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A COMPARATIVE STUDY ON THE EFFICIENCY OF WATER SOLUBLE PHOSPHATES AND A DRY PHOSPHATE LICK FOR SHEEP FED ON MATURE GRASS HAY

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Abstract

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In a study with adolescent Merino sheep on a diet of mature grass hay, the supplementation with phosphates alone, either in the drinking water or as a dry lick, did not prevent loss of condition. Furthermore, in metabolism studies the phosphorus and nitrogen balances under these conditons were negative.

However, the daily inclusion of small allowances of lucerne hay and maize samp to the diet resulted in increased intakes of protein and carbohydrate and ensured positive metabolism balances for phosphorus and nitrogen. Under these improved feeding conditions body weights increased. The result of feeding this diet suggested that phosphate feeding at certain times may be unnecessary under practical conditions.

Introduction

Theiler (1920, 1931) first demonstrated that a phosphorus deficiency in the veld grass in some parts of South Africa during much of the year was responsible for stunted growth and characteristic bone lesions in cattle. These were, initially, incidental observations made after he had advocated the feeding to stock of sterilized bonemeal to prevent osteophagia, and thus lamsiekte, caused by the ingestion of carrion material containing the toxins of *Clostridium botulinum*. This feeding of bonemeal also corrected the phosphorus deficiency in the diet and prevented aphosphorosis. These findings stimulated investigations into various aspects of animal growth, blood composition and mineral content of the natural pasture, and on the efficiency of various phosphate supplements in the diet.

The results of mineral metabolism studies led to the development of methods of administering inorganic phosphates to stock in their drinking water (Bekker, 1932; Reinach & Louw, 1952; Truter & Louw, 1952). Since certain water soluble phosphates were expensive at that time, a cheaper method was devised in 1952 by Reinach & Louw whereby defluorinated superphosphate could be safely used in the drinking water. The prescribed formula ensured an average daily intake of 5.7 g phosphorus by a bovine. Bisschop (1964) reported remarkably favourable results in an experiment in which the feeding of superphosphates in drinking water was compared with that of bonemeal. Deductions from farmers' reports on practical phosphate feeding, however, indicate that stock grazing natural veld do not always show such good results. It has also been demonstrated by Murray, Romyn, Haylett & Ericksen (1936) and Murray & Romyn (1937) that in the sandveld pastures of the Matopa area of Rhodesia, young growing stock and lactating cows did not benefit from the feeding of phosphates.

Du Toit, Louw & Malan (1940) presented evidence that during the dry winter season of the summer rainfall area the extreme deficiency of protein in our pastures is possibly as important as the phosphorus deficiency. Furthermore, the digestibility of the desiccated vegetation determines the availability of the protein at various stages in the growth of the pasture (Myburgh, 1937; Louw, 1938; Louw, Bodenstein & Quin, 1948).

The study presented here was initiated to confirm the theory that the ineffective results obtained in practical phosphate feeding were partly due to the low nutritive state of the natural pasture. In similar studies on drought feeding of cattle, Morris (1958) reported that young heifers fed bush hay with mineral supplements, lost an average of 20 lb (9kg) body weight over a period of 26 weeks. In comparison, heifers fed additional daily supplements of 1.3 lb (0.59 kg) and 3 lb (1.36 kg) of lucerne chaff per head over the same period gained an average of 21 lb (9.53 kg) and 28 lb (12.70 kg) respectively. In his experiment neither the body weight of the heifers nor their intake of hay was increased by providing a lick containing sterilized gelatinous bone flour.

Materials and Methods

The project was divided into three separate experiments, in each of which the same animals were used. Sixteen adolescent Merino wethers, weighing between 34.6 and 36.8 kg, were divided into four groups, of which three received a different form of phosphate supplementation to their feed rations. The latter varied in each of the three experiments; in Experiment 1 it consisted of mature veld grass hay (i.e. *the basal ration*) *ad lib.*; in Experiment 2 the basal ration *ad lib.* plus 200 g lucerne hay a day per sheep, and in Experiment 3 the basal ration *ad lib.* plus a daily allowance per sheep of 200 g lucerne hay and 200 g maize samp (degerminated maize). The mature grass hay used throughout came from one large batch obtained from a single source. The phosphate supplements to the daily ration of the groups varied slightly in amount in the three experiments (see Table 1) and, apart from the control group which received no phosphate, were as follows:-

Group 1. Defluorinated superphosphate [prepared as described by Reinach & Louw (1952)] in the drinking water.

Group 2. Monosodium phosphate in the drinking water.

Group 3. Degelatinized bonemeal as a dry lick.

