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Paresis in Pigs in Relation to Nutritional Deficiencies.

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I. INTRODUCTION.

PARESIS or posterior paralysis of swine is a condition which occurs fairly frequently on pig farms in South Africa. The available literature as well as our own experience shows that it can form part of the symptom complex of a good many etiologically different diseases such as for instance:—

Nutritional deficiencies, e.g., vitamin, minerals, etc.

Acute infectious diseases, e.g., swine fever.

Specific bacterial neuritis and arthritis.

Intoxications, e.g., lead, arsenic, etc.

Epidural abscesses and growths pressing on cord.

Trauma, i.e., fractures of spine or pelvis.

The type of paresis which we set out to study belongs to the first group mentioned above, namely that of nutritional origin.

Usually growing pigs are affected and sometimes whole litters at once. The condition may develop at any time of the year, but frequently makes its appearance towards the end of winter in the summer rainfall areas and the end of summer in the winter rainfall areas. It is particularly prevalent in

the western or drier parts of the Highveld where maize growing can still be carried on and where pigs are kept as a sideline mainly to utilize spoilt grain. The diet here consists in the majority of cases of white maize unsuitable for the trade on account of being mouldy, discoloured, or light and immature through being frostbitten. In addition skim milk and green feed may be given as and if available.

During the periods mentioned, green feed becomes exceedingly scarce or totally absent, as few farmers in those areas are in a position to grow it under irrigation. For the same reasons milk is also usually scarce at the same time.

The observation had already been made that when sufficient green feed was provided such a paresis did not occur in these same areas and under otherwise similar circumstances.

It was desirable, however, to establish the cause of the condition more specifically in the light of recent work on deficient nutrition and also to determine the best and cheapest curative and preventive treatment under conditions peculiar to the areas concerned. Since vitamin A and calcium were the essentials most likely to be deficient in the diet, experiments were planned in the first instance with rations deficient in one or other or both these substances. It was hoped in this way to determine to what extent the symptoms and lesions so produced corresponded to those seen in cases occurring naturally. At the same time control groups receiving adequate rations containing yellow maize, lucerne meal or bone meal, would indicate to what extent these readily procurable feeds could replace green-stuffs as a preventive when this was not available locally.

II. Historical.

Vitamin A.—The conditions under which avitaminosis A manifests itself in pigs, its symptomatology, its response to treatment and the vitamin A requirements of pigs have already been described by various investigators [Hughes *et al.* (1928), (1929); Hostetler and others (1935); Dunlop (1935, 2); Guilbert and co-workers (1937); Hart and Guilbert (1937); and Møllgaard (1938)]. Furthermore, Foot and co-workers (1938) have recently published such an extensive review and excellent discussion of the literature relative to the vitamin A problem in swine husbandry that no attempt is made here to review the literature again.

Calcium.—As far as the writers are aware Bohstedt and co-workers (1926) were the first to describe " posterior paralysis " in pigs as associated with poorly calcified bones, due to a ration low in certain minerals, especially calcium.

The immediate cause of the posterior paralysis was found to be fractured vertebrae in the lumbo-sacral region. According to these authors it appeared as if the poorly ossified lumbar vertebrae were unable to withstand any sudden and severe contraction of the powerful back muscles, such as occurs when slipping on the floor or when frightened. One or other vertebra would collapse under the crushing effect of such a strain resulting in a comminuted fracture with inward bulging and pressure on the spinal cord, thus acting as a nerve block for the rear extremities. Out of 24 animals on this diet, 8 were afflicted with posterior paralysis and, as stated by the authors, several of these after they got into this paralysed condition

dragged their rear extremities extended behind them. Recently Wintrobe (1939) also reported that when an inadequate supply of minerals was given to pigs spontaneous fractures of the long bones and spinal column occurred.

In view of the excellent review by Mitchell and McClure (1937) on the "Mineral Nutrition of Farm Animals", no attempt is made, as in the case of vitamin A, at a comprehensive review of the literature on the calcium requirements of swine, and only work related to the immediate background of the present experiments will be cited later.

III. Experimental. Work.

A. *Management of Pigs.*

As far as possible the animals were kept in individual pens in a central, well ventilated, brick building. The pens measured 6 ft. by 5½ ft. Adjacent to each pen was a runway to which the animals had free access and where they were exposed to an abundance of sunshine. The runway measured 12 ft by 5½ ft. Both the pen and runway were paved with concrete floors. Each unit (pen and runway) was completely separated from the adjacent ones by brick walls so that the faeces and urine could not get into adjoining pens. The animals remained constantly in their quarters except on one day a week when they were driven for about 50 yards to scales for weighing purposes. A wooden board was placed in each pen for the animals to sleep on but as soon as the animals began to show signs of incoordination in their movements, they were supplied with a very poor quality of dry grass for bedding in order to prevent the affected animals from bruising themselves too much.

The pigs were hand-fed once a day in the morning and the mash was offered in the form of a slop. Fresh tap water was at all times available to the animals in the runway.

B. *Experimental Methods.*

1. *The calcium and phosphorus* contents of the rations were determined according to the methods described by Malan and van der Lingen (1931).

2. *The protein* contents were determined by the Kjeldahl method. The protein was calculated from the total nitrogen by the factor 6·25.

3. *The carotene* was determined in the individual constituents of the rations according to the method of Guilbert (1934).

4. *Vitamin A*:—(*a*) The vitamin A determinations in liver were made on unsaponifiable extracts by means of a Lovibond tintometer according to the method of Davis (1933). The results were calculated according to the method of Moore (1930) and the values expressed as Moore Blue Units. (M.B.U.).

(*b*) The vitamin A content in cod liver oil was determined according to the methods of Holmes and others (1937) and the value expressed as in the case of liver.

5. *Determination of Bone Ash.*—Immediately after slaughtering or death of animals the femurs were dissected free from soft tissues and weighed. The bones, after being broken up by means of an iron pestle and mortar, were placed in beakers and dried thoroughly at 105° C. in an electric oven. They were then wrapped in filter paper and extracted with ether in a fat extractor. After removal from the extractor, the bones were pulverized and about 1 gm. samples were placed in crucibles and dried again in an electric oven in order to obtain their dry fat-free weights. The samples were then ashed in an electric furnace in order to obtain the weights of their ash.

6. *Haemoglobin.*—For the determination of haemoglobin the samples of blood were taken from the marginal vein of the ear. The ear was rubbed with clean cotton wool moistened with absolute alcohol, the rubbing being continued until the vein was clearly dilated. The ear was then pricked with a sterilized needle, 20 c.mm. samples taken for analysis and the haemoglobin level determined by the acid haematin method of Newcomer (1919).

C. *First Experiment.—The Production and Prevention of Paresis in Swine on a Straightforward Vitamin A Deficient Ration.*

1. *Type of Pigs used.*—The animals were bred and raised in the piggeries of this Institute. They included Large Whites, Large Blacks, and crosses between large white sows with a large black boar. They were started on experiment shortly after weaning and were from 22 to 28 lb. in weight.* The dams of these piglets received a ration very rich in carotene inasmuch as the mash contained about 65 per cent. of yellow maize. In addition each sow received about 8 to 10 lb. of fresh lucerne per day. After weaning, and until the piglets were put on experiment, they received the same mash as their mothers together with an abundance of green food and it can be assumed, therefore, that by the time they were put on the experiment they should already have stored appreciable amounts of vitamin A.

2. *The Experimental Rations.*—The composition of the rations used is given in Table 1 and the carotene and vitamin A contents of the various ingredients are tabulated in Table 2. From these tables it is clear that all three rations are optimum in proteins, calcium and phosphorus. Rations II and III are also very rich in the carotenoid pigments. When calculated from the values given in Table 2 and, disregarding the carotene figures for meat meal and bone meal, it is found that ration II contained 242 mg. and ration III 440 mg. carotene per 100 lb. of food whereas Dunlop (1935, 2) gives 60 mg. per 100 lb. food for maintenance and normal growth. That is, these rations contained from 4 to 7 times the optimum amount of carotene for normal growth. Ration I, on the other hand, was extremely low in carotene. Even when the highest carotene values are taken for white maize meal, meat meal and bone meal, ration I only contained about 6·1 mg. carotene per 100 lb. food. In other words, a pig weighing 100 lb. and consuming, say, 5 lb. of this ration will only get about 0·3 mg. carotene per day which, according to Guilbert and others (1940) is only one-fourth of the minimum carotene requirement.†

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* The males were castrated about a week before the experiment started. See Table 5 for plan of experiment.

† According to Guilbert and coworkers (1940) the minimum carotene requirement for swine was found to be 25 to 39 micrograms daily per kilogram body weight, that is, 1·14 to 1·77 mg. carotene per 100 lb. body weight.

3. *Results.*

(*a*) *Growth of Pigs.*—The results given in Table 3 show that the pigs* on the high carotene rations gained about three times as much as those on the low carotene diet. The average daily gains were 0·45, 1·48 and 1·35 lb. for Groups I, II and III respectively. Furthermore, Group II (yellow maize) made the best use of their food and Group I the poorest, when expressed on the basis of feed per 100 lb. gain. Group III required 20 lb. more feed than Group II in order to make 100 lb. gain, which was probably due to the greater fibre and lower metabolizable energy content of ration III. Figures 1, 2 and 3 emphasize further the differences in growth and appearance of the various groups. (See Figures 1, 2 and 3.)

(*b*) *Curative Treatment.*—Three pigs were subjected to a curative treatment after symptoms of a vitamin A deficiency had developed. Figure 4 illustrates " Posterior paralysis " in pig No. 42 after it had been fed on ration I for 129 days. At this stage 100 ml. of cod-liver oil daily for 10 days was given and thereafter the animal was killed (Figure 5). " Anterior paralysis " and marked scoliosis were seen in pig No. 30 after 186 days (Figure 6). Figure 7 represents the same animal after it had received cod-liver oil (50 ml. daily for the first 4 days and 25 ml. from then onwards) for 18 days. The scoliosis remained even after 102 days of such treatment (Figure 8).

