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# On the Feeding of a Phosphorus Supplement to Mother-Reared Calves, prior to Weaning, under Open Range Conditions in Bechuanaland.

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## Introduction.

Theiler, Green and Du Toit (1924) first drew attention to a marked phosphorus deficiency in the pastures of such parts of the Union, as Bechuanaland and the Transvaal highveld. Du Toit and Bisschop (1929) showed how this deficiency materially affected growth, development, production and reproduction in cattle on the Veterinary Research Station, "Armoedsvlakte" in Bechuanaland.

Henrici (1938), Du Toit, *et. al.* (1930-1935) made an extensive survey of the feeding value of natural pasture grasses in the Union, and found a phosphorus deficiency to exist practically throughout the country. In order to prevent the effects of this deficiency, farmers were advised to supply their cattle with the necessary phosphorus supplement from the age of weaning (at 6-9 months) onwards. Prior to this age, calves of phosphorus-fed cows usually show satisfactory growth and development, and since it is a tedious process to dose young calves with bonemeal this lower age limit was introduced. For the time being the question whether or not phosphorus supplementation to calves prior to weaning, would be profitable, was left in abeyance.

At "Armoedsvlakte" a long term experiment has been in progress since 1925, in which indigenous females have been graded up systematically with purebred bulls of both indigenous and exogenous cattle breeds. In this experiment it was found that the halfbred calf generation, born out of bonemeal-fed dams, developed quite satisfactorily up to weaning age, without a phosphorus supplement. The higher bred exogenous calves, that is, the $\frac{3}{4}$ and $\frac{7}{8}$ bred

grades out of bonemeal mothers, did not do so well as the halfbred calves up to weaning age, and the question whether such calves would not benefit by bonemeal feeding prior to weaning, had to be considered.

## Object of the Experiment.

The object of the experiment was to ascertain, whether during the first 9 months of life, calves of bonemeal-fed mothers which run under open range conditions, will grow and develop more satisfactorily when supplied with a phosphorus supplement, than under the present system of management of the grade herds at " Armoedsvlakte ", i.e., where no phosphorus supplement is fed to calves until after weaning at the age of 9 months.

## Plan of the Experiment.

The experiment was conducted during 1936, 1937 and 1938 at the Veterinary Research Station, " Armoedsvlakte ", near Vryburg, Cape Province, where the original researches of Theiler, Green and Du Toit were carried out 20 years ago.

### A. *Experimental Animals.*

These consisted of $\frac{7}{8}$ bred Redpoll calves, born on the Station out of $\frac{3}{4}$ bred, bonemeal-fed Redpoll cows, and sired by purebred Redpoll bulls. These calves were passed into the " Bonemeal " and " Control " groups alternately in sequence of their date of birth and sex. Table No. 1 gives details of the experimental animals in each group.

As will be seen from this table, one calf died in each group and a further calf had to be discharged from the Control group on account of its dam developing mastitis. The bonemeal and control groups, therefore, finally consisted respectively of 9 and 7 calves.

### B. *Bonemeal Supplement.*

The " control " calves received no supplement prior to weaning. From the 271st day of age, to the end of the test at 480 days of age, they received 3 oz. of bonemeal per head per day.

The " bonemeal " calves were treated as follows:—

From date of birth to 30 days old, no supplement.

From 31 days old, to 60 days old, $\frac{1}{2}$ oz. of bonemeal per day per head.

From 61 days old, to 120 days old, 1 oz. of bonemeal per day per head.

From 121 days old, to 180 days old, 2 oz. of bonemeal per day per head.

From 180 days old onwards, 3 oz. of bonemeal per day per head.

TABLE No. I.

| BONEMEAL. | | | | | | CONTROL. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of Calf. | Sex. | Date of Birth. | No. of Dam. | No. of Sire. | Remarks. | No. of Calf. | Sex. | Date of Birth. | No. of Dam. | No. of Sire. | Remarks. |
| 6727 | M. | 24/11/36 | 4882 | 5399 | — | 6714 | M. | 18/11/36 | 3117 | 5371 | — |
| 6730 | F. | 26/11/36 | 3186 | 5371 | — | 6728 | F. | 24/11/36 | 3243 | 5371 | — |
| 6736 | M. | 2/12/36 | 4981 | 5399 | — | 6742 | M. | 7/12/36 | 5518 | 5399 | — |
| 6740 | M. | 4/12/36 | 4915 | 5399 | — | 6743 | M. | 7/12/36 | 4941 | 5399 | — |
| 6761 | F. | 17/12/36 | 4883 | 5399 | — | 6748 | M. | 8/12/36 | 3037 | 5371 | — |
| 6773 | F. | 28/12/36 | 3177 | 5371 | — | 6749 | F. | 9/12/36 | 3109 | 5371 | — |
| 6775 | F. | 28/12/36 | 4881 | 5399 | Born dead. | 6768 | F. | 26/12/36 | 3302 | 5371 | — |
| 6777 | M. | 30/12/36 | 3041 | 5371 | — | 6776 | F. | 29/12/36 | 4752 | 6285 | Died 17/1/37. Suspected Arsenical poisoning. |
| 6789 | F. | 23/ 1/37 | 3321 | 5371 | — | 6799 | M. | 12/ 2/37 | 3263 | 5371 | 1/4/37 Discharged on account of its dam, suffering from mastitis. |
| 6790 | M. | 24/ 1/37 | 3381 | 5371 | — | | | | | | |

The very young calves were dosed by opening their mouths and pouring the dry bonemeal into it. At first a few of the calves ejected some of the bonemeal, but they all soon became accustomed to this method, which worked quite satisfactorily. When the calves were older they were dosed according to standard method employed at the Station, i.e., with moistened bonemeal, by means of a spoon.

### C. *Milk Rations.*

In order to obtain data concerning the milk-production of the cows, and hence concerning the milk intake of the experimental calves, it has been necessary to adopt an unusual procedure in all the experiments at "Armoedsvlakte": Where cows are dependent upon the natural pasture for their sustenance and receive no additional production ration, hand-rearing of calves is unpractical. If the calves are taken away, the cows dry up in about 10-12 weeks after parturition. Even where the calves are reared on their dams, the average lactation period is relatively short. Bonemeal fed cows usually do not give more than 2-3 lb. of milk per day after the 30th week of lactation.

The calves are allowed half their mother's milk. During the first week they suck the two right teats of the udder and the two left teats are milked for recording purposes. The following week the calves suck the left half of the udder and the right half is milked. Each Wednesday the whole udder is milked, in order to estimate whether the milk from one half, actually represents 50 per cent. of the production of the whole udder.

For the first 14 weeks (98 days) the cows are milked twice a day—for the next 16 weeks (up to and including the 210th day) only once a day. From the 211th day until weaning at 270 days of age, the calves run with their dams.

### D. *Calf Management.*

The calves were brought to the milking sheds at milking times, from calf paddocks approximately 10 morgen (± 21 acres) in extent, where there was good grazing, shelter and water supply.