TABLE 1 *Daily intake of phosphorus (g) in respective rations*

Group	Exp. 1	Exp. 2	Exp. 3
1.	1.98	2.00	2.52
2.	1.97	2.24	2.57
3.	2.78	2.98	2.79
4.	0.45	0.69	0.81

Before each experiment a period of adaptation to the feed and environmental conditions was allowed for at

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TABLE 2 *Chemical composition of the dry matter of rations* (per cent)

	N	Protein (N × 6.25)	P	Ca	Ash	Fibre	N.F.E.	Ether ext
Basal ration								
Exp. 1. Grass hay	0.77	4.80	0.075	0.35	2.25	36.3	55.06	1.59
2. ,, ,,	0.76	4.80	0.07	0.32	2.20	36.0	55.48	1.52
3. ,, ,,	0.75	4.70	0.07	0.36	2.40	36.0	55.40	1.50
Feed Supplements:								
Exp. 2. Lucerne hay	2.56	16.20	0.17	1.12	8.9	28.4	43.30	3.20
3. ,, ,,	2.96	18.50	0.17	1.00	9.5	26.0	42.20	3.80
Exp. 3. Maize samp	1.26	7.90	0.05	0.01	0.34	0.34	90.77	0.68

TABLE 3 *Metabolism data. Retention of N, P and Ca*

Experiment	Group	Phos. sup.	Daily intake g			Retentions g (average)			Percentage		
			N	P	Ca	N	P	Ca	N	P	Ca
1	1	Superphos.	3.88	1.98	2.56	—0.47	+0.03	—0.31	—12.7	+ 2.0	—12.1
2	1	,,	8.88	2.00	4.42	+2.94	+0.11	+0.55	+33.1	+ 5.5	+12.5
3	1	,,	12.94	2.52	4.82	+5.39	+0.88	+1.22	+41.6	+34.8	+25.3
1	2	Mono-Na-phos.	4.16	1.97	2.07	—0.44	—0.09	—0.19	—11.4	— 4.6	— 9.2
2	2	,,	8.88	2.24	3.42	+2.68	+0.27	+0.33	+28.1	+12.1	+ 9.6
3	2	,,	12.94	2.57	4.26	+5.19	+1.23	+1.10	+40.0	+47.7	+25.8
1	3	Bone meal	3.77	2.78	7.89	—0.37	+0.69	+2.09	—10.4	+24.8	+26.5
2	3	,,	0.96	2.98	9.54	+2.16	+0.63	+2.62	+24.2	+21.2	+27.5
3	3	,,	12.18	2.79	8.76	+4.95	+0.84	+2.11	+41.1	+30.1	+24.1
1	4	Nil	4.38	0.45	2.18	—0.24	—0.29	—0.62	— 5.6	—64.5	—28.5
2	4	,,	8.88	0.69	3.94	+2.87	—0.11	+0.90	+32.7	—15.9	+22.9
3	4	,,	12.50	0.81	4.02	+5.53	+0.27	+0.82	+44.3	+32.1	+20.4

Experiment 1: Basal ration (grass hay)
,, 2: ,, ,, plus lucerne hay
,, 3: ,, ,, plus lucerne hay and maize

TABLE 4 *Metabolism data. Digestible protein for maintenance requirement*

Group	Body weights (Aver.) kg	Daily intake D.M. (Aver.) kg	Intake digest. protein g (Aver.)	Digest. protein maintenance requirements calculated g per Aver. body weight	Body weight gains or losses calculated per week kg
			Experiment 1		
1	32.4	0.528	6.9	20.6	—0.40
2	32.3	0.564	6.8	20.6	—0.33
3	33.4	0.513	5.24	21.3	—0.43
4	33.6	0.595	6.5	21.5	—0.46
			Experiment 2		
1	31.1	0.700	33.7	19.9	+0.39
2	31.8	0.700	33.3	20.3	+0.45
3	32.7	0.697	31.0	20.9	+0.57
4	31.8	0.700	34.1	20.3	+0.35
			Experiment 3		
1	37.0	1.000	48.0	23.6	+0.54
2	38.1	1.000	46.8	24.3	+0.57
3	39.1	0.874	47.5	24.9	+0.51
4	36.8	0.933	49.0	23.5	+0.45

Dig. prot. (maintenance) = 29 g per 45.5 kg B.W.
According to formula $P = 0.88\ W^{0.734}$ (Smuts and Marais, 1938)

least 4 weeks, and between experiments all the animals received the same feeding. For each experiment the sheep were divided at random into groups of four animals. The three consecutive experimental periods were 14, 8 and 16 weeks respectively and towards the end of every experiment each animal was confined for the conventional ten-day period to a metabolism cage while various data were recorded and specimens for chemical analyses taken (see Tables 2 to 7 and Appendix Tables 1 to 6). Analytical data were obtained by the use of the techniques described in A.O.A.C. (1960).

During the experiments blood samples were taken monthly for the determination of phosphorus and calcium contents, and the sheep were weighed weekly.

