1-1-1939

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The Composition of Different Skeletal Parts of Experimental Animals

by C. E. WEAKLEY, JR., and R. B. DUSTMAN

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The Composition of Different Skeletal Parts of Experimental Animals

by C. E. WEAKLEY, JR., and R. B. DUSTMAN

DURING THE PAST two or three decades a large amount of work has been directed toward a study of mineral deposition in the bones of experimental animals. In this work a wide diversity of methods has been used by various investigators in procuring and applying data on skeletal composition. In recent years the tendency has been toward the determination of total ash on moisture-free, fat-free bones as one suitable means of measuring mineral deposition. However, procedures for preparing, sampling, and extracting bones are by no means uniform among research workers. Various bones have been employed for analysis, especially the femur, humerus, tibia, fibula, ulna, radius, rib, or combinations of these. Some investigators have analyzed whole bones, some whole bones exclusive of cartilages, while others have analyzed longitudinal cross-sections and still others, horizontal cross-sections. Various fat solvents likewise have been employed. Occasionally investigators have used bones from one side of an animal for one type of determination and the corresponding bone from the other side for a different type of determination with the implied assumption that the bones from the two sides were identical in composition or other properties.

Because of this diversity of methods employed, and because of the readily apparent lack of information dealing with variability between different parts of the same skeleton, it seemed desirable to make a detailed study of the several parts ordinarily used in such work. By this study it was hoped to gain additional information on such important points as: the degree of variation in composition of different bones from the same animal; bilateral variation in composition, if any; the significance and relative importance of the moisture and ether-extractable portions in experiments involving mineral deposition; the bones most likely to be affected in deficiency feeding; and other questions which might arise.

Acknowledgment

The authors wish to express their indebtedness and appreciation to various colleagues and cooperators without whose assistance the work herein reported would not have been possible: to Miss Hazel Cameron, of the Department of Plant Pathology and Bacteriology, for growing the rats and dissecting out their bones; to T. B. Clark, of the Department of Animal Husbandry, for growing the chicks and assisting with the removal of their bones; to J. H. Longwell (resigned Sept. 31, 1938), of the Department of Animal Husbandry, for supplying the swine and for removing all bones from both the pigs and the dairy heifers; to H. O. Henderson, of the Department of Dairy Husbandry, for supplying the dairy animals; to I. J. Duncan, of the Department of Agricultural Chemistry, for assistance with the preparation of the swine and cattle bones for analysis and for the determination of magnesium, calcium, and phosphorus in the ash of the swine bones; and to A. H. VanLandingham, of the Department of Agricultural Chemistry, for assistance with the preparation of the swine and cattle bones for analysis.

Review of Literature

There is an extensive literature bearing on the general field of bone analysis and bone composition, particularly in relation to various factors of nutrition. No attempt has been made to review this literature exhaustively. In the following pages brief reference only is made to the results of certain other workers which relate to those herein reported. In 1925 Hammett (7) reported on changes in weight, moisture, ash, and organic-matter content of the humeri and femurs of white rats during growth. He found the ash percentage of the humerus greater than that of the femur in both sexes at all ages, and a higher percentage of ash in both bones in the female than in those of the male. Due largely to deposition of ash the percentage of water decreased with age in the bones of both sexes, the increase in percentage of organic matter being a minor factor. Chick and her associates (5) published the effects of diets deficient in fat-soluble vitamins and in phosphorus on the composition of the skeletons of young rats. They reported the composition of rachitic bones as characterized by a content of ash much below the normal, a water content much above the normal, a slightly increased proportion of fat and of organic material, and a very low value of the ash/organic-matter ratio. They state that if chemical examination is used in the diagnosis of rickets, the best criterion of defective calcification is given by the A/R ratio: i. e., the ratio of the amount of ash to the amount of organic material contained in the fat-extracted bone. About the same time Maynard and his co-workers (17) showed that sunlight exerted a favorable influence on the mineral nutrition of growing pigs, causing an increase in the ash content of the bones, and Bohstedt and his associates (4) published the results of their studies upon the mineral requirement of pigs and the effect of diet on bone development. They found stiffness associated with poorly calcified and ossified bones, and therefore a possible manifestation of rickets or osteoporosis or both. An immediate cause of posterior paralysis was found to be fractured vertebrae in the lumbar-sacral region of the spinal column. Good bone development was not synonymous with good physical development in other respects, as some pigs that grew dense, hard, strong bones on certain rations were nevertheless physically stunted, and on the other hand a relatively weak skeletal system sometimes supported a vigorous, rapidly-growing pig up to heavy market weight. Evans (6) found the main effect of a low-calcium ration on bone development in swine to be a low ash content. The ratio of lime to phosphate was almost the same in different bones of the same individual and also in normal and rachitic bones, the composition of the ash remaining unchanged.

