium balance data are set out in Table XVII. Here also magnesium ingestion in all the groups was almost the same and the balances too were positive. The retention of this mineral in the control group was the highest and no difference in retention attributable to the higher levels of potassium ingestion was noted in the other two groups. Statistical analysis of the data given in Table XX also does not reveal any significant variation from group to group. Thus, although with the same level of magnesium ingestion its retention was almost double in the low potassium group, because of lack of statistical support the conclusion can not be confirmed.

Burch and Wolton (1961) observed that pastures containing 0.2% of magnesium in the dry ration might not produce hypo-magnesaemia. Assuming this to be the requirement level the needs of the animals appear to have been adequately met as from the ration they were receiving about 0.25% of magnesium on dry matter basis. It seems, therefore, that any adverse effect that may follow high potassium ingestion and wide sodium:potassium ratio can not show itself up when the level of magnesium feeding is already adequate or more than that. There is no doubt that a large volume of evidence exists in support of the theory that high potassium ingestion affects magnesium metabolism and may produce hypomagnesaemia grass tetany. This has been fully reviewed in Chapter I. On the other hand, work of Negi (loc. cit.) and Ray et al. (loc. cit.) has shown that increased potassium ingestion in the form of supplemental potassium oxalate on a rape cake + wheat bhoosa ration or in the form of untreated paddy straw did not influence magnesium retention.

Sodium and potassium balance data

Sodium balance data are shown in Table XVIII and those of potassium in Table XIX. From the Tables it will be seen that while sodium ingestion remained almost the same in all the groups, potassium increased considerably from one group to another reaching its maximum in the last. The latter, of course, is due to the supplemental potassium feeding resorted to in the last two groups. But while potassium excretion and retention both increased from group to group, sodium excretion increased progressively, without, however, a similar retention. Sodium retention, on the contrary, declined. It was the highest in the control group and almost the same but much lower in the other two groups. It is also to be noted that sodium excretion was encouraged and helped by a higher potassium ingestion.

The statistical analysis of both the data shown in Table XX does not reveal any significant differences in retention of sodium and potassium from group to group.

Nitrogen and mineral excretion in faeces and urine vis-a-vis their ingestion

The daily excretion in the faeces and urine of nitrogen and the minerals is given respectively in Tables XXI and XXII. Their percentages *vis-a-vis* the amounts ingested are also shown there.

A reference to Table XXI will show that the amounts of nitrogen, calcium and magnesium excreted in the faeces daily did not differ from group to group *vis-a-vis* the amounts ingested, whereas the excretion of phosphorus, sodium and potassium varied considerably, of which phosphorus was rather more conspicuous than the other two. It formed only about 50 per cent of the total ingested in the control group and increased to about 81% in the 2% potassium and about 90% in the 4% potassium supplemented groups. Both sodium and potassium excretion by way of faeces, on the other hand, declined in the supplemented group, although the decline was more pronounced in the case of potassium than in that of sodium.

Table XXI

Average excretion of nitrogen and minerals in faeces per day

Trial I

Animal No.	Nitrogen (g.)	Calcium (g.)	Phosphorus (g.)	Magnesium (g.)	Sodium (g.)	Potassium (g.)
Group I (Control)						
58	7.14	4.98	0.863	1.250	0.52	2.02
53	8.21	5.52	0.692	1.230	0.13	2.97
62	7.99	5.31	0.633	1.090	0.51	2.11
78	7.38	4.72	0.886	1.180	0.61	2.31
Average	7.68	5.13	0.769	1.190	0.44	2.35
Av. % of intake	66.68	76.91	49.97	61.15	23.78	36.78
Group II (ca 2% K level)						
50	7.16	5.70	1.342	1.460	0.22	2.66
60	7.38	5.01	1.310	1.160	0.18	1.23
54	6.64	5.24	1.037	1.470	0.06	2.64
72	5.97	4.52	0.981	1.220	0.12	1.31
Average	6.79	5.12	1.168	1.330	0.15	1.96
Av.% of intake	61.28	79.75	80.72	72.09	9.04	11.30
Group III (ca 4% K level)						
61	7.08	4.73	1.558	1.200	0.04	1.73
56	6.47	4.49	1.351	1.310	0.21	1.62
59	5.46	4.22	1.188	0.960	0.51	1.91
71	6.65	4.57	1.121	1.510	0.22	1.93
Average	6.42	4.50	1.305	1.250	0.26	1.80
Av.% of intake	57.68	69.66	89.63	67.39	15.48	5.60

Table XXIII

Average excretion of nitrogen and minerals in urine per day

Trial I

Animal No.	Nitrogen (g.)	Calcium (g.)	Phosphorus (g.)	Magnesium (g.)	Sodium (g.)	Potassium (g.)
Group I (Control)						
58	3.89	0.33	0.013	0.55	0.08	1.97
53	2.92	0.17	0.007	0.31	0.12	0.95
62	3.05	0.18	0.009	0.52	0.05	1.20
78	3.33	0.20	0.007	0.46	0.00	1.22
Average	3.30	0.22	0.009	0.46	0.06	1.34
Av.% of intake	28.60	3.30	0.58	23.64	3.24	20.97
Group II (ca 2% K level)						
50	4.16	0.27	0.005	0.39	2.44	10.70
60	3.89	0.36	0.009	0.40	0.49	13.8
54	4.33	0.18	0.100	0.28	0.03	9.47
72	4.48	0.38	0.005	0.47	0.35	13.40
Average	4.22	0.30	0.030	0.39	0.83	11.84
Av.% of intake	38.09	4.67	2.07	21.14	50.00	68.28
Group III (ca 4% K level)						
61	5.18	0.51	0.004	0.37	0.28	25.89
56	3.43	0.61	0.003	0.38	0.26	21.20
59	6.08	0.34	0.035	0.54	0.04	11.88
71	4.07	0.49	0.004	0.36	0.12	23.50
Average	4.69	0.49	0.012	0.41	0.68	20.62
Av.% of intake	42.14	7.59	0.820	22.10	40.48	64.12

Referring to Table XXII, where the excretion pattern in urine is shown, it seems that the pattern of excretion of nitrogen, calcium, phosphorus and magnesium in urine in all the groups remains practically the same whether potassium is fed or not, except that there was a slight tendency for the 2 and 4% potassium groups to excrete more of the first two nutrients vis-a-vis their intake. In the case of sodium and potassium, however, the picture is altogether different. Here not only potassium excretion vis-a-vis ingestion increases enormously, as it should, sodium excretion also is seen to increase tremendously. Thus, while the daily excretion of the mineral in the urine vis-a-vis ingestion was only 3.24% in the control, it was 50% in the 2% potassium supplemented group and 40% in the 4% one.

This shows that high potassium ingestion impoverishes the body of sodium, and the sodium requirement under this condition goes up. It seems to be in harmony with the theory of Bunge that excess of potassium impoverished the organism of sodium and chlorine (cited by Brouwer, 1961).

The influence of variations in the sodium-potassium ratio on water metabolism

Of the three factors, water, salts and food, water is the most important for life and, hence, it is considered as an essential principle in dietetics. Besides its numerous physiological functions, it also acts as a vehicle for various physiological processes, such as (a) for absorption of food materials from the intestine, (b) for re-absorption from kidney tubules, (c) for the transport of various food stuff from place to place, (d) for the drainage and excretion of the end products of metabolism, (e) for the manufacture of various secretions such as digestive juices etc., (f) for carrying the hormones to their places of activity etc.