### E. *Body Weights.*

Body weights were taken every 30 days, from date of birth onwards until the conclusion of the experiment at 480 days of age.

### F. *Pica Tests.*

Pica Tests were conducted at intervals of 14 days. The object was to determine the degree of osteophagia, or craving for bones, exhibited by the calves. The pica tests were conducted in the usual manner (see Du Toit and Bisschop, 1929) by first allowing the animals access to a trough containing sterilized rotten bones. Any animals picking up and chewing such bones were marked down as "rotten bone" cravers. The remainder were then passed into a pen containing a trough with sterilized "sweet" bones. The calves which picked up and chewed these were recorded as "sweet bone" cravers. Those that chewed neither rotten nor sweet bones were recorded as "non-cravers".

### G. *Body Measurements.*

Body measurements were taken every 30 days from the dates of birth onwards. The well-known Deriaz system was employed. The measurements taken were:—

(*a*) Length of body.
(*b*) Height at withers.
(*c*) Height at hookbones.
(*d*) Depth of chest.
(*e*) Width of chest.
(*f*) Length of rump.
(*g*) Width between hookbones.
(*h*) Width between thirls.
(*i*) Width between pinbones.
(*j*) Length of head.
(*k*) Width between eyes.
(*l*) Heart girth or body circumference.

### H. *Blood Analysis.*

A blood sample was taken from each calf at the ages of 30, 60, 120 and 180 days of age and analysed for inorganic phosphorus. Thereafter all the experimental animals were bled for similar tests once a month from October 1937 to March 1938, i.e. from the approximate average ages of 11 months to 16 months.

### I. *Histological Studies of Bones.*

The experimental programme called for rib-resections at the costo-chondral junction, of all the experimental calves at the ages of 90 and 210 days, but on account of the time required for a number of these operations, it was decided to select one heifer and one "tolly calf"[1] from each group. These 4 calves were operated on in the middle of February and again in the middle of June 1937, approximately at the ages of 65 and 180 days. The resected pieces of ribs were examined histologically to ascertain whether calcification was taking place normally and at the same rate, in both groups.

### J. *Statistical Analysis of Data.*

All data were analysed statistically according to Fisher (1936). Only such differences which proved to be significant in terms of Fishers $P = 0{\cdot}05$ or $P = 0{\cdot}01$ have been used in arriving at conclusions.

## IV. Experimental Results.

### A. *Body Weights.*

Table No. 2, which has been divided into three parts, gives in Section A the average body weights of the Bonemeal and Control calves at 30 day intervals from birth until 480 days of age.

(1) "*Tolly calf*": A castrated bull calf. "Tollies" are castrated bull calves up to the age of 18 months.

TABLE No. 2.

LIVE WEIGHTS.—*Bonemeal Group compared with Control Group.*

| Group. A. | No. of Animals per Group. | AVERAGE WEIGHT PER CALF PER GROUP AT DIFFERENT AGES, GIVEN IN DAYS. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 330 | 360 | 390 | 420 | 450 | 480 |
| Bonemeal | 9 | 110 | 153 | 204 | 242 | 273 | 284 | 288 | 296 | 306 | 342 | 367 | 416 | 473 | 529 | 561 |
| Control | 7 | 108 | 149 | 199 | 229 | 265 | 279 | 280 | 291 | 293 | 331 | 338 | 375 | 439 | 496 | 545 |
| Actual Difference | — | + 2 | + 4 | + 5 | + 13 | + 8 | + 5 | + 8 | + 5 | + 13 | + 11 | + 29 | + 41(5) | + 34 | + 33 | + 16 |
| Percentage Difference | — | + 1·85 | + 2·68 | + 2·51 | + 5·68 | + 3·02 | + 1·79 | + 2·86 | + 1·72 | + 4·44 | + 3·32 | + 8·58 | + 10·93 | + 7·74 | + 6·65 | + 2·94 |

| Group. B. | No. of Animals per Group. | AVERAGE WEIGHT PER CALF PER GROUP AT DIFFERENT AGES, GIVEN IN DAYS. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 330 | 360 | 390 | 420 | 450 | 480 |
| Bonemeal | 4 | 104 | 143 | 192 | 229 | 257 | 269 | 273 | 285 | 298 | 338 | 361 | 415 | 466 | 519 | 541 |
| Control | 3 | 102 | 140 | 185 | 221 | 245 | 261 | 261 | 275 | 277 | 309 | 316 | 357 | 413 | 466 | 508 |
| Actual Difference | — | + 2 | + 3 | + 7 | + 8 | + 12 | + 8 | + 12 | + 10 | + 21 | + 29 | + 45 | + 58 | + 53 | + 53 | + 33 |
| Percentage Difference | — | + 1·96 | + 2·14 | + 3·78 | + 3·62 | + 4·90 | + 3·07 | + 4·60 | + 3·64 | + 7·58 | + 9·39 | + 14·24 | + 16·25 | + 12·83 | + 11·37 | + 6·50 |

| Group. C. | No. of Animals per Group. | AVERAGE WEIGHT PER CALF PER GROUP AT DIFFERENT AGES, GIVEN IN DAYS. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 330 | 360 | 390 | 420 | 450 | 480 |
| Bonemeal | 5 | 115 | 161 | 214 | 252 | 286 | 296 | 300 | 308 | 310 | 345 | 372 | 416 | 478 | 538 | 578 |
| Control | 4 | 113 | 156 | 209 | 244 | 280 | 293 | 295 | 303 | 306 | 348 | 354 | 388 | 458 | 518 | 573 |
| Actual Difference | — | + 2 | + 5 | + 5 | + 8 | + 6 | + 3 | + 5 | + 5 | + 4 | + 3 | + 18 | + 28 | + 20 | + 20 | + 5 |
| Percentage Difference | — | + 1·77 | + 3·21 | + 2·39 | + 3·28 | + 2·14 | + 1·02 | + 1·69 | + 1·65 | + 1·31 | + 0·86 | + 5·08 | + 7·22 | + 4·37 | + 3·86 | + 0·87 |

*N.B.*—(5) Indicates significance at P = 0·05.
(1) Indicates significance at P = 0·01.

The original experimental programme covered the period from birth to weaning. At this latter stage, it was decided to continue the test to 480 days of age, but in the meantime a number of calves had not been weighed when 300 days old. The weight column for this age has therefore been excluded from the table.

The actual differences between the average weights of the bonemeal and control calves are given on the 5th horizontal line. In horizontal line No. 6 these differences are given as percentages of the control (basal) weights. Significant differences are printed in heavy type and to show the degree of significance either a 5 or a 1 has been placed in brackets above and to the right of such significant differences.

Section B gives similar data as Section A, for the heifer calves in the two experimental groups and Section C for the tolly calves. The three ages of importance in the test were, firstly that at 30 days, when the bone meal group was placed upon its phosphorus supplement; secondly at 270 days, when both groups were weaned, and the control group was placed upon a bonemeal ration, equal to that of the bonemeal group; and thirdly at 480 days, when both groups had received an equal phosphorus supplement for 7 months, and when the test was terminated.