In 1929, and again in 1933, Bethke and co-workers (1,2) published the results of their studies on the effect of calcium/phosphorus ratios on bone formation in pigs and chicks and stated the optimum for each. Holmes and co-workers (10) found calcium and phosphorus

deposited in a fairly constant ratio in the tibiae of growing chicks regardless of the completeness or incompleteness of bone development. These authors (11) studied also the influence of sex on size and composition of tibiae in growing chicks. They reported the ash, calcium, and phosphorus content of tibiae from males slightly higher than from females at three weeks of age, whereas at six weeks the reverse was true, and at nine weeks the difference was still greater in favor of the female tibiae. Schroeder (18) likewise found a higher rate of calcification in female chicks. In 1928 Kruger and Bechdel (14) reported on the normal deposition of minerals in the bones of male Holstein calves at two to six months of age. They analyzed ribs, femurs, humeri, and frontal bones. Because of early calcification they regarded a section of the frontal bone as less valuable than the others and considered complete bones as giving a truer picture of mineral deposition than cross-section portions. The percentage of ash based on fat- and moisture-free bone and ash per cubic centimeter of bone volume proved to be the most valuable data. They found that the percentage of calcium and phosphorus in bone ash varied only slightly with the age of the animal and proposed the ratio of ash to organic residue in fresh bone as a possible useful index of bone condition. The percentage of water decreased with age while the ash and organic matter increased. They reported that ash replaced the greater part of the decrease in water percentage. Two years later Henderson and Weakley (9) published the results of a study of the effect of feeding different amounts of calcium and phosphorus upon the growth and development of dairy heifers. This report included analyses of both blood and bones. They state that when fed rations low in phosphorus, growing dairy animals cannot draw sufficient phosphorus from their bones to maintain the normal supply of inorganic phosphorus in the blood, and that rations which contain less than 0.35 percent of calcium or less than 0.20 percent of phosphorus give rise to a bone which is low in ash and consequently low in calcium and phosphorus but high in moisture and extractable material. The ash of the bones contained approximately the same percentage of calcium and phosphorus regardless of the rations fed, and ribs, femurs, or humeri could be used for analysis with the same general results.

As already indicated, analytical procedures for bone have varied widely in the hands of different investigators. In 1933 St. John, Kempf, and Bond (19) made a plea for standardization of the method for determining ash in bones. The following year Bethke and Record (3) reported that bones (of chicks) can be extracted as effectively with hot 95 percent alcohol as with alcohol followed by ether, and suggested that the percentage of ash be expressed on a moisture-free, fat-free basis. In 1935 Lachat (15) stated the situation clearly and described some of the variations in technic employed. In collaboration with other workers he undertook a solution of the problem as applied to Vitamin D assay. This and later reports by the same author show the need for standardization and the degree of agreement to be expected from uniform and non-uniform procedures.

Animals and Rations

In the study herein reported four different kinds of animals were under experiment, viz., rats, chickens, pigs, and dairy heifers. In all instances the animals being compared were of similar breeding and were placed on rations designed to produce differences in bone development, the object being to analyze and compare skeletal parts under both normal and deficient feeding. Appreciable differences were obtained in bone composition with three of the four kinds of animals, the pigs being the exception. In the swine-feeding experiment there were pronounced symptomatic effects in the animals on the deficient rations, but these effects did not influence the composition of the bones to a very great extent.

Rats: The 20 rats used were albinos — ten males and ten females; five of each sex were fed a normal ration (Sherman's stock diet No. 13) and five of each sex were fed a rachitic ration (Steenbock and Black's diet No. 2965). The rats were killed at 65 and 70 days of age.

Chicks: The 20 chicks were White Leghorns — ten males and ten females; five of each sex were fed a normal diet and five of each sex were fed a rachitic diet. The normal diet was made up of corn meal, wheat bran, wheat middlings, alfalfa, meat scrap, dried buttermilk, salt, and codliver oil. The rachitic diet consisted mainly of corn meal with small amounts of calcium carbonate and salt, with skim milk *ad libitum*. The chicks were killed at 35 days of age.

Pigs: The 19 pigs were bred and selected in such a manner as to be closely comparable. They included eight Poland China, four Duroc Jersey, three Berkshire,¹ and four cross-bred animals. There were fourteen males and five females. Lot 1 received a normal ration made up of yellow corn, tankage, linseed oil meal, alfalfa meal, and codliver oil; Lot 2 received a vitamin A- and D-deficient ration made up of white corn, buckwheat middlings, and tankage; Lot 3 received a ration consisting of white corn, oats, linseed oil meal, and tankage; Lot 4 received the same ration as Lot 3, but Lot 4 was allowed the freedom of an outdoor paved lot whereas Lot 3 was kept continuously indoors. Lots 1 and 2 likewise were confined continuously indoors. All lots were given a mineral mixture made up of ground limestone, bone meal, and salt. Each lot contained two Poland China, one Duroc Jersey, one Berkshire,¹ and one cross-bred animal. Pigs not showing severe symptoms of deficiency before reaching approximately 225 pounds weight were allowed to attain that weight, at which time they were slaughtered. Animals showing severe symptoms before reaching 225 pounds weight were removed

¹Originally there were four Berkshires — one in each of the four lots. However, the Berkshire in Lot 3 died while on the experiment. No records for it were retained, and no analyses of its bones were made.

and killed. For this reason the individuals ranged in age from 193 to 288 days at time of slaughter.

Dairy Heifers: Only two animals were available for the bone comparisons in dairy cattle. They were grade Holstein heifers; one was fed a normal ration composed of timothy hay, corn meal, ground oats, wheat bran, and corn-gluten meal; the other was fed a ration low in phosphorus composed of timothy hay, polished rice, wheat gluten, and beet pulp or wheat flour. Both animals were slaughtered at the age of 15 months.

Sampling and Methods of Analysis

PREPARATION OF BONES FOR ANALYSIS

One precaution strongly emphasized throughout the analyses herein reported is that of care in preparing and handling the material for and during the various analytical procedures. To avoid variation in sampling, whole bones only were employed. In certain instances two or more bones from the same side were combined to form a single composite sample.