Thus, water plays a major role in the utilisation of nutrients in the body. Ritzman and Benedict (1924) have reported that the water intake of animals is significantly correlated with their dry matter intake. The water intake is also influenced by the protein and salt contents of the diet (Negi and Mullick,1959). The above workers concluded that the ratio of water intake to dry matter ingested and digested is influenced both by the dry matter intake and atmospheric conditions, viz. air-temperature, relative humidity etc. They also stated that at all atmospheric temperature and relative humidity levels, the ratio between water intake and dry matter varied within a narrow range. They, therefore, recommended that the water intake of animals on maintenance rations should be 3 to 5 times that of dry matter intake; in summer it may be 3.5 - 5 times and in winter 2.5 - 3.5 times.

Ritzman and Benedict (loc. cit.) and Leitch and Thomson (1944) also reported that the difference between the mean water intake per unit of dry matter ingested at different planes of nutrition was not statistically significant.

In the present investigation, the influence of potassium feeding at the levels of approximately 0.7, 2 and 4% of dry ration respectively to group I, II and III on water metabolism has been studied. The experimental details have already been dealt with in Chapter II. Two metabolism trials were conducted in the winter months of November, 1967 and February, 1968. The total water intake of an individual was calculated as the sum total of (a) free water drunk ad lib. + (b) water from the feeds ingested + (c) metabolic water derived from the metabolism of nutrients in the body.

Apparent insensible loss or insensible perspiration was calculated, as usual, from the total water intake minus total water excreted as urine and faeces, assuming that the rest of the water was lost by the evaporative mechanisms through lungs and skin.

Since large amount of water is constantly appearing and dis-appearing from the body and inspite of it a fairly accurate balance is maintained between production and loss, it is obvious that there must be a strong regulating mechanism which is very intricate and is not yet fully known.

The water metabolism data have been presented in Tables XXIII and XIV.

It will be seen from Table XXIII that while the water ingested from feed and that derived from the metabolism of nutrients were practically the same in all the three groups, free water ingestion increased enormously from group to group, so that the total water ingestion from all sources was about one and a half and two times respectively more in the 2% and 4% potassium supplemented groups than in the control. Its outgo through urine likewise increased, but the increase was at least four fold in the case of the 4% potassium supplemented group compared to the two fold increase seen in the 2% potassium group, excretion by way of faeces being almost the same in all the groups. Simultaneously, there was an enormous increase in the amount of total solids in the urine of the potassium supplemented groups, the increase being

Table XXIII

Water metabolism data (Average water balance per day)

(Basal ration - concentrate mixture + Pakar leaves + wheat bhoosa (washed))

Trial I

Animal No.	Water Intake (ml.) Free drink	From feeds	Metabolic water	Total	Water outgo (ml.) In faeces	In urine	Total in urine and faeces	Insensible perspiration (ml.)	Total solids in urine(g.)
				Group I (Control)					
58	1571.0	248.5	241.0	2060.5	517.2	829.4	1346.6	713.9	25.1
53	929.0	246.5	235.0	1410.5	613.3	158.1	771.4	639.1	17.0
62	1071.0	242.5	220.0	1533.5	503.8	241.9	745.7	787.8	17.5
78	1286.0	245.5	230.0	1761.5	639.1	666.0	1305.1	456.4	18.1
Average	1214.0	245.8	232.0	1691.5	568.4	473.9	1042.2	649.3	19.4
				Group II (ca 2% K level)					
50	1786.0	241.5	217.0	2244.5	601.1	487.1	1088.2	1156.3	43.2
60	2643.0	241.5	225.0	3109.5	559.0	1988.1	2547.1	561.4	48.0
54	1643.0	235.5	108.0	2086.5	776.0	1046.5	1822.5	264.0	29.9
72	1571.0	233.5	184.0	1988.5	317.1	936.4	1253.5	735.0	41.2
Average	1911.0	238.0	209.0	2357.3	563.3	1114.5	1677.8	679.5	40.6
				Group III (ca 4% K level)					
61	3321.0	242.5	223.0	3786.5	594.0	2540.3	3134.3	652.2	72.9
56	2250.0	238.5	207.0	2695.5	519.8	1311.2	1831.0	864.5	64.9
59	2786.0	220.5	226.0	3232.5	545.1	1918.6	2463.7	768.8	52.0
71	2833.0	236.5	186.0	3255.5	497.1	2193.4	2690.5	565.0	64.3
Average	2798.0	234.5	211.0	3242.5	539.0	1990.9	2529.9	712.6	58.5

Table XXIV

Metabolism of water and dry matter (Basal ration - concentrate mixture + pakar leaves + wheat bhoosa (washed)

Trial I

Animal No.	Total water intake (g. or ml.)	Total dry matter intake (g.)	Dry matter digested (g.)	Ratio of water intake to dry matter: Intake	Ratio of water intake to dry matter: Digested	Vol. of urine/(ml.)/$Na^+ + K^+$ ions (milli-equiv.)
Group I (Control)						
58	2060.5	874.2	444.7	2.4	4.6	15.4
53	1410.5	852.1	427.5	1.7	3.3	5.7
62	1533.5	788.7	398.1	1.9	3.9	7.5
78	1761.5	827.2	420.6	2.1	4.2	21.6
Average	1691.5	835.5	422.7	2.0	4.0	12.6
Group II (ca 2% K level)						
50	2244.5	769.3	394.4	2.9	5.9	2.3
60	3109.5	777.3	414.4	4.0	7.5	5.3
54	2086.5	689.1	382.4	3.0	5.5	4.3
72	1988.5	654.4	342.3	3.0	5.8	2.6
Average	2357.3	722.5	383.5	3.2	6.2	3.6
Group III (ca 4% K level)						
61	3786.5	786.7	411.3	4.8	9.2	3.8
56	2695.5	729.0	383.6	3.7	7.0	2.1
59	3232.5	724.7	425.5	4.5	7.6	6.4
71	3255.5	697.2	345.7	4.7	9.4	3.7
Average	3242.5	734.4	391.5	4.4	8.3	4.0

double and three fold in the 2 and 4% potassium groups respectively.

Again, a reference to Table XXIV will show that the ratio of water intake to dry matter ingested and digested progressively increased from group to group. This evidently shows that potassium increases the water requirement per unit of dry matter ingested and digested considerably, and at the same time there is diuresis. It appears to be in harmony with the following observations concerned with the diuretic effects of potassium.

Warth (1923; 1926) suggested that high potassium intake under paddy straw feeding was partly responsible for increased urination.

Feeding of paddy straw with napier grass, which involved a heavy ingestion of potassium, was also accompanied by heavy urinary output (cited by Negi, 1955).

Ray et al. (1947) and Pandittesekere (1952) observed that animals fed on water-washed paddy straw which contained lesser potassium, exhibited reduction in diuresis.

Negi (loc. cit.) also found that by reducing the potassium content of paddy straw by lime treatment the extent of urination was decreased, which was again enhanced when the basal ration comprising of wheat bhoosa as roughage was supplemented with potassium oxalate providing potassium upto the level present in paddy straw.