Section A of Table No. 2 shows that at none of these ages did there exist any significant difference in body weight between the experimental groups. Only one significant difference is seen in the table, i.e. in Section A at 390 days. Since, however, this significant difference is preceded and succeeded by a series of insignificant differences, its appearance is most difficult to explain and does not appear to be of any biological importance.

It appears warranted to conclude therefore that as far as bodyweight is concerned, the feeding of bonemeal to calves prior to weaning was without effect.

Sections B and C of Table 2, show that there is no significant differences between bonemeal and control heifers, and between bonemeal and control tollies. There is, however, a very material difference between the two sexes at the same age. This aspect will be dealt with in a separate article.

## B. *Pica.*

Table No. 3 gives the results of the pica tests for each individual animal and for each group, at fortnightly intervals, up to 480 days of age. Three symbols are used:-

(*a*) A minus sign, –, denotes a non-craver.

(*b*) A cross, ×, denotes a rotten bone craver.

(*c*) A plain circle, ○, denotes a sweet bone craver.

The table is divided into two parts. The upper half gives the pica results of the bonemeal group, the lower half those for the control group. The thick vertical line at 30 days in the upper half denotes the beginning of bonemeal supplementation to the bonemeal

group and a similar line in the lower half at 271 days, the beginning of bonemeal feeding to the control group. In the horizontal line below each group, are found, the group pica totals for all age points. In the last 3 vertical columns are found, for each animal and for each group the total number of occassions on which rotten and sweet bones were eaten and the total craving per group.

The table needs no explanation. The calves of the bonemeal group show a negligible degree of craving. Five out of the nine animals never craved at all and of the four that did, the worst (No. 6777), chewed rotten bones only on one occasion and sweet bones only on 3 occasions, during 34 consecutive tests. The total craving for the group amounts to 9 out of a possible number of 306, i.e. 2·94 per cent.

The total craving for the control group amounts to 88 out of a possible 238, i.e. 36·97 per cent. This is 12½ times as much as in the bonemeal group. This high degree of pica is, however, not common to all the calves in the control group. It will be noticed that although no calves were non-cravers throughout the course of the experiment, two were practically so. The rest were all marked cravers. As a group it will be noticed that the degree of pica increased up to the time when all the calves were weaned, i.e. as long as the animals received no bonemeal. From then onwards the pica in the control group, dropped steadily until, for the last 3 tests, only one calf showed craving.

From the data given in Table No. 2 one is justified to conclude—

(*a*) that in the bonemeal group, the phosphorus supplement prevented craving almost entirely;

(*b*) that in the control group, until weaning age, the degree of pica, indicative of aphosphorosis, increased steadily;

(*c*) that the bonemeal supplement given to the calves of the control group, from weaning onwards, reduced the degree of pica to a negligible amount by the end of the test.

### C. *Body Measurements.*

Because all the calves were not measured at 30 days of age, Table No. 4 does not include data for that age. It gives the average body measurements in cm. of the calves in both groups, for the ages of 60, 270 and 480 days. As in Table No. 2, the actual and percentage differences (in terms of the control measurements) are given for each age, and significant differences are printed in thick type, with the degree of significance given within brackets above and to the right of the significant differences.

It will be noticed from Table No. 4 that no significant differences were found between the bonemeal and control groups, in the body measurements, at any of the three ages given. In fact, although the calves were measured every 30 days, no significant difference between the 2 groups, was found at any stage during the test and it is, therefore, justified to conclude that the bonemeal supplement had no effect upon the body measurements taken.

Table No. 3

*Pica*

| Group. | No. of Animal. | 14 | 28 | — | 42 | 56 | 70 | 84 | 98 | 112 | 126 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bonemeal..... | 6727 | — | — | Bone supplement from 30 days onwards. | — | — | — | — | — | — | — |
| Bonemeal..... | 6730 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6736 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6740 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6761 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6773 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6777 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6789 | — | — | | — | — | — | — | — | — | — |
| Bonemeal..... | 6790 | — | — | | — | — | — | — | — | — | — |
| TOTALS..... | ..... | — | — | | — | — | — | — | — | — | — |
| Control..... | 6714 | — | — | | — | — | — | — | — | — | — |
| Control..... | 6728 | — | — | | — | — | — | — | — | — | — |
| Control..... | 6742 | — | — | | — | — | — | — | — | — | — |
| Control..... | 6743 | — | — | | — | — | — | — | ○ | — | ○ |
| Control..... | 6748 | — | — | | — | — | — | ○ | ○ | × | × |
| Control..... | 6749 | — | — | | — | — | ○ | ○ | × | × | — |
| Control..... | 6768 | — | — | | — | — | — | — | ○ | × | × |
| TOTALS..... | | — | — | | — | — | 1 | 2 | 4 | 3 | 3 |

p329-330b →

p329-330a

TABLE No. 3. (Cont.)

*Pica.*

AGE OF CALVES IN DAYS.

| 140 | 154 | 168 | 182 | 196 | 210 | 224 | 238 | 252 | 266 | — | 280 | 294 | 308 | 322 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | × | — | — | — | | — | — | — | — |
| — | — | — | — | — | ○ | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| — | — | — | — | — | 1 | 1 | — | — | — | | — | — | — | — |
| — | — | — | — | — | — | — | — | — | × | Received bonemeal from 271 days onwards. | — | — | ○ | — |
| — | — | ○ | × | ○ | ○ | ○ | ○ | ○ | ○ | | ○ | ○ | ○ | — |
| — | — | — | — | — | — | — | — | — | — | | — | — | — | — |
| ○ | ○ | × | ○ | × | ○ | ○ | ○ | × | × | | × | × | × | ○ |
| × | × | × | × | × | × | × | × | × | × | | — | × | × | ○ |
| ○ | × | × | × | × | × | × | × | ○ | — | | × | × | × | — |
| × | × | × | ○ | × | ○ | ○ | × | × | × | | × | × | × | — |
| 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 4 | 5 | 6 | 2 |

p329-330a

p329-330c

p329-330b

Table No. 3 (cont.)
*Pica*

| 336 | 350 | 364 | 378 | 392 | 406 | 420 | 434 | 448 | 462 | 476 | Total. × | Total. ○ | Grand Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| — | × | — | — | — | — | × | × | — | — | — | 3 | — | 3 |
| — | — | — | — | ○ | — | — | — | — | — | — | — | 1 | 1 |
| — | — | — | — | — | — | — | — | — | — | — | 1 | — | 1 |
| — | — | — | — | — | × | ○ | ○ | — | — | — | 1 | 3 | 4 |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| p329-330b 1 | | — | — | 1 | 1 | 2 | 2 | — | — | — | 5 | 4 | 9 |
| — | — | — | — | — | — | — | — | — | — | — | 1 | 1 | 2 |
| — | — | — | — | — | — | — | — | — | — | — | 1 | 10 | 11 |
| — | × | — | — | — | — | — | — | — | — | — | 1 | — | 1 |
| — | — | — | — | — | — | — | — | — | — | — | 7 | 9 | 16 |
| × | — | — | ○ | × | × | — | — | × | × | ○ | 19 | 5 | 24 |
| — | — | — | — | ○ | × | — | × | — | — | — | 14 | 5 | 19 |
| — | — | — | — | — | — | — | — | — | — | — | 12 | 4 | 16 |
| 1 | 1 | — | 1 | 2 | 2 | — | 1 | 1 | 1 | 1 | 54 | 34 | 88 |

