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A CHEMICAL STUDY OF THE NUTRITION OF SWINE

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One of the important problems of the Corn Belt is the economical use of corn. The feeding of corn *is* a problem because there are some purposes which it serves exceedingly well, and others which it serves very poorly. Swine are fed more largely on corn than on any other food, and a large percentage of the American corn crop is fed to swine. It is important, therefore, that we understand the specific effects of corn when fed to animals, especially to swine, and also the effects of those supplementary foods which are fed with corn. The object of this investigation was to furnish such evidence on this subject as could be obtained by balance experiments, in which by the chemical analysis of food and excreta, it is possible to determine the nutritive status of the animal with reference to each one of the food constituents. Thus, with reference to calcium: while fed on corn alone the growing pig receives in the food a certain amount of this element. In the urine and feces we find more calcium than was present in the food; that is, on corn alone the pig loses calcium; the calcium balance is negative. Such is the evidence.

Especial attention is given in this study to the mineral nutrients, because corn is deficient in some of these, and also to those supplementary foods which are used with corn, since they differ much in their ability to make good these mineral deficiencies.

This investigation as a whole was intended as a preliminary to a further and more extensive study of this problem, especially by feeding and carcass-analysis experiments. The observations cover the following points:

1. Digestion of foods.
2. The balance of mineral acids to bases.
3. Effects of magnesium on calcium metabolism.
4. The significance of creatinin excretion.
5. Mineral requirements and paths of elimination.

PLAN OF EXPERIMENT

Five cross-bred Yorkshire-Chester White barrows, 6 months old and all from the same litter, were the subjects of this experiment. Confined in metabolism crates they were taken through eight 10-day collection periods, separated by 7-day intervals on the next ration to follow, the change of food being made abruptly at the end of each collection period. The five animals were given the same food, our results, therefore, being based on five repeats.

The foods used in the several periods were as follows:

1. Corn.
2. Corn; soybeans.
3. Corn; linseed oil meal.
4. Corn; wheat middlings.
5. Corn; meat meal (digester tankage).
6. Corn; skim milk.
7. Corn.
8. Rice polish; wheat bran.

They were, therefore, the common practical foods for swine in this country, except ration No. 8, composed of rice polish and wheat bran, these feeds being selected on account of their very high content of magnesium in proportion to calcium. Corn was fed alone in the first and seventh periods to show any such changes as might be due to the long continued routine or to increasing age.

The observations covered the usual proximate analysis of foodstuffs and feces, daily nitrogen, creatinin and ammonia estimations on the urine, also determinations of the sodium, potassium, calcium, magnesium, sulphur, phosphorus and chlorine on foods, urines and feces, and further, a slaughter test on the five animals after the termination of the experiment.

METHODS OF EXPERIMENTATION

The metabolism crate used combines features from Gies's dog crate, Grindley's sheep crate, and McCollum's pig crate with ideas of our own, and was found to be entirely satisfactory for the purpose. Four of the crates are shown in Plate I, p. 227. The objects which we sought to attain in designing this crate were freedom of movement of the animal, free circulation of air, and the accurate collection, without admixture or contamination, of the excreta.

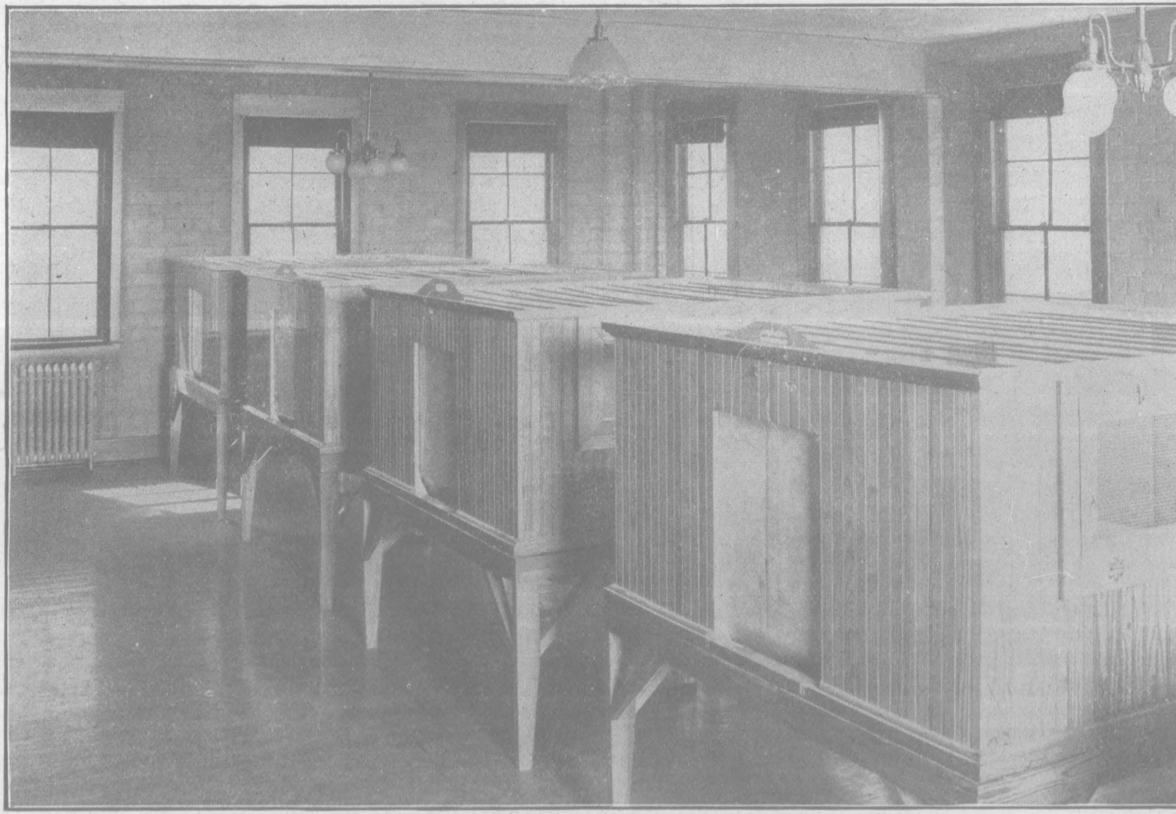

PLATE I Metabolism crates—Five such were used.

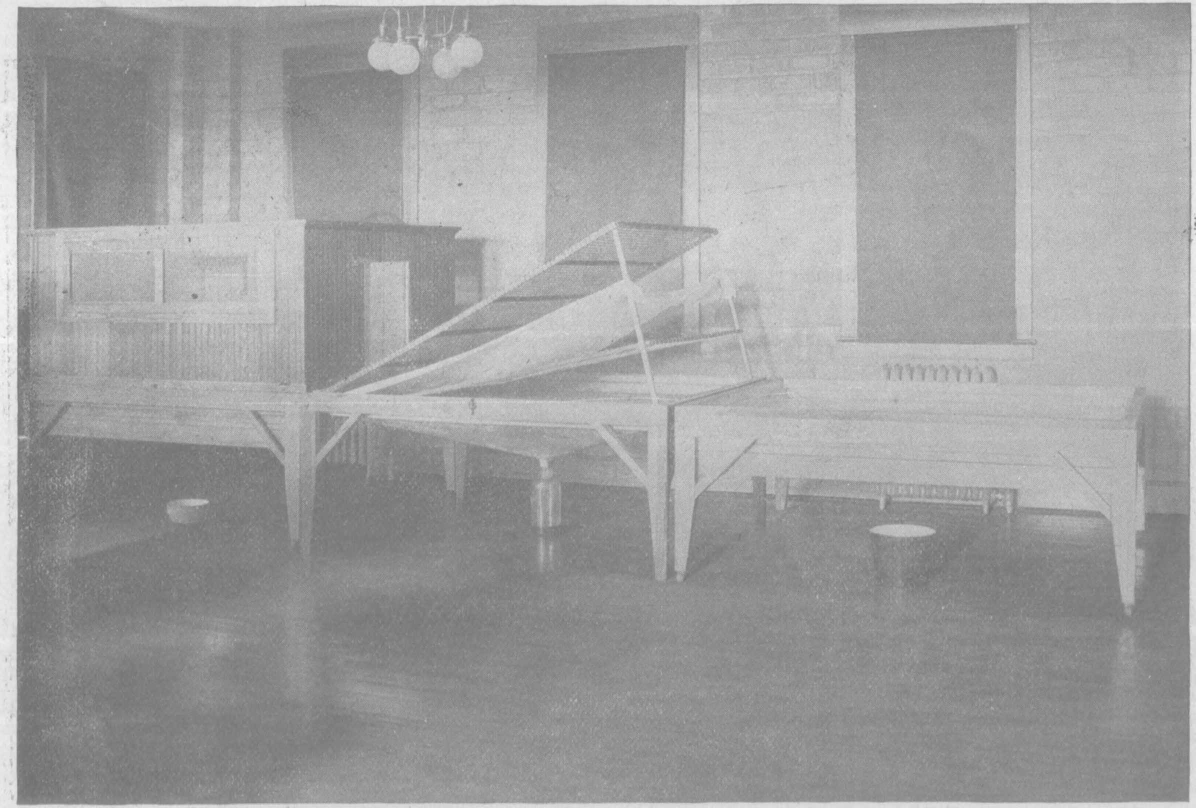

PLATE II Metabolism crate—Top removed, screens and cloth elevated.

PLATE III Metabolism crate, feed box, equipment for weighing.

In Plate II, p. 228, the removable crate, which runs on rollers, has been shoved over onto the cleaning table, the pig walking along with the crate, and the screens have been elevated to show their relation to one another. When in place, the light screen below rests four inches beneath the heavy upper one on which the pig stands. It is used simply to support a fine cloth which retains the feces but allows the urine to pass through into the hopper, and then through a plug of cotton into a bottle under the crate. The cotton and bottle are both treated with thymol. The drain table at the right is used in scrubbing the heavy screen. The two cleaning tables mentioned are covered with galvanized iron, and are built to drain to an outlet. They are on casters and are pushed from crate to crate for the daily cleaning and collection program.

Plate III, p. 229, shows the chute, weighing crate and scales used in weighing the pigs, and also a feed box. The food was placed in the boxes in another room, and the boxes were then attached to the crates with a single hook, each, after raising the sliding doors shown in Plate I. After the food was comsumed water was given in the same trough by pouring it in through the hole shown in the end of the feed box. This hole is closed with a slide door. Small amounts of food sometimes falling upon the little platform attached to the feed box were returned to the trough, and were consumed with the next feed.

The pigs were fed twice daily. The foods given during each period were all weighed at the beginning of the period, and samples for moisture and fat determination were taken at this time, complete analyses having been made before the beginning of the experiment.

Repeated attempts were made to apportion the food in accord with the creatinin elimination, and the water in accord with the amount of food, but we found it impracticable to adhere in all periods to the first principle, and the second was abandoned entirely, the desire of the animal for water standing in no definite relation to the food consumed. Water, therefore, was generally given *ad libitum*, but measured.

The pigs were scrubbed daily with distilled water to which was added a little phenol, but no account was taken of cutaneous elimination in the experimental work. During intermediate periods the pigs were scrubbed with soap.

Unless the pigs were washed frequently they became sticky and uncomfortable. Then they rubbed off hair which fell into the feces, and had to be picked out in the preparation of the samples for analysis.

One would naturally suppose that the comfort of so dirty an animal as a hog would require no washing, but as a matter of fact a pig does not prefer to be dirty. Because of his heavy overcoat of fat he wants first to be cool. To be cool, he must be wet. His only way to get wet, ordinarily, is to wallow in mudholes. Incidentally, he also frees his skin from its secretions, and thus completes his comfort.

By the use of wire brushes the feces were removed daily from the upper screen and from the cloth, and were placed in friction-top cans in a cooling room at about 0° F. The urine cloth was washed daily in boiling distilled water, as also were the lower screen and urine hopper. These washings were added to the urine sample. The heavy screen was scrubbed at the end of each 10-day period, and this wash water was also added to the urine sample.

The urine was collected morning and evening, and kept in a cooling-room at 32° F. Each morning the urines from the day before were measured, and aliquots taken out for preservation and for the daily determinations. The determination of the inorganic elements in the urines of the first period was omitted because of errors due to the precipitation of phosphates in the urine bottles. This difficulty was obviated in subsequent periods by the use of 10 c. c. of acetic acid in the day's urine on placing it in the cooler. The feces were marked by the feeding of carmine, and were sampled at the end of the period by grinding in a frozen condition, in a power sausage mill.

Chemical analyses were made in triplicate by methods as follows:

Moisture: Vacuum method, over sulphuric acid.

Nitrogen: Kjeldahl method; on foods and feces by the Gunning-Arnold-Dyer modification; on urine, according to Hawk.

Fat: Ether extract.

Ash: On foods by the hydrochloric acid leaching method; on feces by the water leaching method.

Crude fiber: Original; see Ohio Bul. 255.

Carbohydrates: By difference.

Metabolic nitrogen: Pepsin digestion method.

Urinary ammonia: Folin method, as modified by Steel.

Creatinin: Folin method.