All bones were removed from the fresh carcass and freed from adhering tissue as uniformly as possible. In dissecting out the bones all muscle, tendons, and ligaments were removed. The periosteum and articular cartilages, however, were left intact on the shaft and included in all samples. The rat and chick bones were weighed, crushed between the jaws of pliers, cut into small lengths with cutting pliers and placed in fritted-bottom Jena glass crucibles. They were then dried, extracted, and ashed without transfer. After removal from the carcass the bones from the dairy heifers were broken open with a cleaver and the marrows were separated and removed as completely as was practicable from all bones except the ribs. Marrows, and bones exclusive of marrows, were weighed and analyzed separately. The analytical results were combined later to represent the values for whole bones. Both pig and cattle bones were ground twice — first in a power-driven Mann bone-grinder and immediately thereafter in a small hand-operated food chopper. The few pieces failing to pass through the bone-grinder were collected and reduced by hand in a covered iron mortar at the same time that the bulk of the material was being passed through the food chopper. Every reasonable precaution was taken to avoid losses of either material or moisture. Five persons worked simultaneously: one dissected out and prepared the bones, two operated the power grinder and mortar, one operated the food chopper, and one weighed the samples. The grinding, chopping, and weighing operations together required no more than ten minutes for any one sample, and the entire procedure was accomplished within an hour of the time the bone was first removed from the carcass. In the interim the cleft bones were wrapped in waxed paper and placed in large, wide-mouth, stoppered glass bottles to prevent loss of moisture.

METHODS OF ANALYSIS

In weighing the pig and cattle bones obviously there was a choice of making the weight before or after grinding. If weighings were made before grinding, any loss or gain of particles in cleaning the machines would be counted as moisture and so affect the accuracy of that determination; if weighings were made after grinding there would be some slight loss of moisture from each sample due to exposure during grinding. By the latter method the loss would be proportional to size of sample in all cases. After due consideration it was decided to make the time of grinding as short as possible and to take all green weights on the ground samples. This procedure appeared to reduce the chance for error to a minimum.

All drying was carried out in vacuo at 75° C. and approximately 50 mm. pressure of mercury for 48 hours. All extractions were made with anhydrous ethyl ether in extractors operated continuously for 48 hours. The rat and chick bones were extracted in a modified Bailey-Walker extractor (20) and the pig and cattle bones were extracted in Soxhlet extractors equipped with ground glass joints. Ash was determined on the dried, extracted, whole bones contained in the glass extraction crucibles in the case of the rat and chick bones. For the pig and cattle bones the vacuum-dried material was weighed, poured out, thoroughly mixed on a glass plate, and quartered. The sample was transferred to Whatman paper thimbles, dried, weighed, and extracted. After weighing, the extracted material was ground to pass a 1 mm. sieve in a Wylie mill, sampled, and ash determined on 5-gram samples in porcelain crucibles. All ashing was accomplished in an electric-heated muffle furnace equipped with a pyrometer, the temperature being near 600° C. for the rat and chick bones and near 650° for the pig and cattle bones.

The determinations made on all bones were green weight, moisture, ether extract, ash, and organic non-fat — the last mentioned being determined by difference. In the pig bones the percentages of calcium, phosphorus, and magnesium were determined on the ash from the right femur, right 7th and 8th ribs, and 2nd and 3rd lumbar vertebrae. In the cattle bones, refractive index and iodine absorption number were determined on the clear extracted marrow fat of all bones except the ribs. Refractive index at 40° C. was determined by the use of a Bausch & Lomb dipping refractometer, and iodine absorption number was determined according to the method of Hanus. Iodine absorption number alone was determined on the fats obtained from the ether extracts of all chick bones.

BONES TAKEN FOR ANALYSIS

The bones taken for analysis from the various kinds of animals were the long bones ordinarily employed in such work. In addition, certain others were included to permit a study of the possibility of less extensive mineral deposition in special regions. The following outline shows the bones taken:

Bones Taken for Analysis from Each Animal

BONES AND COMBINATIONS OF BONES USED

Animal	
Rat	Femur-tibia-fibula (composite); Humerus-ulna-radius (composite). Lefts and rights in each case — total of four samples.
Chicken	Femur; humerus; tibia; ulna-radius (composite). Lefts and rights in each case and in addition the sternum — total of nine samples.
Pig	Femur; humerus; tibia; ulna-radius (composite); 7th and 8th ribs (composite). Lefts and rights in each case and in addition the 2nd and 3rd lumbar vertebrae (composite) — total of eleven samples.
Dairy Heifer	Femur; tibia; metatarsus; humerus; ulna-radius (composite); metacarpus; 7th and 8th ribs (composite); 13th rib. Lefts and rights in each case — total of sixteen samples.

Results

In the succeeding pages the analytical results are set forth in tabular form. For convenience in making comparisons, animals on normal and deficient rations are grouped separately.

Tables 1a and 1b show the data for the rat bones; Tables 2a to 2e show the data for the chick bones; Tables 3a to 3h show the data for the pig bones; and Tables 4a and 4b show the data for the bones from the dairy heifers.

General Discussion

EFFECT OF RATIONS FED ON WEIGHT AND COMPOSITION OF BONES

Tables 1 to 5, inclusive (see Appendix),* show the extent to which it has been possible to modify the weight and composition of the bones of the various animals by feeding different rations. As would be anticipated, the outstanding effect has been the production of lighter bones of higher moisture and of lower ash by the animals on the rachitic rations. This result occurred with three of the four types of animals under experiment, the exception being the swine.