Although pig No. 53 had been kept on a vitamin A deficient diet for 129 days no clinical symptoms except unthriftiness and retarded growth developed (Figure 9). Thereafter it received 25 ml. cod-liver oil daily for 121 days. Marked improvement occurred as shown in Figure 10.†

Treatment was only started after the symptoms in the two " paralysed " animals were well advanced. For the first few days the oil and some food had to be given in the form of a thin slop by a stomach tube. Two days after the commencement of the treatment the spasms stopped, and after two more days (of treatment) both animals were able to stand up again and support their body on all four legs. The growth curves of two of these pigs before and during treatment are illustrated in Figure 11 and the growth and clinical symptoms of these animals are tabulated in Table 4. (See Figures 4, 5, 6, 7, 8, 9, 10 and 11.)

(*c*) *Vitamin A Content of the Livers.*—The data on the vitamin A content of the livers are set out in Table 5. From the results it is clear that no trace of vitamin A was found in the livers of the pigs receiving only the vitamin A deficient ration (ration I). However, when this ration was supplemented with cod-liver oil, the animals stored considerable amounts of vitamin A in their livers. For instance, the feeding of 100 ml. of cod-liver oil daily for 10 days to a vitamin A depleted animal (Pig No. 42, female, before slaughtering) resulted in a storage of over 67,000 M.B. Units. This amount of vitamin A was about as much as the average amount of vitamin A stored in the livers of pigs on rations II and III where an abundance of carotene was supplied in the forms of yellow maize and lucerne meal respectively.

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* There were 7 pigs in Group I (low carotene) and 3 each in Groups II and III (both high in carotene).

† According to Foot and coworkers (1939) this quantity given daily should be more than sufficient to produce normal growth and health in pigs on a vitamin A deficient basal ration.

D. *Second Experiment.—The Production and Prevention of Paresis in Pigs on a Ration Deficient in Vitamin A and/or Calcium.*

1. *The Pigs Used.*—These animals were also bred at this Institute and consisted of Large Whites and crosses between Large White sows with a Large Black boar. Their management was similar to that of the pigs in the previous experiment. When started on experiment the pigs in Groups IV (lot 1), V, VII and VIII (see Table 3) weighed from 18 to 27 lb. In view of the fact that the pigs in Group IV, lot 1, fared so badly,* the work on this group was repeated with a second lot of animals. In order to allow these pigs more time in which to store vitamin A and calcium, the animals, at the start of the experiment, were older and weighed on the average about 11 lb. more than those in lot 1. As these pigs received white maize and skim milk as ration, it was decided to include also a conformable group on yellow maize and skim milk. These animals constituted Groups IV (lot 2) and VI (Table 3).

2. *The Rations Used and a Discussioin of their Composition.*—In view of the fact that the socalled " posterior paralysis " occurs so often amongst pigs in this country when fed grains and skim milk, it was deemed advisable also to produce the condition in pigs on rations consisting of grain or grain mixtures and skim milk. The composition of the grain mixtures is given in Table I. These mixtures were fed with skim milk in the proportion of 1 : 1, that is, 1 ml. of milk to every gram of grain. The Ca, P and protein contents of the dry skim milk-grain mixtures are given in Table 6. The carotene content of these rations was calculated from the carotene values of the various ingredients in the rations.

(*a*) *The Proteins.*—The skim milk and grain were fed in the proportion of 1 : 1, because according to Hart, Steenbock and Letcher (1920) the best utilization of this protein mixture was obtained when fed to pigs in the above proportion. Almost similar and simultaneous results were obtained by Osborne and Mendel (1920) with rats.

Table 6 shows that the protein content of the rations varied from 12 to 13 per cent. According to Mitchell and Hamilton (1935) such levels are too low to produce maximum growth in young pigs. Contrary to the above, based on the results of their experiments, Woodman and co-workers (1939), (1940) concluded that no difference in the growth of pigs kept on rations of 12 per cent. and higher protein content occurred if the growth period was limited to produce a 200 lb. live weight. Only during the earliest stage of the feeding period did the pigs on the low protein diet (12 per cent.) show a slight, though significantly lower rate of live weight increase and poorer efficiency of food conversion than the pigs on standard and high protein diets," " but such differences had ceased to be manifested by the time the pigs had arrived at 60 lb. live weight, and the slight initial disadvantage experienced by the low-protein pigs was wiped out during the later stages of the feeding period ". As a matter of fact their results show that the initial setback on the low-protein ration was actually made up again in the period from 150-200 lb. live weight. Therefore, the rations used in the present experiment with only about 12 per cent. proteins of which 28 per cent. is supplied by milk should give good growth in pigs, as was found to be the case, provided the rations are complete in all other respects.

* Three out of four animals fractured their vertebral columns whereas the remaining one made very poor growth and frequently suffered from diarrhoea.

(*b*) *Calcium.*—From Table 6 it is evident that rations IV and VI are very low in calcium, with an average of only 0·13 per cent. Ca in the dry ration. This level is, according to various investigators [Møllgaard (1934), Dunlop (1935, 1), Theiler, du Toit and Malan (1937) and Mitchell and McClure (1937)] by far too low for normal calcification whereas the concentration of calcium in the remaining rations was optimum for growth and bone formation.

(*c*) *Phosphorus.*—According to the publications of Dunlop (1935, 1), Aubel, Hughes and Lienhardt (1936, 1), (1936, 2), Mitchell and co-workers (1937) and Mitchell and McClure (1937) pigs at weaning age require about 0·3 per cent of phosphorus in their ration and it is, therefore, clear that the phosphorus contents in our rations were adequate for growth and calcification.

(*d*) *Iron.*—Ranganathan (1938) gives the iron content of dry maize as 2·3 mg. iron per cent. on an average and that of skimmed milk as 0·24 mg. per 100 ml. Therefore, a pig weighing 25 lb. and consuming 500 g. maize and 500 ml. milk will receive 12·7 mg. Fe and a pig of 150 lb. and consuming at least four times as much food will get 50·8 mg. iron. Although the amount of iron to maintain a positive balance in pigs is not known with certainty, it seems that the above amounts of iron in the food should be adequate to maintain a normal haemoglobin concentration in the blood.*

(*e*) *Copper.*—According to the feed analyses of Elvehjem and co-workers (1929) 100 g. of dry maize contain about 4·5 mg. Cu per Kg. and it seems, therefore, that the copper requirements of pigs should be adequately supplied by a ration consisting of equal parts of maize meal and skim milk.†

(*f*) *Sodium.*—From the figures given by Sherman (1937) a ration consisting of skim milk and maize as fed in this experiment would contain about 0·079 per cent. sodium. This is almost nine times the minimum level fed by Schoorl (1936) and, judging from his results and those of Sinclair (1939), it would seem that for pigs a skim milk and maize ration should not be deficient in sodium.

(*g*) *Chlorine.*—According to Sherman's (1937) compilation a pig weighing 50 lb. and consuming at least 1,000 g. maize and 1,000 ml. milk per day will receive about 1·5 g. of chlorine which, as judged from the results of Woodman and others (1937), seem to be adequate for the normal functioning of the body.

(*h*) *Vitamins: thiamin, pyridoxin, riboflabin and nicotinic acid.*—From the work of Chick and others (1938, 1), (1938, 2) and Hughes (1939) it is evident that, of the vitamin B-complex thiamin (vitamin B_1), pyridoxin (vitamin B_6), riboflavin and nicotinic acid are all essential in the nutrition of the pig.

Judged from the minimum requirements of thiamin and riboflavin for the growing pig as stated by Hughes (1940, 1), 1940, 2) and Van Etten *et al* (1940), and the vitamin tables compiled by Fixsen and Roscoe (1940),

* For human beings Sherman (1937)) gives 12 mg. of iron per adult per day as the standard requirement.

† From the copper balance experiments made by Chou and Adolph (1935) the copper requirement of man is approximately 2 mg. per day.

it seems that a ration consisting of equal parts of maize and skim milk should contain adequate amounts of these factors for normal growth. Although the minimum requirement of nicotinic acid for swine has not yet been determined, one is forced to conclude from the work of Chick *et al.* (1938, 2) and Hughes (1939), and from the distribution of nicotinic acid in foods (Bacharach, 1941) that the maize-milk ration, as fed in this experiment, contains enough nicotinic acid for swine. Similarly, the work of Schneider and co-workers (1939) and Swaminathan (1940) lead one to the conclusion that the ration used in this experiment is optimum with respect to vitamin B_6.

(*i*) *Carotene.*—From Table 6 it is clear that the rations of Group VI, VII and VIII contain more than enough carotene for normal growth. Their carotene contents varied from 250 to 408 mg. per 100 lb. of food with an average value of 305 mg. which is more than five times the amount given by Dunlop (1935, 2) as necessary for normal growth. The rations of Groups IV and V only contained about 6·8 mg. carotene per 100 lb. food which is about a ninth of the optimum standard laid down by Dunlop. The carotene contents of rations IV and V are slightly better than that of ration I (Table 1) and it is evident, therefore, that these two rations are also very deficient in the provitamin A factor.

From the above discussion it would seem that the grain-skim milk rations as used in this experiment are optimum for growth except for a few which were low in carotene and/or calcium as indicated in Table 6.

3. *Results.*

(*a*) *Growth of Pigs.*—The results presented in Table 3 show that the pigs on normal rations (Groups VII and VIII) required the smallest amount of feed per 100 lb. of gain, that is, they made the best use of their food. Next in order came the calcium deficient (Group VI), the vitamin A deficient (Group V) and lastly the animals on a calcium and vitamin A deficient ration (Group IV, lots 2 and 1). The results (Group VI) also show that, if young pigs were allowed enough time to store appreciable amounts of calcium in their bone system, they could safely be changed over and fed to market weight on a very economical ration of skim milk and yellow maize with excellent results in growth and well-being. When killed, No. 84, male, weighed 343 lb. after having been on skim milk and yellow maize for 196 days. When the grain is white maize (Group IV, lot 2), retardation in the growth of pigs sets in presumably as soon as their vitamin A reserves are exhausted. The differences in growth between the various groups are further shown in Figures 12, 13, 14, 15, 16 and 17.

(*b*) *Haemoglobin Level in Blood.*—The results of these haemoglobin determinations are given in Table 7. From these figures it is seen that the great majority of them fall between 10-12 grams haemoglobin per 100 ml. of blood. This range is somewhat higher than the " normal " haemoglobin value for pigs (8-10 grams per 100 ml. of blood) as found by Hart and co-workers (1930) but it is in close agreement with the normal values of Hamilton and associates (1930) and Chick and co-workers (1938, 2) for young pigs. The results also support the work of Hart and associates (1930) in so far that a ration of skim milk and maize is optimum for haemoglobin synthesis in young pigs.