A representative sample of the ration used in each metabolism trial was analysed for its protein, calcium, phosphorus, fibre, ash, nitrogen-free extract and fat contents.

The mean phosphorus, calcium and nitrogen retentions were calculated from data obtained in metabolism trials.

At the conclusion of the experiments the various data obtained in each experiment were compared in order to determine the influence of the different methods and rates of phosphorus supplementation and protein supplementation on the basal metabolism.

RESULTS

The detailed results of the metabolism data are given in Appendix Tables 1 to 6.

Composition of the rations

The analyses of the rations are given in Tables 1 and 2.

Although it was intended that the intake of phosphorus from the bonemeal supplements should be the equivalent of the intakes of water soluble phosphorus, it proved to be somewhat higher than had been anticipated. All the sheep in the four groups in Experiment 1, however, lost weight (Table 5).

Balance trials: Calculated retentions of phosphorus, calcium and nitrogen

The data for the balances of phosphorus and calcium are given in Appendix Tables 1, 2 and 3 and those of nitrogen in Appendix Tables 4, 5 and 6. In order to facilitate comparison the retentions of those substances are given in a summarized form in Table 3.

Protein digestibilities

The average calculated daily intakes of digestible protein for each group of sheep in the three experiments appear in Table 4. For comparison the calculated daily requirement of digestible protein for maintenance of body weight is also given. This figure is based on the formula $P = 0.88W^{0.734}$, where P = protein and W = body weight, and is the equivalent of 29 g of digestible protein per 45.5 kg live weight for sheep (Smuts & Marais, 1938).

The loss of weight of all the sheep in Experiment 1, in which they received only the basal ration, must have been partly due to the deficit of digestible protein.

Net energy values and requirements

The net energy requirements per body weight of the sheep in the three experiments are given in calories in Table 5, and are based on the recommendations of the National Research Council, Washington (Morrison, 1954). Smuts & Marais (1938) stated that the basal energy needs of sheep may be predicted and, by applying their equation for the relationship between endogenous nitrogen and basal metabolism, a figure of 1.16 Therms (1160 calories) of basal heat per sheep weighing 45.5 kg was obtained.

According to Mitchell (1937) the net energy system affords the most accurate method by which to evaluate rations as sources of energy. It is obvious that the basal ration alone, as fed in Experiment 1, did not meet the energy requirements of the sheep (Morrison, 1954) which consequently lost weight (Table 6). The rations

TABLE 5 *Metabolism data. Dry matter and energy digestibilities and digestible energy content of rations*

Group	Body weight (Aver.) kg	Intake D.M. (Aver.) kg	Digestibility D.M. (Aver.) %	Energy digestibility (Aver.) %	Digestible energy (Cal./g)	Calculated basal energy met. per aver. B.W. (Cal.)	Dig. energy per average intake (Cal.)	Net. energy req. (Cal.)
Experiment 1 - Grass hay ration								
1.	32.4	528	47.3	47.06	2.022	820	1067	1250
2.	32.3	564	49.7	49.06	2.132	820	1202	1250
3.	33.4	513	42.9	43.06	1.817	850	937	1300
4.	33.6	595	42.8	42.86	1.812	860	1078	1300
Experiment 2 - Grass hay - lucerne hay ration								
1.	31.1	700	56.5	54.26	2.442	790	1709	1100
2.	31.8	700	55.8	54.66	2.412	810	1688	1100
3.	32.7	678	48.9	48.46	2.092	830	1420	1250
4.	31.8	700	57.3	56.06	2.482	810	1737	1100
Experiment 3 - Grass hay - lucerne hay - maize ration								
1.	37.0	1000	60.5	59.06	2.622	950	2622	1400
2.	38.1	1000	58.5	57.16	2.532	970	2532	1500
3.	39.1	874	59.4	58.06	2.602	990	2280	1500
4.	36.8	933	61.9	60.26	2.692	940	2520	1400

Energy digestibility (regression equation) according to Moir (1961)
$y = 0.907\,x + 4.061$ ($r = +0.925$)
where y = dig. of energy (%)
x = dry matter digestibility (%)
Digestible energy: according to Moir (1961)
$y = 0.0462\,x - 0.158$ ($r = 0.981$)
where y = digestible energy (Cal./g)
x = dry matter digestibility (%)

Basal energy metabolized, according to Smuts and Marais (1938)
Calculated from formula $\frac{1.16 \text{ Therms per } 45.5 \text{ kg}}{\text{B.W.}}$

Net energy req. according to Appendix Table III Morrison (1952 in Experiments 2 and 3, however, provided sufficient calories of digestible energy and no weight losses were recorded.

Digestible energy

The digestible energy contents of the three rations are also recorded in Table 5 and were calculated according to the formula of Moir (1961). The digestible energy content (y, in cal./g) was estimated from the percentage of dry matter digestibility (x) by the equation:

$$y = 0.0462x - 0.158 \quad (r = 0.98)$$

The dry matter digestibility, therefore, gives a simple and accurate indication of the digestible energy content of foodstuffs.

