Onderstepoort Journal of Veterinary Research,
Volume 27, Number 4, December, 1958.

THE UTILIZATION OF THE PHOSPHORUS FROM AN ALUMINIUM-IRON ROCK PHOSPHATE. II. BY SHEEP.

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In a study reported elsewhere in this journal (Reinach and Louw, 1958) it was shown that an iron-aluminium rock phosphate from the Middelburg (Transvaal) area was a poor source of phosphorus for growth and bone development in the rat. Phosphate supplements are, however, widely fed to ruminants, which may utilize these feeds in a manner and to an extent different from monogastric laboratory animals. Furthermore, most studies on the effects of iron and aluminium on phosphorus utilization have been carried out with small laboratory animals as experimental subjects [Cox, Dodds, Wigman & Murphy (1931); Deobald & Elvehjem (1935); Jones (1938); Rehm & Winters (1940) and Street (1942)]. It was considered advisable, therefore, to test the availability of the phosphorus in the rock phosphate in question also in the ruminant.

This paper reports the results on rock phosphate from Middelburg and Groblersdal and on "bone pellets" supplied by a commercial firm. The formula for the "bone pellets" was the following: 60 per cent $CaHPO_4$, 12 per cent $CaCO_3$, 10 per cent NaCl, 10 per cent Molasses, 5 per cent $MgSO_4$ and 3 per cent trace elements.

EXPERIMENTAL.

The three phosphatic products were compared with bone meal and the analyses of these products are given in Table 1.

TABLE 1.
Composition of phosphatic products.

Product.	% P.	% Ca.	% Al_2O_3.	% Fe_2O_3.	% SiO_2.
Middelburg Rock Phosphate.....	13·4	—	15·3	15·5	15·1
Groblersdal Rock Phosphate.....	9·07	—	16·7	7·0	41·0
Bone pellets.....	12·02	21·1	—	—	—
Bone meal.....	10·89	24·1	—	—	—

Received for publication on 8 March, 1957.—Editor.

Twenty young merino wethers about five months old were divided into four groups of five each, and placed on a basal ration low in phosphorus. The daily basal ration consisted of 300 gm. veld hay, 300 gm. samp (endosperm of maize), 100 gm. green lucern, 50 gm. blood meal and 4 gm. salt. Complete consumption of this ration ensured a daily intake of 0·48 gm. of phosphorus 1·1 gm. of calcium and 80 gm. of protein. In addition to the basal ration, the lambs received the phosphatic supplements described in Table 1. Group A animals each received 10 gm. of bone meal daily, group B animals 11 gm. of the Groblersdal rock phosphate, group C animals 7·5 gm. of the Middelburg rock phosphate and group D animals 8·75 gm. of the " bone pellets ". The animals were dosed daily with the intention of raising the phosphorus (P) intake of each sheep to approximately 1·5 gm. per day, an amount considered barely sufficient for normal growth and skeletal development.

After seven weeks on the supplemented ration, the sheep were placed in metabolism cages of the Forbes type and allowed ten days for adjustment to the new environment. For the purpose of establishing the retention of calcium and phosphorus, the feed intake and output of urine and faeces were thereafter determined in the customary manner for a period of twelve days. All the sheep were then returned to individual feeding pens where, for a period of four months, they continued to receive the same supplemented rations. They were allowed daily exercise in a concrete-floored enclosure. At the conclusion of this period they were again transferred to the metabolism cages for a second and final collection period.

Blood samples for the determination of inorganic phosphorus were taken and live weights registered at fortnightly intervals throughout the entire experimental period. Finally, two sheep from each group, except group D, were slaughtered and a femur and rib removed from each animal for examination.

Results and discussion.

(*a*) *Blood inorganic phosphorus.*

The group averages for the inorganic phosphorus of the blood are presented graphically in Figure 1.

The inorganic phosphorus of the blood of the sheep of groups A and D, receiving supplements of bone meal and " bone pellets " respectively, fluctuated between 5 and 7 mg. per cent with averages of 6·25 and 6·15 for the entire experimental period of 33 weeks. These values correspond with those reported by du Toit, Malan & Rossouw (1930) and Martin & Peirce (1934) for normally-fed sheep of the same age.