Sodium: Original; see Ohio Bul. 255.

Potassium: Lindo-Gladding method.

Calcium: McCrudden's method.

Magnesium: McCrudden's method.

Sulphur: Peroxide and carbonate methods.

Chlorine: Provisional method of the A. O. A. C.

Phosphorus: Official gravimetric method after nitric-sulphuric acid digestion.

NOTES ON METABOLIC NITROGEN DETERMINATION

The nitrogen of the feces is found in (1) food residues, (2) bacteria, and products of their metabolism, (3) epithelium from the digestive tract and (4) residues from bile and digestive juices.

From this heterogeneous group of substances we desire to separate those portions which represent digestible food constituents. This fraction is of interest especially as giving us a basis for the determination of the amount of nitrogen in the feces which represents *indigestible* food constituents. The digestibility of the food nitrogen is determined by dividing its amount into the same, *minus* that of the indigestible feces nitrogen.

At best, from the nature of the case, this estimation embraces a considerable element of conventionality. Certainly no known method gives a scientifically accurate result; still there is considered to be ample warrant for the determination, in its practical usefulness.

The largest sources of error in the determination of metabolic nitrogen by the usual pepsin-hydrochloric acid method are as follows: (1) The indigestible food nitrogen may have become partially soluble in pepsin-hydrochloric acid during its passage through the alimentary tract. This factor would tend to exaggerate the metabolic nitrogen and thus to lead to overstatement of the digestibility of the food nitrogen. (2) The digestibility of bacteria and their metabolic products contributes to the determination an element of error the nature and degree of which have not been determined.

As to the practical accuracy of the method, we find one bit of evidence in our results. The nitrogen of skim milk, which presumably is practically all digestible, appears, from our results with the pepsin-hydrochloric acid method, to be digestible to the extent of 99.12 percent. The net error of the method, therefore, would seem not to be large.

BEHAVIOR OF THE ANIMALS

The progress of the experiment was marked by no unfavorable incidents of moment. The pigs remained in good health, and did not appear to suffer from the confinement. In hot weather they were kept comfortable with electric fans. The gain in weight was very satisfactory for pigs so fed, and it seems to use unlikely that such an investigation could well be carried out under more favorable circumstances than attended this series of experiments.

DIGESTION OF FOODS

The literature of animal husbandry is strikingly poor in data on the digestibility of foodstuffs by swine, and the experimental work upon which rest the very few figures available is exceedingly scanty.

The digestion coefficients which we are reporting (Table IX, p. 248) are based on five repeats, the detailed data being given in previous tables.

The digestibility of corn in the first and seventh periods is very nearly the same, the only notable difference being that the crude fiber of the corn in the seventh period seemed to be less digestible than in the first. In consideration of the small amount of crude fiber in corn this difference in digestibility in the two periods is of no importance.

The digestibility of the protein of the cereal and leguminous seed products is remarkably constant, the averages of results from the five individuals varying but two percent. The protein of meat meal, however, is several percent less digestible, and the protein of milk is several percent more digestible than the protein of the foods of vegetable origin. The low digestibility of the protein of the meat meal is perhaps due to the presence of hair and other refractory nitrogenous substances, or to the high degree of heat to which it is subjected.

The admixture of soybeans, meat meal or skim milk with corn so increases the digestibility of the starch of the corn that the apparent digestibility of the carbohydrates of the supplementary foods becomes over 100 percent.

In the same way meat meal and skim milk, when fed with corn cause such a decrease in feces ether extract as to make the digestibility of the fat of these foods apparently much more than perfect, the percentage of digestibility of the fat of skim milk seeming to be about 162 percent, and of the meat meal 139 percent, which facts suggest the prominence of bile residues in feces ether extract, and also the fact that the determination of digestibility of ether extract is, to borrow an expression from Thudichum, "a ceremonious delusion."

A still more anomalous condition exists with reference to the effect of meat meal and skim milk on the digestibility of the crude fiber of corn. These supplements so decrease the digestibility of the crude fiber of the corn with which they are fed that the crude fiber of meat meal which is present to the extent of 4 or 5 percent, because of the inclusion of a certain amount of paunch contents, seems to be digestible to the extent of 101 percent less than nothing, while the skim milk when fed with corn becomes chargeable with an extensive minus digestibility of crude fiber, of which, of course, it contains none at all. These effects of the supplementary feeds on the digestibility of the crude fiber of corn may be considered as an expression of their influence on the bacterial flora of the alimentary tract.

Digestion coefficients of less than nothing, and of more than 100 percent, show that the determination of digestibility of supplementary foods by difference, in the usual way, is not free from objection, since the supplement affects the digestibility of the basal ration, which the method assumes to be constant. It seems to us more nearly correct, however, to use the figures obtained than to call all minus coefficients zero, and to give a value of 100 percent to all those which seem to be above that figure.

In general our digestion coefficients are decidedly higher than the collected figures for some of the same foods as quoted by Henry in his "Feeds and Feeding."

Consideration of the magnitude of possible analytical errors and their bearing on the above results leads us to the conclusion that the anomalous character of the digestion coefficient for the nitrogen-free extract of soybeans is possibly, though not probably, due to experimental error. We are not able to account for any of the other coefficients of more than 100 or less than zero in this way. They apply, however, to constituents which are present in small amounts, and hence are not of great practical significance.

THE BALANCE OF MINERAL ACIDS TO BASES

Each of the rations contained an excess of acid to basic mineral elements. (See Table X, p. 249.) The magnitude of this acid-excess proves the pig to possess an extensive acid-neutralizing capacity.

The urinary ammonia excretion was found to vary directly with the excess acid of the ration (See Table X) provided that the protein of the ration remained about the same in amount, but any considerable increase in the latter also increased the urinary ammonia.

From the figures in Tables X, XI and XXI we do not see evidence of a close relation between calcium retention and either the excess of acid over basic mineral elements in the ration, or the urinary ammonia. This factor, therefore, seems not to be important in this connection in practical rations for swine, though of this fact we can not be certain, since we are unable to differentiate between the effects of calcium deficiency and acid excess.

With a constant calcium content such variations in mineral acidity as were present in these rations would doubtless affect calcium retention, but the variations in calcium intake in these cases were of so much greater magnitude than the variations in mineral acidity that the effects of the latter on calcium retention were not discernible.

The retention of calcium, however, (Table XII, p. 251) appears to be closely related both to the intake of calcium and to the ratio of calcium to magnesium in the food, stated in chemically equivalent units; but our evidence does not make it possible to judge with certainty of the relative influence of these two factors. The greater loss of calcium in Period VIII than in Periods II and VII, however, in spite of greater intake, is probably due to the much greater proportion of magnesium to calcium in the food. The excess of magnesium to calcium in Indian corn is probably not an important factor, since neither one was present in sufficient amount to maintain equilibrium in these growing pigs.

CREATININ EXCRETION IN SWINE

Creatinin excretion (See Tables X and XIII, pp. 249 and 251) was shown to be a definite function of the individual animal, to increase with the growth of the animal, and to be entirely independent of the amount or kind of food.

A slaughter test at the end of the experiment (See Table XIII) showed that the five individuals compared with one another as to creatinin excretion in exactly the same order as with regard to the weight of each of the following: the live animal, the dressed carcass, the total flesh, the blood, and the bones. In regard to the internal organs, brain, lungs, liver, kidneys, and spleen, we failed to note such a regular correspondence with creatinin excretion.

During the first and seventh periods the pigs were fed on corn alone, the amount fed in the seventh period being slightly less than the amount fed in the first. In the seventh period, however, the pigs weighed 2½ times as much as in the first, and they excreted 2½ times as much creatinin. The relative creatinin excretion of the five pigs remained practically the same during five months.

These observations are in harmony with the conclusion of Folin that the creatinin of the urine is a product of endogenous nitrogen metabolism.

MINERAL REQUIREMENTS AND PATHS OF ELIMINATION

The extensive series of mineral balances in Tables XIV-XX show that in such a variety of practical rations it is impossible to reckon mineral requirements in a definite way, the reason being that the amount of a given mineral element necessary to maintain equilibrium is much affected by the other constituents of the ration. An amount which is quite sufficient for maintenance, or which even provides for marked retention, may be quite insufficient for maintenance under other dietary conditions. We shall, then, place emphasis more especially on the foodstuffs, as such, in relation to mineral balances, than upon the amount of their mineral constituents.

Table XXI sets forth the average daily rations and mineral balances for the five pigs together for each period; Table XXII shows the relative outgo of the several mineral elements in urine and feces as affected by the foods used in the different periods; and Table XXIII is a similar presentation, but with the retention, or loss, included; that is, urine, feces and retention (or loss) are all expressed in percentages of the intake.

Salt was fed in all periods at a uniform rate of one part, by weight, to 256 parts of other food, except that the skim milk fed in Period VI was not considered in this connection. This allowance of salt seems to be more than sufficient to maintain equilibrium.

The balance of intake to outgo of sodium was much affected by the water drunk. Those individuals which drank the least water in proportion to sodium intake retained the most sodium. Those which drank the most water retained the least sodium, and eliminated the largest proportion of the sodium intake in the urine. We are not able to explain the slight negative balances of sodium in Periods V and VII (see pp. 255 and 257), but incline to ascribe them to influence of temperature, respiration, perspiration and water drinking, and therefore to consider them as not particularly significant.

A large sodium intake (see Table XXI, p. 259) increases the feces sodium as well as the urine sodium, but not to nearly so great an extent. Much less than half of the sodium outgo is usually contained in the feces; but in one period, during the feeding of the ration of wheat bran and rice polish, the feces contained 46 percent of the outgoing sodium, accompanied by a very small amount of chlorine. The peculiarities of the mineral metabolism on this ration were enormous urinary potassium (an average of 15 grams per day) unaccompanied by equivalent amounts of mineral acid, and a like excessive amount (14.9 gm.) of feces phosphorus accompanied by magnesium and other bases in abundance.

As with sodium, so with chlorine, the pigs which drank little water retained much of the element. The chlorine balances were almost all positive, but did not vary at all closely with the sodium. The only negative chlorine balances were on the meat meal ration during the maximum chlorine intake of the whole series. The feces usually contain less than one percent of the outgoing chlorine.

In the light of these results it is suggested that the salt retention of fever may be, in part, due to the relation of water to salt-balance. With elevated temperature and increased respiration the water intake may be insufficient to meet the increased outgo.

The potassium balances were all positive except during the period of greatest intake, on a ration of wheat bran and rice polish; here they were all negative. With the minimum intake of 5.9 gm. of potassium on corn alone there was a retention of 1-1.5 gm. of this element, but with an intake of 17.5 gm. on rice polish and wheat bran, there was loss. On this intake of 17.5 gm. per day there was an outgo of 15 gm. through the urine, as we have said before, unaccompanied by corresponding amounts of mineral acid, the urine thus possessing the general character of that of the herbivora. This negative balance of potassium may be considered as due to an over-response of the organism in its protective elimination of the excessive amount of potassium absorbed. Probably the entire loss of potassium represents storage in excess of the requirement during previous periods on other rations. The urinary excretion shows that the loss is not due either to a failure of the animal to digest and absorb potassium or to a reexcretion into the intestine, and the large retention of phosphorus coincident with a loss of calcium would favor potassium retention.

Urinary excretion of potassium is low if the retention is high, and is high if the retention is low. The proportion of potassium to sodium in the intake did not determine the proportion of urine to feces sodium, nor the outgo of sodium.

All of the sulphur balances in these experiments were positive. The greatest sulphur retention occurred during the periods of greatest calcium retention, and the lowest sulphur retention likewise was during low calcium retention. So close a correspondence of nitrogen and sulphur retention was not observable. The urinary sulphur is usually much greater than the feces sulphur, but may be less in individual cases. This proportion is much affected by the kind of food, but also, in prominent ways by individuality.

On the rations containing meat meal and milk, and on these only, calcium storage was liberal. In this connection we would mention the considerable bone content of the meat meal. Grain foods were shown to be more deficient in calcium than in any other of the mineral elements studied. This means that under ordinary farm conditions the use of forage crops is necessary to furnish the calcium in which the grains are deficient. On a cereal diet calcium starvation is the rule.

The negative calcium balance on corn alone was to be expected, but the negative balance on corn and soy beans was a surprise. With each pig on this ration the feces alone contained more calcium than the food. It is not known if this fact is at all related to the high fat-content of the soy beans, or to indigestibility of their calcium compounds; but soy beans are not rich in calcium; at best they could not possibly sustain liberal calcium retention. The high calcium content of leguminous plants as a whole is much more characteristic of their leaves and stems than of their seeds.

It is not apparent that in any case an abundance of feces phosphorus is responsible for negative calcium balances.

The magnesium balance was not at all closely in accord with the intake. On about 2.25 gm. intake with soy beans there was retention; with about 9.25 gm. intake on wheat bran and rice polish there was loss. The magnesium loss was through the feces. This high fecal outgo of magnesium seems to have been due in part to the enormous phosphorus intake, but apparently not to this factor alone.