Variation in body weight

The body weights were averaged and losses or gains calculated on a weekly basis. These figures are reflected in Table 6.

It is obvious that in Experiment 1 the mature grass hay, either with or without phosphatic supplementation, did not maintain body weight. Sheep in the groups lost a weekly average of from 0.33 to 0.46 kg, and, as mentioned above, these losses must be attributed to the low intakes of both digestible energy and protein. Phosphate supplementation did not influence the subnormal metabolism in any way.

In the second experiment, the addition of 200 g of lucerne hay to the basal ration raised both the digestible energy and digestible protein contents to an adequate growth level. The addition of 200 g of maize samp to the diet of grass hay and lucerne hay considerably raised the daily intakes of both digestible calories and protein and all the sheep gained weight. At this level of high nutrient intake the utilization of phosphorus was, as expected, highly efficient (Table 3).

Blood levels of inorganic phosphorus and calcium

Summaries of the average monthly values of blood phosphorus and calcium are given in Table 7.

Inorganic phosphorus

The inorganic phosphorus levels of the blood of the phosphate supplemented groups were higher than the control groups in the three experiments. The average values of 4.5, 4.23 and 4.02 mg/100 ml blood for the control groups were comparatively low. Similar low values for sheep on phosphorus deficient diets were found by Du Toit, Malan & Groenewald (1931), and Reinach & Louw (1958).

In all three experiments the response to the feeding of phosphate was reflected in the blood levels of phosphorus. An unexpected feature was the high average values shown by the sheep on the basal diet of mature grass hay, namely 6.3, 6.47 and 5.37 mg/100 ml blood, when compared with the average values of the second and third experiments. This indicates that the phosphate

TABLE 6 *Body weight gains and losses* (Averaged)

Group	Initial Weight kg	Final Weight kg	Gain or Loss kg	Weekly Gain or Loss kg
	Experiment 1			
1	35.2	29.6	−5.6	−0.40
2	34.6	30.0	−4.6	−0.33
3	36.4	30.4	−6.0	−0.43
4	36.8	30.4	−6.4	−0.46
	Experiment 2			
1	29.6	32.7	+3.1	+0.39
2	30.0	33.6	+3.6	+0.45
3	30.4	35.0	+4.6	+0.57
4	30.4	33.2	+2.8	+0.35
	Experiment 3			
1	32.7	41.4	+8.7	+0.54
2	33.6	42.7	+9.1	+0.57
3	35.0	43.2	+8.2	+0.51
4	33.2	40.4	+7.2	+0.45

TABLE 7 *Inorganic P and Ca content of blood* (Averages - monthly)

	Inorg. P mg/100 ml blood			Total Ca mg/100 ml blood		
	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3
Group 1: Range	6.2–6.5	5.2–5.4	5.0–5.8	8.5–9.2	8.0–8.4	8.0–8.3
Aver.	6.3	5.3	5.32	9.0	8.15	8.2
	Basal + superphos.	Basal + luc.h. + superphos.	Basal + luc.h. + maize + superphos.			
Group 2: Range	6.1–6.8	5.6–6.0	5.3–6.1	8.3–9.0	8.1–8.2	8.0–8.7
Aver.	6.47	5.8	5.58	8.7	8.15	8.2
	Basal + mono. sod. phos.	Basal + luc.h. + mono. sod. phos.	Basal + luc.h. + maize + mono. sod. phos.			
Group 3: Range	5.1–5.5	4.7–5.0	4.2–5.0	8.6–9.3	8.3–8.3	8.7–9.3
Aver.	5.37	4.9	4.5	9.03	8.3	8.8
	Basal + bone flour	Basal + luc.h. + bone flour	Basal + luc.h. + maize + bone flour			
Group 4: Range	4.5–5.0	4.1–4.4	3.7–4.5	8.6–9.9	8.4–8.7	8.4–9.1
Aver.	4.5	4.23	4.02	9.27	8.53	8.75
	Basal (no suppl.)	Basal + luc.h (no suppl.)	Basal + luc.h. + maize (no suppl.)			

was well absorbed, not only in the experiments where more balanced rations were fed, but also in Experiment 1 where the diet was poor. Each of the three experiments revealed that, according to the blood phosphorus levels, absorption of phosphate by the sheep from the water soluble phosphates was better than from the dry lick. There did not appear to be any differences in this respect between the two types of phosphate supplementation in the drinking water.

Calcium

The blood calcium levels of all groups in the three experiments varied considerably, and were within or slightly below normal limits. The blood of the control groups contained higher average values.

Metabolism data

The metabolism data, expressed as percentage retentions of the intake of nitrogen, phosphorus and calcium, are given in Table 3.