p329-330c

## Table No. 4.

*Body Measurements.*

| Age of Calves in Group. | Bonemeal or Control. | Body Measurements. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length of Body. | Height at Withers. | Height at Hook-bones. | Depth of Chest. | Width of Chest. | Heart Girth. | Length of Rump. | Width between Hook-bones. | Width between Thirls. | Width between Pin Bones. | Length of Head. | Width between Eyes. |
| 60 days..... | Bonemeal.. | 76·5 | 78·9 | 83·6 | 33·9 | 16·8 | 89·4 | 26·7 | 20·0 | 23·4 | 5·5 | 27·7 | 11·0 |
| | Control.... | 76·6 | 79·9 | 84·1 | 33·6 | 15·6 | 88·8 | 26·6 | 19·5 | 23·1 | 5·6 | 27·7 | 11·0 |
| Actual difference.... | — | − 0·1 | − 1·0 | − 0·5 | + 0·3 | 1·2 | 0·6 | 0·1 | 0·5 | 0·3 | 0·1 | — | — |
| Percentage Difference | — | − 0·13 | − 1·25 | 0·59 | + 0·89 | 7·69 | 0·68 | + 0·38 | + 2·56 | 1·30 | 1·79 | — | — |
| 270 days..... | Bonemeal.. | 96·1 | 97·5 | 102·0 | 45·0 | 19·8 | 115·3 | 34·6 | 28·5 | 29·9 | 7·5 | 35·1 | 13·3 |
| | Control.... | 94·9 | 96·9 | 101·0 | 44·4 | 19·2 | 113·6 | 34·4 | 28·2 | 29·6 | 7·3 | 34·3 | 13·6 |
| Actual difference.... | — | + 1·2 | + 0·6 | 1·0 | + 0·6 | 0·6 | 1·7 | + 0·2 | 0·3 | 0·3 | 0·2 | + 0·8 | 0·3 |
| Percentage difference | — | 1·26 | + 0·62 | 0·99 | + 1·35 | 3·13 | 1·50 | 0·58 | + 1·06 | 1·01 | 2·74 | + 2·33 | − 2·21 |
| 480 days..... | Bonemeal.. | 113·4 | 110·0 | 113·1 | 53·6 | 24·5 | 140·0 | 39·6 | 35·2 | 34·1 | 8·1 | 40·9 | 15·4 |
| | Control.... | 111·6 | 108·1 | 111·7 | 53·2 | 23·3 | 136·9 | 38·7 | 34·4 | 33·8 | 7·7 | 40·2 | 15·7 |
| Actual difference.... | — | + 1·8 | 1·9 | + 1·4 | 0·4 | 1·2 | 3·1 | + 0·9 | 0·8 | 0·3 | 0·4 | + 0·7 | − 0·3 |
| Percentage difference | — | 1·61 | 1·76 | 1·25 | 0·75 | 5·15 | 2·26 | 2·33 | 2·33 | 0·89 | 5·19 | 1·74 | 1·91 |

### D. *Blood Analysis.*

In Table No. 5 is given the inorganic blood phosphorus in milligrams per 100 c.c. for each calf, at different ages throughout the experiment. Below each group the group totals and averages, at the given age, are found. In the last 2 horizontal columns the actual and percentage differences (in terms of the control figures) are given. Significant differences are shown in the usual way.

For reasons already explained no analysis was conducted when the calves were 270 days old. Unfortunately it is, therefore, impossible to compare the 3 important ages of 30, 270 and 480 days. Nevertheless, the figures in the last horizontal column are most interesting. At the age of 30 days there was no significant difference in inorganic blood phosphorus between the two groups, although the average of the control group is slightly higher than that of the bonemeal group. At 60 days the difference is still not significant but now the bonemeal group is slightly higher than the controls. At 120 days the bonemeal calves show an inorganic blood phosphorus content, which is 21 per cent. higher than that of the controls. At 180 days this significant difference has increased to 45 per cent. It seems safe to assume that at 270 days, when the controls were placed upon a bonemeal ration, the difference would probably have been at least as marked as at 180 days.

The next analysis, at 11 months of age, i.e. after the controls had been on a bonemeal supplement for 2 months shows a distinct drop in the percentage difference between the 2 groups. This difference, however, remains highly significant. At 13 months of age, the inorganic blood phosphorus of the controls was actually significantly higher than that of the bonemeal groups. From this point onwards there was no difference between the two groups.

Comparing the average $P_2O_5$ figures for the two groups, it will be noticed, that after the high figures of all the experimental calves, up to 60 days (a high inorganic blood phosphorus content is normal for young calves—see Green and Macaskill, 1928) the bonemeal group retains a level of approximately 6 milligrams per 100 c.c. throughout, while in the control group there is a distinct decline until weaning age, but from the time when these calves too were placed upon a phosphorus supplement, the averages show a definite upward trend.

From these figures it is concluded, that the bonemeal group of calves received sufficient available $P_2O_5$ to maintain a constant level of inorganic blood phosphorus, as judged by our analysis. On the other hand the control group of calves probably did not receive sufficient available $P_2O_5$, and although no conformational evidence of an insufficiency could be detected, the analysis nevertheless revealed a drop in the inorganic blood phosphorus. After the control calves had also been placed upon a bonemeal supplement, their inorganic blood phosphorus, rose to a level, equivalent to that of the bonemeal calves.

In addition it must be emphasized that the average values of 5·52, 4·33 and 5·10 milligrams phosphorus per 100 c.c. blood of the control calves respectively at 4, 6 and 11 months of age, are