The magnesium of the food is shown to be a prominent factor in the partition of the phosphorus between urine and feces, an increased proportion of magnesium to phosphorus in the food increasing the proportion of feces phosphorus to urine phosphorus. There was no such prominent effect of magnesium to restrict phosphorus retention.

Magnesium balances were negative on the rations containing linseed oil meal, meat meal, rice polish and wheat bran, and also on the ration of corn alone. Magnesium was retained only from rations containing soy beans, wheat middlings and skim milk. That magnesium should be so commonly deficient in these practical rations is surprising.

The phosphorus balances in these experiments were all positive except for one individual on the ration of corn alone. In no case, however, was there any considerable retention of phosphorus on this ration. Except in one case the phosphorus retention in the several periods was in the same order as the intake. This exception was the ration containing wheat middlings. The peculiarity of the phosphorus of this ration was a large proportion of triticonucleic acid, and the phosphorus of this ration was much less efficiently retained than the phosphorus of the rations containing meat meal and milk. With a much smaller intake of phosphorus in meat meal and milk the retention was much greater. Two circumstances unfavorable to phosphorus retention in the wheat middlings ration were the presence of much less calcium and much more magnesium than in the meat meal and milk rations. The results were increase in both urine and feces phosphorus.

During the feeding of skim milk there were lower proportions of potassium, magnesium, sulphur, chlorine and phosphorus in the feces than during any other period; and this period was also characterized by the maximum percentage retention of the calcium, magnesium, sulphur and phosphorus intake.

Corn is shown to be more deficient in calcium than in any other nutrient; its magnesium content is also low, and its phosphorus content allows of but slight retention. At the same time the nitrogen retention is quite considerable. It is true that the pigs were not on what would ordinarily be considered as full feed, but we do not believe that this fact decreases the significance of our results, since the amount of corn consumed was sufficient to provide for considerable nitrogen storage. In spite of the slight retention of phosphorus we consider its amount insufficient, since we have here hardly more than the requirement for maintenance, at a time of life which would naturally be characterized by extensive storage of phosphorus.

The results, in general, show that the mineral requirements of swine are apt not to be satisfied during cereal feeding. A dry-lot fattening process probably involves, as a rule, considerable draft upon mineral stores previously accumulated during periods of access to green feeds.

Other ideas than those in this article, have been expressed, regarding the nutritive deficiencies of corn. Thus T. B. Osborne (Science, Jan. 31, 1913) writes:

"The results here presented leave no doubt that the deficiency observed in the practical feeding of corn meal is explained largely, if not wholly, by the unique chemical constitution zein which forms such a large part of its proteins."

Our results show that, whatever the protein deficiencies of corn, its mineral deficiencies are more pronounced, since, in balance experiments, the deficiencies in calcium and other minerals are immediately made manifest by negative balances or deficient storage, while the protein deficiencies, whatever their nature, allow liberal nitrogen retention.

A considerable degree of independence exists between nitrogen and mineral metabolism, such that, for limited periods, mineral retention may occur coincident with nitrogen loss, but a complete final dependence of mineral retention on nitrogen metabolism is suggested by the work of Gregersen (Zeitschr. physiol. Chem. 71 (1911), 49-99) who found, in experiments with rats that, no matter how great the need for phosphorus, there was no phosphorus retention even from an overabundant intake, if this was furnished with a *nitrogen-free* ration.

In the light of this work it is not difficult to understand that, whatever the fundamental protein deficiency of corn, when an animal has been confined to a corn diet until the disturbance to nitrogen metabolism has become acute, we need not look for marked improvement from the giving mineral nutrients, especially in an inorganic form.

From a practical point of view only those nutritive deficiencies of corn are of importance which are still manifest in the mixed rations in which corn is used. Successful farmers long since ceased feeding corn by itself to any animal, except under such conditions as allow the animal to pick up for himself in other foods those nutrients in which corn is deficient.

We all know that for practical feeding purposes the protein of corn is deficient in amount. We have also been shown that zein, the principal, but by no means the only protein in corn is, *by itself* an incomplete food, in the sense of being unable to sustain growth in rats, but we have no evidence that corn possesses protein deficiencies which remain manifest in the practical mixed rations in which we use corn.

These balance experiments show that the mineral deficiencies of corn are also to a large extent characteristic of the practical mixed grain rations in which many successful farmers use corn for hogs. It is true that in these experiments our periods were short, though they were longer than in most such investigations. The five repeats, however, are thought to go a long way toward protecting us from fair criticism on the ground of insufficiency of evidence. In considering the desirability of longer collection periods and more data it may be enlightening to some of our readers to learn that this experiment represents a full year's work for four men.

SUMMARY

Five pigs from the same litter, were used in a metabolism experiment involving eight 10-day collection periods, separated by 7-day intervals.

The foods used were corn alone in Periods I and VII; corn supplemented by soy beans, linseed oil meal, wheat middlings, meat meal (digester tankage) and skim milk in Periods II to VI, and a ration of rice polish and wheat bran in Period VIII.

The most important result of this investigation is the demonstration of the unsatisfactory character of corn, wheat middlings, linseed oil meal, soy beans, wheat bran and rice polish as sources of calcium for growing swine. Rations composed of these foods will not maintain normal growth of bone. The bony framework determines the size of the animal, and has much to do with determining its strength.

These pigs stored *9 to 10 times as much* calcium from rations containing milk and meat meal as from *the best one* of the rations of grain alone. These results emphasize the importance not so much of milk and of tankage as of *pasture*, *forage crops* and *dry roughage*, especially of leguminous plants, for these are our cheapest sources of those nutrients which the grain foods are shown to lack.

The important deficiencies of corn are considered to be calcium, phosphorus and nitrogen.

Phosphorus balances were positive, that is, phosphorus was stored on all rations, but phosphorus was insufficient for maximum growth in the ration of corn alone.

In the ration of rice polish and wheat bran, which contained 12 times as much magnesium as calcium, the excess of magnesium appeared to cause a loss of calcium from the animal. In the usual practical rations, however, this effect is not apparent.

These practical rations all contained an excess of acid over basic mineral elements. This excess acidity, however, did not appear to affect calcium retention, though we are not able certainly to distinguish between the effects of acid excess and calcium deficiency.

The ammonia of the urine was found to increase with the excess mineral acidity and the total protein of the ration.

One part of salt to 256 parts of other food seems to be more than sufficient for growing swine.

The balances of sodium and chlorine were largely controlled by the amount of water drunk.

There is an extensive metabolism of sodium apart from chlorine. The feces may contain an abundance of sodium but are nearly free from chlorine.

Magnesium tends to deflect the phosphorus excretion from urine to feces, and excessive phosphorus content of the ration limits the absorption of magnesium. With an intake of 2.17 gm. magnesium and 5.40 gm. phosphorus there was storage of magnesium; with an intake of 9.28 gm. magnesium and 20.71 gm. phosphorus there was loss of magnesium, combined with phosphorus, through the feces.

The potassium of these rations was more than enough in all cases. With the maximum intake, however, on the ration of wheat bran and rice polish, there was a loss of potassium, apparently through an excretion of previously stored excess.

The urinary potassium varies inversely as the retention.

Nitrogen and sulphur balances were all positive.

Sodium, potassium, sulphur and chlorine were excreted in larger proportion in the urine than in the feces, while calcium, magnesium and phosphorus left the body more largely in the feces.

The digestibility of the starch of corn is increased by the feeding with it of soy beans, tankage and milk. Tankage and milk also increase the digestibility of the fat, and decrease the digestibility of the crude fiber of corn.

Creatinin excretion in the urine was shown to be entirely independent of the food, and to vary among the several individuals in the same order as live weight, and weight of dressed carcass, flesh, bones and blood.

TABLE I. Composition of Foods—Percent Fresh Basis.

Foods	Moisture	Protein (Nx6.25	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Corn (Period I)	10.425	9.074	72.349	4.048	2.841	1.263	0.355	0.027	0.013	0.113	0.153	0.065	0.271
" (" II)	10.565	9.060	72.236	4.042	2.837	1.261	0.354	0.027	0.013	0.113	0.153	0.065	0.271
" (" III)	10.500	9.066	72.288	4.045	2.839	1.262	0.354	0.027	0.013	0.113	0.153	0.065	0.271
" (" IV)	11.110	9.005	71.796	4.017	2.820	1.253	0.352	0.027	0.013	0.112	0.152	0.065	0.269
" (" V)	11.315	8.984	71.630	4.008	2.813	1.250	0.351	0.027	0.013	0.112	0.152	0.065	0.269
" (" VI)	"	"	"	"	"	"	"	"	"	"	"	"	"
" (" VII)													
Soy beans	7.385	40.706	21.951	18.465	4.995	5.155	1.982	0.5692	0.20764	0.2358	0.4208	0.0331	0.635
Linseed oil meal	9.305	35.922	31.191	6.391	11.329	5.862	1.1101	0.256	0.366	0.493	0.413	0.086	0.713
Wheat middlings	10.915	18.859	54.921	5.203	5.977	4.125	1.022	0.166	0.096	0.383	0.234	0.026	0.877
Meat meal	9.500	58.302	3.236	9.193	4.339	15.430	0.544	1.656	2.934	0.144	0.605	2.432	1.619
Skim milk	90.410	3.211	5.520	0.177	......	0.687	0.122	0.047	0.128	0.014	0.034	0.091	0.094
Rice polish	11.127	12.475	53.296	12.770	3.200	7.132	1.1370	0.1100	0.0267	0.6585	0.168	0.134	1.497
Wheat bran	10.020	15.750	55.300	4.260	8.620	6.060	1.320	0.201	0.125	0.531	0.267	0.090	1.110
Salt	0.000	......	......	......	......	......	0.000	38.220	0.240	0.000	0.160	59.130	0.000

Composition of Foods—Dry Basis

Foods	Moisture	Protein (Nx6.25	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
Corn	......	10.130	80.769	4.519	3.172	1.410	0.396	0.030	0.014	0.126	0.171	0.073	0.303
Soy beans	......	43.952	25.152	19.937	5.393	5.566	2.140	0.615	0.224	0.255	0.454	0.036	0.686
Linseed oil meal	......	39.607	34.392	7.047	12.491	6.463	1.224	0.282	0.403	0.544	0.455	0.095	0.786
Wheat middlings	......	21.170	61.650	5.841	6.709	4.630	1.147	0.186	0.108	0.430	0.263	0.029	0.984
Meat meat	......	64.422	3.576	10.158	4.794	17.050	0.601	1.830	3.242	0.159	0.669	2.687	1.789
Skim milk	......	33.493	57.498	1.841	.....	7.168	1.272	0.488	1.336	0.146	0.357	0.953	0.979
Rice polish	......	14.036	61.097	13.243	3.600	8.024	1.279	0.124	0.030	0.741	0.189	0.151	1.684
Wheat bran	......	17.500	61.460	4.730	9.580	6.730	1.460	0.223	0.139	0.590	0.297	0.100	1.230

TABLE II. Total Foods Consumed—Grams Fresh Basis.

Periods	Foods	Pig I	Pig II	Pig III	Pig IV	Pig V
I 12 days	Corn Salt	16567 64.968	24862 97.500	20655 81.000	14720 57.724	22749 89.211
II 10 days	Corn Soy beans Salt	10459 2092 49.219	17266 3453 81.250	14942 2988 70.313	10973 2195 51.641	14219 2844 66.914
III 10 days	Corn Linseed oil meal Salt	13945 2789 65.625	19257 3852 90.625	17266 3453 81.250	13281 2656 62.500	15772 3154 74.219
IV 10 days	Corn Wheat middlings Salt	10133 7645 69.719	11713 8836 80.586	12298 9277 84.609	10442 7878 71.842	10949 8259 75.324
V 10 days	Corn Meat meal Salt	14995 1500 64.688	20393 2039 87.969	18219 1822 78.593	15448 1545 66.640	16209 1621 69.922
VI 10 days	Corn Skim milk Salt	15599 31751 61.172	19145 38968 75.078	18687 38036 73.277	13866 28224 54.375	17113 34833 67.109
VII 10 days	Corn Salt	15599 61.172	19145 75.078	18687 73.281	13866 54.375	17113 67.109
VIII 10 days	Rice polish Wheat bran Salt	11699 3900 61.172	....	....	10399 3467 54.375	11206 3735 58.594

TABLE III. Total Foods Consumed—Grams Dry Matter

Periods	Foods	Pig I	Pig II	Pig III	Pig IV	Pig V
I	Corn Salt	14839.9 64.968	22270.1 97.500	18501.7 81.000	13185.4 57.724	20377.4 89.211
II	Corn Soy beans Salt	9354.0 1937.5 49.219	15441.8 3198.0 81.250	13363.4 2767.3 70.313	9813.7 2032.9 51.641	12716.8 2634.0 66.914
III	Corn Linseed oil meal Salt	12480.8 2529.5 65.625	17235.0 3493.6 90.625	15453.1 3131.7 81.250	11886.5 2408.9 62.500	14115.9 2860.5 74.219
IV	Corn Wheat middlings Salt	9007.2 6810.5 69.719	10411.7 7871.6 80.586	10931.7 8264.4 84.609	9281.9 7018.1 71.842	9732.6 7357.5 75.324
V	Corn Meat meal Salt	13298.3 1357.5 64.688	18085.5 1845.3 87.969	16157.5 1649.0 78.593	13700.1 1398.2 66.640	14375.0 1467.0 69.922
VI	Corn Skim milk Salt	13834.0 3044.9 61.172	16978.7 3737.0 75.078	16572.6 3647.7 73.277	12297.1 2706.7 54.375	15176.7 3340.5 67.109
VII	Corn Salt	13834.0 61.172	16978.7 75.078	16572.6 73.281	12297.1 54.375	15176.7 67.109
VIII	Rice polish Wheat bran Salt	10397.3 3509.2 61.172	....	....	9241.9 3119.6 54.375	9959.1 3360.8 58.594

TABLE IV. Total Food Constituents—Grams Dry Matter.