The average value for the inorganic phosphorus of the blood of the other two groups of sheep receiving the rock phosphates as supplements, was 6·3 when the experiment started, and gradually dropped, reaching a figure of 4·0 after 10 weeks, a level which is generally accepted as indicative of an insufficient supply of phosphorus for young sheep. This figure dropped still further to a value of 2·0 after 21 weeks, indicative of extreme aphosphorosis.

Since the phosphorus intake was the same for all four groups, and the different supplements supplied about 70 per cent of the daily phosphorus intake, the very low values for the inorganic phosphorus content of the blood, observed for groups B and C, can only be explained on the basis of differences in availability of the phosphorus in the different supplements. Aluminium-iron rock phosphate, therefore seems to be a very poor source of phosphorus also for the ruminant.

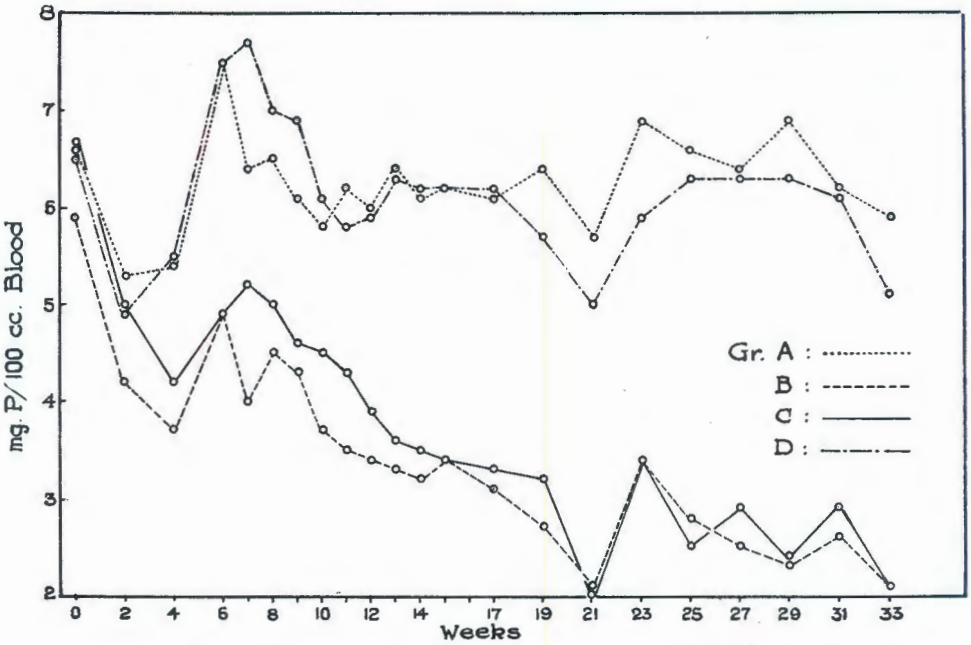

Fig. 1. Group averages for inorganic phosphorus of the blood.

(*b*) *Live weights.*

The average weights of the four groups are presented graphically in Figure 2.

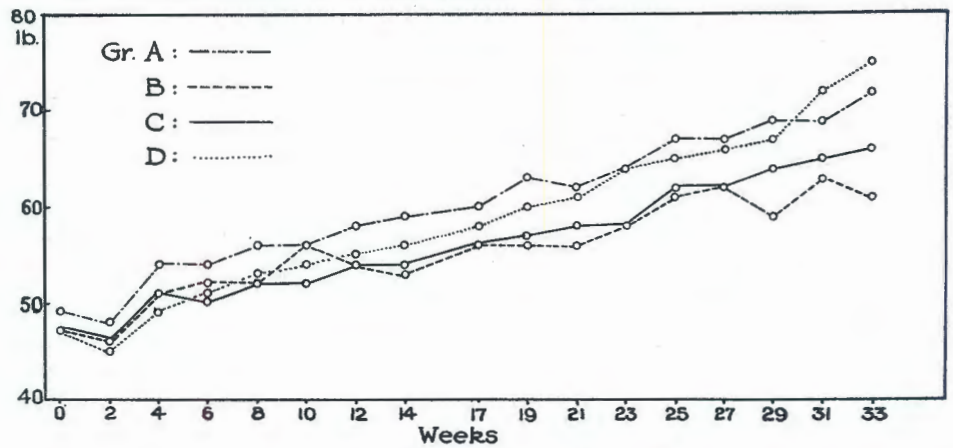

Fig. 2. Group averages for the weights of the sheep.