Wright (1956) has reported that isotonic potassium chloride solution (1.3%), if administered by mouth, is rapidly excreted like urea or other waste products and gives rise to a marked diuresis.

Meyer and Cohn (1911) suggested that potassium salts as a rule, cause increased elimination of water (cited by Richards, et al., loc. cit.).

Diuresis is a mechanism by which the kidneys get rid of surplus accumulation of harmful ingredients of the ration or products of metabolism. Under this condition not only there is an excessive urination, there is also a greater consumption of water. This is actually what we find in this experiment, where in order to efficiencly eliminate from the body the large quantities of potassium ingested, water intake and excretion went progressively up along with the increased levels of the harmful mineral.

However, when the ratio of the volume of urine in ml. to the sum of $Na^{+} + K^{+}$ ions excreted in urine in terms of milli-equivalents (presented in the last column of Table XXIV), is considered, it becomes clear that the excretion of each of the Na^+ or K^+ ion by way of urine is effected in every 12.6 ml. of urine in the case of control animals against 3.6 and 4.0 ml. of urine in the case of experimental ones. Evidently, the kidneys are able to excrete $Na^+ + K^+$ ions in a more concentrated form in the case of potassium supplemented groups as compared to the control, thus effecting the water economy proportionately. It is, however, interesting to find that an increase of potassium in the ration from 2 to 4% does not appear to alter the amount of sodium or potassium ions per ml. of urine.

SUMMARY

The relation, if any, existing between sodium: potassium ratio, on the one hand, and the digestibility and metabolism of nutrients, on the other, was studied and the results are presented in this Chapter.

The results show that when the level of sodium in the ration was kept constant at 0.22% and the potassium percentage varied from 0.77 to 4.38, so that the ratio of

sodium and potassium progressively rose from 1:3.5 to 1:19.2 through 1:10.4, the digestibility of the organic nutrients did not show any statistically significant variation from group to group.

The balance studies with respect of nitrogen, calcium, phosphorus, magnesium sodium and potassium also did not show that a change in the retention of nitrogen, calcium and magnesium was brought about in any significant manner by a widening in the sodium:potassium ratio. Perhaps, a still lower level of these nutrients in the ration could have brought about a more sustained lowering in retention of these nutrients, a trend of which only was discernible. This was, however, more pronounced in the case of phosphorus, which was fed at about the requirement level, showing statistically significant ($P < .01$) lowering in retention from group to group as the ratio widened. Sodium also showed a progressive lowering in retention but this was not statistically significant.

The average excretion pattern of nitrogen and the minerals through the urinary and faecal routes was then studied. In urine, the pattern of excretion of nitrogen, calcium, phosphorus and magnesium was not affected. But so far as sodium and potassium excretion through this channel is concerned, it seem that high potassium ingestion impoverishes the body of sodium and the sodium requirement under this condition perhaps goes up. In the faeces, on the other hand, the excretion of phosphorus, in particular, went so high as to constitute about 81 per cent in the 2 per cent potash fed group and 90 per cent in the 4 per cent group compared to 50 per cent in the control group (0.77 per cent K). Potassium excretion by way of faeces, however, declined with increasing potassium in the ration.

The result of water metabolism studies conducted during this investigation shows that free water ingestion increased enormously from group to group so that the total water ingestion from all sources was about 1½ and 2 times more respectively in the 2 per cent and 4 per cent potassium supplemented groups than in the control. Its outgo through urine also increased simultaneously, but the increase was at least four fold in the case of the 4 per cent potash group compared to the two fold increase in the 2 per cent group. Excretion of total solids in the urine likewise increased progressively.

Potassium (and wide sodium:potassium ratio) was also found to increase the water requirement per unit of dry matter ingested and digested, and also lowered the appetite which was significant at 5% level.

Indication of water economy in the excretion of the alkali metals in the potassium supplemented animals was also noted.

CHAPTER IV

STUDIES ON SODIUM:POTASSIUM RATIO AS AFFECTING THE NUTRIENT METABOLISM IN ADULT SHEEP - PART II

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CHAPTER IV

STUDIES ON SODIUM:POTASSIUM RATIO AS AFFECTING THE NUTRIENT METABOLISM IN ADULT SHEEP

PART II

The second feeding trial, which is being presented in this Chapter, as already discussed earlier, was undertaken with the object of studying the influence of different sodium:potassium ratios, other than those studied earlier and presented in Chapter III, on the digestibility and metabolism of certain nutrients, particularly when the supply of potassium, as far as practicable, is from natural feeds. Berseem is rich in this mineral and so is unwashed wheat straw. These, therefore, were the main ingredients of the ration with a small quantity of potassium chloride added to them, where necessary, in order to bring the ratio of the minerals to the desired levels. Their ratios in the three groups were 1:4.5, 1:8.1 and 1:10.3 as shown in Table XXV, the percentage of sodium and potassium in the basal ration being 0.42 and 1.85 respectively.

Table XXV

Levels of sodium and potassium ingestion during the trial period

Trial II

Animal No.	% Na in the ration	% K in the ration	Na ingested (g.)	K ingested from feeds (g.)	K ingested from KCl supplement (g.)	Total K ingested (g.)	Na:K ratio of ingestion	Na + K ingested (g.)
				Group I (Control)				
58	0.39	1.8	3.48	15.86	-	15.86	1: 4.6	19.34
53	0.40	1.8	3.40	15.37	-	15.37	1: 4.5	18.77
62	0.44	1.9	3.15	13.87	-	13.87	1: 4.4	17.02
72	0.43	1.9	3.22	14.29	-	14.29	1: 4.4	17.51
Average	0.42	1.85	3.31	14.85	-	14.85	1: 4.5	18.16
				Group II (ca 3% K level)				
61	0.42	3.5	3.29	14.72	12.78	27.80	1: 8.4	31.09
56	0.40	3.2	3.38	15.25	12.03	27.28	1: 8.1	30.66
59	0.43	3.4	3.21	14.25	11.51	25.76	1: 8.0	28.97
54	0.44	3.4	3.16	13.96	10.46	24.42	1: 7.7	27.58
Average	0.42	3.4	3.26	14.55	11.77	26.32	1: 8.1	29.58
				Group III (ca 4% K level)				
50	0.44	4.8	3.16	13.92	20.92	34.84	1:11.0	38.00
60	0.39	4.0	3.47	15.79	19.87	35.66	1:10.2	39.13
71	0.47	4.9	3.00	13.00	18.31	31.31	1:10.4	34.31
78	0.42	4.0	3.28	14.78	16.74	31.42	1: 9.6	34.70
Average	0.43	4.4	3.23	14.35	18.96	33.31	1:10.3	36.54

RESULTS AND DISCUSSION

Nutrient Digestibility

The dry matter consumption of the animals is shown in Table XXVI, which is the same in all the groups. Its digestibility figures, set out in Table XXVII, also are similar without any variation. The live weight changes within the short period of the experiment (25 days) shown in Table XXVIII likewise show a similarity with the experiment reported in Chapter III, indicating a progressive loss in weight as the level of potassium feeding increased and the ratio of sodium and potassium widened. The analysis of variance data for dry matter ingested, digested and digestibility (%) have been set out in Table XXIX, which do not show any statistically significant variation from group to group.