Period No.	Pig No.	Protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
I	1	1503.3	11986.0	670.6	470.7	209.2	58.766	29.283	2.234	18.698	25.480	49.246	44.965
	2	2256.0	17987.3	1006.4	706.4	314.0	88.190	43.946	3.352	28.060	38.238	73 909	67.478
	3	1874.2	14943.6	836.1	586.9	260.9	73.267	36.509	2.784	23.312	31.768	61.401	56.060
	4	1335.7	10649.7	595.8	418.2	185.9	52.214	26.018	1.985	16.614	22.639	43.757	39.952
	5	2064.2	16458.6	920.9	646.4	287.3	80.695	40.213	3.067	25.676	34.988	67.632	61.744
II	1	1799.2	8042.4	809.0	401.2	239.7	78.505	33.534	5.768	16.727	24.870	36.629	41.634
	2	2969.9	13276.6	1335.4	662.3	395.7	129.584	55.355	9.521	27.612	41.054	60.467	68.727
	3	2570.0	11489.5	1155.6	573.1	342.4	112.139	47.902	8.239	23.895	35.528	52.327	59.475
	4	1887.6	8437.7	848.8	420.9	251 6	82.366	35.183	6.052	17.549	26.093	38.431	43.682
	5	2445.9	10933.7	1099.8	545.5	325.9	106.727	45.589	7.841	22.740	33.811	49.797	56.601
III	1	2266.2	10950.5	742.3	711.9	339.5	80.385	35.959	12.099	29.486	32.956	50.318	57.699
	2	3129.6	15122.0	1025.0	983.1	468.8	111.013	49.660	16.710	40.722	45.513	69.488	79.680
	3	2805.8	13558.4	919.0	881.4	420.3	99.527	44.521	14 979	36.507	40.804	62.299	71.483
	4	2158.2	10429.3	707.0	677.9	323.3	76.556	34.247	11.522	28 081	31.386	47.921	54.950
	5	2562.8	12385.1	839.8	805.1	383.9	90.912	40.668	13.682	33.346	37.273	56.908	65.254
IV	1	2354.2	11473.7	804.8	742.6	442.3	113.785	42.018	8.783	40.634	33.426	49.775	94.244
	2	2721.1	13262.2	930.3	858.4	511.3	131.517	48.565	10.152	46.967	38.635	57.535	109.004
	3	2857.0	13924.4	976.7	901.3	436.7	138.083	50.990	10.659	49.311	40.563	60.406	114.445
	4	2426.0	11823.5	829.3	765.2	163.4	117.254	43.297	9.051	41.873	34.445	51.291	97.182
	5	2543.5	12406.8	869.6	802.3	171.3	122.932	45.384	9.490	43.900	36.114	53.778	101.888
V	1	2221.6	10789.4	738.9	486.9	419.0	60.820	53.555	46.027	18.924	31.926	84.434	64.580
	2	3020.9	14673.5	1004.7	662.2	569.6	82.709	72.817	62.568	25.722	43.412	114.801	87.811
	3	2699.1	13109.3	897.7	591.6	509.4	73.894	65.062	55.912	22.980	38.787	102.576	78.458
	4	2288.5	11115.4	761.1	501.6	431.6	62.655	55.167	47.408	19.485	32.888	86.975	66.525
	5	2401.3	11663.0	798.6	526.3	452.8	65.742	57.883	49.741	20.446	34.507	91.257	69.801
VI	1	2421.2	12924.4	681.3	438.8	413.4	93.514	42.389	42.764	21.877	34.624	75.288	71.727
	2	2971.5	15862.2	836.1	538.6	507 3	114.771	52.026	52.483	26.849	42.490	92.402	88.030
	3	2900.5	15482.9	816.1	525.7	495.2	112.026	50.779	51.229	26.207	41.478	90.190	85.926
	4	2152.2	11488.5	605.5	390.1	367.4	83.126	37 680	38.015	19.446	30.778	66.924	63.759
	5	2656.2	14178.8	747.3	481.4	453.4	102.591	46.504	46.915	24.000	37.985	82.596	78.688
VII	1	1401.4	11173.6	625.2	438.8	195.1	54.783	27.530	2.084	17.431	23.754	46.270	41.917
	2	1719.9	13713.5	767.3	538.7	239.3	67.236	33.789	2.557	21.393	29.154	56.789	51.446
	3	1678.8	13385.5	748.9	525.7	233.7	65.627	32.980	2.496	20.881	28.456	55.429	50.215
	4	1245.7	9932.2	555.7	390.1	173.4	48.696	24.471	1.852	15.494	21.115	41.129	37.260
	5	1537.4	12258.1	685.8	481.4	214.0	60.100	30.202	2.286	19.123	26.059	50.761	45.985
VIII	1	2073.5	8509.2	1542.9	710.5	1070.5	184.215	44.098	8.145	97.748	30.171	55.380	218.173
	4	1843.1	7563.8	1371.5	631.6	951.6	163.760	39.199	7.240	86.888	26.819	49.226	194.005
	5	1986.0	8150.2	1477.9	680.5	1025.3	176.446	42.239	7.801	93.626	28.899	53.046	209.049

TABLE V. Total Urinary Constituents—Grams.

Period No.	Pig No.	Total nitrogen	Ammonia nitrogen	Creatinin	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus
II	1	152.120	16.486	8.278	33.101	9.350	0.752	2.109	12.330	31.332	10.892
	2	234.024	28.307	10.421	40.170	11.971	1.151	3.017	19.321	47.028	14.915
	3	209.996	22.086	10.277	61.958	17.861	0.967	2.456	17.743	40.631	13.789
	4	148.065	25.200	6.974	50.199	13.827	0.803	1.256	12.974	31.577	8.765
	5	189.716	21.809	8.827	54.038	9.663	0.940	2.254	15.701	37.444	12.088
III	1	194.972	18.842	11.933	44.003	20.519	0.957	4.869	12.394	40.880	10.809
	2	263.476	26.419	16.390	56.737	21.544	1.721	6.732	21.559	54.905	12.772
	3	254.500	23.987	14.561	55.743	25.704	1.055	6.126	18.065	52.780	14.175
	4	180.724	29.010	11.338	37.924	19.251	0.931	3.490	10.231	38.373	8.130
	5	221.947	22.680	12.959	44.351	22.609	0.776	4.290	18.119	44.556	11.678
IV	1	190.637	25.866	15.713	55.855	25.681	2.092	4.414	13.014	46.331	33.888
	2	196.557	33.559	21.701	58.293	18.432	1.964	5.925	16.820	52.170	35.369
	3	246.682	36.208	21.257	68.105	26.321	2.376	5.960	18.636	56.842	42.281
	4	191.380	42.661	14.053	62.686	19.658	1.461	4.805	20.450	47.473	38.458
	5	214.910	30.114	17.798	57.461	18.538	1.192	5.277	15.959	48.128	37.683
V	1	188.043	24.818	19.022	36.535	52.553	2.114	3.783	10.457	85.374	20.074
	2	288.410	49.470	23.500	48.300	54.216	2.925	3.917	9.582	110.078	23.946
	3	263.857	30.234	22.939	47.107	59.482	2.154	3.963	10.209	102.776	25.246
	4	192.528	45.822	17.025	38.516	50.145	2.053	2.495	16.047	88.039	17.463
	5	200.727	24.360	20.997	37.861	49.113	1.318	2.889	11.832	49.964	19.537
VI	1	201.734	19.741	20.565	72.654	31.871	1.702	4.789	13.875	68.614	24.387
	2	296.737	34.857	24.925	90.297	31.858	2.766	4.823	22.607	82.972	27.251
	3	305.631	22.083	23.290	91.549	39.772	1.978	5.062	20.275	83.367	29.491
	4	205.344	35.788	18.157	69.133	24.481	1.643	2.351	12.238	61.966	19.171
	5	254.890	21.801	22.501	79.137	28.380	1.225	3.969	19.083	30.059	24.571
VII	1	143.568	19.375	24.296	28.198	28.620	1.190	2.978	12.374	42.681	17.262
	2	157.498	26.683	29.670	27.167	24.005	1.785	2.995	14.809	50.547	15.433
	3	165.607	18.289	28.475	30.073	32.408	1.394	3.163	15.864	49.865	18.009
	4	130.905	32.735	20.699	27.161	21.506	1.347	2.154	13.325	36.727	15.266
	5	162.278	18.852	26.390	30.591	28.117	0.879	2.607	13.697	45.591	17.495
VIII	1	167.079	24.248	28.587	162.019	11.479	1.159	5.268	12.023	37.887	9.374
	4	140.118	41.243	24.164	140.529	12.380	1.324	3.734	8.116	38.802	7.543
	5	168.537	22.909	28.984	149.298	13.426	0.833	4.092	9.928	34.574	8.982

TABLE VI. Total Weight of Feces—Grams as Sampled*

Pig No.	Period I	Period II	Period III	Period IV	Period V	Period VI	Period VII	Period VIII
I	1794	3305	5384	8098	4564	3934	3592	9566
II	3000	7745	9418	10954	7324	5685	5631	....
III	2330	5557	6594	8982	6036	5105	4803	....
IV	1569	4025	5795	8315	5647	3828	3556	9971
V	2510	5383	6623	8635	5000	4616	4129	9484

*The feces from Period I were dried in an air oven at 50° and sampled dry; all others were refrigerated and were then sampled moist.

TABLE VII. Feces Constituents—Percent, As Sampled.