The rat bones were affected in greatest degree. Table 5 shows that in the rat bones the rachitic ration decreased the average normal weight by about one-third, increased the moisture content by approximately one-third, and reduced the ash by somewhat more than half. The bones of the rear leg (femur-tibia-fibula composite) average approximately three percent higher in moisture, and a like amount lower in ash than the corresponding bones of the fore leg (humerus-ulna-

*Tables 1a and 1b show individual values for rat bones; Tables 2a to 2f for chick bones; Tables 3a to 3h for swine bones; and Tables 4a and 4b for dairy cattle bones.

radius composite). This statement holds true for both the normal and the rachitic ration. The effect of ration on ether extract was almost nil for the bones of the fore leg, and for the bones of the rear leg the ether extract was reduced only moderately by the rachitic ration. The organic non-fat fraction averages about three percent higher in the bones from both fore and rear legs of animals on the rachitic ration.

The chick bones, like the rat bones, show a lighter weight, higher moisture, and lower ash content for the chicks on the rachitic ration, but the extent of change in moisture and ash brought about by the deficient ration is somewhat less in the case of the chicks. On the other hand, the ration has greatly affected the ether extract portion in the chick bones, the normals averaging four to six times as much as the rachitics, as shown in Table 5. The organic non-fat fraction averages slightly higher for the bones from the normal ration, a condition which is the reverse of that obtaining for the rat bones.

Although only two animals supplied bones for the study with dairy cattle, it is apparent that here, also, the rachitic ration has brought about changes in weight, moisture, and ash content corresponding to those described for the rat and chick bones. Table 4a shows an average increase in moisture content of approximately one-third and a like decrease in ash for the bones from the animal on the rachitic ration. It is of interest to note that the ether-extract portion of the cattle bones seems not to have been affected. The organic non-fat fraction of the cattle bones is slightly higher in the bones from the normal ration, as was true also for the chick bones.

The results with swine bones afford an interesting departure from those obtained with other animals in regard to effect of ration. In comparing data for the various bones from the four lots of swine it should be kept in mind that the animals varied in age and breed as well as in ration consumed. For these reasons Lot 2 is most nearly comparable with Lot 1, and Lot 3 with Lot 4. Tables 3 (a, b, c, d, e, f, g) and 5 show that the different rations fed had little effect upon the composition of the bones analyzed. There was, however, abundant symptomatic evidence of nutritional disturbance in animals on the deficient rations. At the time they were slaughtered, all the animals in Lot 1 were vigorous and thrifty and showed no abnormalities, but in the other three lots none was entirely free from symptoms of malnutrition. In these three lots only four individuals finished to the desired weight of 225 pounds, and all fourteen in greater or less degree showed signs of paralysis, sore, inflamed eyes which sometimes resulted in blindness, loss of appetite, or difficult breathing. Notwithstanding these physiological disturbances, which in some individuals were very pronounced, the bone analyses fail to show clear-cut differences attributable to the rations fed. The conclusion to be drawn here seems to be that swine on rations of this type show continuous and severe symptoms of malnutrition long before the percentage composition of the bones is affected in appreciable degree.

MOISTURE/ASH RATIO

Since the rat, chick, and cattle bones all were affected by the ration fed, it is pertinent to examine the data carefully to learn if similar tendencies did not exist also in the swine bones. Because of the small number of pigs in each lot, statistical methods are not as suitable as they otherwise might be for such comparison. Perhaps the most consistent and outstanding effect of ration on the bones of animals other than swine was that of increased moisture and decreased ash content produced by the deficient rations. Since these two constituents are inversely related it seemed possible that a study of moisture/ash ratios might assist in bringing out any consistent changes in composition. Table 6 shows the values obtained by dividing the average percentage of moisture by the average percentage of ash for the various animals and bones. In all instances except one the moisture/ash ratio is higher for the bones of animals on deficient rations, the exception being the swine tibiae of Lots 1 and 2. Even though the ratio differences in the hog bones are small throughout, all the bones of all four lots of hogs except the tibiae in Lots 1 and 2 fall into a regular and consistent arrangement which suggests that, even in the case of the swine, the composition of the bones was modified slightly by the deficient rations fed, although the change is scarcely detectable in the percentage columns of the various constituents. The orderliness of this arrangement also suggests that the moisture/ash ratio is a rather sensitive measure of change from the normal in mineral deposition studies.

If this is true then moisture/ash ratio may be used also to determine what part of the skeleton, if any, is most likely to be affected by deficient feeding, or what bone or bones would be most subject to change and for that reason possibly more suitable from the standpoint of analytical comparisons. The last column in Table 6 shows values representing a ratio of ratios or the relative change in moisture/ash ratio of bones from animals on deficient rations, with the moisture/ash ratio of normals as the denominator. In this column the bones showing the largest values are necessarily those in which greatest changes in moisture and ash occurred. The values indicate that in the rat the femur-tibia-fibula composite was affected somewhat more than the humerus-ulna-radius composite. In the chick the ulna-radius, sternum, and humerus were affected more than the femur and tibia. This outcome is interesting inasmuch as the tibia is perhaps the bone most frequently used in work with chicks. Of course, considerations such as ease of removal from the carcass, lack of interference with sale value, and perhaps others would affect the choice of bone to be used for analytical purposes. Nevertheless in these experiments the tibia was the bone showing least effect of ration in the chick.