## TABLE NO. 5.

*Inorganic Blood Phosphorus.*

| Group. | No. of Animal. | Inorganic Blood Phosphorus of Calves at Day Ages of. | | | | Inorganic Blood Phosphorus of Calves at the following Approximate Month Ages. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 30 | 60 | 120 | 180 | 11 | 12 | 13 | 15 | 16 |
| Bonemeal | 6727 | 4·5 | 8·1 | 6·6 | 6·0 | 6·0 | 6·5 | 6·0 | 7·3 | 6·3 |
| | 6730 | 8·3 | 8·8 | 7·3 | 6·2 | 6·0 | 6·0 | 5·6 | 8·5 | 5·0 |
| | 6736 | — | 8·2 | 6·7 | 5·7 | 6·3 | 6·2 | 6·2 | 6·5 | 6·2 |
| | 6740 | 8·2 | 7·8 | 6·0 | 5·9 | 6·4 | 5·0 | 5·5 | 4·4 | 5·7 |
| | 6741 | 7·0 | — | 6·9 | — | 7·2 | 5·9 | 6·2 | 7·3 | 6·2 |
| | 6773 | — | 9·4 | 5·6 | 6·5 | 7·1 | 6·5 | 6·2 | 8·7 | 5·9 |
| | 6777 | 8·7 | 8·2 | 5·8 | 6·5 | 5·7 | 6·5 | 6·1 | 7·7 | 5·3 |
| | 6789 | — | 8·8 | 7·9 | 6·8 | 8·2 | 7·2 | 6·0 | 6·5 | 5·8 |
| | 6790 | 8·7 | 8·0 | 7·3 | 6·6 | 7·5 | 6·4 | 6·3 | 8·2 | 5·7 |
| TOTALS | — | 45·4 | 67·3 | 60·1 | 50·2 | 60·4 | 56·2 | 54·1 | 65·1 | 52·1 |
| AVERAGES | — | 7·57 | 8·41 | 6·68 | 6·28 | 6·71 | 6·24 | 6·01 | 7·23 | 5·79 |
| Control | 6714 | 7·7 | 8·7 | 5·6 | 3·8 | 5·5 | 6·2 | 5·7 | 7·7 | 5·5 |
| | 6728 | 5·0 | 8·3 | 5·7 | 5·9 | 5·7 | 6·2 | 6·8 | 7·3 | 5·6 |
| | 6742 | 9·7 | 8·2 | 5·7 | 4·2 | 5·0 | 5·3 | 6·7 | 7·1 | 5·2 |
| | 6743 | 9·9 | 7·6 | 4·6 | 3·7 | 5·3 | 7·7 | 7·0 | 6·9 | 6·6 |
| | 6748 | — | 9·0 | 4·3 | 4·1 | 5·2 | 6·1 | 6·7 | 7·1 | 5·7 |
| | 6749 | 8·2 | — | 5·8 | 3·9 | 5·2 | 5·7 | 6·9 | 6·2 | 5·9 |
| | 6768 | 8·2 | 8·2 | 5·9 | 4·7 | 3·8 | 6·9 | 6·6 | 9·0 | 5·8 |
| TOTALS | — | 48·7 | 50·0 | 37·6 | 30·3 | 35·7 | 44·1 | 46·4 | 51·3 | 40·3 |
| AVERAGES | — | 8·17 | 8·33 | 5·52 | 4·33 | 5·10 | 6·30 | 6·63 | 7·33 | 5·76 |
| Actual differences | | − 0·60 | + 0·08 | − 1·16 | + 1·95 | + 1·61 | − 0·06 | − 0·62 | − 0·10 | + 0·03 |
| Percentage differences | — | − 7·34 | + 0·96 | **+21·01**(1) | **+45·03**(1) | **+31·57**(1) | − 0·95 | **− 9·35**(1) | − 1·36 | + 0·52 |

(5) Indicates significance at P = 0·05.
(1) Indicates significance at P = 0·01.

indicative of aphosphorosis. The value 4·44 especially, is only just above the minimum accepted as sufficient for mature cattle, and is therefore rather low for 6 months old calves. This provides evidence, that the control calves suffered from a phosphorus deficiency, which however, was not manifested conformationally.

### E. *Bone Histology.*

The histological examination of the costo-chondral junctions showed good calcification with long and closely knit primary trabeculae, both in the rib-resections taken at 65 and at 180 days of age. Up to 6 months of age, therefore, the skeletons of the calves examined were found to be normal in terms of phosphorus. It is unfortunate that no histological examinations were done on resections from calves at 9 months of age.

In the resections taken in June 1937 (180 days old) the costo-chondral junctions of calves Nos. 6714 (control group) and 6727 (bonemeal group) revealed the presence of a fibrosis, probably osteodystrophic in nature, which is, however, as far as we know, not associated with aphosphorosis.

## V. Discussion.

Note.—In the discussion of the experimental results the word " function " is used in such phrases as " functional efficiency ", " functionally subnormal ", " functional abnormalities ", etc. The reader may interpret the word " function " as the sum total of an animal's physiological manifestations. In the present discussion such an interpretation is not intended. The actual functions referred to are clearly described in paragraphs (*b*) (1) and (*b*) (2), below.

The results of the experiment show, that in terms of the experimental criteria employed:—

(*a*) *The bonemeal supplement had no effect upon growth and development, i.e. upon external conformation*: At no time during the course of the investigation, either before or after weaning, were significant differences found between the average body weights or body measurements of the two groups.

(*b*) *The bonemeal supplement improved functional efficiency*: The bonemeal calves, functioned on a higher plane of efficiency than did the control calves, from the time they were placed upon a phosphorus supplement, until the control calves too received the same supplement.

(1) In comparison with the controls, they exhibited practically no osteophagia, and showed a higher and much more constant level of inorganic blood phosphorus up to weaning age.

(2) From the age of weaning onwards, when the control calves also received bonemeal, the manifestations of a phosphorus deficiency exhibited by them abated and finally disappeared. At the conclusion of the experiment, the control calves were, in terms of the experimental criteria, in every way comparable to the bonemeal calves.

The experimental results show up an apparent anomaly. At weaning age the control calves, although conformationally normal, were functionally subnormal. How can subnormal function maintain normal conformational development? Theiler, Du Toit and Malan (1937) conducted mineral metabolism investigations on pigs. They found that a group which received an adequate ration, except for a deficiency in phosphorus, showed as rapid a weight increase, as did the group on a completely adequate ration, for the first 5 months of the experiment, i.e. up to a live weight of approximately 140 lb. This normal conformational development took place notwithstanding the fact, that 4 months after the commencement of the test, the inorganic blood phosphorus of the group on the deficient ration averaged only 3·65 milligrams $P_2O_5$ per 100 c.c. as compared with 8·9 milligrams per 100 c.c. for the group on a complete ration.

Up to a point, therefore, the deficient skeleton was able to support normal increase in body weight. After this limital point had been passed, the phosphorus deficient group showed a rapid decline in the rate of bodyweight increase in comparison to the group which received phosphates.

It would appear as if, *up to a point*, the skeletons of growing animals are able to do with less than their normal mineral requirements, and nevertheless function sufficiently well to support normal increase in body weight and size.

This idea explains the apparent anomaly encountered in the experiment under discussion. The control calves, although receiving a phosphorus deficient diet, had not reached the "critical point", at weaning age, and therefore, showed no externally determinable symptoms of the deficiency, which, when removed by subsequent bonemeal feeding, allowed the animals to build up the functional abnormalities back to normal by the time they were 480 days old.

It must be remembered, however, that the calves of both experimental groups were born out of bonemeal fed cows, and received, through the milk of their dams, quite an appreciable amount of available phosphates, up to weaning age.

On the average each calf of the bonemeal group received 1,251 lb. of milk during the 210 day period over which the production of its dam was recorded. The control calves each received on the average 1,288 lb. of milk. The difference of 37 lb. per calf between the 2 groups is insignificant. Even if the difference was significant it would be in favour of the control group.