Period No.	Pig No.	Total protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen	Metabolic nitrogen	Metabolic protein	Indigestible protein
1	1	16.625	51.833	12 911	6.047	8.711	1.120	0.205	0.423	0.955	0.255	0.011	1.869	2.660	1.609	10.056	6.569
	2	17.363	51.651	13.318	5.753	8.201	1.115	0.176	0.445	0.942	0.273	0.031	1.681	2.778	2.206	13.788	3.575
	3	16.975	51.271	13.637	5.825	8.616	1.028	0.402	0.471	0.980	0.250	0.009	1.824	2.716	1.805	11.281	5.694
	4	15.719	51.465	13.859	5.972	9.017	0.938	0.307	0.561	1.043	0.235	0.026	1.869	2.515	1.604	10.025	5.694
	5	17.425	49.939	13.776	5.980	8.647	1.092	0.221	0.407	0.975	0.259	0.031	1.755	2.788	1.803	11.269	6.156
2	1	9.306	16.388	6.033	4.721	4.036	0.487	0 114	0.230	0.457	0.147	0.005	0.801	1.489	0.911	5.694	3.612
	2	8.613	10.708	5.624	3.673	3.150	0.507	0.096	0.162	0.312	0.114	0.006	0.593	1.378	0.895	5.594	3.019
	3	7.169	13.405	4.893	4.137	3.337	0.508	0.087	0.163	0.368	0.107	0.004	0.689	1.147	0.760	4.750	2.419
	4	8.525	14.122	4.504	4.356	3.210	0.395	0.159	0.183	0.390	0.124	0.005	0.731	1.364	0.882	5.513	3.012
	5	8.506	12.388	6.265	4.395	3.419	0.538	0.070	0.156	0.366	0.120	0.005	0.670	1.361	0.864	5.400	3.106
3	1	7.825	15.747	5.554	6.913	4.229	0.465	0.129	0 137	0 474	0.129	0.008	0.772	1.252	0.724	4.525	3.300
	2	6.763	13.412	4.111	5.668	3.469	0.435	0.115	0.123	0.375	0 107	0.005	0.641	1.082	0.660	4.125	2.638
	3	6.788	15.436	4.862	7.085	4.133	0.464	0.102	0.137	0.474	0.120	0.003	0.778	1.086	0.597	3.731	3.057
	4	7.050	15.305	4.218	6.077	3.914	0.411	0.114	0.153	0.435	0.120	0.006	0.746	1.128	0.716	4.475	2.575
	5	6.325	15.043	4.449	6.522	4.146	0.523	0.093	0.143	0.453	0.126	0.010	0.750	1.172	0.757	4.731	2.594
4	1	5.513	15.388	2.937	5.876	3.275	0.502	0 166	0.065	0.432	0.105	0.006	0.635	0.882	0.577	3.606	1.907
	2	5.381	14.084	2.548	5.073	3.021	0.495	0.108	0.069	0.362	0 096	0.029	0.572	0.861	0.587	3.669	1.712
	3	5.313	16.153	3.376	6.553	3.561	0.594	0.050	0.087	0.488	0 105	0.015	0.689	0.850	0.546	3.413	1.900
	4	5.169	15.361	2.499	5.894	3.160	0.424	0.133	0 075	0.430	0.097	0.006	0.579	0.827	0.528	3.300	1.869
	5	4.906	15.149	2.704	6.113	3.268	0.497	0.122	0.093	0.445	0.097	0.016	0.603	0.785	0.502	3.138	1.768
5	1	10.681	15.543	3.401	5.406	3.751	0.222	0.204	0.301	0.342	0.180	0.006	0.606	1.709	0.955	5.969	4.712
	2	10.731	13.450	3.613	4.753	3.695	0.303	0.184	0.258	0 306	0.174	0 007	0.604	1.717	1 093	6.831	3.900
	3	10.994	14.650	3.103	5.519	3.730	0.288	0.158	0.320	0.347	0.183	0.005	0.609	1.759	0.952	5.950	5.044
	4	10.056	13.655	2.819	4.957	3.607	0.252	0.200	0.305	0.320	0.170	0.006	0.609	1.609	0.918	5.738	4.318
	5	10.675	14.994	3.239	5.635	4.025	0.290	0.187	0.353	0.367	0.190	0.007	0.637	1.708	0.996	6.225	4.450
6	1	7.244	19.895	5.188	4.645	3.661	0.335	0.200	0.284	0.410	0.112	0.003	0.709	1.159	0.717	4.481	2.763
	2	6.344	17.335	4.085	3.994	3.547	0.366	0.170	0.307	0.361	0.100	0.002	0.705	1.015	0.694	4.338	2.006
	3	5.906	16.001	4.302	4.150	3.505	0.356	0.134	0.282	0.387	0.090	0.002	0.714	0.945	0.579	3.619	2.287
	4	6.419	16.600	4.054	4.250	3.743	0.287	0.190	0.318	0.412	0.101	0.002	0.765	1.027	0.637	3.981	2.438
	5	7.144	15.949	4.747	3.863	3.807	0.375	0.132	0.294	0.409	0.118	0.004	0.742	1.143	0.700	4.375	2.769
7	1	5.893	17.441	5.833	4.360	3.397	0.452	0.096	0.120	0.423	0.098	0.005	0 677	0.943	0.512	3.200	2.693
	2	6.063	15.512	5.250	3.856	3.094	0.440	0.132	0.113	0.354	0.092	0.008	0.616	0.970	0.663	4.144	1.919
	3	5.450	16.686	5.387	4.398	3.231	0.422	0.111	0.117	0.401	0.088	0.005	0.649	0.872	0.374	2.338	3.112
	4	5.281	17.538	5.051	4.524	3.227	0.383	0.156	0.132	0.405	0.087	0.007	0.623	0.845	0.494	3.088	2.193
	5	5.831	17.454	5.777	4.420	3.435	0.459	0.119	0.122	0.426	0.101	0.010	0.673	0.933	0.592	3.700	2.131
8	1	4.506	11.592	3.066	5.727	6.781	0.416	0.152	0.111	1.046	0.086	0.006	1.588	0.721	0.413	2.581	1.925
	4	4.206	10.713	2.978	4.346	6.245	0.405	0.106	0.123	0.902	0.080	0.005	1.455	0.673	0.419	2.619	1.587
	5	4.038	12.804	3.148	4.708	6.871	0.488	0.075	0.126	1.027	0.086	0.007	1.589	0.646	0.416	2.600	1.438

TABLE VIII. Total Feces Constituents—Grams

Period No.	Pig No.	Total weight feces	Indigestible protein	Nitrogen-free extract	Ether extract	Crude fiber	Ash	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Nitrogen	Total protein	Metabolic protein
I	1	1794	117.848	929.884	231.623	108.483	156.275	20.093	3.678	7.589	17.133	4.575	.197	33.530	47.720	298.252	180.405
	2	3000	107.250	1549.530	399.540	172.590	246.030	33.450	5.280	13.350	28.260	8.190	.930	50.430	83.340	520.899	413.640
	3	2330	132.670	1194.614	317.742	135.723	200.753	23.952	9.367	10.974	22.834	5.825	.210	42.499	63.283	395.518	262.847
	4	1569	89.339	807.486	217.428	93.701	141.477	14.717	4.817	8.802	16.365	3.687	.408	29.325	39.460	246.631	157.292
	5	2510	154.516	1253.469	345.778	150.098	217.040	27.409	5.547	10.216	24.473	6.501	.778	44.051	69.979	437.368	282.852
II	1	3305	119.377	541.623	199.391	156.029	133.390	16.095	3.768	7.602	15.104	4.858	.165	26.473	49.211	307.563	188.187
	2	7745	233.822	829.335	435.579	284.474	243.968	39.267	7.435	12.547	24.164	8.829	.465	45.928	106.726	667.077	433.255
	3	5557	134.424	744.916	271.904	229.893	185.437	28.230	4.835	9.058	20.450	5.946	.222	38.288	63.739	398.381	263.958
	4	4025	121.233	568.411	181.286	175.329	129.203	15.899	6.400	7.366	15.698	4.991	.201	29.423	54.901	343.131	221.898
	5	5383	167.196	666.846	337.245	236.583	184.045	28.961	3.768	8.397	19.702	6.460	.269	36.066	73.263	457.878	290.682
III	1	5384	177.672	847.818	299.027	372.196	227.689	25.036	6.945	7.376	25.520	6.945	.431	41.564	67.408	421.298	243.626
	2	9418	248.447	1263.142	387.174	533.812	326.710	40.968	10.831	11.584	35.318	10.077	.471	60.369	101.903	636.939	388.493
	3	6594	201.579	1017.850	320.600	467.185	272.530	30.596	6.726	9.034	31.256	7.913	.198	51.301	71.611	447.601	246.022
	4	5795	149.221	886.925	244.433	352.162	226.816	23.817	6.606	8.866	25.208	6.954	.348	43.231	65.368	408.548	259.326
	5	6623	171.801	996.298	294.657	431.952	274.590	34.638	6.159	9.471	30.002	8.345	.662	49.673	77.622	485.135	313.334
IV	1	8098	154.429	1246.120	237.838	475.838	265.210	40.652	13.443	5.264	34.983	8.503	.486	51.422	71.424	446.443	292.014
	2	10954	187.532	1542.761	279.108	555.696	330.920	54.222	11.830	7.558	39.653	10.516	3.177	62.657	94.314	589.435	401.902
	3	8982	170.658	1450.862	303.232	588.590	319.849	53.353	4.491	7.814	43.832	9.431	1.347	61.886	76.347	477.214	306.556
	4	8315	155.407	1277.267	207.792	490.086	262.754	35.257	11.059	6.236	35.575	8.066	.499	48.144	68.765	429.802	274.395
	5	8635	152.667	1308.116	233.490	527.858	282.192	42.916	10.535	8.031	38.426	8.376	1.382	52.069	67.785	423.633	270.966
V	1	4564	215.056	709.383	155.222	246.730	171.196	10.132	9.311	13.738	15.609	8.215	.274	27.658	77.999	487.481	272.425
	2	7324	285.636	985.078	264.616	348.110	270.622	22.192	13.476	18.896	22.411	12.744	.513	44.237	125.753	785.938	500.302
	3	6086	306.978	891.599	188.849	335.886	227.008	17.528	9.616	19.475	21.118	11.137	.304	37.064	107.053	669.095	362.117
	4	5647	243.837	771.098	159.189	279.922	203.687	14.230	11.294	17.223	18.070	9.600	.339	34.390	90.860	567.862	324.025
	5	5000	222.500	749.700	161.950	281.750	201.250	14.500	9.350	17.650	18.350	9.500	.350	31.850	85.400	533.750	311.250
VI	1	3934	108.696	782.669	204.096	182.734	144.024	13.179	7.868	11.173	16.129	4.406	.118	27.892	45.595	284.979	176.283
	2	5685	114.041	985.495	232.232	227.059	201.647	20.807	9.665	17.453	20.523	5.685	.114	40.079	57.703	360.656	246.615
	3	5105	116.751	816.851	219.617	211.858	178.930	18.174	6.841	14.396	19.756	4.595	.102	36.450	48.242	301.501	184.750
	4	3828	93.327	635.448	155.187	162.690	143.282	10.986	7.273	12.173	15.771	3.866	.077	29.284	39.314	245.719	152.393
	5	4616	127.817	736.206	219.122	178.316	175.731	17.310	6.093	13.571	18.879	5.447	.185	34.251	52.761	329.767	201.950
VII	1	3592	96.733	626.481	209.521	156.611	122.020	16.236	3.448	4.310	15.194	3.520	.180	24.318	33.873	211.677	114.944
	2	5631	108.059	873.481	295.628	217.131	174.223	24.776	7.443	6.363	19.934	5.181	.440	34.687	54.621	341.408	233.349
	3	4803	149.469	801.429	258.738	211.236	155.185	20.269	5.331	5.620	19.260	4.227	.250	31.171	41.882	261.764	112.294
	4	3556	77.983	623.651	179.614	160.873	114.752	13.619	5.547	4.694	14.402	3.094	.249	22.154	30.048	187.792	109.809
	5	4129	87.989	720.676	238.532	182.502	141.831	18.952	4.914	5.037	17.590	4.170	.413	27.788	38.524	240.762	152.773
VIII	1	9566	184.146	1108.891	293.294	547.845	648.670	39.795	14.540	10.618	100.060	8.227	.574	151.908	68.971	431.044	246.898
	4	9971	158.240	1068.193	296.936	433.340	622.689	40.383	10.569	12.264	89.938	7.977	.499	145.078	67.105	419.380	261.140
	5	9484	136.380	1214.331	298.556	446.507	651.646	46.282	7.113	11.950	97.401	8.156	.664	150.701	61.267	382.964	246.584

TABLE IX. Coefficients of Digestibility of Foodstuffs With Swine

Period No.	Foodstuff	Pig No.	Protein	Nitrogen-free extract	Ether extract	Crude fiber
I	Corn meal	1	92.16	92.24	65.46	76.95
		2	95.25	91.39	60.30	75.57
		3	92.92	92.01	62.00	76.87
		4	93.31	92.42	63.51	77.59
		5	92.51	92.38	62.45	76.78
		Ave.	93.23	92.09	62.74	76.75
VII	Corn meal	1	93.10	94.39	66.49	64.31
		2	93.72	93.63	61.47	59.69
		3	91.10	94.01	65.45	59.82
		4	93.74	93.72	67.68	58.76
		5	94.28	94.12	65.22	62.09
		Ave.	93.19	93.97	65.26	60.93
Ave. I and VII	Corn meal	1	92.63	93.32	65.98	70.63
		2	94.49	92.51	60.89	67.63
		3	92.01	93.01	63.73	68.35
		4	93.53	93.07	65.60	68.18
		5	93.40	93.25	63.84	69.44
		Ave.	93.21	93.03	64.01	68.85
II	Soybeans	1	94.18	92.43	85.61	34.08
		2	89.50	113.04	74.49	27.00
		3	97.84	101.38	90.42	35.84
		4	93.63	96.26	92.91	30.41
		5	92.09	103.99	75.35	20.26
		Ave.	93.45	101.42	83.76	29.52
III	Linseed oil meal	1	91.56	79.95	39.90	19.01
		2	89.00	81.65	66.46	18.23
		3	93.83	86.50	69.49	20.24
		4	92.53	73.26	64.88	22.83
		5	93.17	76.96	68.31	17.41
		Ave.	92.02	79.66	61.81	19.54
IV	Wheat middlings	1	93.95	81.90	75.02	14.22
		2	92.23	81.19	79.32	15.02
		3	95.30	83.64	74.30	13.65
		4	93.63	82.49	84.50	15.80
		5	94.38	83.08	82.68	12.17
		Ave.	93.90	82.46	79.16	14.17
V	Meat meal	1	86.76	(116.72)	(135.71)	(—88.71)
		2	84.46	(265.19)	(129.36)	(—83.51)
		3	83.41	(134.94)	(145.37)	(—119.57)
		4	82.90	(91.47)	(137.87)	(—111.39)
		5	86.63	(164.78)	(148.96)	(—102.55)
		Ave.	84.83	(154.62)	(139.45)	(—101.15)
VI	Skim milk	1	99.47	(97.93)	(115.32)	(—)
		2	98.46	(101.94)	(198.63)	(—)
		3	101.42	(105.66)	(177.39)	(—)
		4	98.60	(103.40)	(172.24)	(—)
		5	97.64	(104.75)	(146.93)	(—)
		Ave.	99.12	(102.74)	(162.10)	(—)

TABLE X. Average Daily Mineral Intake with Balance of Acid and Basic Elements—Grams