In the dairy heifers the femur and tibia showed the greatest degree of change, while in the swine there was little difference among the various bones used, other than the lumbar vertebrae, which it

must be admitted are rather difficult to remove and prepare satisfactorily for analysis.

PAIRING OF LEG BONES WITH RESPECT TO COMPOSITION

In the larger animals, particularly, there is a natural pairing of the bones of the leg with respect to moisture and ash content in relation to skeletal position. The bones nearest the vertebral column are highest in moisture and lowest in ash with corresponding decreases and increases, respectively, toward the extremities. Table 7 shows this tendency. For purposes of comparison the values for ribs and lumbar vertebrae are included in the table.

In Table 7 it may be seen that the femur and humerus are higher in moisture than the tibia and ulna-radius, while these in turn are higher than the metacarpus and metatarsus. The ash content varies in the opposite direction being lowest in the femur and humerus, and highest in the metacarpus and metatarsus. Table 4b shows that this tendency obtains in certain characteristics of the marrow-fats also.

EFFECT OF AGE ON MOISTURE AND ASH CONTENT OF SWINE BONES

It is a well known fact that bones tend to decrease in moisture content and increase in ash with increasing age. The extent to which this change occurs in swine may be shown in part by a study of the bones from the eight Poland China pigs.

These animals may be divided into three groups with respect to age when slaughtered. Table 8 shows the number of animals in each group, together with the average age and average composition of all bones analyzed for each group.

EFFECT OF BREED ON ETHER-EXTRACT CONTENT OF SWINE BONES

In a similar manner the data available indicate that, although breed has little or no effect upon moisture and ash content, it may influence the ether extract fraction of the bone. Table 9 shows these data. (Averages for all bones.)

Table 8 shows that with the Poland Chinas a difference of two months in age produced a difference of approximately $4\frac{1}{2}$ percent each in moisture and ash, the former decreasing while the latter increased. Table 9 shows that at the same age, on identical rations, the Berkshires averaged about three percent lower in ether extract than the Duroc Jersey and Poland China animals. Perhaps the tendency of certain breeds to produce and store fat is reflected in the composition of the bones as well as in the character of the flesh.

COMPARISONS OF ASH ON "GREEN" vs. "DRY-EXTRACTED" BASIS

In mineral deposition studies it is customary to report ash analyses on the "dry-extracted" bone, and many comparisons are made on this basis. Perhaps the chief reason for this procedure is the difficulty

of making accurate determinations of moisture and ether extract. This feature is evident particularly with bones from larger animals. Moisture cannot be determined without grinding, and grinding, difficult at best, cannot be accomplished without some loss of moisture. Fatty materials also interfere with ease of manipulation. For these reasons many investigators disregard both moisture and ether extract and make their comparisons on the ash content of the dry extracted bone. A study of Tables 1 to 4 shows that for any given bone the organic non-fat fraction (the portion of dry, extracted bone other than ash) is one of the most constant or least variable fractions determined. Moisture, on the other hand, varies considerably as does also ether extract. This situation obtains irrespective of the kind of animal or the particular bone under consideration. On the dry-extracted basis, variations in ash content are less pronounced and therefore less apparent than when the ash is determined on the green basis and considered in relation to moisture as moisture/ash ratio. As pointed out earlier in this discussion, since moisture varies inversely with ash, the change in moisture/ash ratio becomes a rather sensitive test of change in mineral deposition. This feature is brought out more forcibly in a consideration of the swine bones listed individually in Tables 3a to 3f.

Table 10 shows the average ash content of the various bones of all four types of animals on the dry-extracted basis as compared with the green basis.

On the dry-extracted basis the swine bones in Lot 2 show a higher ash content than Lot 1 for all bones except the lumbar vertebrae. This cannot be attributed to differences in age as the animals in Lot 1 averaged four days older at time of slaughter than those in Lot 2. Since Lot 1 received the normal ration, the bones from these animals would be expected to show a higher ash content on any proper basis of comparison. On the green basis the situation is improved considerably, as four of the six bones show higher values for Lot 1 than for Lot 2, but even so, some of the differences are not very convincing. Lots 3 and 4 are more consistent on either basis of comparison, Lot 4 showing higher ash values for all bones than Lot 3. If, however, change in moisture/ash ratio is used as the criterion (Table 6) rather than change in percentage of ash alone, then in eleven of the twelve comparisons the lots fall into the sequence that would be anticipated and show lower ratios for the normal or less deficient rations.

Where the composition of the bone is affected in considerable degree, as was true for the rats, chicks, and dairy heifers, changes in composition are apparent on any of the three bases of comparison discussed.

EFFECT OF RATION ON IODINE ABSORPTION NUMBER AND REFRACTIVE INDEX OF BONE AND MARROW FATS

Chick Bones: Table 2f shows the iodine absorption numbers of the fats extracted from the chick bones. In comparing these data it should be kept in mind that many of the values were determined on relatively small amounts of material (31 on five milligrams or less), that the entire extract was used for each determination, thus precluding the possibility of replication, and that the average weight of extract available was between 60 and 70 milligrams. As already indicated (Table 5), extracts from the rachitic bones, particularly, were low in weight.

Two features stand out clearly in these values: (1) the iodine absorption numbers for the extracts from the normal chicks are fairly constant for all bones and average approximately 50, and (2) iodine absorption numbers for the extracts from the rachitic chicks fluctuate widely and average approximately 70. The rachitic ration seems to have decreased the amount of bonefat and also to have made this fat more highly unsaturated and more subject to variation in degree of unsaturation.