The groups of sheep receiving the rock phosphates as supplements showed an average increase in weight of 16·5 lb. for the experimental period of 33 weeks, while those whose diets were supplemented with bone meal and "bone pellets" recorded average increases of 23 lb. and 28 lb., respectively, over the same period. This means that the sheep receiving the bone meal and "bone pellets" grew about 50 per cent better than those on the rock phosphates. These rock phosphates are, therefore, inferior to bone meal and "bone pellets" as sources of phosphorus for the growth of sheep.

(*c*) *Phosphorus retention.*

The mean phosphorus retention calculated from the available data for the two periods are given in Table 2.

TABLE 2.

Mean daily phosphorus retention of sheep for the two periods on the supplemented basal ration.*

Group.	Period.	P Intake (mg.).	P Retained (mg.).	% P Retained.
A	First	1553	300	19·3
B	First	1499	−44	−3·9
C	First	1512	−76	−5·6
D	First	1505	343	22·7
A	Second	1621	345	22·5
B	Second	1532	155	7·9
C	Second	1543	73	1·9
D	Second	1706	399	23·4

* 5 Sheep were used in each group.

During the first collection period, the sheep of groups A and D retained on an average 19·3 per cent and 22·7 per cent of the ingested phosphorus and during the second period 22·5 per cent and 23·4 per cent, respectively. The animals of groups B and C were, on the contrary, in a negative phosphorus balance during the first period, changing to slight positive balances four months later, the figures for percentage retention being 7·9 and 1·9, respectively. The difference between the groups receiving the bone meal and "bone pellets" on the one hand and those receiving the rock phosphates on the other was highly significant at $P = 0·01$.

The low retention figures for phosphorus obtained for the sheep of groups B and C can only be ascribed to the poor utilization of the phosphorus in the rock phosphates which in turn led to a phosphate deficiency as revealed by the low inorganic phosphorus content of the blood. In such circumstances the animals would be compelled to draw on their skeletal reserves for their phosphorus requirements and this in turn would lead in the course of time to partial depletion of the skeletal stores.

That this actually took place during the six months the sheep were on rations in which 70 per cent of the ingested phosphorus was supplied by the rock phosphates, is clearly illustrated by the X-ray photographs taken of the femurs (Fig. 3) and ribs (Fig. 4) as well as by the chemical and pathological examination of the bones of the sheep slaughtered at the end of the experiment.

(*d*) *The skeletal structures.*

7 4 14 10 1 12

Fig. 3. X-ray photograph of femurs of sheep as numbered on plate.

Sheep 1 and 4 received the bone meal as supplement, sheep 7 and 10 the Groblersdal rock phosphate and sheep 12 and 14 the Middelburg rock phosphate. The differences in the density of the bones, thickness of the cortex and the amount of trabeculae present, between bone meal and rock phosphate-supplemented animals, are clearly revealed by an inspection of the photographs.

The pathological examination of the bones of sheep 1 and 4 (bone meal group) showed practically normal calcification, while distinct changes were noticed with signs of osteomalacia and atrophy of the spongiosa in the bones of sheep 7 and 10 (Groblersdal rock phosphate). The bones of sheep 12 and 14 showed most pronounced changes with signs of advanced osteomalacia.

