Onderstepoort Journal of Veterinary Research,
Volume 25, *Number* 4, *December,* 1952.

The Government Printer, Pretoria.

THE EFFECT OF BODY STORES AND OF METHOD OF SUPPLEMENTATION ON THE EFFICIENCY OF CALCIUM AND PHOSPHORUS UTILIZATION BY SHEEP.

N. REINACH, J. G. LOUW, AND J. W. GROENEWALD,

Onderstepoort Laboratory.

Studies of the mineral content of natural pastures in the Union of South Africa have revealed a widespread deficiency of phosphorus, related largely to a marked seasonal variation in the nutritive value of these pastures (du Toit *et al.*, 1940 a). For instance, it has been estimated (du Toit *et al.*, 1940 b) that the daily intake of a sheep on the grass veld of the summer rainfall area varies from approximately 0·5 gram of phosphorus in winter to about 1·3 grams in summer. These different levels of intake may be expected to induce different degrees of saturation of the animals' stores, a state of affairs reported to affect the efficiency of utilization of calcium by rats [Fairbanks and Mitchell (1936); Rottenstein (1938)].

Phosphate supplementation is considered a prerequisite to successful cattle and sheep raising on the natural veld of the greater part of this country. The study of factors affecting the utilization of such supplements at levels of tissue saturation attainable under veld conditions is, therefore, a matter of major practical importance. The object of this report is to record the calcium and phosphorus metabolism of young growing sheep maintained for a period of seven months on a phosphorus deficient ration (referred to in the text as the basal ration) and then on the same ration supplemented with bone meal at the rate of (*a*) 10 grams per sheep per day and (*b*) three times that amount given every third day.

EXPERIMENTAL.

The daily basal ration consisted of veld hay, 300 grams; samp (endosperm of maize), 300 grams; green feed (oats or lucerne), 100 grams; blood meal, 50 grams; and salt, 3 grams. The veld hay, a mixture of mature grasses representative of natural grazing during the dry season, was of poor quality, low in protein and minerals. Complete consumption of this ration ensured a daily intake of approximately 0·48 gram of phosphorus, 1·13 grams of calcium, 79 grams of protein and supplied sufficient energy for maintenance and moderate growth.

Ten Merino wethers about 12 months old were placed on this ration to serve as a control group in other work. After a period of seven months, by which time they weighed on an average 60 lb. they were placed in metabolism cages of the Forbes type and allowed ten days for adjustment to the new environment.

Received for Publication on 20th June, 1950.—Editor.

Feed intake and outgo of faeces and urine were thus determined in the customary manner for a period of 8 days, after which they were divided into two groups of 5 each.

The sheep in Group A were given 10 grams of bone meal per day calculated to raise the per capita phosphorus intake to approximately 1·5 grams per day, an amount considered sufficient for normal skeletal development. Those in Group B were given the same total bone meal supplement, but received 30 grams every third day.

Blood was collected for inorganic phosphorus determinations before the first bone meal supplement was given, then each day, before feeding, for a period of 12 days. The sheep were then removed to individual feeding pens where they continued to receive the same supplemented basal ration and were allowed daily exercise in a concrete floored enclosure. During this period of 8 weeks, blood was collected every sixth day after which they were returned to the metabolism cages for a final 12 day collection period.

Results and Discussion.

All the data were analysed statistically by the analysis of variance method.

Blood inorganic Phosphorus.

The group averages are presented graphically in figure 1. During the course of the 7 months period on the basal ration the values dropped gradually, finally reaching the average levels of 2·3 and 1·7 for groups A and B, respectively, indicative of extreme aphosphorosis. This condition was to be expected considering that the daily intake on the basal ration was about 0·5 gram of P, a figure representing normally one third of the dietary requirements for maintenance and growth (du Toit *et al.*, 1930; Martin and Peirce, 1934).