The digestibility data of crude protein, ether extract, crude fibre and nitrogen-free extract, given in Tables XXX, XXXI, XXXII and XXXIII respectively also do not show any statistically significant variation from group to group as shown in Table XXXV. All these results are in no way different from those found earlier with the animals fed pakar leaves, water-washed wheat straw and concentrate mixture plus the potassium chloride supplement. This shows that under the conditions of feeding, irrespective of whether potassium is fed in the form of natural feed or as the salt, sodium:potassium ratio ranging between 1:3.5 and

Table XXVI

Average live weight and dry matter consumption of individual animals per day

Trial II

Animal No.	Live weight (kg.)			Dry matter consumption (g)			
	At the start of collection period	At the end of collection period	Average during collection period	From green berseem	From wheat bhoosa	Total	Per kg. live weight
Group I (Control)							
58	31.50	32.00	31.75	278.80	618.62	897.42	28.27
53	29.50	31.50	30.50	278.80	573.07	851.87	27.93
62	27.00	27.50	27.25	278.80	435.12	713.92	26.20
72	23.00	25.00	24.00	278.80	474.17	752.97	31.37
Average	27.75	29.00	28.38	278.80	525.25	804.05	28.44
Group II (ca 3% K level)							
61	31.50	31.50	31.50	278.80	513.86	792.66	25.16
56	28.00	28.50	28.25	278.80	562.01	840.81	29.76
59	26.00	24.50	25.25	278.80	469.61	748.41	29.64
54	24.00	24.00	24.00	278.80	443.58	722.38	30.10
Average	27.38	27.13	27.25	278.80	497.27	776.07	28.67
Group III (ca 4% K level)							
50	31.00	30.00	30.50	278.80	439.68	718.48	23.56
60	29.00	30.00	29.50	278.80	611.47	890.27	30.18
71	24.50	22.00	23.25	278.80	355.08	633.88	27.26
78	24.50	24.00	24.25	278.80	509.95	788.75	32.53
Average	27.25	26.50	26.88	278.80	479.04	757.84	28.38

Table XXVII

Trial II

Dry matter digestibility data

Animal No.	Total intake (g.)	Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
Group I (Control)				
58	897.42	396.10	501.32	55.86
53	851.87	402.10	449.77	52.80
62	713.92	324.30	389.62	54.57
72	752.97	307.50	445.47	59.16
Average	804.05	357.50	446.55	55.60
Group II (ca 3% K level)				
61	792.66	348.60	444.06	56.02
56	840.81	350.40	490.41	58.33
59	748.41	371.40	377.01	50.37
54	722.38	321.40	400.98	55.51
Average	776.07	348.00	428.07	55.06
Group III (ca 4% K level)				
50	718.48	321.80	396.68	55.21
60	890.27	392.50	497.77	55.91
71	633.88	287.50	346.38	54.64
78	788.75	338.90	449.85	57.03
Average	757.84	335.20	422.64	55.70

Table XXVIII

Live weights of animals during the whole feeding period

Animal No.	0 day	8th day	16th day (before expt.)	25th day (after expt.)	Weight gain or loss
			Group I (Control)		
58	31.00	31.0	31.5	32.0	+ 1.0
53	29.00	28.5	29.5	31.5	+ 2.5
62	27.00	26.5	27.0	27.5	+ 0.5
72	22.00	23.5	23.0	25.0	+ 3.0
Average	27.25	27.4	27.8	29.0	+ 1.8
			Group II (ca 3% K level)		
61	31.00	30.5	31.5	31.5	+ 0.5
56	27.50	26.0	28.0	28.5	+ 1.0
59	27.00	26.0	26.0	24.5	- 2.5
54	24.00	23.5	24.0	24.0	Nil
Average	27.37	26.5	27.4	27.1	- 0.25
			Group III (ca 4% K level)		
50	31.50	31.0	31.0	30.0	- 1.5
60	28.50	28.5	29.0	30.0	+ 1.5
71	25.50	25.0	24.5	22.0	- 3.5
78	24.00	23.5	24.5	24.0	Nil
Average	27.37	27.0	27.3	26.5	- 0.9

Table XXIX

Analysis of variance data for dry matter ingested, digested and per cent digestibility

Trial II

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
		Total dry matter ingested		
Between blocks	3	43000.9407	14333.6469	
Between treatments	2	4332.3851	2166.1925	0.59 N.S.
Error	6	22258.9632	3709.8272	
		Total dry matter digested		
Between blocks	3	17583.2269	5861.0756	
Between treatments	2	1252.4381	626.2190	0.42 N.S.
Error	6	9026.4315	1504.4053	
		Per cent dry matter digestibility		
Between blocks	3	25.1597	8.3866	
Between treatments	2	0.9483	0.4742	0.09 N.S.
Error	6	33.4721	5.5787	

N.S. denotes not statistically significant.

Table XXX

Trial II

Crude protein digestibility data

Animal No.	Intake (g.)			Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
	From green berseem	From wheat bhoosa (unwashed)	Total			
			Group I (Control)			
58	60.11	16.45	76.56	36.31	40.25	52.57
53	60.11	15.45	75.56	35.50	40.06	53.02
62	60.11	12.42	72.53	35.06	37.47	51.66
72	60.11	13.28	73.39	31.50	41.89	57.08
Average	60.11	14.40	74.51	34.59	39.92	53.58
			Group II (ca 3% K level)			
61	60.11	14.15	74.26	37.19	37.07	49.92
56	60.11	15.21	75.32	33.44	41.88	55.60
59	60.11	13.18	73.29	32.19	41.10	56.08
54	60.11	12.60	72.71	31.81	40.90	56.25
Average	60.11	13.79	73.90	33.66	40.24	54.46
			Group III (ca 4% K level)			
50	60.11	12.52	72.63	31.69	40.94	56.37
60	60.11	16.30	76.41	36.81	39.60	51.83
71	60.11	10.76	70.87	34.81	36.06	50.88
78	60.11	14.16	74.27	37.31	36.96	49.76
Average	60.11	13.44	73.55	35.16	38.39	52.21

Table XXXI

Ether extract digestibility data

Trial II

Animal No.	Intake (g.)			Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
	From green berseem	From wheat bhoosa (unwashed)	Total			
			Group I (Control)			
58	7.17	5.30	12.47	8.16	4.31	34.56
53	7.17	5.06	12.23	9.69	2.54	20.77
62	7.17	4.31	11.48	7.17	4.31	37.54
72	7.17	4.52	11.69	7.81	3.88	33.19
Average	7.17	4.80	11.97	8.21	3.76	31.52
			Group II (ca 3% K level)			
61	7.17	4.74	11.91	7.25	4.66	39.13
56	7.17	5.00	12.17	6.97	5.20	42.73
59	7.17	4.50	11.67	8.65	3.02	25.88
54	7.17	4.36	11.53	7.49	4.04	35.04
Average	7.17	4.65	11.82	7.59	4.23	35.70
			Group III (ca 4% K level)			
50	7.17	4.34	11.51	7.88	3.63	31.54
60	7.17	5.26	12.43	7.93	4.50	36.20
71	7.17	3.88	11.05	6.10	4.95	44.80
78	7.17	4.72	11.89	7.83	4.06	34.15
Average	7.17	4.55	11.72	7.44	4.28	36.67