Nitrogen retention

It is obvious that the low nitrogen intake of the basal ration in Experiment 1 resulted in negative nitrogen balances. The supplementation of the basal ration with phosphate depressed rather than had a beneficial influence on the utilization of nitrogen, as demonstrated by the increased negative retention. In the second experiment, the inclusion of a small amount of lucerne hay in the ration increased the nitrogen intake to the extent that balances became positive, while in the third experiment the addition of both lucerne hay and maize in small amounts to the basal ration improved the nitrogen utilization considerably, as is reflected by the positive balances.

Phosphorus retention

In Experiment 1, where the intakes of nitrogen of the basal ration were inadequate, the utilization of phosphorus by the sheep was low or nil. The group receiving superphosphate had a phosphorus retention of only 2 per cent whilst none was retained by the group receiving monosodium phosphate. At the very high daily intake level of 2.78 g phosphorus which the group receiving bonemeal was given, the percentage retention of phosphorus was only 24.8, which is still low.

When adequate digestible nitrogen (or protein) and digestible energy were provided by the inclusion of lucerne hay in the ration, the phosphorus utilization was slightly improved. In the groups receiving superphosphate, monosodium phosphate or bonemeal the utilization was 5.5, 12.1 and 21.2 per cent respectively.

The feeding of a more balanced ration with respect to nitrogen and calorie contents in Experiment 3 considerably improved phosphorus utilization by the sheep. The respective average percentage retentions were 34.8 for the superphosphate group, 47.7 for the monosodium phosphate group and 30.1 for the bonemeal group.

Calcium retention

The utilization of calcium by the sheep receiving grass hay in the first experiment was low and in negative balance. Supplementation of the ration with superphosphate and monosodium phosphate resulted in only small improvements of calcium utilization and balances were still negative. Calcium utilization by the group receiving bonemeal, however, was relatively high (26.5 per cent retention) which was no doubt due to the very high calcium intake.

The inclusion of lucerne hay in the ration increased the calcium intake in Experiment 2 and, as was to be expected, this proved effective in increasing the calcium utilization. The percentages of calcium retention in the four groups in this experiment were:- control group, 22.9; superphosphate group, 12.5; monosodium phosphate group, 25.8 and the bonemeal group, 24.1. In Experiment 3, in which a more balanced ration was fed to the sheep, these percentages in the groups were respectively 20.4, 25.3, 25.8 and 24.1. The addition of lucerne hay and maize in small amounts to the feed thus improved calcium utilization whether phosphates were fed or not.

Discussion

Louw *et al.* (1948) demonstrated that sheep subsisting for any length of time on a diet of mature grass hay with a low protein content showed impaired ruminal digestion of cellulose and that, under these low nutritional conditions, supplementation of the diet with a concentrate mix of starch, brewer's yeast and complete mineral mixture did not improve cellulose digestion. The feeding of small supplements of green feed, however, both stimulated the appetite and restored the depressed conditions in the rumen to normal.

The present study was therefore planned to determine the degree of utilization of phosphorus by sheep under the following nutritional conditions: one oflow nitrogen and energy intake, one of adequate intakes of these substances, and one in which a more balanced ration was fed. It was proved that phosphorus is not efficiently utilized when intakes of digestible nitrogen and energy are inadequate. Such conditions frequently prevail in many parts of South Africa in the dry late winter and early spring months, before the new growth of natural pasture has commenced. An inadequate level of nutrition must therefore be regarded as one reason for the inefficiency of phosphorus utilization by sheep when phosphate supplements are fed under practical farming conditions. The metabolism data obtained substantiate this. Furthermore, it was proved in these experiments that by improving the basal ration of mature grass hay by the addition of small amounts of lucerne hay and maize, which could be done cheaply under farming conditions, calcium utilization and protein digestibility are enhanced and the animals increase in weight.

It was also shown in these experiments that when a balanced ration is fed, the phosphorus content may be adequate and there is no need for extra phosphates (as was shown by the sheep in the control group in Experiment 3).

In conclusion, it may be stated that the ratio between the "phosphorus content" and the "energy value" of the grazing will serve as a better guide in evaluating the nutritional value of pasture than only the expression of the percentage of phosphorus in the dry matter (Theiler, 1932). It has been shown that the absorption of phosphorus by sheep is determined not only by the level of this substance in the feed, but also by the amount of digestible energy available. The intake of water soluble phosphates at the level of 1.98 g P daily proved to be inadequate when the diet consisted of mature grass hay. In metabolism trials the sheep showed negative P balances, and also negative N balances. The dry lick of bone flour fed at the level of 2.4 g P, however, resulted in positive P balances, but negative N balances. This feature suggests a disturbed metabolism at relatively high P intakes, due to deficiencies of protein and carbohydrates. As a result sheep could not maintain condition but showed loss of body weight in a feeding period of 14 weeks.