(*c*) *Curative Treatment for Vitamin A Deficiency.*—Four pigs, Nos. 81, 83, 85 and 48, after they showed symptoms of vitamin A deficiency, were subjected to a curative treatment with cod liver oil. Table 4 and figures 18, 19, 20 and 21 show the growth and condition of the animals before and after the curative treatment.

(*d*) *Weight of, and Percentage Ash in Femurs.*—Some of the bones analysed were from pigs that had died rather early in the experiment, or from animals that showed very poor growth. These facts, no doubt, weaken the significance of the values presented in Table 8, especially those of the fresh weight of the femurs for the various groups. Nevertheless, the ash in the femurs of pigs whose rations were supplemented with bone meal, seem to be significantly higher than the ash in femurs of pigs on the low calcium rations. For instance, the percentage of ash in the dry fat-free femurs of the pigs receiving bone meal (Groups V, VII and VIII) was on the average 61·60 per cent. whereas the average percentage of ash in the femurs of pigs fed the low calcium rations (Groups IV and VI) was 55·69, that is, a difference of 5·91 per cent. ash in favour of the bone meal fed animals.

(*e*) *Vitamin A Content of the Livers.*—The data concerning vitamin A content of the livers are tabulated in Table 5. As in the previous experiment the results indicate that there was no trace of vitamin A in the livers of pigs fed the vitamin A deficient rations (Rations IV and V), whereas when these rations were supplemented with cod-liver oil, the animals stored appreciable amounts of vitamin A in their livers. Likewise, the livers of animals fed yellow maize or lucerne meal (Rations VI, VII and VIII) contained large amounts of this vitamin.

IV. Clinical Symptoms.

Groups I and V (−A+Ca) (Ration Deficient in Vitamin A).

The first symptoms appeared from about the 50th day of low vitamin A diet. Our experience that the symptoms vary in different animals coincides with that of other observers. The symptoms enumerated below did not, therefore, necessarily occur in every affected animal.

Usually the first sign observed in pigs on this diet is a falling off of the appetite with consequent retardation of growth noticeable already from the 40th day. The animals appear less thrifty and progressively the skin becomes dry and scaly, the hair or bristles shaggy and dull, soiled and eventually split at their tips. The conjunctiva becomes reddened and a thin sero-mucous secretion running down from the medial canthus tends to soil the skin along its path. Later it becomes more viscid and stains the skin light brown. Gradually the animal's vision becomes affected, the pupils remain in a state of continuous dilation, the eyeball seems to protrude giving rise to a peculiar staring effect, probably on account of increased intraocular pressure. The iris reacts to weak light very slightly or not at all but contracts slowly under influence of bright sunlight.

Excepting one pig (No. 55) which had a slight corneal opacity and ulcer no macroscopic changes could be seen externally to explain the gradual loss of sight. Erosions and bruises of the snout, nostrils and other parts of the skin of the limbs evidently resulted from animals walking into obstacles. Later the animals seemed to become more wary and were able to avoid this, while still able to find their way about to the food trough and return to

their stye. After some time the ears began to droop and in a few animals a ventral or lateral curvature of the spine (lordosis, scoliosis) developed. This was usually accompanied by a twisting of the head to one side (torticollis).

The animals either remain quiet and even lethargic or become restless and irritable, moving about continuously and aimlessly in circles.

The limbs usually become very straight and the gait then becomes awkward, stiff or stilted and short stepped. In other animals owing to swaying of hindquarters and knuckling over at the fetlocks the gait was even more uncertain. The incoordination of movements becomes progressively more severe and leads ultimately to paresis and even paralysis of the hindquarters so that the animal can only raise its body with its fore limbs to assume a sitting posture. Eventually the animal is unable to do this even with assistance and may develop skin abrasions from unsuccessful attempts to rise. In one case (No. 30) paralysis of the forequarters preceded that of the hindquarters, the body being supported on the knees at first. In addition this animal had difficulty in eating and swallowing its food. It would take up some food into its mouth and then raising its head gulp it down with an exaggerated snapping movements of the jaws.

From about the 130th day a nervous collapse occurred in most animals. This was frequently heralded by convulsive fits which were brought about fairly easily when the animal was roused and urged to rise first thing in the morning. When this had passed off, another fit or two could be brought about less easily by exciting the animal. For instance, a fit might be induced by spraying the animal with some insecticidal solution against lice. The animal would be heard to squeal and become agitated. Then it would sag on its haunches with a peculiar stare, and fall on its side. The legs made rapid galloping movements and were later extended stiffly. The head was thrown well back and the respiration became laboured and reduced in number. Finally the animal became exhausted and lay gasping for a minute or two. After several unsuccessful attempts at rising the animal could eventually assume a sitting posture and even get on to its feet and walk with a very uncertain wobbly gait to its trough and start feeding.

These pigs showed a certain tendency to allotriophagia. They were often observed gnawing at the bricks and mortar of their stye and whenever taken out invariably started eating earth and sand. Some of the pigs developed diarrhoea at intervals.

Gilts came on heat at irregular intervals and seemed to remain in this state for unusually long periods.

One pig (No. 52) died after showing surprisingly few symptoms apart from gradual loss of appetite. One day it was found lying down and unable to rise. No pain or other sign of severe illness could be detected and its death a few hours later was quite unexpected. This is in accordance with the work of Foot and others (1938). Observations made on animals after treatment with cod liver oil will be found in Table 4.

Group IV, Lots 1 *and* 2 (*- A - Ca*).—The early and marked retardation of growth in Lot 1 of this group is strikingly illustrated in Figure 12. The earlier symptoms are similar to those of the previous group, except that convulsive fits and impaired vision were not noted. There was the same watering of the eyes with soiling of the skin from the medial canthi down. The gait was similar with short, stiff steps, the limbs being very

straight as if the animal was attempting to tiptoe. Before symptoms could develop further, 3 out of the 4 pigs became suddenly and completely paralysed in the hindquarters due to fracture of a lumbar or posterior thoracic vertebra. The remaining animal had to be killed owing to a severe arthritis of a hind limb.

Group VI (*+A - Ca*). (*Ration Deficient in Calcium*).—Except for pig No. 80 which developed into a runt after weaning and consequently made very poor growth, the remaining three pigs in this group grew well, making excellent gains in weight and showed no abnormal symptoms. (See Figures 22 to 25.)

Groups II and VII (*+A +Ca*).—Carotene was supplied by yellow maize. A painful swelling involving both carpal joints occurred in pig No. 58 after some considerable time. This was manifested by the animal first walking with a stiff gait in the forelimbs and later, as the condition became worse, it lay down and resented to rise even when urged to get up. A carpitis was diagnosed. The remaining 6 pigs in these groups developed well and remained healthy until the end of the experiment.

Groups III and VIII (*+A +Ca*).—Carotene was supplied by lucerne meal. The seven pigs in these groups developed well and remained in a good state of health during the experiment.

V. The Anatomical Pathological Changes.

Groups I, V — *A* + *Ca* { *White maize, meatmeal and bonemeal.* / *White maize, skim milk and bonemeal.*

Of the eleven animals which were kept on this ration four pigs were killed after they had been treated for periods varying from 10 to 140 days. Of the remaining seven, four died as a result of affections of the lungs after they had been in the experiment for periods varying from 99 to 317 days.

We found that not only were the post-mortem findings of the treated animals different from those of the untreated ones, but they even varied from animal to animal in the latter group.

(*a*) *The Post-mortem Findings in the Untreated Animals.*—The following changes were common to all the pigs in this group. The carcass showed signs of retardation of growth. A dry brownish secretion soiled the skin below the medial canthi of both eyes. The hair coat was lustreless and the bristles had a tendency to split at their tips. The surface of the skin was drier than usual and was covered with scabs especially over the back. Abrasions involving the skin over the orbits, the elbow and hock joints, the fetlocks and above the coronet appeared, however, in some of the animals (Pigs Nos. 27, 39, 43 and 55). Small red spots, which tend to form pustules later occurred in different parts of the skin (pig No. 44) and raised papules were distributed over the body (pig No. 42).

General cyanosis of the visible mucous membranes and of the unpigmented skin especially of the abdomen was present in the animals suffering from pulmonary affections (pigs Nos. 27, 39, 43 and 52). In others (Nos. 29, 44 and 55) the conjunctiva was reddish discoloured and the blood-vessels were congested.

On opening the carcass a slight ascites, hydrothorax and hydropericard was found in all the animals.

A fibrinous pleuritis and a necrotic pneumonia (pig No. 27), fibrous adhesions of the left lung to the diaphragm and localized bronchitis (pig No. 29), congestion of lungs and aspirated ingesta in the larynx and trachea (pig No. 39), congestion and oedema of the lungs (pig No. 52), a localized chronic pleuritis involving an area over the 4th to the 6th rib, a purulent pneumonia and an aspirated oily material in the bronchi and trachea (pig No. 43) occurred in the animals with respiratory affections.

In 5 animals the gastro-intestinal mucous membrane was slightly swollen and hyperaemic (pigs Nos. 27, 39, 44, 52 and 55) and a slight ascaris infestation was present in 3 pigs (Nos. 55, 29, and 43).

Fatty changes of the kidneys, a hydronephrosis of the left kidney, distension of the pelvis and the ureter and a posthitis were observed in pig No. 29.

In pig No. 55 a small corneal ulcer occurred on the right eye and a slight opacity blurred the cornea of the left. Calluses involved the distal end of some ribs and on palpitation, these could easily be mistaken for enlarged costochondral junctions.

(*b*) *The Post-mortem Findings in the Treated Animals.*—On the whole the condition of the treated pigs was much better than that of the untreated ones. The secretion soiling the medial canthi was reduced (pig No. 42) or totally absent (pigs Nos. 30, 42 and 53). The hairy coat had improved, the bristles had become more dense and had more lustre than those of the untreated pigs. The skin on the whole had also improved. It was more pliable and less scabby than in the former lot. Raised papules were distributed over various parts of the body, and in addition marked chronic pleuritis, localized pneumonic changes in both lungs and hydronephrosis of the left kidney were seen in pig No. 42.

Except for a fairly pronounced ascaris infestation, no abnormal changes were noted in pig No. 48.