Table XXXII

Crude fibre digestibility data

Trial II

Animal No.	Intake (g.)			Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
	From green berseem	From wheat bhoosa (unwashed)	Total			
			Group I (Control)			
58	74.50	243.26	317.76	130.91	186.85	58.80
53	74.50	222.18	296.68	129.36	167.32	56.40
62	74.50	158.37	232.87	93.72	139.15	59.75
72	74.50	176.43	250.93	92.37	158.56	63.19
Average	74.50	200.06	274.56	111.59	162.97	59.54
			Group II (ca 3% K level)			
61	74.50	194.79	269.29	110.02	159.27	59.14
56	74.50	217.07	291.57	111.22	180.35	61.85
59	74.50	174.32	248.82	111.38	137.44	55.24
54	74.50	162.28	236.78	97.51	139.27	58.82
Average	74.50	187.12	261.62	107.53	154.09	58.76
			Group III (ca 4% K level)			
50	74.50	160.48	234.98	104.23	130.75	55.64
60	74.50	239.95	314.45	126.42	188.03	59.80
71	74.50	121.34	195.84	86.51	109.33	55.83
78	74.50	192.98	267.48	105.57	161.91	60.53
Average	74.50	178.69	253.19	105.68	147.51	57.95

Table XXXIII

Nitrogen-free extract digestibility data

Trial II

Animal	Intake (g.)			Outgo in faeces (g.)	Total digested (g.)	Digestibility coefficient (%)
	From green berseem	From wheat bhoosa (unwashed)	Total			
			Group I (Control)			
58	109.40	313.38	422.78	168.38	254.40	60.17
53	109.40	292.49	401.89	169.69	232.20	57.78
62	109.40	229.23	338.63	153.20	185.43	54.76
72	109.40	247.14	356.54	126.23	230.31	64.60
Average	109.40	270.56	379.96	154.38	225.58	59.33
			Group II (ca 3% K level)			
61	109.40	265.34	374.74	141.74	233.00	62.18
56	109.40	287.42	396.82	147.97	248.85	62.71
59	109.40	245.05	354.45	166.57	187.88	53.01
54	109.40	233.11	342.51	134.73	207.78	60.66
Average	109.40	257.73	367.13	147.75	219.38	59.64
			Group III (ca 4% K level)			
50	109.40	231.32	340.72	130.91	209.81	61.58
60	109.40	310.10	419.50	168.23	251.27	59.90
71	109.40	192.53	301.93	116.52	185.41	61.41
78	109.40	236.55	345.95	138.17	207.78	60.06
Average	109.40	242.63	352.03	138.46	213.57	60.74

Table XXXIV

Actual T.D.N. ingestion per day as compared to the stimulated requirements (N.R.C., loc. cit.) on the basis of average live weights during the trial period

Trial II

	Animal No.	Actual ingestion	Stipulated requirement
		Group I (Control)	
	58	491.20	412.75
	53	446.30	396.50
	62	371.75	354.25
	72	439.49	312.00
Average		437.19	368.83
		Group II (ca 3% K level)	
	61	439.83	409.50
	56	482.78	367.25
	59	373.22	328.25
	54	397.04	312.00
Average		423.22	354.25
		Group III (ca 4% K level)	
	50	389.67	396.50
	60	489.03	383.50
	71	341.94	302.25
	78	415.79	315.25
Average		409.11	349.38

Table XXXV

Analysis of variance data for various nutrient digestibility and actual 'Total digestible nutrients' ingested

Trial II

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
		Crude protein digestibility (%)		
Between blocks	3	4.2315	1.4105	
Between treatments	2	10.3093	5.1547	0.47 N.S.
Error	6	65.9996	10.9999	
		Ether extract digestibility (%)		
Between blocks	3	13.4601	4.4867	
Between treatments	2	60.0369	30.0185	0.44 N.S.
Error	6	407.4120	67.902	
		Crude fibre digestibility (%)		
Between blocks	3	26.4726	8.8242	
Between treatments	2	2.5255	1.2628	0.18 N.S.
Error	6	41.7970	6.9662	

N.S. denotes not statistically significant.

Table XXXV (contd.)

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
		Nitrogen-free extract digestibility (%)		
Between blocks	3	53.5413	17.8471	
Between treatments	2	4.3871	2.1936	0.20 N.S.
Error	6	64.3085	10.7181	
		Actual T.D.N. ingested		
Between blocks	3	19446.8774	6482.2925	
Between treatments	2	1576.7056	788.3528	0.91 N.S.
Error	6	5171.1076	861.8513	

N.S. denotes not statistically significant.

1:19.2 does not effect nutrient digestibility in any manner. Nor does it affect the 'total digestible nutrients' (T.D.N.) ingestion in any significant manner as shown in Table XXXIV and XXXV.

Balance studies

The results of the balance study conducted on these animals were likewise similar. The nitrogen retention shown in Table XXXVI in the control group was positive (+ 1.14 g.) and this was reduced to - 0.64 g. in the 3% potassium fed group and further to - 1.26 g. in the 4% group. Calcium retention also went down from + 0.78 g. in the control group to + 0.41 g. and further to + 0.30 g. in the 3% and 4% potash fed groups (vide Table XXXVII). This trend was practically maintained in the case of phosphorus and magnesium retention as well (vide Tables XXXVIII and XXXIX). Statistical analysis, however, did not reveal these variations to be significantly different, except in the case of phosphorus, which were highly significant between the treatments (vido Table XLII).

Coming to the retention of sodium and potassium, the picture is somewhat different than that we have come across in the earlier study where potassium was mainly supplied as supplement and sodium content of the ration too

Table XXXVI

Nitrogen balance data

Trial II

Animal No.	Intake (g.)			Outgo (g.)			Balance
	From green berseem	From wheat bhoosa (unwashed)	Total	In faeces	In urine	Total	
Group I (Control)							
58	9.62	2.63	12.25	5.81	5.50	11.31	+ 0.94
53	9.62	2.47	12.09	5.68	4.96	10.64	+ 1.45
62	9.62	1.99	11.61	5.61	5.27	10.88	+ 0.73
72	9.62	2.13	11.75	5.04	5.25	10.29	+ 1.46
Average	9.62	2.31	11.93	5.54	5.25	10.79	+ 1.14
Group II (ca 3% K level)							
61	9.62	2.26	11.88	5.95	7.01	12.96	- 1.08
56	9.62	2.43	12.05	5.35	5.14	10.49	+ 1.56
59	9.62	2.11	11.73	5.15	8.26	13.41	- 1.68
54	9.62	2.02	11.64	5.09	7.89	12.98	- 1.34
Average	9.62	2.21	11.83	5.39	7.08	12.47	- 0.64
Group III (ca 4% K level)							
50	9.62	2.00	11.62	5.07	8.18	13.25	- 1.63
60	9.62	2.61	12.23	5.89	6.54	12.43	- 0.20
71	9.62	1.72	11.34	5.57	9.11	14.68	- 3.34
78	9.62	2.27	11.89	5.97	5.82	11.79	+ 0.10
Average	9.62	2.15	11.77	5.62	7.41	13.03	- 1.26