Groenewald (1934) gives an average of 0·221 per cent. of total $P_2O_5$ in bovine milk. Applying this figure to the average milk intake of all the calves born out of bonemeal fed cows, that is to 1,267 lb., we find that each calf received on the average 1,258 grammes of total $P_2O_5$ in 210 days or 6·00 grammes per head per day.

This amount, together with whatever available $P_2O_5$ they obtained through their grazing, was apparently sufficient for the control group to maintain normal conformational development, and to maintain functional efficiency, above the "critical point" up to 270 days of age.

The two groups of calves ran together in the same paddocks and received the same amounts of milk. Therefore the fact that the bonemeal calves were both conformationally and functionally normal, while the control calves, though conformationally normal, were functionally subnormal, can only be attributed to the extra phosphates which the former group received from their supplement. The phosphorus deficiency in the controls was not sufficiently acute to manifest itself conformationally.

So far we have compared groups of calves born of bonemeal fed cows, and which received the same average amount of milk from their dams. Let us next compare the control group of calves, in the test under discussion, with a group of otherwise comparable animals, but born out of non-bonemeal fed cows. To distinguish the two groups, the former will be referred to as the " bonemeal control group " and the latter as the " straight control group ". The data for this latter group have been obtained from the records of other experiments, conducted at " Armoedsvlakte ". No heifer calves and only 3 tollies were found, which were fully comparable to the " bonemeal control " calves, and therefore Table No. 6 gives the data of these 3 tollies against that of the 4 tollies in the " bonemeal control " group.(1)

The table is divided into sections. In Section I, the weights for each of the " bonemeal control " calves are given monthly from birth until the end of the test. Below these weight figures, are found the average daily amounts of milk each calf obtained from its dam, during the preceding month. Because milk recording at " Armoedsvlakte " takes place only for 210 days, only 7 milk averages are given.

Section II gives similar data for the " straight control " group. In Section III, the actual differences in body weight and in milk supply between the two groups, are given in the first and third, and in the second and fourth horizontal lines; these differences are given as percentages of the " straight control " figures. Significant percentage differences are shown in thick print and the degree of significance indicated in the usual manner.

Section No. III of Table No. 6, shows that at birth the " bonemeal control " calves, weighed on the average 7 lb. more than the " straight control " calves. This difference is not significant: in fact Du Toit and Bisschop (1929) found, when working with a much larger number of grade Redpoll calves, that the difference

(1) *Explanatory Note by the Statistician.*—The small number of animals in each group, is a serious objection, since the co-efficient of variation tends to be higher than that of large groups. The statistical test of significance requires that the differences between small groups have, in any case, to be much greater than between large groups, but when coupled with a high coefficient of variation these differences have to be even larger. The lack of significance in the very large percentage differences in the last horizontal line of Section III of Table No. 6 may be explained on this basis. Small groups therefore lead to fewer significant differences, but it should be noted that the power of the statistical analysis is such that the significant differences that are obtained, may be accepted with the same measure of confidence, attributed to differences between larger groups.

between calves of bonemeal fed and non-bonemeal fed cows, at birth to be only 1·9 lb., the respective average weights being 69·2 lb. and 67·3 lb. They further found that where similar figures were worked out for four different breeds, the respective average birth weight for calves of bonemeal fed cows was 68·8 lb., and for calves of non-bonemeal fed cows 68·1 lb.—a difference of only 0·7 lb.

In the table under discussion, the insignificant difference in live weight at birth soon became significant and increased until at weaning age the "bonemeal control" calves weighed 53 lb, or 20·95 per cent. more than the "straight control" calves. At 16 months of age this difference had increased to 159 lb., or 38·41 per cent.

In terms of live weight, therefore, the development of the "straight control" calves was subnormal when compared with the development of the "bonemeal control" calves.

It may, however, be argued that the ever-increasing differences in live weight between the two groups, were the result of the initial difference at birth. In Section No. IV, all the weights have been corrected for the birth difference. [According to R. A. Fishers (1936) "Analysis of co-variance technique".] If now the actual difference in live weight between the 2 groups were but manifestations of the difference which existed at birth, all significant differences should disappear in Section IV. This does not happen, and it is permitted to conclude, that the difference in weight at birth was not the cause of the marked differences later on in life.

What then caused the marked difference in body weights between the two groups?

In Section No. V of Table No. 6 the weights of the two groups of calves, have been corrected for difference in average milk intake (according to R. A. Fishers' 1936 "Analysis of co-variance technique"), and it will be noticed that *all significant differences now fall away*. This proves, that the differences in live weights between the "bonemeal control" and "straight control" groups were caused by the difference in the amounts of milk, which they got from their dams.

Green (1926), Becker, Eckles and Palmer (1927), Groenewald (1934) and others, have shown that, with the exception of fat, the percentage of which is inversely proportional to the amount of milk produced, there is no significant difference in the chemical analysis of the milk of phosphorus fed and non-phosphorus fed cows. The difference in body weights between the "bonemeal control" and "straight control" calves must therefore be attributed to the straight quantitative, and not also to the qualitative difference of their milk intake.

The average milk intake of the four "bonemeal control" tollies which appear in Table No. 6, amounted to 1,278 lb. in 210 days. The three "straight control" calves each received 782 lb. during the same period: a difference of 496 lb., or 63·4 per cent. of the average "straight control" figure.

We have seen that both the " bonemeal " and bonemeal control " calves were born out of bonemeal fed cows. On the average they all got 1,267 lb. of milk in 210 days. This milk intake enabled them to develop normally and equally in terms of body weights and body measurements. Functionally, however, the " bonemeal control " calves were subnormal until they also received a bonemeal supplement, but their functional efficiency never fell to below the " critical point ". In them an intake of 1,267 lb. of milk over 210 days, prevented functional efficiency from becoming so depressed as to produce conformational effects. In the " straight control " calves, the very low milk intake depressed functional efficiency to below the " critical point " during the pre-weaning period, and resulted conformationally in subnormal body weights very early in life. In the comparison between " bonemeal " and " bonemeal control " calves, the difference in functional efficiency was definitely due to the difference in $P_2O_5$ intake. As shown, this amounted to about 12 grammes of available $P_2O_5$ per calf per day in favour of the " bonemeal " group. In the comparison of the " bonemeal control " and " straight control " groups, the subnormal body weights of the latter were not due only to a lesser $P_2O_5$ intake. Applying composition figures given by Davis (1936) and Groenewald (1934), the 496 lb. milk intake difference betwen the two groups, amounted to a difference per calf per day of 2·3 grammes of $P_2O_5$, 35 grammes of protein and 135 grammes of carbohydrates, apart from differences in other food constituents.

Graph No. 1 gives curves for the average body weights of the two groups from birth to 7 months of age, and for the average accumulative amounts of milk the calves received from month to month over the same period.

The graph illustrates quite definitely how the weight curves follow the milk curves.