Feed supplements such as those given in subsequent periods (Exp. 2 and 3), changed the entire picture, as shown by body weight gains, and enhanced P utilization, as indicated by positive balances.

The use of defluorinated superphosphate in drinking water of ruminants has been recommended since 1939, and advocated for practical use (Reinach & Louw, 1952) with considerable success for cattle in phosphorus deficient areas (Bisschop, 1964). Furthermore, it has proved to be most economical.

The efficacy of the phosphates tested here was reflected by their percentage retention in an otherwise well balanced diet (Exp. 3).

Summary

Mature grass hay as a basal feed supplemented with phosphate at substantially high levels of phosphorus intakes, cannot maintain the live weight of adolescent sheep. This loss of condition was ascribed to low protein and low energy intakes.

The daily feeding of small additional feed supplements, such as lucerne hay and maize, provided adequate intakes of protein and carbohydrate to ensure the efficient utilization of phosphate supplements. This is of practical importance in phosphate feeding when ruminants are grazing in winter.

The utilization of the phosphorus in both the water-soluble form and the dry lick was efficient when the diet was better balanced with respect to protein and energy. However, the combination of lucerne hay and maize as feed supplements in a diet of grass hay, suggested that supplementary phosphate feeding at certain periods may be obviated. This conclusion could be drawn from the positive retention for phosphorus in the control ration, though the inorganic P values of the group rather suggest low availability of phosphorus.

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APPENDIX TABLE 1 *Metabolism data. Phosphorus and calcium balances. Experiment 1 - Trials*

Group	Sheep	Intake ration		Supplements		Total intake		Excretion				Balances	
								Faecal		Urinary			
		P	Ca	P	Ca	P	Ca	P	Ca	P	Ca	P	Ca
1 . . .	1	0.45	2.10	1.71	0.76	2.16	2.86	1.97	3.02	0.02	0.14	+0.17	—0.30
	2	0.30	1.40	1.14	0.51	1.44	1.91	1.24	2.00	0.12	0.13	+0.08	—0.22
	3	0.41	1.91	1.71	0.76	2.12	2.67	2.10	3.01	0.02	0.17	0.00	—0.50
	4	0.43	2.00	1.75	0.78	2.18	2.78	2.21	2.89	0.11	0.11	—0.13	—0.22
Mean .	. . .	0.40	1.58	1.58	0.70	1.98	2.56	1.88	2.73	—	—	+0.03	—0.31
2 . . .	5	0.34	1.60	1.54	0.10	1.88	1.70	1.90	1.80	0.04	0.08	—0.06	—0.18
	6	0.45	2.10	1.70	0.10	2.15	2.20	2.22	2.31	0.02	0.12	—0.09	—0.23
	7	0.45	2.10	1.68	0.10	2.13	2.20	2.43	2.61	0.08	0.07	—0.38	—0.48
	8	0.45	2.10	1.27	0.08	1.72	2.18	1.56	1.98	0.02	0.07	+0.12	+0.13
Mean .	. . .	0.42	1.98	1.55	0.10	1.97	2.07	2.03	2.17	—	—	—0.09	—0.19
3 . . .	9	0.28	1.33	2.40	6.10	2.68	7.43	1.78	4.44	0.013	0.064	+0.89	+2.93
	10	0.37	1.72	2.40	6.10	2.77	7.82	2.14	5.70	0.015	0.08	+0.62	+2.04
	11	0.43	2.03	2.40	6.10	2.83	8.13	2.35	6.41	0.014	0.096	+0.47	+1.62
	12	0.45	2.10	2.40	6.10	2.85	8.20	2.04	6.35	0.021	0.077	+0.79	+1.77
Mean .	. . .	0.38	1.79	2.40	6.10	2.78	7.89	2.08	5.73	—	—	+0.69	+2.09
4 . . .	13	0.43	2.03	—	0.10	0.43	2.13	0.76	2.75	0.015	0.096	—0.34	—0.72
	14	0.45	2.10	—	0.10	0.45	2.20	0.72	2.70	0.01	0.096	—0.28	—0.60
	15	0.45	2.10	—	0.10	0.45	2.20	0.70	2.67	0.017	0.058	—0.27	—0.53
	16	0.45	2.10	—	0.10	0.45	2.20	0.69	2.71	0.015	0.115	—0.25	—0.62
Mean .	. . .	0.45	2.08	—	0.10	0.45	2.18	0.72	2.71	—	—	—0.29	—0.62

APPENDIX TABLE 2 *Metabolism data. Phosphorus and calcium balances. Experiment 2 - Trials*