Group IV (1) *and* (2) (*– A – Ca*) *White Maize Meal and Skim Milk in Proportion of* 1 : 1.

Of the seven animals kept on this ration for periods varying from 69 to 290 days, three (Nos. 81, 83 and 85) were treated with cod liver oil for from 12 to 42 days and the remaining four received no treatment. Of the latter animals three suffered from a fractured spine. Of the former one animal (No. 81) died after faulty drenching and the remaining two were killed at the end of the experiment.

(1) *Post-mortem Findings in the Untreated Animals.*—Similar changes to those described for the untreated animals in Groups I and V were seen in the four pigs (Nos. 41, 50, 54 and 57) kept on this ration. The signs of stunted growth and cachexia, however, were more pronounced, and the marked softening of the skeleton was of interest. Evidence of it was reflected in the callus formation on several ribs on both sides of the thorax. In three animals (Nos. 41, 54 and 57), there was fracture of the spine at the second last thoracic vertebra, the fourth lumbar vertebra and the third lumbar vertebra. The consistence of the ribs was markedly reduced, they bent like cardboard and broke without a snap. A peri-arthritis and arthritis occurred in the left tarsus of pig No. 50.

In these animals, as the result of struggling before death, excoriation of the skin occurred in various places. The point of the medial claw of both fore limbs was worn through (pig No. 41) and bleeding occurred. Retention of urine occurred in one pig (No. 41). Several pigs were affected with some lice (*Haematopinus suis*).

Signs of diarrhoea, colitis and a slight ascaris infestation were seen in pig No. 50.

Marked haemorrhages occurred in the neighbourhood of the fractured vertebra and the blood infiltrated into the adjacent portion of the psoas muscles.

The prepuce was swollen and catarrhal changes were present (pig No. 41).

(2) *Post-mortem Findings in the Treated Animals.*—On the whole the condition of these animals was better than that of the untreated lot. Nothing unusual was noticed except multiple calluses involving several ribs on both sides of the thorax. The consistence of the ribs increased proportionally to the period of treatment. The calluses are very distinct, bulging deeply into the thoracic cavity and the consistence of the ribs was either soft or brittle. A varying infestation of ascaris was present, which was fairly heavy in pig No. 81. In addition cyanosis of the visible mucous membranes, deformity of the claws with ulceration below and a necrotic stomatitis occurred in pig No. 81.

Group VI (+A −Ca) Yellow Maize.—The four animals kept on this ration were killed at the end of the experiment. They had received no cod liver oil. On autopsy nothing unusual was observed, except that the consistence of the ribs was slightly reduced. The ribs broke with a snap on being bent and pressure applied, but in one case (pig No. 80) the lower portion of the ribs bent like cardboard. Incidentally this pig had been kept the shortest period on the diet and it was on the whole unthrifty.

A few ascaris were found in the intestine of all the animals, and there were haemorrhages in the thoracic cavity.

Groups II and VII (+A +Ca) Carotene supplied by Yellow Maize.—The autopsy on seven pigs kept on this ration revealed nothing unusual, except a slight ascaris infestation. Several pigs were infested with lice (*Haematopinus suis*).

A carpitis sicca involving both fore-limbs was diagnosed in one animal (pig No. 58).

Groups III and VIII (+A +Ca) Carotene supplied by Lucerne Meal.—The seven pigs were killed at the conclusion of the experiment. The results of the autopsy were similar to those of the former two groups, except that no carpitis was diagnosed.

Considerable material has been collected from these experiments for histological study, which unfortunately could not be completed in time This part of the work is intended for later publication.

VI. Conclusions.

(1) Evidence so far accumulated seems to show that under veld conditions in South Africa, a vitamin A deficiency occurs fairly frequently amongst pigs. The following are the conditions that are probably chiefly responsible for the occurrence of this type of malnutrition in this country.

(*a*) *Climatic.*—In the winter rainfall areas the dry season usually extends from October to March and in the summer rainfall areas from March to October or even later. On most farms during these periods, lasting 6 to 7 months, little or no green food is available. Based on the evidence of our experiments it would seem that such a period of low vitamin A intake is long enough to manifest its deleterious effects, particularly in the young of fast-growing species such as the pig. The appearance of symptoms and degree of affection will depend naturally on the amount of vitamin A previously stored in the animal's body.

(*b*) *Feeding.*—When supplementary feeding is practised, the rations in the winter rainfall areas are usually composed of barley or rye meal plus one or more of the following ingredients: wheaten bran, minerals, meat meal, peanut meal and skim milk. In the summer rainfall areas the same ingredients are incorporated in the rations except that maize is usually substituted for barley or rye. Unfortunately, on account of the better market, white maize is planted mainly in the summer rainfall areas and it constitutes the staple concentrated stock feed in these areas. It is also well known that the feeds listed above are all deficient in the carotenoid pigments and are, therefore, unable to supply the vitamin A requirement.

(2) In order to rectify the adverse feeding conditions during the dry seasons in this country attention should not only be given to the probable energy, protein and mineral deficiencies in the pasture but also to the vitamin A requirements of the grazing stock.

(3) The most practical and probably also the most economical way of supplying the essential carotene (vitamin A) to the animals during the dry seasons seems to be in the form of yellow maize and lucerne meal (hay). Considering the variable carotene content in different samples of these products and allowing for a margin of safety, it seems that 30 to 50 per cent. of yellow maize or 5 to 8 per cent. of lucerne meal in the ration should supply enough carotene to tide the animals over the adverse seasons.

However, the recommended levels of maize in the ration of pigs may have an undesirable effect on the quality of the fat. Therefore, it may be advisable for those farmers who go in for the production of baconers, further to reduce the proportion of maize in their rations and to include also some lucerne meal or 0·5 per cent. cod liver oil as recommended by Foot and associates (1939).

(4) A rather common fattening ration for pigs in this country consists of a cereal meal with skim milk. If the cereal is yellow maize and if it is fed with skim milk in equal amounts by weight, the ration will be complete with respect to growth except that it is low in calcium. This can be rectified by the addition of either 1·5 per cent of fluorine-low agricultural lime or 2 per cent. of bone meal to the maize meal. To improve the palatability 1 per cent. of common salt may also be added. If the cereal is white maize or if it belongs to the barley, rye, etc., group, provision should not only be made for the calcium but also for the necessary carotene or vitamin A in the cheapest and most readily form available, e.g., green stuff, pumpkin, lucerne meal or even cod liver oil.

VII. Summary.

1. A form of paralysis or paresis prevalent in some parts of the Union in young pigs is described. There was evidence already that it was due to a deficient diet.

2. Experiments were carried out to establish the cause of this disease more definitely by feeding to young pigs rations low in vitamin A, in calcium or both.

3. The pigs deficient in vitamin A developed symptoms which in the earlier stages at any rate correspond with those seen in the natural disease. An account of the symptoms and pathological changes noted in this artificial avitaminosis is given.

4. The pigs on a combined vitamin A and Ca deficient diet developed such a softéning of the skeleton that within 80 days three out of four fractured their spine and had to be destroyed. Other pigs started on the same ration when somewhat older, and which presumably, therefore, had a greater calcium (+ vitamin A)reserve in their body, did not develop such extreme lesions.

5. Gilts on a vitamin A deficient diet showed irregularity in the oestrous cycle. Oestrus occurred more frequently and persisted for abnormally long periods.

6. A ration of equal parts by weight of skim milk and white maize is physiologically complete for growth in pigs except that it is low in calcium and in vitamin A.

The incorporation of 2 per cent. bonemeal and 10 per cent. lucerne meal in such a diet or the substitution of yellow maize and bone meal for white maize resulted in normal growth and good health in pigs. Where green feed or other cheap sources of vitamin A are not available in adequate quantities, such a supplementation should prevent all tendency to paralysis and poor growth.

7. Cod liver oil administered to animals even in advanced stages of the deficiency effected rapid and striking improvement in health. Some of the lesions, however, could not be cured completely, e.g., bad cases of scoliosis and blindness.

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APPENDIX.

TABLE 1.

Composition of Rations in Percentage by Weight.

Group No.	I. − A + Ca.	II. + A + Ca.	III. + A + Ca.
Type of Ration.*	Carotene-poor (White Maize Meal).	Carotene-rich (Yellow Maize Meal).	Carotene-rich (Lucerne Meal).
White maize meal	86	—	77
Yellow maize meal	—	86	—
Meat meal (safco)	10	10	9
Lucerne meal	—	—	10
Bone meal	3	3	3
Sodium chloride	1	1	1
	100	100	100
Proteins.....Per cent.	15·70	16·17	16·08
Ca..... „	0·70	0·77	0·89
P..... „	0·52	0·51	0·57
Ca : P ratio	1·35 : 1	1·51 : 1	1·56 : 1

TABLE 1 (*contiued*).

Composition of Grain Mixtures.

Group No.	IV.	V.	VI.	VII.	VIII.
White maize meal	100	97	—	—	87
Yellow maize meal	—	—	100	97	—
Lucerne meal	—	—	—	—	10
Bone meal	—	2	—	2	2
Sodium chloride	—	1	—	1	1
	100	100	100	100	100

* The signs (−) = deficient; (+) = optimum; and (A) = provitamin A.

TABLE 2.

The Carotene and Vitamin A Contents of Various Feeds.

Feed.	Weight of Sample (on Air Dry Basis).	Carotene Content (on Air Dry Basis).	Vitamin A. Content.
	g.	Mg. Per cent.	
Yellow maize meal	100	0·62	—
White maize meal	100	<0·01	—
Lucerne meal	30	9·70	—
Meat meal (safco)	100	<0·04	—
Bone meal	200	<0·03	—
Skim milk (Willstaedt and With, 1938)	100 ml.	0·005 + ≡ 0·007	3 I.U.*
Cod liver oil	0·037 g.	—	535 M.B.U. per gram or 495 M.B.U. per ml.

* One I.U. ≡ 0·6 microgram of pure beta carotene (Daniel and Munsell (1937).]
< Means less than.

TABLE 3.

Gains and Feed Consumption of Pigs on Rations Low and High in Carotene Content. (Period 129 days. All weights expressed in pounds.)