Cattle Bones: Table 4b shows the iodine absorption numbers and the refractive indices of the extracted marrow fats from the leg bones of the dairy heifers. It may be seen that in each instance the marrow fat resulting from the rachitic ration is higher in iodine absorption number and in refractive index than the corresponding marrow fat resulting from the normal ration. It may be seen also that there is a tendency toward pairing of the leg bones with respect to these determinations. The humerus and femur run lowest, followed in turn by the ulna-radius and tibia, while the metacarpus and metatarsus are highest by a considerable margin. This tendency toward pairing is in accord with the facts already mentioned in connection with moisture and ash content (Table 7).

Apparently the feeding of deficient rations has resulted in bone and marrow fats of a more highly unsaturated nature in both chicks and cattle, but the significance of the production of such fats by animals on rachitic rations remains obscure.

CALCIUM, MAGNESIUM, AND PHOSPHORUS CONTENT OF THE ASH OF SWINE BONES

When the swine experiment was planned it was thought possible that certain bones might show changes in the calcium, phosphorus, and magnesium content as a result of deficient feeding. To gain evidence on this point these constituents were determined on the ash from the right femurs, right 7th and 8th ribs, and the 2nd and 3rd lumbar vertebrae. Table 3g shows individual values for the various animals and bones as well as average values for the several lots. It is evident that the different rations had no appreciable effect upon the percentage of calcium, magnesium, or phosphorus present in the

ash from the various bones. Furthermore, bones as different in structure and function as vertebra and femur show similar contents of calcium and phosphorus. The failure to modify the percentage of calcium and phosphorus in the ash of swine bones by deficient feeding in this experiment is in accord with the results reported by Henderson and Weakley (9) for dairy animals.

BILATERAL VARIATION IN WEIGHT AND COMPOSITION OF THE LONG BONES

The study of the results from the standpoint of bilateral variation has been published elsewhere (21), and no attempt will be made to repeat the data here. However, certain features not included in the former report may be of interest. Since most of the bones analyzed were paired as lefts and rights from the same individual it is permissible to apply Student's method and study the tendency, if any, for one side to dominate over the other with respect to a given determination. In this study no attention need be given to the character of the ration since the pairing exists in equal degree for all individuals irrespective of the ration fed. A statistical examination of the data for the rat bones showed no significant differences in green weight, or in percentages of moisture, ash, or organic non-fat between the left and right sides. This outcome is in accord with values reported by other investigators (12, 13) on the ash content of dry extracted femurs, or tibiae and femurs, from the left and right sides of the rat. The dairy animals were only two in number, and hence the data are insufficient to be of much value in making comparisons of this type. There seemed, however, to be a tendency toward heavier bones on the right side. For reasons indicated, the comparison data for the rat and cattle bones will be omitted. The chick and swine bones showed some differences and the values for these are given herewith. Since the former study dealt with percentage differences in moisture, ash, ether extract, and organic non-fat, the present discussion will deal with weights (rather than percentages) of constituents on either side.

Table 11 gives the average weights of green bone, moisture, ash, and organic non-fat for the chick and swine bones, and Table 12 shows the significance of the differences between the two sides for individual bones and for combined values with Livermore's (16) table of odds.

Examination of Table 11 shows that the bones from the left side average higher in both green weight and moisture than those from the right side. With one exception this statement holds true for both chicks and pigs, the exception being the average value for the chick femurs. In Table 12 it is shown that the differences are significant for certain bones of each species, as are also the combined values for all bones of either kind of animal. No explanation is available for the failure of the chick femurs to conform to the general trend of higher values for green weight and moisture on the left side. Reference to Table 12 shows that the difference in this instance is not significant. It is of interest to note that in the chick the humerus

and tibia are the bones showing the most significant differences for these determinations, and this tendency appears to hold true to a lesser extent for the swine bones also, although in the latter the femur likewise shows considerable differences.

Weights of ash and ether extract are much less consistent in their behavior, and the odds for these determinations are significant in only one instance, viz., the ash of the chick femur being higher for the right side.

With respect to the organic non-fat fraction, weights for this constituent show considerable differences, again in favor of the left side, as was the case for moisture and green weight. Combined values for all bones likewise show significant differences, the left side showing the higher value.

It appears, then, that in general for the chicks and pigs the bones of the left side have tended to average slightly higher in green weight and in weight of moisture and organic non-fat than the bones of the right side, but in only a few instances were the differences of sufficient magnitude and consistency to render them significant when subjected to statistical analysis. Because of the interdependence and inverse relationship between moisture and ash the latter also shows significant differences, if considered on a percentage basis, as was shown in an earlier publication (21).

Summary and Conclusions

A study was made of the composition of different skeletal parts of the rat, chick, pig, and dairy heifer. Whole bones were used for analysis throughout, and the determinations made were green weight, moisture, ash, ether extract, and organic non-fat. Comparisons included analyses from animals fed normal rations and from animals fed rachitic rations designed to produce deficient bone development.

1. In general the deficient feeding resulted in lighter bones of higher moisture and lower ash content.

2. The swine proved to be an exception to this behavior, as only very slight differences, if any, could be detected in the analyses of the bones produced on normal and rachitic rations. On the other hand, symptomatic evidence of physiological disturbance was abundant in the pigs on deficient rations, showing that malnutrition may be strongly indicated by certain types of disorder without affecting the composition of the bone in appreciable degree.