Group	Sheep	Total intake (g)		Excretion (g)				Balances (g)	
				Faecal		Urinary			
		P	Ca	P	Ca	P	Ca	P	Ca
1	1	1.97	4.25	1.83	3.83	0.02	0.07	+0.12	+0.35
	2	1.94	4.44	1.70	3.85	0.02	0.07	+0.22	+0.52
	3	2.09	4.52	1.93	3.78	0.01	0.08	+0.15	+0.66
	4	2.01	4.47	2.00	3.72	0.05	0.06	—0.04	+0.69
Mean .	. . .	2.00	4.42	1.87	3.79	—	—	+0.11	+0.55
2	5	2.17	3.92	1.86	3.70	0.02	0.05	+0.29	+0.17
	6	2.36	3.93	1.95	3.30	0.02	0.08	+0.39	+0.55
	7	2.24	3.92	1.96	3.63	0.02	0.08	+0.26	+0.21
	8	2.21	3.92	2.07	3.48	0.02	0.05	+0.12	+0.39
Mean .	. . .	2.24	3.92	1.96	3.55	—	—	+0.27	+0.33
3	9	2.93	9.35	2.15	6.47	0.02	0.10	+0.76	+2.78
	10	2.99	9.60	2.02	6.32	0.02	0.09	+0.95	+3.19
	11	2.99	9.60	2.62	7.48	0.02	0.14	+0.34	+1.98
	12	2.99	9.60	2.53	6.95	0.02	0.12	+0.44	+2.53
Mean .	. . .	2.98	9.54	2.33	6.80	—	—	+0.63	+2.62
4	13	0.69	3.94	0.64	2.70	0.02	0.05	+0.03	+1.19
	14	0.69	3.94	0.85	3.43	0.01	0.09	—0.17	+0.42
	15	0.69	3.94	0.83	2.65	0.02	0.06	—0.16	+1.23
	16	0.69	3.94	0.80	3.07	0.02	0.12	—0.14	+0.75
Mean .	. . .	0.69	3.94	0.78	2.96	—	—	—0.11	+0.90

APPENDIX TABLE 3 *Metabolism data. Phosphorus and calcium balances. Experiment 3 - Trials*

Group	Sheep	Total intake (g)		Excretion (g)				Balances (g)	
				Faecal		Urinary			
		P	Ca	P	Ca	P	Ca	P	Ca
1	1 2 3 4	2.42 2.34 2.61 2.72	4.70 4.76 4.88 4.92	1.60 1.47 1.72 1.73	3.52 3.55 3.43 3.54	0.01 0.01 0.01 0.03	0.07 0.083 0.086 0.061	+0.81 +0.86 +0.88 +0.96	+1.11 +1.09 +1.36 +1.32
Mean .	. . .	2.52	4.82	1.63	3.51	—	—	+0.88	+1.22
2	5 6 7 8	2.56 2.61 2.56 2.56	4.26 4.26 4.26 4.26	1.34 1.31 1.30 1.35	3.02 2.95 3.03 3.38	0.02 0.02 0.02 0.02	0.06 0.06 0.08 0.05	+1.20 +1.28 +1.24 +1.19	+1.18 +1.25 +1.15 +0.83
Mean .	. . .	2.57	4.26	1.33	3.84	—	—	+1.23	+1.10
3	9 10 11 12	2.68 2.79 2.82 2.88	8.17 8.74 8.91 9.21	1.63 2.36 1.65 2.05	5.15 6.66 6.52 7.80	0.013 0.015 0.013 0.015	0.10 0.11 0.13 0.12	+1.04 +0.33 +1.16 +0.82	+2.92 +1.97 +2.26 +1.29
Mean .	. . .	2.79	8.76	1.92	6.53	—	—	+0.84	+2.11
4	13 14 15 16	0.69 0.84 0.86 0.86	3.40 4.15 4.26 4.26	0.56 0.56 0.43 0.52	3.31 3.13 2.93 3.12	0.022 0.017 0.018 0.018	0.064 0.054 0.07 0.118	+0.11 +0.26 +0.41 +0.24	+0.03 +0.97 +1.26 +1.02
Mean .	. . .	0.81	4.02	0.52	3.12	—	—	+0.26	+0.82