	GROUP I. (Low Carotene).	GROUP II. (High Carotene).	GROUP III. (High Carotene).
Source of carotene	—	Yellow maize	Lucerne meal
Average initial weight	24·0	22·3	22·0
Average final weight	82·5	214·0	195·7
Average gain	58·5	191·7	173·7
Average total food	241·0	555·0	539·0
Average daily gain	0·45	1·48	1·35
Average daily feed per pig	1·87	4·30	4·17
Average feed per 100 lb. gain	411·0	289·0	310·0

TABLE 3 (*continued*).

Gains and Feed Consumption of Pigs Fed Rations containing various levels of Carotene and Calcium. (Period 147 days. All weights expressed in pounds.)

Type of Ration.*	Group IV.		Group V.	Group VI.	Group VII.	Group VIII
	Lot 1. −A−Ca.	Lot 2. −A−Ca.	−A+Ca.	+A−Ca.	+A+Ca.	+A+Ca.
Source of Carotene	—	—	—	Yellow maize	Yellow maize	Lucerne meal
Average initial weight	22·5	33·0	21·2	32·3	22·0	18·2
Average final weight	51·0	152·0	76·7	192·3	160·3	173·0
Average gain	28·5	118·7	55·5	160·0	138·3	154·8
Average total food	182·0	475·0	215·0	557·0	420·0	485·0
Average daily gain	0·19	0·81	0·38	1·09	0·94	1·05
Average daily feed per pig	1·24	3·23	1·46	3·79	2·86	3·30
Average feed per 100 lb. gain†	638·0	400·0	387·0	348·0	304·0	313·0

* The signs (−) = deficient; (+) = optimum; and (A) = provitamin A.
† Daily feed and feed per 100 pounds of gain on basis of milk being reduced to a moisture content of 4 per cent., that is, 100 ml. of skim milk ≡ 10 g. skim milk powder containing 4 per cent. of moisture.

TABLE 4.

Curative Treatment with Cod Liver Oil.

No. of pig and sex.	Symptoms prior to feeding of cod liver oil.	Growth and food consumption immediately preceeding feeding of cod liver oil lb. per day for 10 week period.		Cod liver oil fed.	Growth and food consumption immediately following commencement of feeding cod liver oil., lb. per day for 10 week period.		Effect of feeding cod liver oil on the symptoms.
		Growth.	Feed intake		Growth.	Feed intake	
42 Female..	The pig was growing fairly up to the time when it went down with "posterior paralysis" after having been on experiment for 129 days. From 56th day on experiment this pig was in heat for an unusually long time. At this period it also became very restless and nervous. Its vision became impaired and the dilated pupils did not respond to strong light. First spasms noticed on 105th day. From 129th day shoulders and sides were full of red papules. Pig collapsed when weighed on 129th day	—	—	100 ml. of cod liver oil daily for 10 days when animal was killed	—	—	Two days after the commencement of cod liver oil treatment the spasms stopped and after two more days of treatment the animal was able to stand up on all four legs. When killed on the 10th day of treatment the gait was still unsteady with hindquarters swaying.
53 Female..	This pig was growing very poorly but had shown no other definite symptoms. It was thin and leggy	0·49	1·71	25 ml. daily from 129 to 269 days on experiment	1·1	3·93	Made good progress and continued in excellent health. Pupils responded normally to light.
30 Male....	This animal grew very poorly and after it had been on experiment for 109 days, it started to show impaired vision, incoordination and spasms. Shortly afterwards the pig began to turn in circles, with its head held on one side. It also had difficulty in eating as it slopped the wet mash up in dog fashion. On the 186th day the animal showed severe scoliosis and spasms. It was prostrated with partial paralysis of its forequarters	0·22	2·04	50 ml. daily from 187 to 190 days and 25 ml. daily from 191 to 289 days on experiment	0·67	3·56	Two days after commencement of liver oil treatment the spasms stopped but it took the animal 12 days before it could walk again. After the animal had received cod liver oil for a week, it broke out in prominent red papules all over its neck and sides. After three more weeks the pustules had dried up leaving the skin hard and scaly. This condition together with the scoliosis and impaired vision lasted right up to the end of three months' treatment.

TABLE 4 (*continued*).

No. of pig and sex.	Symptoms prior to feeding of cod liver oil.	Growth and food consumption immediately preceeding feeding of cod liver oil lb. per day for 6 week period.		Cod liver oil fed.	Growth and food consumption immediately following commencement of feeding cod liver oil., lb. per day for 6 week period.		Effect of feeding cod liver oil on the symptoms.
		Growth.	Feed intake		Growth.	Feed intake	
83 Male.... (Group IV)	In spite of the fact that this pig started to show watering eyes and impaired vision from the 5th month on experiment, it made good growth for the first 7½ months on experiment. From then on its gait became incoordinated and its sides full of red papules. After 9 months on experiment the animal showed severe spasms and partial "posterior paralysis"	0·57	4·91	75 ml. daily from 291 to 293 days on experiment, 50 ml. daily for the next three days and 25 ml. daily for the remaining 36 days	1·62	6·35	The animal made a quick recovery from its partial "posterior paralysis" and gained much in weight during the period of cod liver oil treatment.
85 Male.... (Group IV)	This animal made excellent growth for the first 6 months on experiment. From the 217th day its gait became incoordinated and from the 235th day it showed a severe scoliosis	1·24	7·20	75 ml. daily from 291 to 293 days on experiment 50 ml. daily for the next three days and 25 ml. daily for the remaining 36 days	2·07	8·29	The animal made a considerable increase in weight during the curative treatment, and after 42 days of treatment the scoliosis had practically disappeared.
		For 10 *week period.*			*For* 10 *week period.*		
48 Female (Group V)	This animal, shortly after being put on experiment, developed into a runt. Its appetite was very poor and it subsequently gained very little in weight	0·12 lb. (per day)	—	25 ml. cod liver oil daily from 117 to 237 days on experiment	0·57 lb. (per day)	—	The animal made a gradual recovery and eventually made good progress.
81 Female.. (Group IV, Lot 2)	From the 5th month this animal started to show watering eyes but made good gains until end of 7th month. From the 217th day animal became very nervous and showed continuous oestrus for more than a month. On 257th day ulcers were noticed below claws of the right fore leg. From 278th day when animal became paralysed in hindquarters it was dosed with cod liver oil.	—	—	50 ml. cod liver oil daily from 278 to 289 days on experiment	—	—	Unfortunately due to faulty drenching the animal died on 290th day from gangrenous pneumonia

TABLE 5.

Vitamin A Reserves in Livers of Experimental Pigs.

Group No.	Pig No. and sex.	Type of Ration.*	Days of ration (died or killed).	Weight of pig at termination of life.	Weight of liver (*g*).	Vitamin A.	
						M.B.U. per gram of liver.	M.B.U. in whole liver.
				lb.			
I	29 Male....	Deficient in carotene (or vitamin A) —A+Ca	129 (killed).....	102	682	0	0
	44 Male....		129 (killed).....	182	1,230	0	0
	27 Female..		111 (died).....	98	575	0	0
	52 Female..		99 (died).....	53	497	0	0
	42 Female..		139 (killed).....	108	1,055	63·8	67,309†
	30 Male....		289 (killed).....	147	985	436·8	430,248†
	53 Female..		269 (killed).....	257	1,338	586·0	784,068†
II	31 Male....	Normal +A+Ca (carotene supplied by yellow maize	146 (killed).....	187	1,376	67·2	92,467
	33 Male....		140 (killed).....	226	1,590	64·6	102,714
	34 Female..		134 (killed).....	262	1,825	25·7	46,902
III	32 Male....	Normal +A+Ca (Carotene supplied by lucerne meal)	146 (killed).....	226	1,865	28·2	52,593
	35 Male....		140 (killed).....	206	1,512	25·2	38,102
	36 Female..		134 (killed).....	207	1,684	22·4	37,722
IV	54 Male....	—A—Ca.....	69 (died from fractured spinal column)	67	—	—	—
Lot 1	41 Male....		74 (killed—fractured spinal column)	62	592	0	0
	57 Female..		111 (killed—fractured spinal column)	—	485	0	0
	50 Female..		161 (killed).....	50	417	0	0
Lot 2	81 Female..	—	290 (died gangrenous pneumonia)	185	1,866	4·6	8,584‡
	83 Male....		332 (killed).....	354	1,467	67·2	98,582‡
	85 Male....		332 (killed).....	404	2,066	30·8	63,633†

Notes on next page.

TABLE 5 (*continued*).

Group No.	Pig No. and sex.	Type of Ration.*	Days of ration (died or killed).	Weight of pig at termination of life.	Weight of liver (*g*).	Vitamin A.	
						M.B.U. per gram of liver.	M.B.U. in whole liver.
				lb.			
V	39 Male....	−A+Ca.....	202 (died).....	70	802	0	0
	43 Male....		317 (died).....	131	1,408	0	0
	55 Female..		252 (killed).....	143	801	0	0
	48 Female..		237 (killed).....	155	1,044	588	613,872‡
VI	80 Male....	+A−Ca (yellow maize).....	150 (killed).....	88	622	50·4	31,349
	84 Male....		196 (killed).....	343	2,142	95·7	204,989
	82 Female..		196 (killed).....	280	2,246	73·8	165,755
	61 Female..		200 (killed).....	204	1,145	123·0	140,835
VII	37 Male....	+A+Ca (yellow maize).....	147 (killed).....	183	1,179	73·9	87,128
	58 Male....		140 (killed).....	168	1,414	24·6	34,784
	45 Female..		158 (killed).....	137	895	78·4	70,168
	40 Female..		158 (killed).....	123	1,006	46·2	46,477
VIII	38 Male....	+A+Ca (lucerne meal).....	151 (killed).....	195	1,481	32·8	48,577
	59 Female..		151 (killed).....	170	1,267	29·8	37,757
	88 Female..		129 (killed).....	274	1,945	80·6	156,767
	86 Female..		129 (killed).....	274	2,226	79·8	177,635

* The signs (−) = deficient; (+) = optimum; and (A) = provitamin A.

† Pig No. 42 received cod liver oil for the last 10 days, pig No. 30 for the last 101 days and pig No. 53 for the last 110 days on experiment (See also Table 4).

‡ These animals, after they started to show symptoms of vitamin A deficiency, were fed cod liver oil for various periods of time (for particulars see Table 4).

TABLE 6.