If we make a closer study of Sections I and II of Table No. 6 we find that in general, weight reacts to milk intake to a marked degree. For example, calf No. 6714 weighed 66 lb. at birth, while calf No. 6742 weighed 81 lb. For the first 3 months the latter received more milk than the former and more than maintained its advantage in weight. From the fourth to the seventh month the milk intake of No. 6742 dropped to below that of No. 6714, the live weights of which progressively approached those of No. 6742, and passed them from the 7th month, onwards. In the table this same phenomenon occurs between any two animals which commence their life with different amounts of milk, and where the one, which received the lesser amount to start off with, receives the larger amount during the latter part of the pre-weaning period. When in the comparison of any two animals in the Table, the milk supply of one remains higher than that of the other throughout the pre-weaning period, the body weights will show the same relationship. A comparison for example between Nos. 6714 and 6748, which had similar birth weights, illustrates the latter point.

| Group. | No. of Calf. | No. of Dam. | Degree of Breeding. | Sex. | Date of Birth. | Criteria. |
|---|---|---|---|---|---|---|
| Bonemeal Control... | 6714 | 3117 | 7/8 | M. | 18/11/36 | Body weight.....<br>Milk per day..... |
| Bonemeal Control... | 6742 | 5518 | 7/8 | M. | 7/12/36 | Body weight.....<br>Milk per day..... |
| Bonemeal Control... | 6743 | 4941 | 7/8 | M. | 7/12/36 | Body weight.....<br>Milk per day..... |
| Bonemeal Control... | 6748 | 3037 | 7/8 | M. | 8/12/36 | Body weight.....<br>Milk per day..... |
| I. *Body Weights*—<br>(*a*) Totals.....<br>(*b*) Averages..... | | | | | | |
| II. *Milk*—<br>(*a*) Total milk per group per day.....<br>(*b*) Average milk per calf per day..... | | | | | | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Straight Control..... | 6509 | 3242 | 7/8 | M. | 11/11/35 | Body weight.....<br>Milk per day..... |
| Straight Control..... | 6611 | 3139 | 7/8 | M. | 22/12/35 | Body weight.....<br>Milk per day..... |
| Straight Control..... | 6759 | 4977 | 7/8 | M. | 13/12/36 | Body weight.....<br>Milk per day..... |
| I. *Body Weights*—<br>(*a*) Totals.....<br>(*b*) Averages..... | | | | | | |
| II. *Milk*—<br>(*a*) Total milk per group per day.....<br>(*b*) Average milk per calf per day..... | | | | | | |

*Body Weights*—
(*a*) Actual difference between groups.....
(*b*) Percentage difference between groups.....

*Milk*—
(*a*) Actual difference between groups.....
(*b*) Percentage difference between groups.....

*Body Weights*—
(*a*) Averages for "Bonemeal-control" group.....
(*b*) Averages for "Straight-control" group.....
(*c*) Actual differences.....
(*d*) Percentage differences.....

*Body Weights*—
(*a*) Averages for "Bonemeal-control" group.....
(*b*) Averages for "Straight-control" group.....
(*c*) Actual differences.....
(*d*) Percentage differences.....

A



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## Table No. 6.

*Section No. I.*

| Body Weights at Birth and thereafter Monthly. Milk | | | | | | | |
|---|---|---|---|---|---|---|---|
| Birth. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 66 | 106 | 150 | 202 | 238 | 275 | 292 | 310 |
| — | 7·68 | 7·73 | 8·34 | 7·10 | 5·30 | 3·49 | 2·21 |
| 81 | 118 | 163 | 221 | 242 | 278 | 295 | 286 |
| — | 8·85 | 11·10 | 9·68 | 6·28 | 4·69 | 2·87 | 2·34 |
| 77 | 115 | 166 | 216 | 260 | 299 | 314 | 313 |
| — | 8·36 | 10·04 | 9·04 | 6·81 | 5·71 | 3·20 | 2·57 |
| 67 | — | 143 | 196 | 237 | 266 | 270 | 269 |
| — | 7·66 | 7·97 | 6·69 | 4·94 | 3·72 | 1·88 | 1·35 |
| 291 | 339 | 622 | 835 | 977 | 1,118 | 1,171 | 1,178 |
| 73 | 113 | 156 | 209 | 244 | 280 | 293 | 295 |
| — | 32·55 | 36·84 | 33·75 | 25·13 | 19·42 | 11·44 | 8·47 |
| — | 8·14 | 9·21 | 8·44 | 6·28 | 4·86 | 2·86 | 2·12 |

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*Section No. II.*

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 57 | 86 | 128 | 166 | 201 | 226 | 261 | 267 |
| — | 3·89 | 5·03 | 5·31 | 4·33 | 3·16 | 2·09 | 1·32 |
| 64 | 95 | 115 | 143 | 177 | 202 | 210 | 213 |
| — | 6·40 | 4·49 | 3·80 | 2·81 | 1·85 | 0·90 | 0·53 |
| 77 | 100 | 138 | 175 | 222 | 242 | 259 | 260 |
| — | 7·65 | 8·31 | 6·28 | 4·50 | 2·73 | 1·30 | 1·53 |
| 198 | 281 | 381 | 484 | 600 | 670 | 730 | 740 |
| 66 | 94 | 127 | 161 | 200 | 223 | 243 | 247 |
| — | 17·94 | 17·83 | 15·39 | 11·64 | 7·74 | 4·29 | 3·38 |
| — | 5·98 | 5·94 | 5·13 | 3·88 | 2·58 | 1·43 | 1·13 |

*Section No. III.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| + 7 | + 19 | + 29 | + 48 | + 44 | + 57 | + 50 | + 48 |
| 10·61 | **20·21**(5) | **22·83**(5) | **29·81**(1) | **22·00**(5) | **25·56**(1) | **20·58**(5) | **19·43**(5) |
| — | 2·16 | 3·27 | 3·31 | 2·40 | 2·28 | 1·43 | 0·99 |
| — | 36·12 | 55·05 | **64·52**(5) | **61·86**(5) | **88·37**(5) | **100·00**(5) | 87·86 |

*Section No. IV.—Body Weights Corrected for Birth Weights.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| — | 109·9 | 153·0 | 205·7 | 240·5 | 276·6 | 290·2 | 294·3 |
| — | 97·1 | 130·7 | 165·1 | 204·3 | 227·2 | 246·4 | 247·8 |
| — | 12·8 | 22·4 | 40·6 | 36·2 | 49·4 | 43·8 | 46·5 |
| — | **13·18**(1) | **17·13**(5) | **24·55**(1) | **17·72**(5) | **27·74**(5) | 17·78 | 18·77 |

*Section No. V.—Body Weights Corrected for Milk Supply.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| — | 108·0 | 148·5 | 194·4 | 232·0 | 264·3 | 277·4 | 277·6 |
| — | 99·0 | 137·0 | 180·5 | 216·0 | 243·8 | 263·9 | 269·6 |
| — | 9·0 | 11·5 | 13·9 | 16·0 | 20·5 | 13·5 | 8·0 |
| — | 9·09 | 8·39 | 7·70 | 7·41 | 8·43 | 5·12 | 2·97 |

*N.B.*—(5) Indicates significances P. = 0·05; (1) Indicates significances P. = 0·01.