Period and Food	Pig No.	Potassium	Sodium	Calcium	Magnesium	Sulphur	Chlorine	Phosphorus	Excess acid (c. c. normal sol.)	Ammonia nitrogen in urine	Creatinin in urine
I	I	4.897	2.440	0.186	1.558	2.123	4.104	3.747	.....	1.712	0.819
Corn	II	7.349	3.662	0.279	2.338	3.187	6.159	5.623	.....	2.599	1.162
Salt	III	6.105	3.042	0.232	1.942	2.647	5.117	4.672	.....	1.954	0.957
	IV	4.351	2.168	0.165	1.384	1.887	3.646	3.329	.....	2.637	0.766
	V	6.724	3.351	0.255	2.139	2.916	5.636	5.145	.....	1.848	0.970
	Ave.	5.885	2.933	0.223	1.872	2.548	4.932	4.503	145.8	2.150	0.935
II	I	7.851	3.353	0.577	1.673	2.487	3.663	4.163	.....	1.649	0.828
Corn	II	12.958	5.536	0.952	2.761	4.105	6.047	6.873	.....	2.831	1.042
Soybeans	III	11.214	4.790	0.824	2.390	3.553	5.233	5.948	.....	2.209	1.028
Salt	IV	8.237	3.518	0.605	1.755	2.609	3.843	4.368	.....	2.520	0.697
	V	10.673	4.559	0.784	2.274	3.381	4.980	5.660	.....	2.181	0.883
	Ave.	10.187	4.351	0.748	2.171	3.227	4.753	5.402	18.9	2.278	0.896
III	I	8.039	3.596	1.210	2.949	3.296	5.032	5.770	.....	1.884	1.193
Corn	II	11.101	4.966	1.671	4.072	4.551	6.949	7.968	.....	2.642	1.639
Linseed oil meal	III	9.953	4.452	1.498	3.651	4.080	6.230	7.148	.....	2.399	1.456
Salt	IV	7.656	3.425	1.152	2.808	3.139	4.792	5.495	.....	2.901	1.134
	V	9.091	4.067	1.368	3.335	3.727	5.691	6.525	.....	2.268	1.296
	Ave.	9.168	4.101	1.380	3.363	3.759	5.739	6.581	63.2	2.419	1.344
IV	I	11.379	4.202	0.878	4.063	3.343	4.978	9.424	.....	2.587	1.571
Corn	II	13.152	4.857	1.015	4.697	3.864	5.754	10.900	.....	3.356	2.170
Wheat middlings	III	13.808	5.099	1.066	4.931	4.056	6.041	11.445	.....	3.621	2.126
Salt	IV	11.725	4.330	0.905	4.187	3.445	5.129	9.718	.....	4.266	1.405
	V	12.293	4.538	0.949	4.390	3.611	5.378	10.189	.....	3.011	1.780
	Ave.	12.471	4.605	0.963	4.454	3.664	5.456	10.335	116.3	3.368	1.810
V	I	6.082	5.356	4.603	1.892	3.193	8.443	6.458	.....	2.482	1.902
Corn	II	8.271	7.282	6.257	2.572	4.341	11.480	8.781	.....	4.947	2.350
Meat meal	III	7.389	6.506	5.591	2.298	3.879	10.258	7.846	.....	3.023	2.294
Salt	IV	6.266	5.517	4.741	1.949	3.289	8.698	6.653	.....	4.582	1.703
	V	6.574	5.788	4.974	2.045	3.451	9.126	6.980	.....	2.436	2.010
	Ave.	6.916	6.090	5.233	2.151	3.631	9.601	7.344	92.2	3.494	2.070
VI	I	9.351	4.239	4.276	2.188	3.462	7.529	7.173	.....	1.974	2.057
Corn	II	11.477	5.203	5.248	2.685	4.249	9.240	8.803	.....	3.486	2.493
Skim milk	III	11.203	5.078	5.123	2.621	4.148	9.019	8.593	.....	2.208	2.329
Salt	IV	8.313	3.768	3.802	1.945	3.078	6.692	6.376	.....	3.579	1.816
	V	10.259	4.650	4.692	2.400	3.799	8.260	7.869	.....	2.180	2.250
	Ave.	10.121	4.588	4.628	2.368	3.747	8.148	7.763	81.0	2.685	2.189
VII	I	5.478	2.753	0.208	1.743	2.375	4.627	4.192	.....	1.938	2.430
Corn	II	6.724	3.379	0.256	2.139	2.915	5.679	5.145	.....	2.668	2.967
Salt	III	6.563	3.298	0.250	2.088	2.846	5.543	5.022	.....	1.829	2.848
	IV	4.870	2.447	0.185	1.549	2.112	4.113	3.726	.....	3.274	2.070
	V	6.010	3.020	0.229	1.912	2.606	5.076	4.599	.....	1.885	2.639
	Ave.	5.929	2.979	0.226	1.886	2.571	5.008	4.537	147.0	2.319	2.591
VIII Rice polish	I	18.422	4.410	0.815	9.775	3.017	5.538	21.817	.....	2.425	2.859
Wheat bran	IV	16.376	3.920	0.724	8.869	2.682	4.923	19.401	.....	4.124	2.416
Salt	V	17.645	4.224	0.780	9.363	2.890	5.305	20.905	.....	2.291	2.898
	Ave.	17.481	4.185	0.773	9.276	2.863	5.255	20.708	232.8	2.947	2.725

TABLE XI. Mineral Elements in Average Daily Rations Computed to Cubic Centimeters of Normal Solution.

Period No.	Average daily rations Grams, Fresh Basis	Potassium	Sodium	Calcium	Magnesium	Total base	Sulphur	Chlorine	Phosphorus	Total acid	Excess acid
I	Corn ....1659.2 Salt 6.507	150.5	127.2	11.1	153.9	442.7	158.9	139.1	290.5	588.5	145.8
II	Corn ....1357.2 Soy beans .... 271.4 Salt 6.387	260.5	188.7	37.3	178.5	665.0	201.3	134.1	348.5	683.9	18.9
III	Corn ....1590.4 Linseed oil meal .... 318.1 Salt 7.484	234.5	177.9	68.8	276.6	757.8	234.5	161.9	424.6	821.0	63.2
IV	Corn ....1110.7 Wheat middlings .... 837.9 Salt 7.642	319.0	199.7	48.0	366.3	933.0	228.6	153.9	666.8	1049.3	116.3
V	Corn ....1705.3 Meat meal .... 170.5 Salt 7.356	176.9	264.2	261.0	176.9	879.0	226.5	270.9	473.8	971.2	92.2
VI	Corn ....1688.2 Skim milk ....3436.2 Salt 6.620	258.8	199.0	230.8	194.7	883.3	233.7	229.8	500.8	964.3	81.0
VII	Corn ....1688.2 Salt 6.620	151.6	129.2	11.3	155.1	447.2	160.3	141.2	292.7	564.2	147.0
VIII	Rice polish ....1110.1 Wheat bran .... 370.1 Salt 5.805	447.1	181.5	38.6	762.8	1430.0	178.6	148.2	1336.0	1662.8	232.8

TABLE XII. Relation of Magnesium to Calcium Metabolism

Period No.	Ca Retention Grams	Ca Intake Grams	Ratio of Ca : Mg intake*	Excess mineral acid per day (c. c. normal sol.)	Urinary ammonia per day (N) Grams
VIII	—0.498	0.773	0.0833	232.8	2.947
VII	—0.427	0.226	0.120	147.0	2.425
IV	+0.083	0.963	0.216	116.3	3.368
II	—0.243	0.748	0.344	18.9	2.278
III	+0.344	1.380	0.410	63.2	2.419
VI	+3.047	4.628	1.954	81.0	2.685
V	+3.282	5.233	2.432	92.2	3.494

*In terms of chemically equivalent amounts.

TABLE XIII. Slaughter Test—Animals Arranged in Order of Creatinin Elimination—Kg.

No. of animal	Live weight	Dressed carcass	Flesh	Blood	Bones	Hoofs	Heart	Lungs	Liver	Kidneys	Spleen	Brain
II	121.0	102.7	91.4	4.288	6.454	0.310	0.316	0.407	1.255	0.201	0.120	0.110
III	111.0	94.6	83.9	3.733	6.242	0.294	0.261	0.525	1.155	0.177	0.128	0.108
V	108.6	92.1	81.9	3.588	.....	0.284	0.299	0.449	1.062	0.184	0.121	0.111
I	94.0	78.7	70.1	3.275	5.394	0.214	0.247	0.355	1.005	0.160	0.093	0.115
IV	89.0	75.0	66.7	3.024	.....	0.252	0.280	0.419	1.124	0.165	0.096	0.104

TABLE XIV. PERIOD II: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	43	Corn	1045.9	7.851	3.353	0.577	1.673	2.487	3.663	4.163	28.787
		Soy beans	209.2	3.310	0.935	0.075	0.211	1.233	3.133	1.089	15.212
		Salt	4.922	1.610	0.377	0.760	1.510	0.486	0.017	2.647	4.921
		Water	2967	+2.931	+2.041	−0.258	−0.048	+0.768	+0.513	+0.427	+8.654
II	64	Corn	1726.6	12.958	5.536	0.952	2.761	4.105	6.047	6.873	47.518
		Soy beans	345.3	4.017	1.197	0.115	0.302	1.932	4.703	1.492	23.402
		Salt	8.125	3.927	0.744	1.255	2.416	0.883	0.047	4.593	10.673
		Water	4019	+5.014	+3.595	−0.418	+0.043	+1.290	+1.297	+0.788	+13.443
III	55	Corn	1494.2	11.214	4.790	0.824	2.390	3.553	5.233	5.948	41.120
		Soy beans	298.8	6.196	1.786	0.097	0.246	1.774	4.063	1.379	21.000
		Salt	7.031	2.823	0.484	0.906	2.045	0.595	0.022	3.829	6.374
		Water	4074	+2.195	+2.520	−0.179	+0.099	+1.184	+1.148	+0.740	+13.746
IV	42	Corn	1097.3	8.237	3.518	0.605	1.755	2.609	3.843	4.368	30.201
		Soy beans	219.5	5.020	1.383	0.080	0.126	1.297	3.158	0.877	14.807
		Salt	5.164	1.590	0.640	0.737	1.570	0.499	0.020	2.942	5.490
		Water	3297	+1.627	+1.495	−0.212	+0.059	+0.813	+0.665	+0.549	+9.904
V	56	Corn	1421.9	10.673	4.559	0.784	2.274	3.381	4.980	5.660	39.134
		Soy beans	284.4	5.404	0.966	0.094	0.225	1.570	3.744	1.209	18.972
		Salt	6.691	2.896	0.377	0.840	1.970	0.646	0.027	3.607	7.326
		Water	2949	+2.373	+3.216	−0.150	+0.079	+1.165	+1.209	+0.844	+12.836

TABLE XV. PERIOD III: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	51	Corn..........1394.5	8.039	3.596	1.210	2.949	3.296	5.032	5.770	36.259
		Linseed oil meal..... 278.9	4.400	2.052	0.096	0.487	1.239	4.088	1.081	19.500
		Salt..... 6.563	2.504	0.695	0.738	2.552	0.695	0.043	4.156	6.741
		Water..... 5313	+1.135	+0.849	+0.376	−0.090	+1.362	+0.901	+0.533	+10.018
II	76	Corn.......1925.7	11.101	4.966	1.671	4.072	4.551	6.949	7.968	50.073
		Linseed oil meal..... 385.2	5.674	2.154	0.172	0.673	2.156	5.491	1.278	26.348
		Salt..... 9.063	4.097	1.083	1.158	3.532	1.008	0.047	6.037	10.190
		Water..... 6053	+1.330	+1.729	+0.341	−0.133	+1.387	+1.411	+0.653	+13.535
III	66	Corn.......1726.6	9.953	4.452	1.498	3.651	4.080	6.230	7.148	44.892
		Linseed oil meal..... 345.3	5.574	2.570	0.106	0.613	1.807	5.278	1.418	25.450
		Salt..... 8.125	3.060	0.673	0.903	3.126	0.791	0.020	5.130	7.161
		Water..... 5935	+1.319	+1.209	+0.489	−0.088	+1.482	+0.932	+0.600	+12.281
IV	59	Corn.......1328.1	7.656	3.425	1.152	2.808	3.139	4.792	5.495	34.531
		Linseed oil meal..... 265.6	3.792	1.925	0.093	0.349	1.023	3.837	0.813	18.072
		Salt..... 6.250	2.382	0.661	0.887	2.521	0.695	0.035	4.323	6.537
		Water..... 5212	+1.482	+0.839	+0.172	−0.062	+1.421	+0.920	+0.359	+9.922
V	67	Corn.......1577.2	9.091	4.067	1.368	3.335	3.727	5.691	6.525	41.004
		Linseed oil meal..... 315.4	4.435	2.261	0.078	0.429	1.812	4.456	1.168	22.195
		Salt..... 7.422	3.464	0.616	0.947	3.000	0.835	0.066	4.967	7.762
		Water..... 3721	+1.192	+1.190	+0.343	−0.094	+1.080	+1.169	+0.390	+11.047

TABLE XVI. PERIOD IV: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily ration	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	60	Corn 1013.3	11.379	4.202	0.878	4.063	3.343	4.978	9.424	37.667
		Wheat middlings 764.5	5.586	2.568	0.209	0.441	1.301	4.633	3.389	19.064
		Salt 6.972	4.065	1.344	0.526	3.498	0.850	0.049	5.142	7.142
		Water 5709	+1.728	+0.290	+0.143	+0.124	+1.192	+0.296	+0.893	+11.461
II	86	Corn 1171.3	13.152	4.857	1.015	4.697	3.864	5.754	10.900	43.537
		Wheat middlings 883.6	5.829	1.843	0.196	0.593	1.682	5.217	3.537	19.656
		Salt 8.059	5.422	1.183	0.756	3.965	1.052	0.318	6.266	9.431
		Water 4476	+1.901	+1.831	+0.063	+0.139	+1.130	+0.219	+1.097	+14.450
III	75	Corn 1229.8	13.808	5.099	1.066	4.931	4.056	6.041	11.445	45.712
		Wheat middlings 927.7	6.811	2.632	0.238	0.596	1.864	5.684	4.228	24.668
		Salt 8.461	5.335	0.449	0.781	4.383	0.943	0.135	6.189	7.635
		Water 5416	+1.662	+2.018	+0.047	—0.048	+1.249	+0.222	+1.028	+13.409
IV	57	Corn 1044.2	11.725	4.330	0.905	4.187	3.445	5.129	9.718	38.816
		Wheat middlings 787.8	6.269	1.966	0.146	0.481	2.045	4.747	3.846	19.138
		Salt 7.184	3.526	1.106	0.624	3.558	0.807	0.050	4.814	6.877
		Water 5727	+1.930	+1.258	+0.135	+0.148	+0.593	+0.332	+1.058	+12.801
V	75	Corn 1094.9	12.293	4.538	0.949	4.390	3.611	5.378	10.189	40.696
		Wheat middlings 825.9	5.746	1.854	0.119	0.528	1.596	4.813	3.768	21.491
		Salt 7.532	4.292	1.054	0.803	3.843	0.838	0.138	5.209	6.779
		Water 4044	+2.255	+1.630	+0.027	+0.019	+1.177	+0.427	+1.214	+12.426

TABLE XVII. PERIOD V: Average Daily Rations and Mineral Balances—Grams.