*Protein, Mineral and Carotene Contents of Dry Skim Milk-Grain Mixtures.**

Group No.	IV.	V.	VI.	VII.	VIII.
Proteins.....Per cent.	12·0	12·3	12·4	12·5	13·0
Calcium..... „	0·13	0·66	0·12	0·66	0·73
Phosphorus..... „	0·29	0·40	0·29	0·40	0·41
Ca : P ratio.....	·45 : 1	1·65 : 1	·45 : 1	1·65 : 1	1·78 : 1
Carotene, mg.....Per cent.	0·015	0·016	0·572	0·555	0·900
Outstanding type of ration†.....	−A−Ca	−A+Ca	+A−Ca (Yellow maize)	+A+Ca (Yellow maize)	+A+Ca (Lucerne maize)

* The skim milk and grain were fed in the proportion of 1 : 1, that is, 1 ml. of milk to every gram of grain. Skim milk contained 9·64 g. solids per 100 ml. of milk when dried at 100° C. The protein, calcium and phosphorus percentages of the rations were made on mixtures consisting of 100 g. air dry grain mixture plus 10 g. of air dry commercial skim milk powder containing 4 per cent. of moisture.

† The signs (−) = deficient; (+) optimum; and (A) = provitamin A.

TABLE 7.

Grams Hæmoglobin per 100 *ml. of Blood.*

Group Number.	Number of Animals Considered.	Days on Ration.					
		6.	47.	70.	105.	145.	Average.
IV	6*	12·41	11·70	12·69	12·10	11·42	12·06
V	3	13·83	11·69	12·09	10·03	10·59	11·65
VI	3	13·77	11·13	11·96	11·38	14·08	12·46
VII	4	13·89	11·55	12·42	10·51	12·84	12·24
VIII	4	13·33	12·18	13·36	14·23	13·08	13·23

* After the 70th day the haemoglobin figures of Group IV are averages of the values of three animals only.

TABLE 8.

Weight and Percentage Ash in Femurs of Young Pigs Fed Skim Milk and Maize Rations.

Group No.	Pig Number and Sex.	Type of Ration.*	Fresh Weight of Femurs.	Percentage of Ash in Dry Fat-free Femurs.
			Grams.	
IV	54 Male		—	54·22
	41 Male		—	52·39
Lot 1	57 Female		139·0	53·76
	50 Female	− A − Ca	105·0	55·26
	81 Female		240·0	62·94
Lot 2	83 Male		298·0	59·44
	85 Male		343·5	59·62
		AVERAGE	225·1	56·80
V	39 Male		157·0	61·44
	43 Male		234·5	60·78
	55 Female	− A + Ca	240·5	64·27
	48 Female		191·0	58·73
		AVERAGE	205·7	61·30
VI	80 Male		112·5	50·86
	84 Male		222·5	54·23
	82 Female	+ A − Ca (yellow maize)	210·5	57·98
	61 Female		201·0	55·29
		AVERAGE	186·6	54·59
VII	37 Male		199·0	62·26
	58 Male		209·5	62·80
	45 Female	+ A + Ca (yellow maize)	181·5	60·73
	40 Female		175·5	63·90
		AVERAGE	191·4	62·42
VIII	38 Male		228·0	60·26
	59 Female		216·0	62·03
	88 Female	+ A + Ca (lucerne meal)	264·5	60·56
	86 Female		258·5	61·55
		AVERAGE	241·7	61·10

* The signs (−) = deficient; (+) = optimum; and (A) = provitamin A.

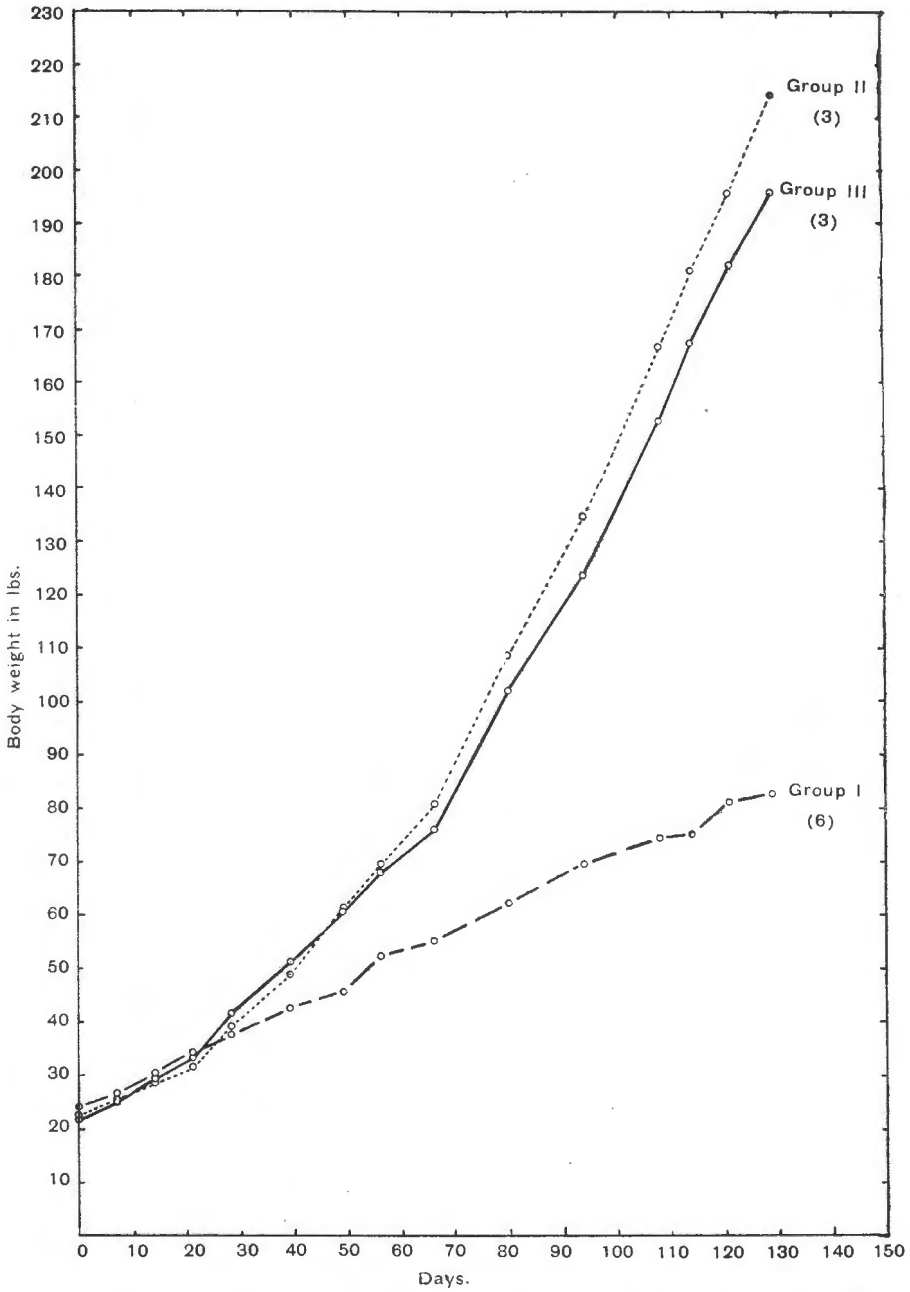

FIG. 1.—Graphs showing rate of growth of pigs in Groups I, II and III. Group I=low vitamin A (white maize); Group II=optimum (yellow maize meal); Group III=optimum (lucerne meal). These curves show that pigs on the vitamin A deficient ration made normal growth for the first month on experiment. For composition of rations see Table 1. The numbers in brackets show the number of animals considered.

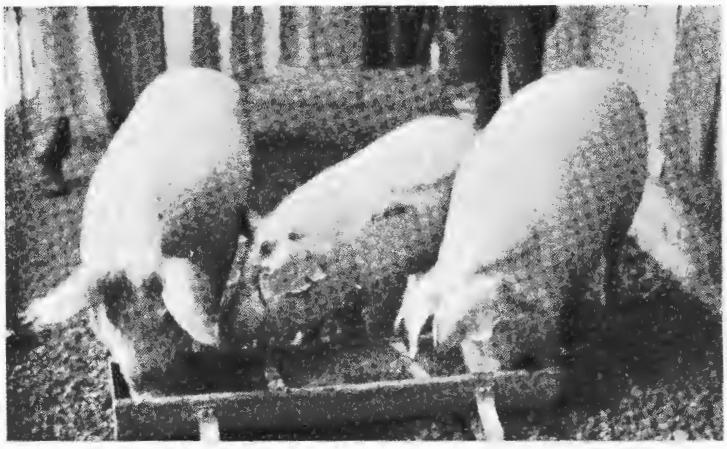

Fig. 2.—Three male litter mates after 129 days on experiment. Pig in centre (No. 44, Gr. I) received the vitamin A deficient ration; pig on right (No. 33, Gr. II) received carotene in yellow maize, and one on left No. 35, Gr. III) received carotene in lucerne meal.

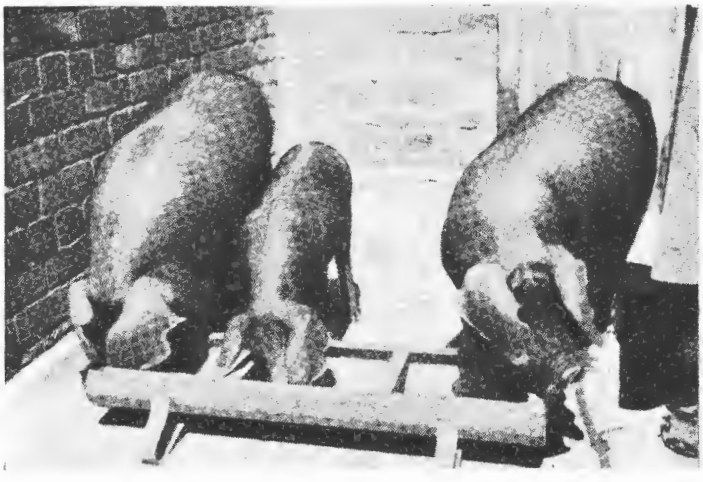

Fig. 3.—Three male litter mates after 129 days on experiment. Pig in centre (No. 30, Gr. I) received the vitamin A deficient ration; pig on right (No. 31, Gr. II) received carotene in yellow maize and one on left (No. 32, Gr. III) received carotene in lucerne meal.