3. The moisture/ash ratio is a sensitive measure of change from the normal in mineral deposition studies.

4. There is a natural pairing of the leg bones with respect to moisture and ash content in relation to skeletal position. The femur and humerus are higher in moisture and lower in ash than the tibia and ulna-radius, while these in turn are higher in moisture and lower in ash than the metatarsus and metacarpus.

5. Bones from the Berkshire breed were found to contain a less amount of ether-extractable material than those from either the Poland China or the Duroc Jersey breed.

6. Comparisons of ash on a green basis as compared with a fat-free, moisture-free basis seem to show certain advantages for the former and especially when ash is considered in relation to moisture as moisture/ash ratio.

7. The feeding of rachitic rations to chicks and dairy calves resulted in the production of bone and marrow fats of a more highly unsaturated nature than those produced on normal rations.

8. The different rations fed to the pigs had no appreciable effect upon the percentage of calcium, magnesium, or phosphorus found in the ash from their bones.

9. A study of bilateral variation in the green weight of the long bones shows a tendency toward heavier bones on the left side in the chick and pig.

10. Examination of the weights of the individual fractions determined shows that where an appreciable difference in weight of green bone was present between the two sides, this difference was chiefly in the moisture fraction, although the organic non-fat fraction also tended to be higher on the left side.

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Appendix

TABLE 1A—*Rat bones: Green weight and composition of femur, tibia, and fibula*

Rat No.	Sex	Ration	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1146	M	Rachitic	0.4957	.5618	58.48	59.26	12.87	12.16	4.32	4.38	24.33	24.20
1144	M	"	.5453	.5348	58.79	58.97	12.32	12.57	4.20	3.95	24.69	24.51
1204	M	"	.4893	.5209	58.27	56.84	13.39	12.82	3.09	3.26	25.25	27.08
1277	M	"	.3586	.3771	58.90	60.28	12.94	12.04	3.07	2.84	25.09	24.84
1275	M	"	.4309	.4639	59.71	60.23	13.25	12.63	2.55	2.39	24.49	24.75
1150	F	"	.5281	.5531	57.00	58.88	13.21	12.09	4.89	4.47	24.87	24.56
1147	F	"	.5451	.5467	58.08	58.02	12.66	12.84	4.35	4.13	24.91	25.01
1207	F	"	.4908	.4993	58.96	58.68	11.61	11.22	3.06	3.29	26.37	26.81
1281	F	"	.3838	.3301	57.71	55.29	13.76	15.57	3.54	3.54	24.99	25.60
1280	F	"	.4251	.3749	61.14	59.59	11.83	13.31	2.56	2.08	24.47	25.02
Average			.4693	.4769	58.70	58.60	12.78	12.72	3.56	3.53	24.95	25.24
General average			0.4731		58.65		12.75		3.55		25.10	
1145	M	Normal	0.3904	.9720	42.42	42.30	31.26	32.17	3.56	3.43	22.76	22.10
1203	M	"	.8421	.8515	41.76	42.14	32.53	32.33	3.86	3.73	21.85	21.80
1205	M	"	.7744	.7822	41.96	41.55	31.83	31.91	3.90	4.19	22.31	22.35
1276	M	"	.7543	.7772	43.18	43.77	31.63	30.65	2.59	2.86	22.60	22.72
1278	M	"	.8528	.8319	44.77	44.27	30.03	30.76	3.49	3.16	21.71	21.81
1149	F	"	.7411	.7087	40.91	39.06	31.40	33.86	4.82	4.90	22.87	22.18
1208	F	"	.8952	.8528	40.39	41.01	32.48	33.06	4.69	4.21	21.84	21.72
1206	F	"	.6167	.5904	39.53	38.70	32.25	33.96	5.55	4.76	22.61	22.58
1279	F	"	.5694	.5358	40.04	38.63	31.98	33.76	5.46	4.83	22.52	22.18
1282	F	"	.5389	.5139	40.36	40.75	32.25	32.03	4.90	4.94	22.49	22.28
Average			.7575	.7416	41.59	41.22	31.76	32.44	4.28	4.10	22.36	22.23
General average			0.7496		41.46		32.10		4.19		22.30	