Table XXXVII

Calcium balance data

Trial II

Animal No.	Intake (g.)			Outgo (g.)			Balance
	From green berseem	'From wheat' bhoosa (unwashed)	Total	In faeces	In urine	Total	
Group I (Control)							
58	5.24	1.30	6.54	6.06	0.09	6.15	+ 0.39
53	5.24	1.22	6.45	6.35	0.03	6.38	+ 0.08
62	5.24	0.95	6.19	4.09	0.05	4.14	+ 2.05
72	5.24	1.03	6.27	5.60	0.07	5.67	+ 0.60
Average	5.24	1.13	6.37	5.53	0.06	5.59	+ 0.78
Group II (ca 3% K level)							
61	5.24	1.10	6.34	5.61	0.12	5.73	+ 0.61
56	5.24	1.20	6.44	5.22	0.20	5.42	+ 1.02
59	5.24	1.02	6.26	5.79	0.14	5.93	+ 0.33
54	5.24	0.97	6.21	6.43	0.08	6.51	- 0.30
Average	5.24	1.07	6.31	5.76	0.14	5.90	+ 0.41
Group III (ca 4% K level)							
50	5.24	0.96	6.20	5.95	0.10	6.05	+ 0.15
60	5.24	1.29	6.53	6.04	0.12	6.16	+ 0.37
71	5.24	0.80	6.04	5.69	0.15	5.84	+ 0.20
78	5.24	1.10	6.34	5.73	0.15	5.88	+ 0.46
Average	5.24	1.04	6.28	5.85	0.13	5.98	+ 0.30

Table XXXVIII

Phosphorus balance data

Trial II

Animal No.	Intake (g.)			Outgo (g.)			Balance
	From green berseem	From wheat bhoosa (unwashed)	Total	In faeces	In urine	Total	
Group I (Control)							
58	0.611	0.619	1.230	0.642	0.058	0.700	+ 0.530
53	0.611	0.575	1.187	0.539	0.011	0.550	+ 0.637
62	0.611	0.443	1.054	0.435	0.032	0.467	+ 0.587
72	0.611	0.481	1.092	0.400	0.033	0.433	+ 0.659
Average	0.611	0.530	1.141	0.504	0.034	0.538	+ 0.603
Group II (ca 3% K level)							
61	0.611	0.519	1.130	0.966	0.061	1.027	+ 0.103
56	0.611	0.565	1.176	0.757	0.041	0.798	+ 0.378
59	0.611	0.476	1.087	1.018	0.065	1.083	+ 0.004
54	0.611	0.451	1.062	0.784	0.457	1.241	- 0.179
Average	0.611	0.503	1.114	0.881	0.156	1.037	+ 0.077
Group III (ca 4% K level)							
50	0.611	0.447	1.058	0.988	0.068	1.056	+ 0.002
60	0.611	0.612	1.223	0.934	0.040	0.974	+ 0.249
71	0.611	0.366	0.777	0.773	0.079	0.852	+ 0.125
78	0.611	0.515	1.126	1.000	0.037	1.037	+ 0.089
Average	0.611	0.485	1.096	0.924	0.056	0.980	+ 0.116

Table XXXIX

Magnesium balance data

Trial II

Animal No.	Intake (g.)			Outgo (g.)			Balance
	From green berseem	From wheat bhoosa (unwashed)	Total	In faeces	In urine	Total	
			Group I (Control)				
58	1.057	0.884	1.941	1.660	0.240	1.900	+ 0.041
53	1.057	0.876	1.933	1.610	0.210	1.820	+ 0.113
62	1.057	0.854	1.911	1.170	0.320	1.490	+ 0.421
72	1.057	0.861	1.918	1.570	0.300	1.870	+ 0.048
Average	1.057	0.869	1.926	1.502	0.268	1.770	+ 0.156
			Group II (ca 3% K level)				
61	1.057	0.867	1.924	1.740	0.380	2.120	- 0.196
56	1.057	0.875	1.932	1.510	0.410	1.920	+ 0.012
59	1.057	0.860	1.917	1.600	0.400	2.000	- 0.083
54	1.057	0.856	1.913	1.640	0.360	2.000	- 0.087
Average	1.057	0.865	1.922	1.623	0.388	2.011	- 0.089
			Group III (ca 4% K level)				
50	1.057	0.855	1.912	1.480	0.460	1.940	- 0.028
60	1.057	0.883	1.940	1.690	0.350	2.040	- 0.100
71	1.057	0.842	1.899	1.500	0.430	1.930	- 0.031
78	1.057	0.866	1.923	1.460	0.470	1.930	- 0.007
Average	1.057	0.862	1.919	1.533	0.428	1.961	- 0.042

was lower, 0.22% against 0.42% in the present instance. It will be seen in Table XL that sodium retention was almost the same in all the groups in contrast to a gradual fall in sodium retention noted in the earlier experiment. Potassium retention too behaved differently here (Table XLI). In the second group where the sodium:potassium ration was 1:8.1 with only 26.32 g. of potassium ingested the retention came to be + 9.55 g. while in the third with a sodium: potassium ratio of 1:10.3 and ingestion of 33.31 g. of potassium the retention was only 8.08 g. The statistical analysis of the data, presented in Table XLII, shows that the potassium retention data are significant at 5% level between treatments.

The results of a probe into the excretion pattern of all these nutrients vis-a-vis their ingestion are shown in Tables XLIII and XLIV for faeces and urine respectively. A reference to Table XLIII will show that of all the nutrients studied phosphorus alone has shown a definite pattern of excretion in the faeces, followed perhaps by potassium. Phosphorus excretion by way of faeces computed on the basis of its percentage in relation to intake increased as the potassium ingestion increased, the increase between the control and 3 per cent potash groups was almost double. Between the 3 and 4 per

Table XL

Sodium balance data

Trial II

Animal No.	Intake (g.)			Outgo (g.)			Balance
	From green berseem	'From wheat' bhoosa (unwashed)	Total	In faeces	In urine	Total	
				Group I (Control)			
58	2.30	1.18	3.48	0.32	0.08	0.40	+ 3.08
53	2.30	1.10	3.40	0.72	0.82	1.54	+ 1.86
62	2.30	0.85	3.15	0.23	0.84	1.07	+ 2.08
72	2.30	0.92	3.22	0.55	0.89	1.44	+ 1.78
Average	2.30	1.01	3.31	0.46	0.66	1.11	+ 2.20
				Group II (ca 3% K level)			
61	2.30	0.99	3.29	0.42	0.63	1.05	+ 2.24
56	2.30	1.08	3.38	0.56	0.42	0.98	+ 2.40
59	2.30	0.91	3.21	0.56	0.28	0.84	+ 2.37
54	2.30	0.86	3.16	0.58	0.17	0.75	+ 2.41
Average	2.30	0.96	3.26	0.53	0.38	0.91	+ 2.36
				Group III (ca 4% K level)			
50	2.30	0.86	3.16	0.35	0.87	1.22	+ 1.94
60	2.30	1.17	3.47	0.31	0.60	0.91	+ 2.56
71	2.30	0.70	3.00	0.09	0.98	1.07	+ 1.93
78	2.30	0.98	3.28	0.14	0.84	0.98	+ 2.30
Average	2.30	0.93	3.23	0.22	0.82	1.05	+ 2.18