APPENDIX TABLE 4 *Metabolism data. N-balances*

Experiment 1 - Grass hay									
Group	Sheep	N intake (g)	Digestible protein intake (g)	Excretion N		Total N Excretion (g)	N Balance (g)	Coefficients digestibility	
				Faecal (g)	Urinary (g)			N (%)	D.M. (%)
1. *Superphos.* .	1 2 3 4	4.42 2.94 3.97 4.20		3.02 2.10 3.00 2.98	1.57 1.40 1.57 1.76	4.59 3.50 4.57 4.74	–0.17 –0.56 –0.60 –0.54	31.7 28.5 24.5 29.0	
Mean . .		3.88	6.8				–0.47	28.4	47.3
2. *Mono-Na-phos.*	5 6 7 8	3.36 4.42 4.42 4.42		2.41 3.20 3.48 3.44	1.38 1.59 1.38 1.49	3.79 4.79 4.86 4.93	–0.43 –0.37 –0.44 –0.51	28.2 27.6 21.5 22.0	
Mean . .		4.40	6.8				–0.44	24.8	49.7
3. *Bone Flour.*	9 10 11 12	2.80 3.61 4.27 4.42		2.25 2.88 3.14 3.43	0.98 1.18 1.35 1.38	3.23 4.06 4.49 4.81	–0.43 –0.45 –0.22 –0.39	19.6 20.2 26.4 22.5	
Mean . .		3.78	5.2				–0.37	22.2	42.9
4. No Supplement	13 14 15 16	4.27 4.42 4.42 4.42		3.56 3.27 3.30 3.23	1.21 1.24 1.29 1.40	4.77 4.51 4.59 4.63	–0.50 –0.09 –0.17 –0.21	16.6 26.0 25.3 26.8	
Mean . .		4.38	6.5				–0.24	23.7	42.8

APPENDIX TABLE 5 *Metabolism data. N-balances*

Experiment 2 - Grass - lucerne hay

Group	Sheep	N Intake (g)	Digestible protein intake (g)	Excretion N		Total N Excretion (g)	N Balance (g)	Coefficients digestibility	
				Faecal (g)	Urinary (g)			N (%)	D.M. (%)
1. *Superphos.*	1	8.88		3.70	2.07	5.77	+3.11	58.4	
	2	8.88		3.15	2.24	5.39	+3.49	64.5	
	3	8.88		3.64	2.63	6.27	+2.61	59.1	
	4	8.88		3.50	2.83	6.33	+2.55	60.6	
Mean. .		8.88	33.8				+2.94	60.6	56.5
2. *Mono-Na-phos.*	5	8.88		3.71	2.47	6.18	+2.70	58.2	
	6	8.88		3.26	2.61	5.87	+3.01	63.3	
	7	8.88		3.54	2.61	6.15	+2.73	60.1	
	8	8.88		3.74	2.85	6.59	+2.29	57.9	
Mean. .		8.88	33.3				+2.68	59.9	55.8
3. *Bone Flour*	9	8.46		4.12	2.75	6.87	+1.59	51.3	
	10	9.12		3.28	2.26	5.54	+3.58	64.0	
	11	9.12		3.67	2.83	6.50	+2.62	59.7	
	12	9.12		4.89	3.30	8.19	+0.93	46.4	
Mean. .		8.95	30.9				+2.16	55.4	48.9
4. No supple-ment	13	8.88		2.83	2.35	5.18	+3.70	68.1	
	14	8.88		3.70	2.46	6.16	+2.72	58.3	
	15	8.88		3.58	2.69	6.27	+2.61	59.7	
	16	8.88		3.58	2.83	6.41	+2.47	59.7	
Mean. .		8.88	33.9				+2.87	61.5	57.3

APPENDIX TABLE 6 *Metabolism data. N-balances*

Experiment 3 - Grass - lucerne hay - maize

Group	Sheep	N Intake (g)	Digestible protein intake (g)	Excretion N		Total N Excretion (g)	N Balance (g)	Coefficients digestibility	
				Faecal (g)	Urinary (g)			N (%)	D.M. (%)
1. *Superphos.*	1	12.94		5.50	1.99	7.49	+5.45	57.5	
	2	12.94		5.34	2.21	7.55	+5.39	58.7	
	3	12.94		4.92	2.63	7.55	+5.39	61.7	
	4	12.94		5.20	2.41	7.61	+5.33	59.7	
Mean. .		12.94	48.0				+5.39	59.4	60.5
2. *Mono-Na-phos.*	5	12.94		5.46	2.19	7.65	+5.29	57.7	
	6	12.94		5.60	2.66	8.26	+4.68	56.7	
	7	12.94		5.40	2.13	7.53	+5.41	58.2	
	8	12.94		5.30	2.27	7.57	+5.37	58.9	
Mean. .		12.94	46.7				+5.19	57.9	58.5
3. *Bone flour.*	9	11.01		2.86	2.47	5.33	+5.68	74.2	
	10	12.21		4.37	2.53	6.90	+5.31	64.2	
	11	12.56		4.84	2.63	7.47	+5.09	61.5	
	12	12.94		6.40	3.07	9.47	+3.71	50.5	
Mean. .		12.18	47.8				+4.95	62.6	59.4
4. No Supple-ment	13	11.40		4.40	1.65	6.05	+5.35	61.4	
	14	12.71		4.67	2.13	6.80	+5.91	63.2	
	15	12.94		4.37	2.66	7.03	+5.91	66.1	
	16	12.94		5.20	2.53	7.73	+5.21	59.7	
Mean. .		12.50	49.0				+5.59	62.6	61.9

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