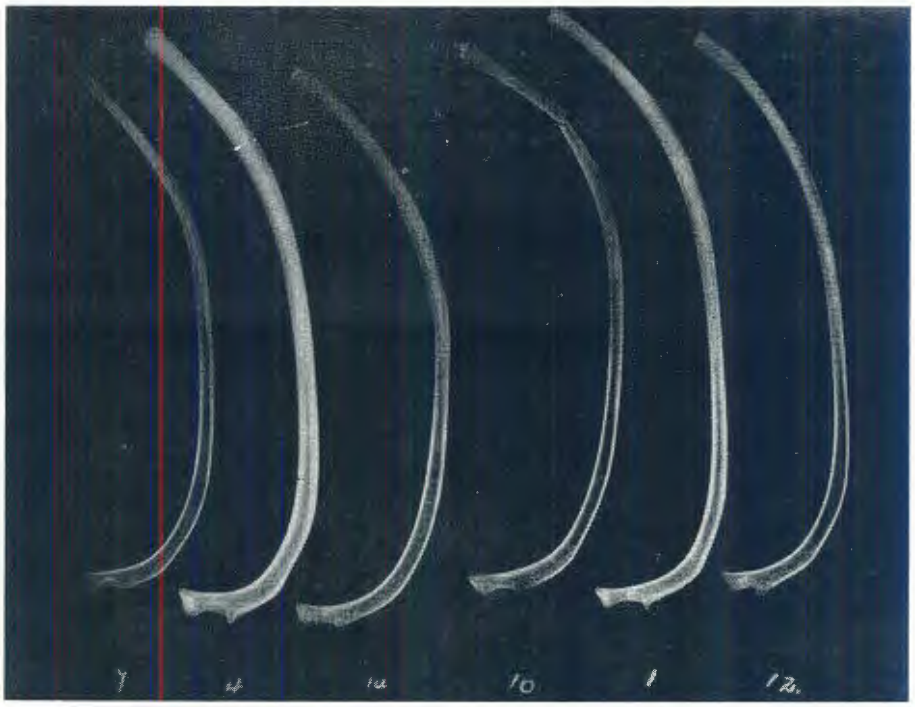

Fig. 4. X-ray photograph of ribs of sheep as numbered on plate.

The sheep of group A supplemented with bone meal developed distinctly larger bones than those of the rock phosphate groups B and C. The weight of the fat-free dry femur and rib as well as the total ash per bone for the six sheep slaughtered at the end of the experiment are presented in Table 3.

TABLE 3.

Weights of dry fat-free bones and ash contents.

Group.	Sheep No.	Bone.	Weight of Fat-free Dry Bone (gm.).		Total Ash per Bone (gm.).	% Ash of Bone.	
A.....	1	Femur.....	50·31	54·92	32·22	64·0	65·5
A.....	4	Femur.....	59·34		39·82	66·9	
B.....	7	Femur.....	29·14	30·90	17·54	60·2	59·8
B.....	10	Femur.....	32·67		19·42	59·4	
C.....	12	Femur.....	39·13	38·75	23·36	59·7	59·7
C.....	14	Femur.....	38·37		22·92	59·7	
A.....	1	Rib.....	5·17	5·99	3·13	60·5	61·3
A.....	4	Rib.....	6·81		4·23	62·1	
B.....	7	Rib.....	2·70	2·74	1·50	55·4	54·7
B.....	10	Rib.....	2·79		1·50	53·9	
C.....	12	Rib.....	3·47	3·15	1·87	53·8	54·7
C.....	14	Rib.....	2·83		1·57	55·6	

The degree of mineralization of these bones was also higher in the sheep receiving the bone meal. Figures for the percentage ash on the fat-free dry basis for the bone meal and rock phosphate groups respectively were: femur 65·5 per cent and 59·7 per cent and for the ribs 61·3 per cent and 54·7 per cent. These differences were highly significant.

SUMMARY.

The availability of the phosphorus in "bone pellets" and aluminium-iron rock phosphates was compared with bone meal.

In evaluating the products, inorganic phosphorus content of the blood, live weight gains, phosphorus retention, X-ray photographs and the pathological and chemical examination of the bones of the sheep were used as criteria.

From the overall results thus obtained it can be concluded that:—

(i) "Bone pellets" are as efficient as bone meal as a source of phosphorus.

(ii) Aluminium-iron rock phosphate is practically useless in this respect and cannot replace bone meal in animal nutrition.

ACKNOWLEDGMENT.

The authors wish to thank Dr. K. C. A. Schulz for the pathological examination of the bones and Mr. J. S. Erasmus for the statistical analysis of the results.

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