Table XLI

Potassium balance data

Trial II

Animal No.	Intake (g.)				Outgo (g.)			Balance
	From green berseem	From wheat bhoosa (unwashed)	From potassium chloride (KCl) supplement	Total	In faeces	In urine	Total	
				Group I (Control)				
58	8.13	7.73	-	15.86	2.18	12.54	14.72	+ 1.14
53	8.13	7.24	-	15.37	2.69	9.39	12.08	+ 3.29
62	8.13	5.74	-	13.87	2.01	11.00	13.01	+ 0.86
72	8.13	6.16	-	14.29	2.15	8.77	10.92	+ 3.37
Average	8.13	6.72	-	14.85	2.26	10.43	12.68	+ 2.17
				Group II (ca 3% K level)				
61	8.13	6.59	13.08	27.80	2.44	13.21	15.65	+12.15
56	8.13	7.12	12.03	27.28	2.10	13.23	15.33	+11.95
59	8.13	6.12	11.51	25.76	2.46	13.87	16.32	+ 9.44
54	8.13	5.83	10.46	24.42	1.74	18.02	19.76	+ 4.66
Average	8.13	6.42	11.77	26.32	2.18	14.58	16.77	+ 9.55
				Group III (ca 4% K level)				
50	8.13	5.79	20.92	34.84	2.09	25.14	27.23	+ 7.61
60	8.13	7.66	19.87	35.66	3.26	25.97	29.23	+ 6.43
71	8.13	4.87	18.31	31.31	1.21	21.87	23.08	+ 8.23
78	8.13	6.55	16.74	31.42	3.19	20.18	23.37	+ 8.05
Average	8.13	6.22	18.96	33.31	2.44	23.29	25.23	+ 8.08

Table XLII

Analysis of variance data for nitrogen and mineral balances

Trial II

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
		Nitrogen balances		
Between blocks	3	9.9638	3.3213	
Between treatments	2	10.6548	5.3274	4.00 N.S.
Error	6	7.9691	1.3282	
		Calcium balances		
Between blocks	3	0.6124	0.2041	
Between treatments	2	0.5106	0.2553	0.58 N.S.
Error	6	2.6604	0.4434	
		Phosphorus balances		
Between blocks	3	0.100958	0.033653	
Between treatments	2	0.688287	0.344144	20.13**
Error	6	0.102554	0.017092	

** Highly significant at 1% level

Critical difference (C.D.) = 0.226

N.S. denotes not statistically significant.

Table XLII (contd.)

Sources of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio 'F'
Magnesium balances				
Between blocks	3	0.042609	0.014203	
Between treatments	2	0.134366	0.067183	4.98 N.S.
Error	6	0.080948	0.013491	
Sodium balances				
Between blocks	3	0.1563	0.0521	
Between treatments	2	0.0721	0.0360	0.18 N.S.
Error	6	1.2219	0.2037	
Potassium balances				
Between blocks	3	6.3794	2.1265	
Between treatments	2	116.9885	58.49425	9.36*
Error	6	37.5029	6.2505	

* Significant at 5% level.
Critical difference (C.D.) = 4.34
N.S. denotes not statistically significant.

Table XLII

Average excretion of nitrogen and minerals in faeces per day

Trial II

Animal No.	Nitrogen (g.)	Calcium (g.)	Phosphorus (g.)	Magnesium (g.)	Sodium (g.)	Potassium (g.)
			Group I (Control)			
58	5.81	6.06	0.641	1.660	0.32	2.18
53	5.68	6.35	0.539	1.610	0.72	2.69
62	5.61	4.09	0.535	1.170	0.23	2.01
72	5.04	5.60	0.400	1.570	0.55	2.15
Average	5.54	5.53	0.504	1.502	0.46	2.26
Av. % of intake	46.44	86.81	44.17	77.99	13.90	15.22
			Group II (ca	K level)		
61	5.95	5.61	0.966	1.740	0.42	2.44
56	5.35	5.22	0.757	1.510	0.56	2.10
59	5.15	5.79	1.018	1.600	0.56	2.45
54	5.09	6.43	0.784	1.640	0.58	1.74
Average	5.39	5.76	0.881	1.623	0.53	2.18
Av. % of intake	45.56	91.28	79.08	84.44	16.26	8.28
50	5.07	5.95	0.988	1.480	0.35	2.09
60	5.89	6.04	0.934	1.690	0.31	3.26
71	5.57	5.69	0.773	1.500	0.09	1.21
78	5.97	5.73	1.000	1.460	0.14	3.19
Average	6.62	5.85	0.924	1.533	0.22	2.44
			[illegible]	[illegible]	6.81	7.33

Table XLIV

Average excretion of nitrogen and minerals in urine per day

Trial II

Animal No.	Nitrogen (g.)	Calcium (g.)	Phosphorus (g.)	Magnesium (g.)	Sodium (g.)	Potassium (g.)
			Group I (Control)			
58	5.50	0.09	0.058	0.240	0.08	12.54
53	4.96	0.03	0.011	0.210	0.82	9.39
62	5.27	0.05	0.032	0.320	0.84	11.00
72	5.25	0.07	0.033	0.300	0.89	8.77
Average	5.25	0.06	0.034	0.268	0.66	10.43
Av. % of intake	44.01	0.94	2.98	13.91	19.94	70.24
			Group II (ca 3% K level)			
61	7.01	0.12	0.061	0.380	0.63	13.21
56	5.14	0.20	0.041	0.410	0.42	13.23
59	8.26	0.14	0.065	0.400	0.28	13.87
54	7.89	0.08	0.457	0.360	0.17	18.02
Average	7.08	0.14	0.156	0.388	0.38	14.58
Av. % of intake	59.85	2.22	14.00	20.19	11.53	55.40
			Group III (ca 4% K level)			
50	8.18	0.10	0.068	0.460	0.87	25.14
60	6.54	0.12	0.040	0.350	0.60	25.97
71	9.11	0.15	0.079	0.430	0.98	21.87
78	5.82	0.15	0.037	0.470	0.84	20.18
Average	7.41	0.13	0.056	0.428	0.82	23.29
Av. % of intake	62.96	2.07	5.11	27.92	25.39	69.92

cent levels, however, there was not much difference. Potassium excretion behaved exactly in the opposite direction and in a similar manner. The urinary excretion pattern, on the other hand, was rather erratic and no systematic variation from group to group could be identified (vide Table XLIV). If comparison is confined to the control and 3% potassium (1:8.1::sodium:potassium) fed groups alone, excretion of nitrogen, calcium, phosphorus and magnesium increased considerably with the higher level of potassium ingestion, while that of sodium and potassium declined as much. But between 3 and 4 per cent potash fed animal, i.e., when the sodium:potassium ratio varied between 1:8.1 and 1:10.3, the difference in the rate of excretion was less pronounced.

In general, it can be stated that while in the first experiment the excretion of phosphorus in the faeces was raised from 50 per cent of that ingested in the control group to almost 80 and 90 per cent in the supplemented groups in the second experiment, also similar increases have been noticed. A similarity in potassium excretion in the two experiments has also been found. But the impoverishment of sodium in the body noted earlier was not so marked in the present experiment.