K IN AMOUNT PER HEAD PER DAY FOR THE MONTH. ALL FIGURES IN LB.

| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| 313 — | 320 — | — — | 347 — | 380 — | 377 — | 463 — | 488 — | 555 — |
| 298 — | 299 — | 312 — | 349 — | 352 — | 395 — | 461 — | 538 — | 597 — |
| 328 — | 331 — | 345 — | 395 — | 380 — | 424 — | 489 — | 572 — | 600 — |
| 273 — | 273 — | 269 — | 299 — | 304 — | 355 — | 420 — | 475 — | 540 — |
| 1,212 | 1,223 | 926 | 1,390 | 1,416 | 1,551 | 1,833 | 2,073 | 2,292 |
| 303 | 306 | 309 | 348 | 354 | 388 | 458 | 518 | 573 |
| — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 270 — | 261 — | 278 — | 271 — | 292 — | 300 — | 360 — | 389 — | 439 — |
| 213 — | 212 — | 215 — | 235 — | 246 — | 305 — | 285 — | 329 — | 315 — |
| 265 — | 285 — | 286 — | 303 — | 303 — | 353 — | 364 — | 440 — | 487 — |
| 748 | 758 | 779 | 809 | 841 | 958 | 1,009 | 1,158 | 1,241 |
| 249 | 253 | 260 | 270 | 280 | 319 | 336 | 386 | 414 |
| — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| + 54 | + 53 | + 49 | + 78 | + 74 | + 69 | + 122 | + 132 | + 159 |
| **21·69**(5) | 20·95 | 18·85 | **28·89**(5) | **30·00**(5) | **21·63**(5) | **36·31**(1) | **34·20**(5) | **38·41**(5) |
| — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 301·1 | 301·7 | 299·9 | 340·2 | 350·5 | 379·1 | 451·5 | 505·1 | 561·2 |
| 251·4 | 258·3 | 269·1 | 279·6 | 284·5 | 329·9 | 341·6 | 401·9 | 428·6 |
| 49·7 | 43·4 | 30·8 | 60·6 | 66·0 | 49·2 | 111·9 | 103·2 | 132·6 |
| 19·77 | 16·80 | 11·45 | 21·67 | 23·20 | **14·91**(5) | **32·80**(5) | **25·68**(5) | **30·94**(5) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — |
| — | — | — | — | — | — | — | — | — |

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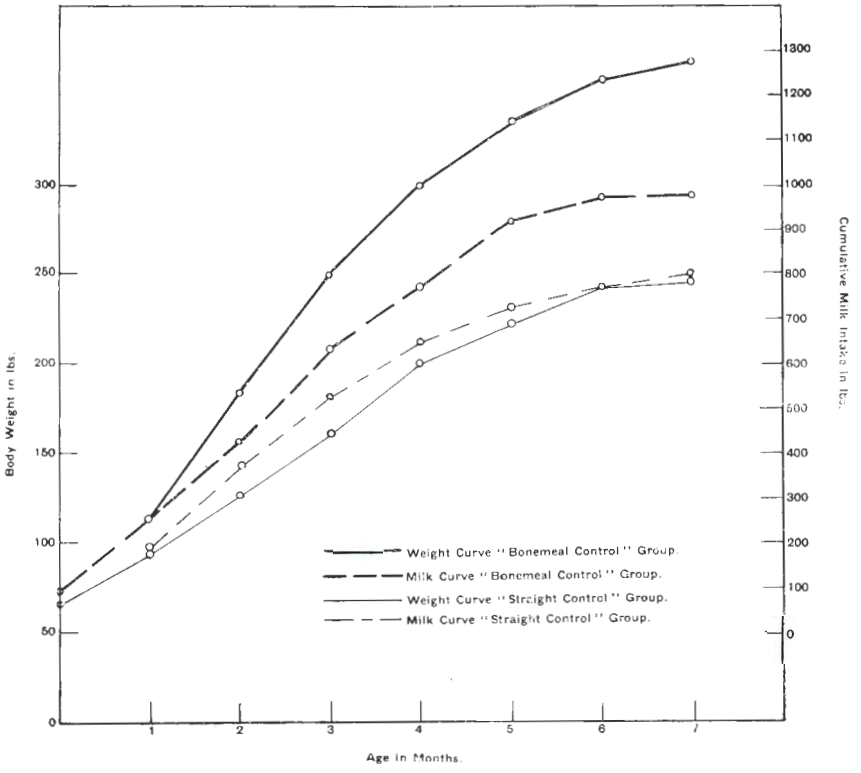
GRAPH No. 1.




## SUMMARY.

The results are presented of an experiment to ascertain whether a regular supplement of bonemeal given to calves up to weaning age would be beneficial to their growth and development, in comparison with a comparable group of calves which received no bonemeal up to weaning. From weaning onwards, both groups received the same supplement. The average milk intake for the groups was the same. All the calves were weighed and measured every 30 days from birth until the conclusion of the test at 480 days of age. They were tested for osteophagia at fortnightly intervals and a blood-sample for inorganic blood phosphorus determination was collected from each calf at approximately monthly intervals.

The results are compared with data which were collected on comparable calves, not included in the experiment. They were born out of cows which received no bonemeal supplement and therefore gave to their calves, on the average 496 lb. less milk than did the bonemeal fed dams of the calves in the experiment. This comparison demonstrates the effect of a decreased milk intake upon growth and development.

## Conclusions.

(*a*) Under open range conditions in Bechuanaland, the quantitave milk intake of a calf during its pre-weaning period of life, determines its body or conformational development.

(*b*) In general, bonemeal fed cows, living under open range conditions in Bechuanaland supply their calves with sufficient milk for normal development up to weaning age.

(*c*) In Bechuanaland, cows which receive no phosphorus supplement, do not as a rule supply their calves with sufficient milk for normal development up to weaning age.

(*d*) Although the milk supply of cows receiving a phosphorus supplement is as a rule sufficient for the normal conformational development of their calves, such calves nevertheless are functionally subnormal as indicated by low inorganic phosphorus in their blood.

(*e*) This phosphorus deficiency can be corrected by feeding phosphates prior to weaning.

(*f*) Such a supplement prior to weaning, however, is not necessary, if the calves receive the necessary phosphates from weaning onwards.

(*g*) Up to a point, skeletons of growing calves are able to do with less than their normal mineral requirements, and nevertheless function sufficiently well to support normal increase in body weight and body size.

(*h*) The "critical point" is not reached prior to weaning age in the calves of bonemeal fed cows, and therefore such calves, although functionally subnormal, are conformationally normal.

(*i*) In the calves of non-phosphorus fed cows this "critical point" is reached prior to weaning. Such calves are both functionally and conformationally subnormal.

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