Bone meal supplementation caused a rise in the inorganic P content of the blood within 24 hours. In the course of the first 10 days the average value for group A rose steadily to 5·1, a figure which was, with minor fluctuations, maintained for the remaining 65 days of the experiment. Although no direct observations were made it is assumed that resorption of bone salts took place to a considerable extent during the period on the basal ration. Also, it seems equally safe to assume that at the rate of bone meal supplementation supplied, it would require a considerable period of time for the bones to attain the degree of saturation associated with adequate Ca and P nutrition. Under these circumstances the sharp rise in the inorganic P content of the blood to a more or less constant level suggests that the soft tissues took precedence over the bones in the process of repletion. A corollary to this would be that if a figure of approximately 5 could be taken as the normal value for 18-months old Merino sheep it does not necessarily reflect the normal state of bone nutrition. However, there is a lack of definite information on this question of normal values. Du Toit *et al.* and Martin and Peirce (loc. cit.), for instance, reported values ranging from about 6·0 to 7·0 for normally fed sheep of approximately the same age as those under discussion. It is felt that this problem of the inorganic P content of the blood in relation to age, P intake and degree of saturation of the bones requires further investigation.

Generally speaking, the inorganic P content of the blood of the sheep in group B followed the same tendency as that of the group A animals. The initial rise was, however, accompanied by marked fluctuations, due no doubt to the method of supplementation: a treble dose followed by two days on which no bone meal was given.

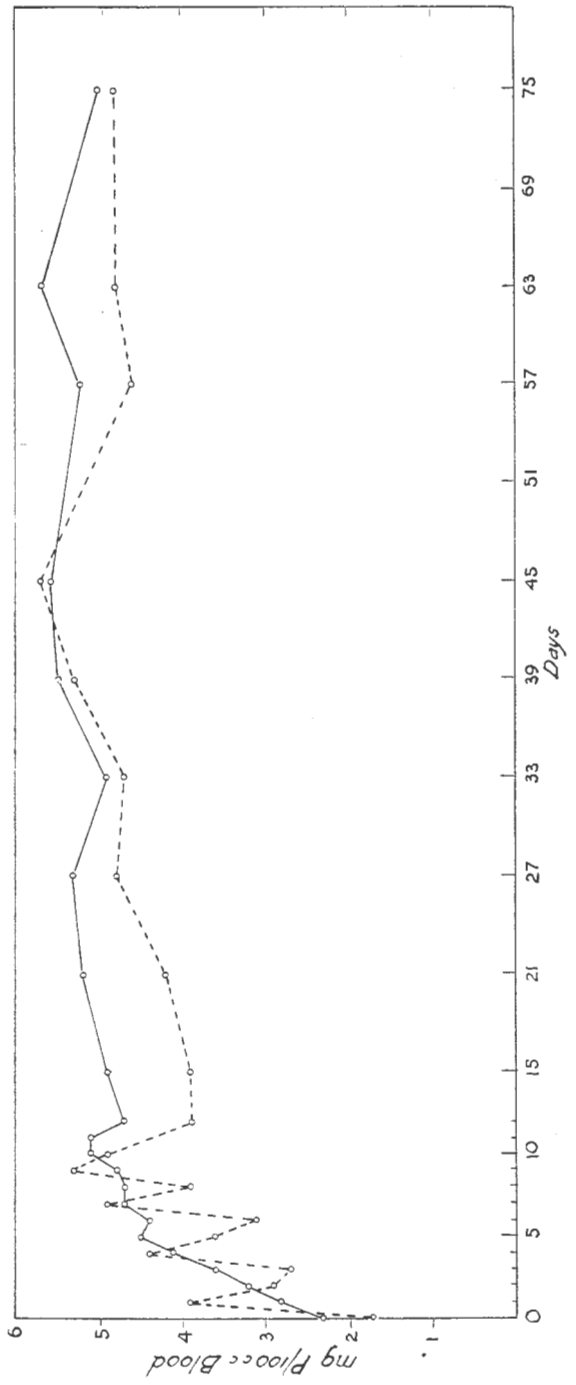

FIG. 1.—*Blood Inorganic Phosphorus.*

Calcium and Phosphorus Balances on basal diet.