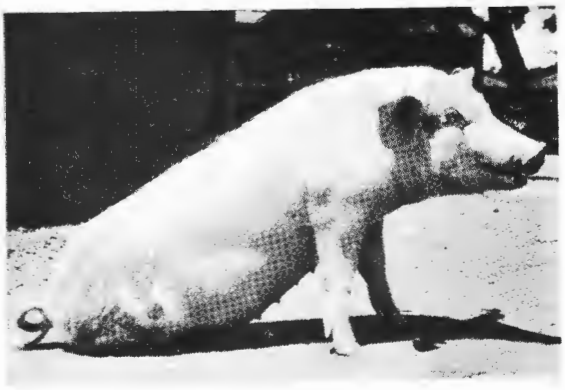

Fig. 4.—Pig 42 ♀, Gr. 1. Paralysis of hind-quarters after 129 days on the vitamin A deficient ration.

Fig. 5.—Pig ♀. Animal able to stand again after receiving 100 ml. cod liver oil daily for 10 days.

Fig. 6.—Pig 30 ♂, Gr. 1. Pig shows scoliosis and paralysis of forequarters after 186 days on the vintamin A deficient ration.

Fig. 7.—Pig 30 ♂. Animal able to stand again after receiving cod liver oil for 18 days. (For particulars see Table 5.)

Fig. 8.—Pig 30 ♂. Animal still shows scoliosis after 102 days of treatment with cod liver oil. (See Table 5.)

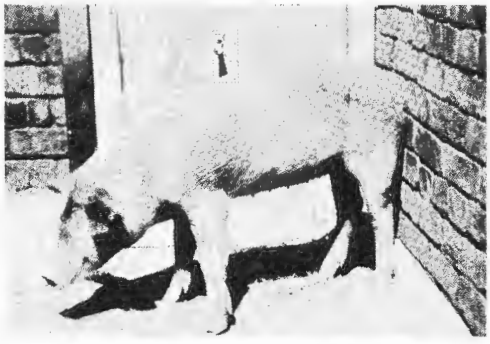

Fig. 9.—Pig 53 ♀, Gr. I. Animal made poor growth and appeared thin and leggy after 129 days on the vitamin A deficient ration.

Fig. 10.—Pig 53 ♀, after receiving 25 ml. cod liver oil daily for 121 days.

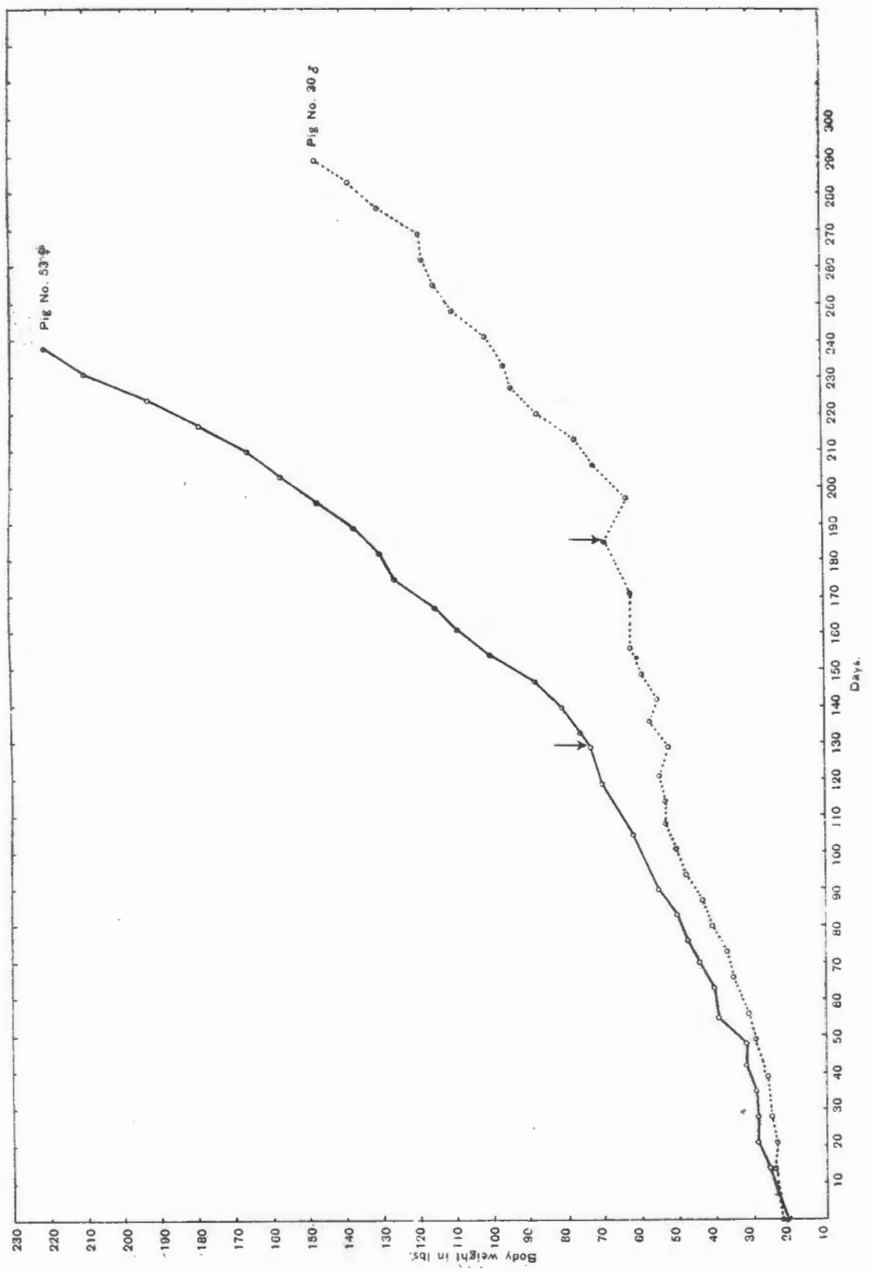

FIG. 11.—Graphs showing rate of growth of pigs 30♂ and 53♀ on vitamin A deficient ration (Ration I) before and during cod-liver oil supplementation. ⬇ Commencement of cod-liver oil feeding. Additions described in Table 5.

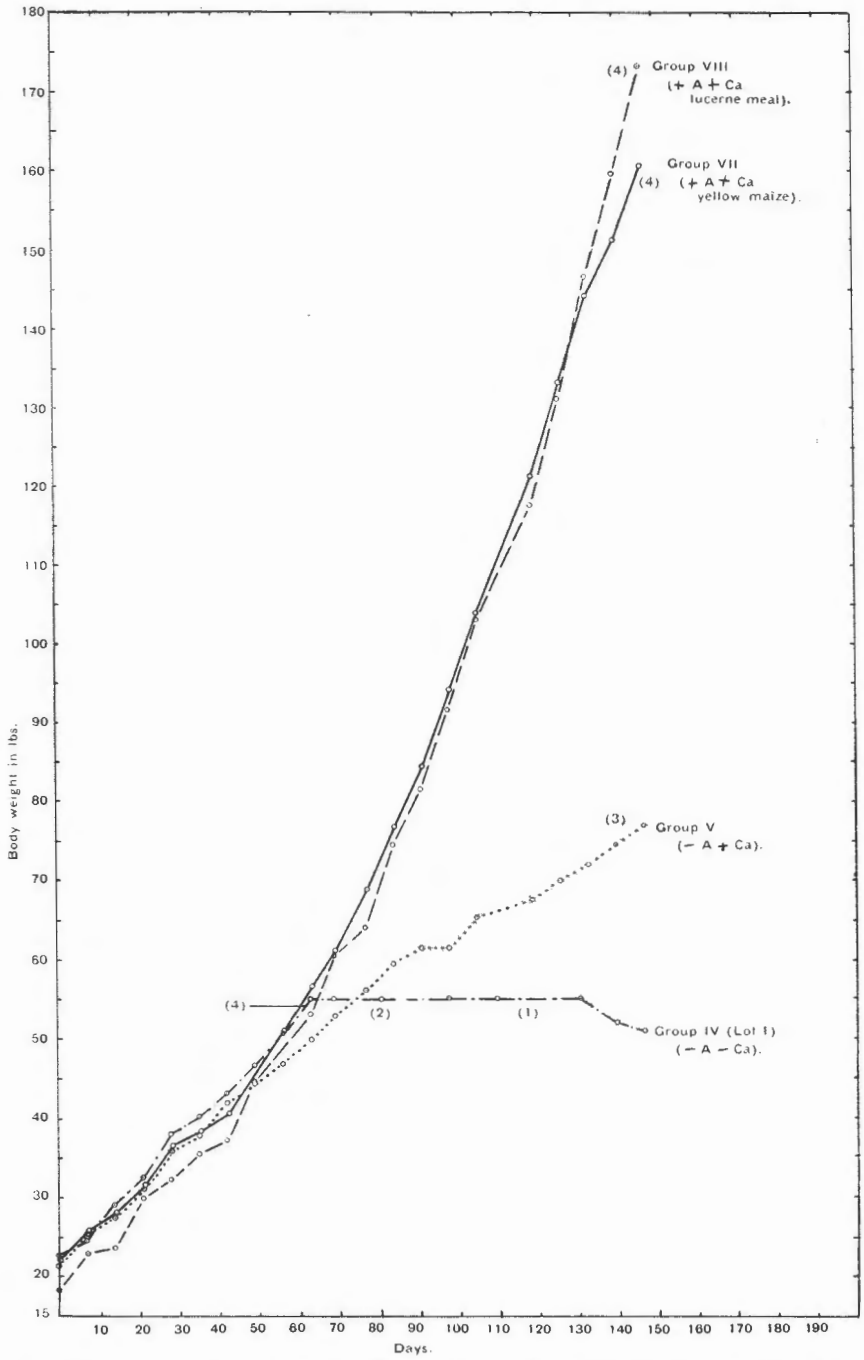

FIG. 12.—Graphs showing rate of growth of the pigs in Groups IV, lot 1, V, VII and VIII. Group IV, lot 1 = −A−Ca; Group V = −A+Ca; Group VII = +A+Ca (yellow maize meal); Group VIII = +A+Ca (lucerne meal). The signs (−) = deficient; (+) = optimum; and A = provitamin A. For composition of rations see Tables 8 and 9. N = number of animals considered. These curves show that the pigs on the vitamin A deficient rations made normal growth for the first two months on experiment. (Groups IV and V.) Unfortnuately two of the pigs in Group IV, lot 1, fractured their vertebral columns rather early in the experiment and the two remaining pigs in this group got infected with *Ascaris lumbricoides* which fact, no doubt, complicated the effects of the vitamin A and Ca deficient ration.