Pig No.	Approximate live weight Kg.	Average daily ration		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	68	Corn........................	1499.5	6.082	5.356	4.603	1.892	3.193	8.443	6.458	35.545
		Meat meal..................	150.0	3.654	5.255	0.211	0.378	1.046	8.537	2.007	18.804
		Salt	6.469	1.013	0.931	1.374	1.561	0.822	0.027	2.766	7.800
		Water.......................	5828	+1.415	−0.830	+3.018	−0.047	+1.325	−0.121	+1.685	+8.941
II	94	Corn........................	2039.3	8.271	7.282	6.257	2.572	4.341	11.480	8.781	48.334
		Meat meal..................	203.9	4.830	5.422	0.293	0.392	0.958	11.008	2.395	28.841
		Salt	8.797	2.219	1.348	1.890	2.241	1.274	0.051	4.424	12.575
		Water.......................	3534	+1.222	+0.512	+4.074	−0.061	+2.109	+0.421	+1.962	+6.918
III	83	Corn........................	1821.9	7.389	6.506	5.591	2.298	3.879	10.258	7.846	43.185
		Meat meal..................	182.2	4.711	5.948	0.215	0.396	1.021	10.278	2.525	26.386
		Salt	7.859	1.753	0.962	1.948	2.112	1.114	0.030	3.706	10.705
		Water.......................	5156	+0.925	−0.404	+3.428	−0.210	+1.744	−0.050	+1.615	+6.094
IV	64	Corn........................	1544.8	6.266	5.517	4.741	1.949	3.289	8.698	6.653	36.616
		Meat meal..................	154.5	3.852	5.015	0.205	0.250	1.605	8.804	1.746	19.253
		Salt	6.664	1.423	1.129	1.722	1.807	0.960	0.034	3.439	9.086
		Water.......................	6350	+0.991	−0.627	+2.814	−0.108	+0.724	−0.140	+1.468	+8.277
V	83	Corn........................	1620.9	6.574	5.788	4.974	2.045	3.451	9.126	6.980	38.420
		Meat meal..................	162.1	3.786	4.911	0.132	0.289	1.183	4.996	1.954	20.073
		Salt	6.992	1.450	0.935	1.765	1.835	0.950	0.035	3.185	8.540
		Water.......................	2971	+1.338	−0.058	+3.077	−0.079	+1.318	+4.095	+1.841	+9.807

TABLE XVIII. PERIOD VI: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	75	Corn........................1559.9	9.351	4.239	4.276	2.188	3.462	7.529	7.173	38.739
		Skim milk..................3175.1	7.265	3.187	0.170	0.479	1.388	6.861	2.439	20.173
		Salt.......................... 6.117	1.318	0.787	1.117	1.613	0.441	0.012	2.789	4.560
		Water...................... 3950	+0.768	+0.265	+2.989	+0.096	+1.633	+0.656	+1.945	+14.006
II	102	Corn........................1914.5	11.477	5.203	5.248	2.685	4.249	9.240	8.803	47.544
		Skim milk..................3896.8	9.030	3.186	0.277	0.482	2.261	8.297	2.725	29.674
		Salt.......................... 7.508	2.081	0.967	1.745	2.052	0.569	0.011	4.008	5.770
		Water...................... 1100	+0.366	+1.050	+3.226	+0.151	+1.419	+0.932	+2.070	+12.100
III	91	Corn........................1868.7	11.203	5.078	5.123	2.621	4.148	9.019	8.593	46.408
		Skim milk..................3803.6	9.155	3.977	0.198	0.506	2.028	8.337	2.949	30.563
		Salt.......................... 7.328	1.817	0.684	1.440	1.976	0.464	0.010	3.645	4.824
		Water...................... 3630	+0.231	+0.417	+3.485	+0.139	+1.656	+0.672	+1.999	+11.021
IV	71	Corn........................1386.6	8.313	3.768	3.802	1.945	3.078	6.692	6.376	34.435
		Skim milk..................2822.4	6.913	2.448	0.164	0.235	1.229	6.197	1.917	20.534
		Salt.......................... 5.438	1.099	0.727	1.217	1.577	0.387	0.008	2.928	3.931
		Water...................... 3900	+0.301	+0.593	+2.421	+0.133	+1.462	+0.487	+1.531	+9.970
V	90	Corn........................1711.3	10.259	4.650	4.692	2.400	3.799	8.260	7.869	42.499
		Skim milk..................3483.3	7.914	2.838	0.123	0.397	.908	3.006	2.457	25.489
		Salt.......................... 6.711	1.731	0.609	1.357	1.888	0.545	0.019	3.425	5.276
		Water...................... 880	+0.614	+1.203	+3.112	+0.115	+1.346	+5.235	+1.987	+11.734

TABLE XIX. PERIOD VII: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations	*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
I	83	Corn........................1559.9	5.478	2.753	0.208	1.743	2.375	4.627	4.192	22.422
		Salt 6.117	2.820	2.862	0.119	0.298	1.237	4.268	1.726	14.357
		Water...................... 5940	1.624	0.345	0.431	1.519	0.352	0.018	2.432	3.387
			+1.034	—0.454	—0.342	—0.074	+0.786	+0.341	+0.034	+4.678
II	110	Corn 1914.5	6.724	3.379	0.256	2.139	2.915	5.679	5.145	27.518
		Salt 7.508	2.717	2.401	0.179	0.300	1.481	5.055	1.543	15.750
		Water...................... 4345	2.478	0.743	0.636	1.993	0.518	0.045	3.469	5.462
			+1.529	+0.235	—0.559	—0.154	+0.916	+0.579	+0.133	+6.306
III	99	Corn........................1868.7	6.563	3.298	0.250	2.088	2.846	5.543	5.022	26.860
		Salt 7.328	3.007	3.241	0.139	0.316	1.586	4.987	1.801	16.561
		Water...................... 6770	2.027	0.533	0.562	1.926	0.423	0.024	3.117	4.188
			+1.529	—0.476	—0.451	—0.154	+0.837	+0.532	+0.104	+6.111
IV	79	Corn..... ....1386.6	4.870	2.447	0.185	1.549	2.112	4.113	3.726	19.931
		Salt 5.438	2.716	2.151	0.135	0.215	1.333	3.673	1.527	13.091
		Water....... 5900	1.362	0.555	0.469	1.440	0.309	0.025	2.215	3.005
			+0.792	—0.259	—0.419	—0.106	+0.470	+0.415	—0.016	+3.835
V	98	Corn... ....1711.3	6.010	3.020	0.229	1.912	2.606	5.076	4.599	24.598
		Salt....... .... 6.711	3.059	2.812	0.088	0.261	1.370	4.559	1.750	16.228
		Water..... 3710	1.895	0.491	0.504	1.759	0.417	0.041	2.779	3.852
			+1.056	—0.283	—0.363	—0.108	+0.819	+0.476	+0.070	+4.518

TABLE XX. PERIOD VIII: Average Daily Rations and Mineral Balances—Grams

Pig No.	Approximate live weight Kg.	Average daily rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
		Rice polish	1169.9	18.422	4.410	0.815	9.775	3.017	5.538	21.817	33.176
I	94	Wheat bran	390.0	16.202	1.148	0.116	0.527	1.202	3.789	00.937	16.708
		Salt	6.117	3.980	1.454	1.062	10.006	0.823	0.057	15.191	6.897
		Water	6470	−1.760	+1.808	−0.363	−0.758	+0.992	+1.692	+5.689	+9.571
		Rice polish	1039.9	16.376	3.920	0.724	8.689	2.682	4.923	19.401	29.489
IV	89	Wheat bran	346.7	14.053	1.238	0.132	0.373	0.812	3.880	00.754	14.012
		Salt	5.438	4.038	1.057	1.226	8.994	0.798	0.050	14.508	6.711
		Water	6835	−1.715	+1.625	−0.634	−0.678	+1.072	+0.993	+4.139	+8.766
		Rice polish	1120.6	17.645	4.224	0.780	9.363	2.890	5.305	20.905	31.776
V	109	Wheat bran	373.5	14.930	1.343	0.083	0.409	0.993	3.457	00.898	16.854
		Salt	5.854	4.628	0.711	1.195	9.740	0.816	0.066	15.070	6.127
		Water	5570	−1.913	+2.170	−0.498	−0.786	+1.081	+1.782	+4.937	+8.795

TABLE XXI. Daily Ration and Mineral Balances per Period—Average for Five Pigs—Grams

Period No.	Approximate live weight Kg.	Rations		*Potassium* Food Urine Feces Balance	*Sodium* Food Urine Feces Balance	*Calcium* Food Urine Feces Balance	*Magnesium* Food Urine Feces Balance	*Sulphur* Food Urine Feces Balance	*Chlorine* Food Urine Feces Balance	*Phosphorus* Food Urine Feces Balance	*Nitrogen* Food Urine Feces Balance
II	52	Corn	1357.2	10.187	4.351	0.748	2 171	3.227	4.753	5.402	37.352
		Soybeans	271.4	4.789	1.253	0.092	0.222	1.561	3.760	1.209	18.679
		Salt	6 387	2.569	0.524	0.900	1 902	0.622	0.027	3.524	6.957
		Water	3461	+2.828	+2.573	−0.243	+0.046	+1.044	+0.966	+0.669	+11.717
III	64	Corn	1590.2	9.168	4.101	1.380	3.363	3.759	5.739	6.581	41.352
		Linseed oil meal	318.1	4 775	2.192	0.109	0.510	1.607	4.630	1.152	22.313
		Salt	7.485	3.101	0.746	0.927	2.946	0.805	0.042	4.923	7.678
		Water	5247	+1.292	+1.163	+0.344	−0.093	+1.346	+1.067	+0.507	+11.361
IV	71	Corn	1110.7	12.471	4.605	0.963	4.454	3.664	5.456	10.335	41.286
		Wheat middlings	837.9	6.048	2.173	0.182	0 528	1.698	5.019	3.754	20.803
		Salt	7.642	4.528	1.027	0.698	3.849	0.898	0.138	5.524	7.573
		Water	5074	+1.895	+1.405	+0.083	+0.076	+1.068	+0.299	+1.058	+12.909
V	78	Corn	1705.3	6.916	6.090	5.233	2.151	3.631	9.601	7.344	40.420
		Meat meal	170 5	4.167	5.310	0.211	0.341	1.163	8.725	2.125	22.671
		Salt	7.356	1.572	1.061	1.740	1.911	1.024	0.035	3.504	9.741
		Water	4768	+1.178	−0.281	+3.282	+0.101	+1.444	+0.841	+1.714	+8.007
VI	86	Corn	1688.2	10.121	4.588	4.628	2.368	3.747	8.148	7.763	41.925
		Skim milk	3436.2	8.055	3.127	0.186	0.420	1.763	6.540	2.497	25.287
		Salt	6 920	1.609	0.755	1.375	1.821	0.480	0.012	3.359	4.872
		Water	2692	+0.456	+0.706	+3.047	+0.127	+1.503	+1.596	+1.906	+11.766
VII	94	Corn	1688.2	5.929	2.979	0.226	1.886	2.571	5.008	4.537	24.266
		Salt	6.620	2.864	2.693	0.132	0.278	1.401	4.508	1.669	15.195
		Water	5733	1.877	0.533	0.520	1.727	0.404	0.031	2.802	3.979
				+1.188	−0.247	−0.427	−0.119	+0.766	+0.469	+0.065	+5.090
VIII	97	Rice polish	1110.1	17.481	4.185	0.773	9.276	2.863	5.255	20.708	31.480
		Wheat bran	370.1	15.062	1.243	0.110	0.436	1.002	3.709	0.863	15.858
		Salt	5.803	4.215	1.074	1.161	9.580	0.812	0.058	14.923	6.578
		Water	6292	−1.796	+1.868	−0.498	−0.741	+1.038	+1.489	+4.922	+9.044

TABLE XXII. Average Daily Intake of Mineral Elements and Partition of Outgo Between Urine and Feces—Urine and Feces Together Equal 100 Percent. Intake (upper figure) in Grams; Urine (middle figure) and Feces (lower figure) in Percent of Outgo.