The results of balance determinations made on the sheep at the end of the period on the basal ration are presented in table 1. With the exception of the slight positive phosphorus balances observed for sheep Nos. 1 and 3 all the animals were in a state of negative calcium and phosphorus balance. It is to be noted that the Ca deficit was considerably greater than that of P. The fact that the intake of the former was about double that of the latter, considered in relation to the circumstance that the animal's requirements of these minerals are about equal, seems to point to poor availability of the calcium in the ration and/or urinary and intestinal excretion of calcium arising from the mobilization of bone salts. The prevailing phosphate deficiency (c.f. also low blood inorganic phosphorus values) would compel the animals to draw on their skeletal reserves and the calcium liberated simultaneously would be largely excreted, being required in considerably smaller amount than phosphorus for the normal metabolism of the soft tissues.

TABLE 1.

Average Daily Calcium and Phosphorus Balances of Sheep on Basal Diet.

Group.	Sheep No.	Ca (mg.).				P (mg.).			
		Intake.	Outgo.		Balance.	Intake.	Outgo.		Balance.
			Faeces.	Urine.			Faeces.	Urine.	
A	1	500	367	256	−122	325	273	10	+42
	3	640	448	301	−109	380	344	11	+25
	5	978	881	245	−148	451	525	10	−84
	7	1,041	930	346	−235	464	457	24	−17
	9	1,115	1,051	485	−421	479	485	9	−15
	Mean	855	735	327	−207	420	417	13	−10
B	2	738	677	404	−343	401	488	10	−97
	4	822	649	476	−303	418	461	12	−55
	6	1,077	1,154	186	−263	471	527	10	−66
	8	1,025	1,004	400	−379	460	529	15	−84
	10	1,095	977	462	−344	475	524	9	−58
	Mean	951	892	386	−326	445	506	11	−72

Excretion of calcium and phosphorus, assumed to occur in certain sections of the intestinal tract, makes it impossible to assess the availability of these minerals in feeding stuffs. However, the low digestibility (about 45 per cent. according to Louw *et al.*, 1943) of the type of grass hay used in the basal ration, coupled with the fact that this hay contributed about 88 per cent. of the calcium of the diet, as may readily be calculated from data in tables 1 and 3, may have been responsible for a low availability of the calcium in the basal ration with resultant deficiency of this mineral.

Calcium and phosphorus Retention on bone meal-enriched basal ration.

The calcium and phosphorus retentions observed on the enriched basal ration were calculated from the available data and are summarized in table 2. During

the first 12 days of bone meal supplementation the sheep of groups A and B retained 24·5 and 20·5 per cent., respectively, of the ingested calcium. Corresponding values for phosphorus were 54·3 and 51·8 per cent. Differences between groups A and B were statistically insignificant.

TABLE 2.

Average Daily Calcium and Phosphorus Retention on Bone Meal Supplemented Basal Ration.

Group.	Sheep No.	Ca RETENTION.				P RETENTION.			
		1st Collection.		2nd Collection.		1st Collection.		2nd Collection.	
		mg.	%.	mg.	%.	mg.	%.	mg.	%.
A	1	519	22·3	666	20·7	689	56·6	575	38·8
	3	953	32·9	336	10·0	830	60·6	495	32·8
	5	729	23·9	261	7·7	635	45·3	401	26·4
	7	648	22·0	559	16·5	829	60·0	537	35·5
	9	674	21·6	381	11·2	696	49·1	380	25·0
	Mean	705	24·5	441	13·2	736	54·3	478	31·7
B	2	637	22·3	574	17·0	697	51·2	646	42·8
	4	584	20·0	386	11·6	709	51·5	503	33·5
	6	744	23·9	556	16·3	803	56·8	483	31·8
	8	540	17·5	117	3·4	774	55·0	352	23·2
	10	587	18·8	437	12·8	631	44·5	490	32·2
	Mean	618	20·5	414	12·2	723	51·8	495	32·7

The data of the second collection period conducted 8 weeks after the first revealed some significant changes in the Ca and P metabolism of the animals. It again made no difference whether the ration was supplemented with bone meal at the rate of 10 grams per sheep per day or three times that amount every third day. However, the figures for percentage retention fell to 13·2 and 12·2, in the case of calcium, and 31·7 and 32·7 in the case of phosphorus for groups A and B, respectively.

The outstanding features in these results are: (*a*) the entirely negative influence of the methods of supplementation investigated, and (*b*) the greatly reduced retentions of Ca and P after 68 days of bone meal supplementation.