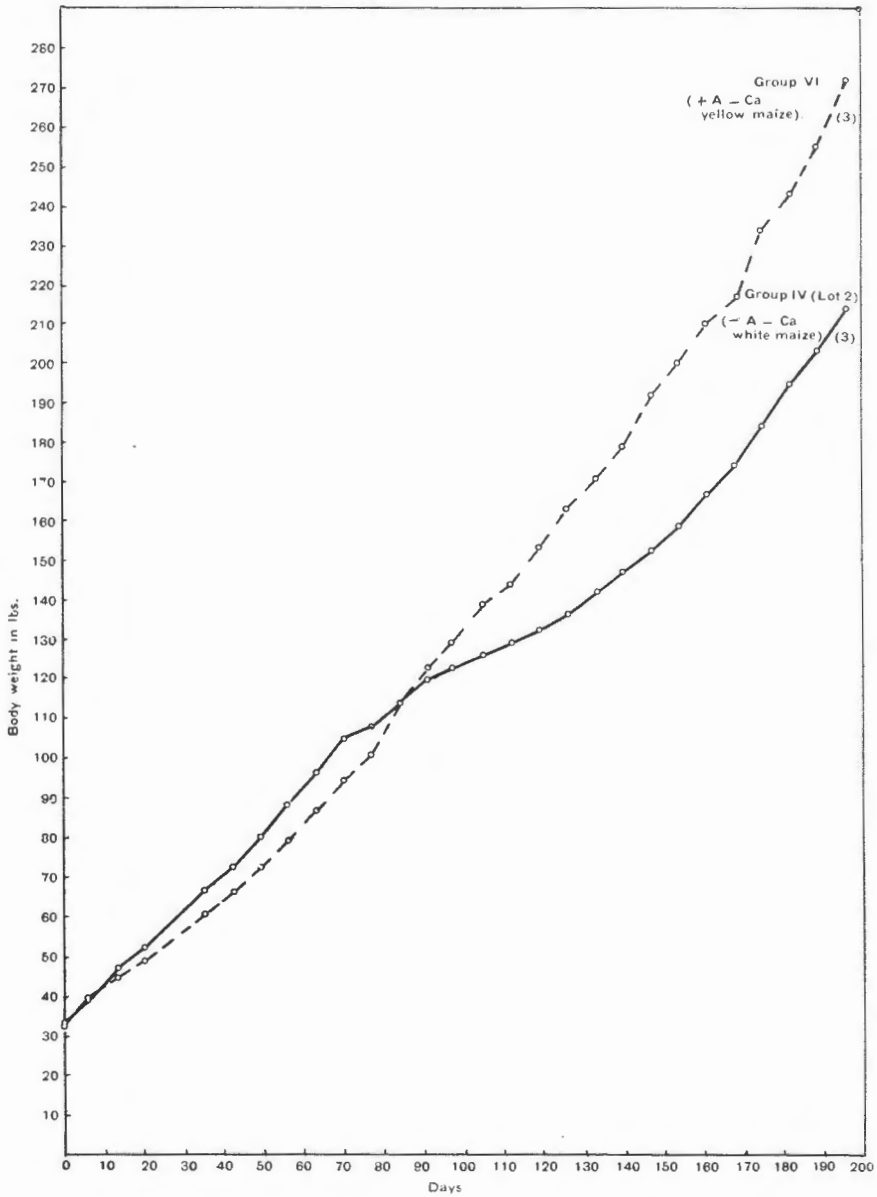

FIG. 13.—Graphs showing rate of growth of the pigs in Group IV, lot 2, and Group VI. Group IV, lot 2 = – A – Ca (white maize meal); Group VI = + A – Ca (yellow maize meal). The signs (–) = deficient; (+) = optimum; and A = provitamin A. For composition of rations see Tables 8 and 9. These curves show that the pigs on the vitamin A and Ca deficient ration made good growth for the first 80 days on experiment, whereas the pigs on the Ca deficient ration made good gains during the whole experimental period. N = number of animals considered.

Fig. 14.—Four hogs after 134 days on experiment. The two small pigs in centre (Nos. 39 and 43 Gr. V) were fed a vitamin A deficient ration of skim-milk, white maize and minerals; pig on left (No. 37, Gr. VII) received yellow maize, and one on right (No. 38, Gr. VIII) lucerne meal as the carotene containing ingredients.

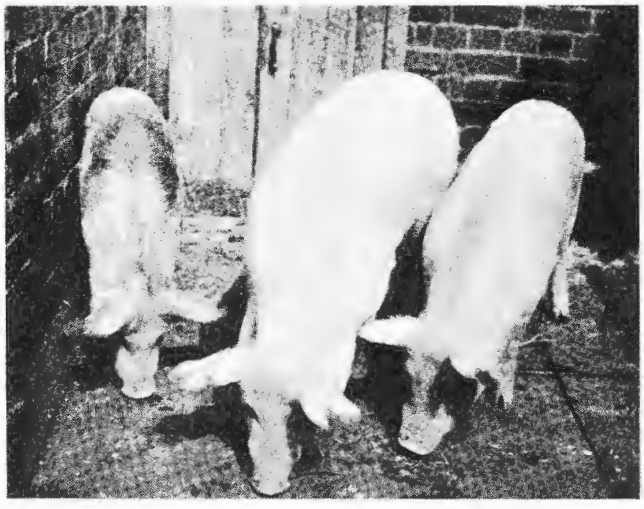

Fig. 15.—Three gilts (litter mates) after 134 days on experiment. Pig on left (No. 50, Gr. IV, lot 1) was fed a Ca and vitamin A deficient ration of skim-milk and white maize. This animal also suffered from *Ascaris lumbricoides* infection. Pig on right (No. 55, Gr. V) was fed a vitamin A deficient ration of skim-mink, white maize and minerals, whereas the pig in centre (No. 59, Gr. VIII) received a normal ration of skim-milk, white maize, lucerne meal and minerals.

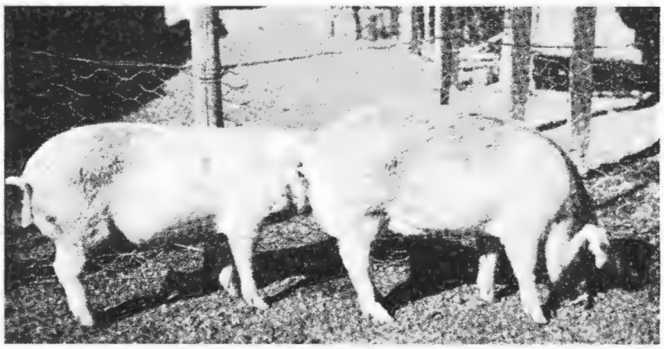

Fig. 16.—Gilts after 133 days on experiment. Pig on left (No. 81, Gr. IV, lot 2) received skim-milk and white maize, and pig on right (No. 82, Gr. VI) received skim-milk and yellow maize.

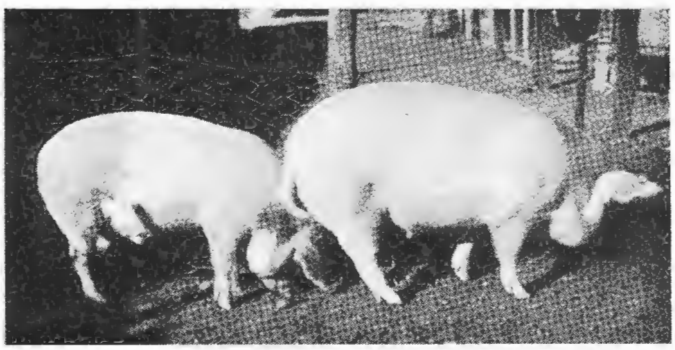

Fig. 17.—Hogs after 166 days on experiment. Pig on left (No. 83, Gr. IV, lot 2) received skim-milk and white maize, and one on right (No. 84, Gr. VI) received skim-milk and yellow maize.

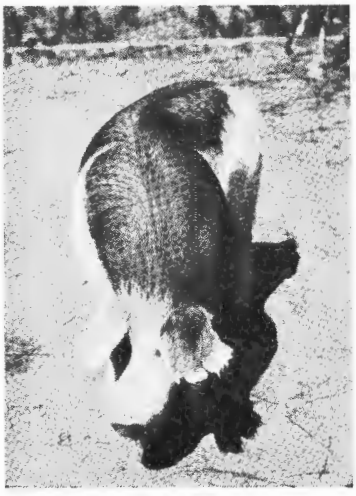

Fig. 18.—Pig 85 ♂, Gr. IV, lot 2, with severe scoliosis after 255 days on a Ca and vitamin A deficient ration of skim-milk and white maize.

Fig. 19.—Pig 85, Gr. IV, lot 2, after receiving cod liver oil for 37 days. Animal has recovered almost completely from scoliosis. (For particulars see Table 13.)

Fig. 20.—Pig 3. Gr. IV, lot 2, with partial "posterior paralysis" after 292 days on a Ca and vitamin A deficient ration of skim-milk and white maize.

Fig. 21.—Pig 83, Gr. IV, lot 2, after receiving cod liver oil for 37 days. (See Table 13.)

Fig. 22.—Pig 41 ♂, Gr. IV, lot 1. Paralysis of hindquarters as the result of a fractured vertebral column which happened 67 daws after commencement of experiment.

Fig. 23.—Pig 81 ♀, Gr. IV, lot 2. Nervous collapse after 279 days on a Ca and vitamin A deficient ration of skim-milk and white maize.

Fig. 24.—Pig 55 ♀, Gr. V. Posterior paralysis after 250 days on a vitamin A deficient ration of skim-milk, white maize and minerals.

Fig. 25.—Pig 43 ♂, Gr. V, after 316 days on a vitamin A deficient ration of skim-milk, white maize and minerals. Animal manifested a dirty, rough coat, runted appearance and drooping ears

Fig. 26.—Natural cases. Animals paralysed, dragging hindquarters.

Fig. 27.—Natural cases. Typical posture when at rest.