Periods	Rations	*Potassium* Intake Urine Feces	*Sodium* Intake Urine Feces	*Calcium* Intake Urine Feces	*Magnesium* Intake Urine Feces	*Sulphur* Intake Urine Feces	*Chlorine* Intake Urine Feces	*Phosphorus* Intake Urine Feces
II	Corn; soy beans	10.187 66.2 33.8	4.021 70.7 29.3	0.748 9.3 90.7	2.171 10.4 89.6	3.227 71.6 28.4	4.753 99.4 0.6	5.402 25.5 74.5
III	Corn; linseed oil meal	9.168 61.5 38.5	4.101 87.3 12.7	1.380 10.4 89.6	3.363 14.6 85.4	3.759 66.2 33.8	5.739 99.1 0.9	6.581 18.8 81.2
IV	Corn; wheat middlings	12.471 57.4 42.6	4.605 67.5 32.5	0.963 20.7 79.3	4.454 12.0 88.0	3.664 65.4 34.6	5.456 97.4 2.6	10.335 40.5 59.5
V	Corn; meat meal	6.916 72.9 27.1	6.090 83.5 16.5	5.233 10.7 89.3	2.151 15.2 84.8	3.631 53.9 46.1	9.601 99.5 0.5	7.344 37.9 62.1
VI	Corn; milk	10.121 83.5 16.5	4.588 80.4 19.6	4.628 11.8 88.2	2.368 18.6 81.4	3.747 78.3 21.7	8.148 99.9 0.1	7.763 42.6 57.4
VII	Corn	5.929 60.9 39.1	2.979 83.5 16.5	0.226 20.3 79.7	1.886 13.9 86.1	2.571 77.8 22.2	5.008 99.3 0.7	4.537 37.7 62.3
VIII	Rice polish; wheat bran	17.481 78.1 21.9	4.185 53.8 46.2	0.773 8.7 91.3	9.276 4.35 95.65	2.863 55.1 44.9	5.255 98.4 1.6	20.708 5.5 94.5

TABLE XXIII: Proportionate Elimination and Retention of Mineral Elements. Averages from Five Individuals—Intake (upper figure) in Grams; Urine (second figure), Feces (third figure), and Retention (lower figure) in Percent of Intake.

Periods	Rations		*Potassium*	*Sodium*	*Calcium*	*Magnesium*	*Sulphur*	*Chlorine*	*Phosphorus*
II	Corn; soy beans	Intake	10.187	4.351	0.748	2.171	3.227	4.753	5.402
		Urine	48.0	28.8	12.2	10.2	48.4	79.1	22.4
		Feces	24.5	12.0	120.3	87.9	19.3	0.6	65.2
		Retention	+27.5	+59.1	−32.5	+1.9	+32.3	+20.3	+12.4
III	Corn; linseed oil meal	Intake	9.168	4.101	1.380	3.363	3.759	5.739	6.581
		Urine	52.0	53.4	7.9	15.0	42.7	80.7	17.4
		Feces	32.5	18.2	67.2	87.7	21.4	0.7	74.9
		Retention	+14.4	+28.3	+24.9	−2.8	+35.8	+18.6	+7.7
IV	Corn; wheat middlings	Intake	12.471	4.605	0.963	4.454	3.664	5.456	10.335
		Urine	48.6	47.2	18.9	11.8	46.3	91.9	36.4
		Feces	36.1	22.3	72.5	86.4	24.5	3.5	53.4
		Retention	+15.3	+30.5	+8.6	+1.8	+29.1	+5.5	+10.3
V	Corn; meat meal	Intake	6.916	6.090	5.233	2.151	3.631	9.601	7.344
		Urine	60.3	87.2	4.0	15.9	32.0	90.8	29.0
		Feces	22.4	17.4	33.2	88.8	28.2	0.4	47.5
		Retention	+17.4	−46.1	+62.7	−4.7	+29.8	+8.7	+23.5
VI	Corn; skim milk	Intake	10.121	4.588	4.628	2.368	3.747	8.148	7.763
		Urine	79.7	68.1	4.0	17.6	47.1	80.2	32.1
		Feces	15.7	16.4	29.7	77.1	12.8	0.1	43.2
		Retention	+4.6	+15.4	+65.8	+5.4	+40.1	+19.5	+24.6
VII	Corn	Intake	5.929	2.979	0.226	1.886	2.571	5.008	4.537
		Urine	48.9	90.4	58.4	14.8	54.5	90.0	37.2
		Feces	31.4	17.9	230.0	91.5	15.7	0.6	61.5
		Retention	+19.8	−8.3	−18.9	−6.3	+29.7	+9.4	+1.3
VIII	Rice polish; wheat bran	Intake	17.481	4.185	0.773	9.276	2.863	5.255	20.708
		Urine	86.1	29.7	14.2	4.7	35.0	70.6	4.2
		Feces	24.2	25.7	150.1	103.3	28.3	0.1	72.2
		Retention	−10.3	+44.6	−64.4	−8.0	+36.2	+28.3	+23.7

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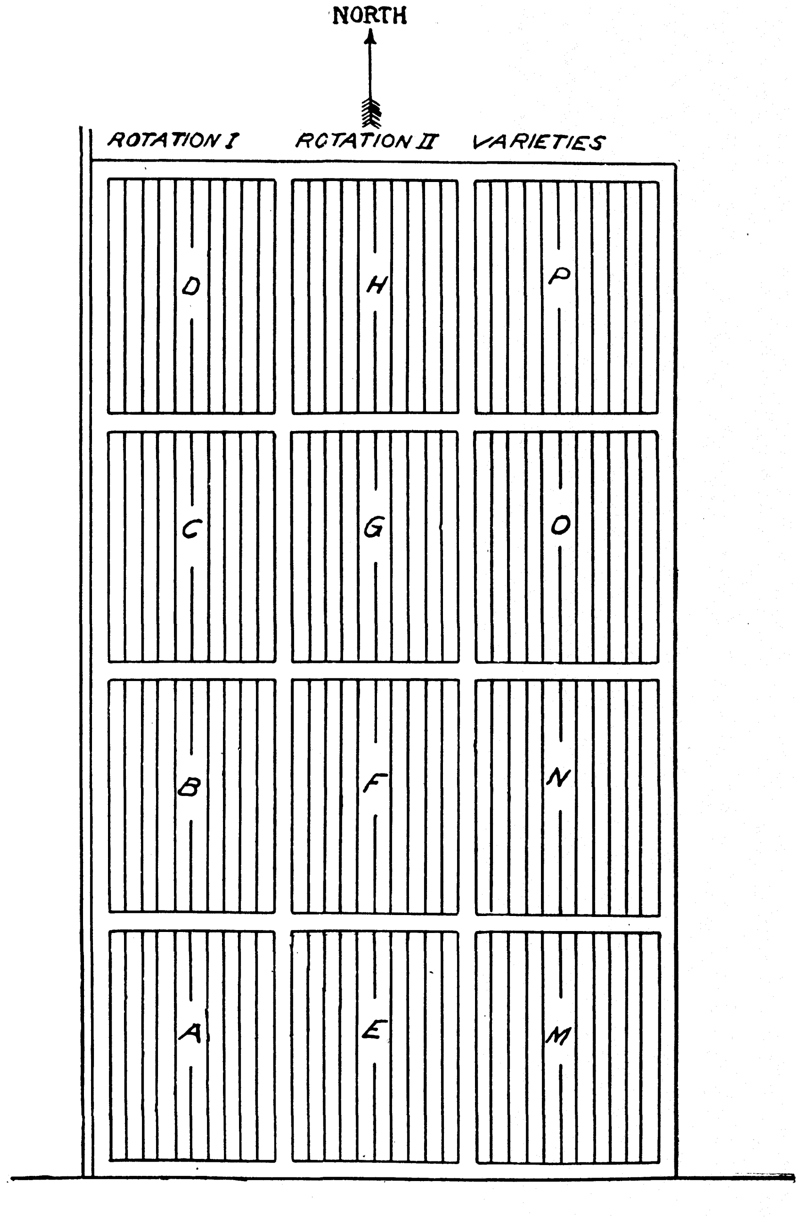
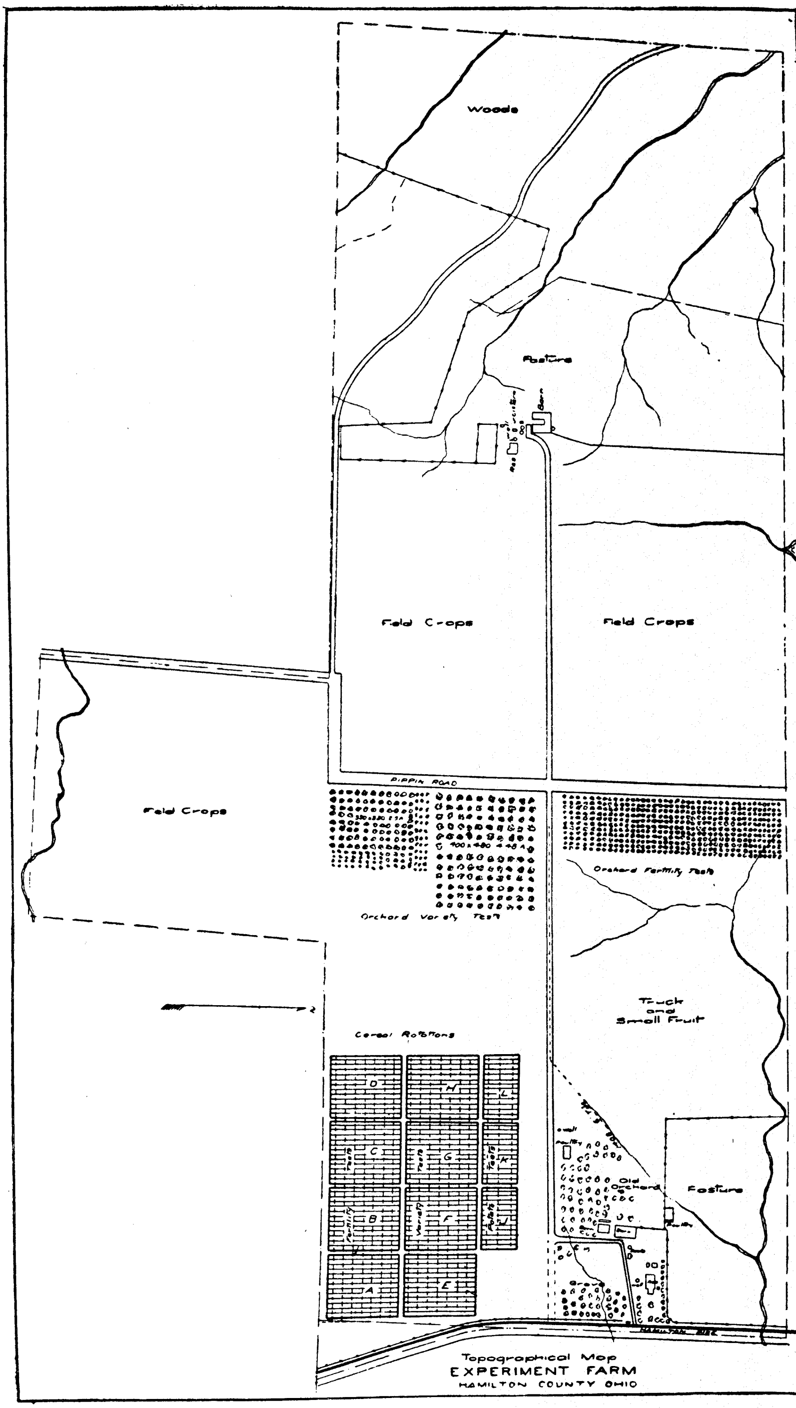


Diagram: Arrangement of plots in cereal rotations
Hamilton County Experiment Farm


Woods
Pasture
Barn
Field Crops
Field Crops
PIPPIN ROAD
Field Crops
Orchard Fertility Tests
Orchard Variety Tests
Truck
and
Small Fruit
Cereal Rotations
D
H
L
C
G
K
B
F
J
A
E
Old
Orchard
Pasture
Grove
Topographical Map
EXPERIMENT FARM
HAMILTON COUNTY OHIO