In view of the results obtained with the basal ration it seems reasonable to assume a certain measure of depletion of the skeletal stores in respect of Ca and P at the time bone meal supplementation was initiated. With enrichment of the ration these stores would gradually tend to become replenished. It seems equally reasonable, therefore, to ascribe the reduction in the efficiency of utilization observed during the final collection period to an improvement in the tissue stores

TABLE 3.

Average Ca and P Content of Daily Rations: A-Basal and B-Bone meal supplemented.

Ingredient.	Calcium (mg.).		Phosphorus (mg.).	
	A.	B.	A.	B.
Grass Hay.....	800	848	166	176
Samp.....	14	14	167	167
Blood Meal.....	26	25	55	54
Green Oats.....	64	64	45	45
Bone Meal.....	—	1,994	—	935
TOTAL.....	904	2,945	433	1,377

The method of supplementation made, as previously indicated, no difference to the retention of calcium and phosphorus. It is not known whether the tissue stores have reached maximum saturation for the particular level of intake, so that it is not possible to assume general applicability for the observed results. However, it would not appear out of place to refer to the practical implication of these findings.

One of the methods of feeding phosphates to stock is by the so-called " crush method " (du Toit *et al.*, 1940 b). In this procedure the correct amount of phosphate is dosed daily to each animal. This involves a considerable amount of labour and undesirable interference with the grazing animal. The advantage of administering the weekly phosphate requirements in two equal doses, on, say, Mondays and Thursdays, instead of daily is thus obvious and needs no elaboration. The adoption of such a method of dosing for animals with depleted stores, a condition often encountered during the dry season and recurrent droughts, is justified by the findings of the present experiment.

SUMMARY.

(1) The Ca and P metabolism of two groups of young sheep, depleted of these minerals, was investigated in a series of three balance studies.

(2) During the first 10 days on the bone meal supplemented ration, the inorganic P of the blood rose sharply from approximately 2·0 to 5·0 mgm. per 100 c.c. of blood, a level which was more or less maintained to the end of the experiment.

(3) Under the conditions obtaining the method of bone meal supplementation had no influence on the efficiency of utilization of Ca and P. The implication of this for the problem of phosphate feeding under practical conditions is briefly discussed.

(4) Ca and P utilization dropped considerably in the course of the 80 days on the enriched ration. Retention figures for Ca decreased from 22·5 to 12·7 per cent. and those for P from 53·1 to 32·2 per cent.

(5) Due to the fact that no observations are available on the extent of replenishment during the period of bone meal feeding the final interpretations of these results must await the outcome of further investigations.

REFERENCES.

DU TOIT, P. J., MALAN, A. I. AND ROSSOUW, S. D. (1930). Studies in Mineral Metabolism. XII. Phosphorus in the Sheep Industry. Preliminary Report. 16*th Rept. Dir. Vet. Serv. Anim. Ind.* pp. 313-326.

DU TOIT, P. J., LOUW, J. G. AND MALAN, A. I. (1940a). A Study of the mineral content and feeding value of natural pastures in the Union of South Africa (Final report). *Onderstepoort Jour.*, Vol. 14, pp. 123-327.

DU TOIT, P. J., MALAN, A. I., VAN DER MERWE, P. K. AND LOUW, J. G. (1940b). Mineral supplements for stock. *Farming in South Africa,* Vol. 15, pp. 233-248.

FAIRBANKS, B. W. AND MITCHELL, H. H. (1936). The relation between calcium retention and the store of calcium in the body, with particular reference to the determination of calcium requirements. *Jour. Nutr.*, Vol. 11, pp. 551-572.

LOUW, J. G. AND VAN DER WATH, J. G. (1943). The influence of varying maize supplements on the digestibility of the cellulose in a poor veld hay in relation to the bacterial population of the rumen of sheep with a note on the nitrogen metabolism. *Onderstepoort Jour.*, Vol. 18, pp. 177-190.

MARTIN, C. J. AND PEIRSE, A. W. (1934). Studies on the phosphorus requirements of sheep. *Counc. Sci. Ind. Res. Bull. No.* 77 (*Comm. Aust.*).

ROTTENSTEIN, K. V. (1938). The effect of body stores on the efficiency of Ca utilisation. *Biochem. Jour.* Vol. 32, pp. 1295.