The results of water metabolism studies are presented in Tables XLV and XLVI. It will be seen from

Table XLV

Water metabolism data (Average water balance per day) - (Basal ration - Green berseem + wheat bhoosa (unwashed)

Trial II

Animal No.	Water intake (ml.)				Water outgo (ml.)			Insensible perspiration (ml.)	Total solids in urine (g.)
	Free drink	From feeds	Metabolic water	Total	In faeces	In urine	Total in urine and faeces		
Group I (Control)									
58	821.0	1786.0	265.0	2872.0	647.6	1411.1	2058.7	813.3	40.1
53	429.0	1782.0	239.0	2450.0	895.5	527.4	1422.9	1027.1	28.0
62	500.0	1769.0	199.0	2468.0	946.8	487.6	1434.4	1033.6	25.4
72	536.0	1772.0	235.0	2543.0	758.9	799.4	1558.3	984.7	23.6
Average	572.0	1777.0	235.0	2583.0	812.2	806.4	1618.6	964.4	29.3
Group II (ca 3% K level)									
61	2070.0	1776.0	236.0	4083.0	929.4	2515.1	3444.5	638.5	56.8
56	1571.0	1781.0	259.0	3611.0	726.5	1722.1	2448.6	1162.4	51.2
59	1036.0	1772.0	199.0	3007.0	788.0	1737.1	2525.1	481.9	53.0
54	857.0	1769.0	212.0	2838.0	543.9	1747.0	2290.9	547.1	51.0
Average	1384.0	1775.0	227.0	3386.0	746.9	1930.3	2677.2	708.8	53.0
Group III (ca 4% K level)									
50	1250.0	1769.0	208.0	3227.0	536.6	1798.1	2334.7	892.3	63.1
60	1893.0	1786.0	262.0	3941.0	790.1	2542.6	3332.7	608.3	66.6
71	536.0	1761.0	182.0	2479.0	376.4	1685.9	2062.3	416.7	60.0
78	1321.0	1776.0	222.0	3319.0	838.7	1723.5	2562.2	756.8	55.7
Average	1250.0	1730.0	219.0	3242.0	635.4	1937.5	2572.9	669.1	61.4

Table XLVI

Metabolism of water and dry matter

(Basal ration - green berseem + wheat bhoosa)

Trial II

Animal No.	Total water intake	Total dry matter intake	Dry matter digested	Ratio of water intake to dry matter: Intake	Ratio of water intake to dry matter: Digested	Vol. of urine (ml.) $Na^+ + K^+$ ions (milli - equiv.)
Group I (Control)						
58	2872.0	897.4	501.3	3.2	5.7	4.3
53	2450.0	851.9	449.8	2.9	5.4	1.9
62	2468.0	713.9	389.6	3.5	6.3	1.5
72	2543.0	753.0	445.5	3.4	5.7	3.0
Average	2583.0	804.1	446.6	3.2	5.8	2.7
Group II (ca 3% K level)						
61	4083.0	792.7	444.1	5.1	9.2	6.9
56	3611.0	840.8	490.4	4.3	7.4	4.8
59	3007.0	748.4	377.0	4.0	8.0	4.7
54	2838.0	722.4	401.0	3.9	7.1	3.7
Average	3385.0	776.1	428.1	4.3	7.9	3.1
Group III (ca 4% K level)						
50	3227.0	718.5	396.7	4.5	8.1	2.6
60	3941.0	890.3	497.8	4.4	7.9	3.7
71	2479.0	633.9	346.4	3.9	7.2	2.8
78	3319.0	788.8	449.9	4.2	7.4	3.1
Average	3242.0	757.9	422.7	4.2	7.7	3.1

Table XLV that the water intake of the animals of groups II and III was about the same and was at least 25 per cent higher than that seen with the animals of the control group. Water outgo through urine followed a similar pattern, only that the outgo in the supplemented groups was almost 2½ times that of the control group against an increase of 1½ times in the free water consumption. The total solids excreted in urine in the supplemented groups were also much higher.

The ratio of water intake to the dry matter ingestion given in Table XLVI also has shown an increase in the potassium supplemented groups but between 3 and 4 per cent levels there was no difference.

SUMMARY

The results obtained in the present experiment, for all practical purposes, corroborate the findings of the previous experiment except in some minor details.

GENERAL SUMMARY AND CONCLUSIONS

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GENERAL SUMMARY AND CONCLUSIONS

An experiment was designed and conducted on twelve adult sheep, distributed in three groups of four animals each, to study the effect of feeding potassium in amounts present in many potassium rich pastures with sodium:potassium ratio varying from 1:3.5 to 1:19.2 on (a) the digestibility of organic nutrients, (b) the retention of nitrogen, calcium, phosphorus, magnesium, sodium and potassium, (c) their excretory pattern in urine and faeces and (d) water metabolism. Its effect on (e) appetite and (f) body weight was also studied. Two feeding trials were conducted. In the first, the basal ration was made a low potassium one, so that potassium was mainly supplied in the form of potassium chloride to raise the sodium:potassium ratio even as high as 1:19.2. In the second experiment, the main source of potassium was the ration itself, the potassium chloride supplement was only fed when necessary, the maximum sodium:potassium ratio in the latter being only 1:10.3.

The results of the digestibility trials and balance studies of both the experiments were almost similar, irrespective of the level of potassium feeding or of the sodium:potassium ratio or even of the source of potassium either in the form of its salt or of natural feeding stuffs. The results of water metabolism and other studies conducted were also similar. They are as follows:

(a) The digestibility of crude protein, ether extract, crude fibre, nitrogen-free extract and dry matter was not affected by the nature or source of potassium nor by the level of potassium feeding (maximum 4 per cent and minimum 0.77 per cent)/sodium:potassium ratio (maximum 1:19.2 and minimum 1:3.5).

(b) The retention of nitrogen, calcium and magnesium was also not affected. But the retention of phosphorus was adversely affected as the sodium:potassium ratio widened up and this was highly significant at 1 per cent level. It is possible that had the levels of nitrogen, calcium and magnesium feeding were still lower than the low levels at which these were fed some significant result could have been obtained as in the case of phosphorus.

(c) The excretory pattern of nitrogen and the minerals by way of urine and faeces was also similar in both the experiments. The pattern in respect of urine remained the same in respect of nitrogen, calcium, phosphorus and magnesium, while that of sodium was different. The excretion declined as the level of potassium feeding rose, indicating that the latter by encouraging excretion in urine impoverished the body of the mineral. In faeces, on the other hand, phosphorus excretion was raised tremendously as a result of the widening of the sodium:potassium ratio.

(d) Free water ingestion was found to increase enormously as the level of feeding or the sodium: potassium ratio increased. Its outgo through urine also increased simultaneously and the increase was at times four fold compared to that in the control.

(e) The potassium feeding (wide sodium:potassium ratio) was also found to increase the water requirement per unit of dry matter ingested.

It is, therefore, concluded that high level of potassium feeding in relation to sodium raises the water intake and produces diuresis. It also considerably lowers the phosphorus retention in the body and impoverishes the body of sodium. But, otherwise, it has no adverse effect on the digestibility and retention of common organic and inorganic nutrients.

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