TABLE 1b--*Rat bones: Green weight and composition of humerus, ulna, and radius*

Rat No.	Sex	Ration	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1146	M	Rachitic	0.2049	.2265	55.88	57.47	15.28	14.48	2.25	2.43	26.59	25.62
1144	M	"	.2114	.2398	57.33	56.92	16.37	14.43	1.32	2.42	24.98	26.23
1204	M	"	.2198	.2205	56.69	56.14	15.65	15.15	1.32	1.95	26.16	26.76
1277	M	"	.1921	.1714	56.95	55.95	14.42	16.16	2.34	1.52	26.29	26.37
1275	M	"	.1951	.1867	55.25	56.03	16.25	16.28	2.20	1.71	26.30	25.98
1150	F	"	.1974	.2173	54.10	55.36	16.82	15.48	2.23	2.16	26.85	27.02
1147	F	"	.2161	.2048	54.37	55.62	16.06	15.38	2.50	2.49	27.07	26.51
1207	F	"	.2155	.2011	53.32	54.50	14.62	16.01	1.53	1.44	30.53	28.05
1281	F	"	.1675	.1506	53.19	51.93	16.90	17.80	2.51	2.52	27.40	27.75
1280	F	"	.1863	.1786	57.17	56.78	15.46	15.85	1.99	2.07	25.38	25.30
Average			.2006	.1997	55.42	55.67	15.78	15.70	2.03	2.07	26.76	26.56
General average			0.2002		55.55		15.74		2.05		26.66	
1145	M	Normal	0.3554	.3793	40.06	39.07	34.65	35.75	1.57	1.56	23.72	23.62
1203	M	"	.3529	.3520	39.33	40.54	34.71	34.18	2.13	1.56	23.23	23.72
1205	M	"	.3060	.3026	37.25	36.55	36.86	37.15	1.77	2.58	24.12	23.72
1276	M	"	.3081	.2922	39.39	38.98	34.50	35.49	1.56	1.71	24.05	23.82
1278	M	"	.3290	.3519	40.06	41.55	35.29	33.19	1.49	1.88	23.16	23.38
1149	F	"	.3054	.3290	37.29	36.57	36.84	33.80	2.75	3.10	23.02	26.53
1208	F	"	.3781	.3388	41.58	40.56	33.75	35.22	2.04	1.49	22.63	22.73
1206	F	"	.2400	.2606	34.75	37.68	38.63	35.11	1.96	3.22	24.66	23.99
1279	F	"	.2401	.2322	37.82	35.75	36.27	35.69	2.79	3.06	23.12	24.30
1282	F	"	.2216	.2191	37.64	37.33	36.01	35.78	2.62	2.56	23.73	24.33
Average			.3077	.3088	38.64	38.46	35.75	35.23	2.06	2.27	23.54	24.03
General average			0.3083		38.55		35.49		2.17		23.79	

TABLE 2A—Chick bones: Green weight and composition of femur

Chick No.	Sex	Ration	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
47	M	Rachitic	1.2490	1.2125	67.73	67.65	10.42	10.58	1.03	.77	20.82	21.00
10	M	"	1.2304	1.1284	71.77	70.88	9.60	9.60	.67	.70	18.74	18.82
69	M	"	.8549	.8564	65.94	65.15	12.41	13.07	.74	.84	20.91	20.94
57	M	"	1.0192	1.2077	69.12	69.78	10.65	10.13	.47	.70	19.76	19.39
49	M	"	.8227	.8528	61.99	62.18	12.77	12.57	4.41	4.32	20.83	20.43
51	F	"	.8139	.8808	67.64	66.27	9.98	10.80	.58	.57	21.80	22.36
2	F	"	.9249	.9245	70.47	69.66	10.04	10.54	.51	.57	18.98	19.23
11	F	"	.8002	.8371	67.01	67.46	11.37	11.05	.84	.76	20.78	20.73
59	F	"	.6926	.6991	67.76	67.19	12.09	12.34	.33	.36	19.82	20.11
66	F	"	1.1107	1.0630	66.88	66.90	10.17	10.17	1.34	1.27	21.61	21.66
Average			.9519	.9662	67.63	67.31	10.87	11.09	1.09	1.11	20.41	20.50
General average			0.9591		67.47		10.98		1.10		20.46	
36	M	Normal	1.5200	1.5193	51.84	51.63	17.51	18.25	9.47	9.10	21.18	21.02
50	M	"	1.3690	1.3824	52.45	53.25	17.72	17.43	8.23	8.17	21.60	21.15
56	M	"	1.8038	1.8418	56.56	55.93	17.53	17.61	9.74	4.95	23.17	21.51
9	M	"	1.4638	1.4283	54.77	53.48	16.70	17.63	7.04	7.56	21.49	21.33
61	F	"	1.5877	1.5693	54.44	54.79	15.20	14.74	9.89	10.13	20.47	20.34
68	F	"	1.3528	1.4058	51.56	51.52	16.00	15.79	11.72	11.72	20.72	20.97
6	F	"	1.3975	1.4132	57.45	58.12	17.41	16.83	2.51	2.64	22.63	22.41
54	F	"	1.2017	1.2172	53.69	52.85	17.18	17.62	7.92	7.96	21.21	21.57
13	F	"	1.5799	1.5839	54.65	54.31	17.00	17.27	6.92	7.06	21.43	21.36
Average			1.4524	1.4575	53.95	53.76	17.02	17.15	7.51	7.78	21.51	21.31
General average			1.4550		53.86		17.09		7.65		21.41	

TABLE 2B—*Chick bones: Green weight and Composition of humerus*

Chick No.	Sex	Ration	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left (gms)	Right (gms)	Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)
47	M	Rachitic	1.0281	.9673	67.36	66.25	10.72	11.48	.47	.32	21.45	21.95
10	M	"	.7088	.6424	73.48	72.65	7.60	9.98	.30	.30	18.62	17.07
69	M	"	.8185	.7747	65.83	64.45	12.63	13.33	1.25	1.10	20.39	21.12
57	M	"	.7524	.7394	70.18	70.88	9.50	8.86	.49	.53	19.83	19.73
49	M	"	.7411	.6998	63.32	63.62	10.47	11.03	6.99	6.04	19.22	19.31
51	F	"	.7334	.6700	68.72	67.94	8.69	9.30	.67	.75	21.92	22.01
2	F	"	.8157	.7656	71.07	70.79	8.97	9.55	1.14	.68	18.82	18.98
11	F	"	.7840	.7458	69.08	68.53	9.17	9.74	1.20	.95	20.55	20.78
59	F	"	.6023	.5616	72.80	71.69	7.69	8.24	.32	.25	19.19	19.82
66	F	"	.9201	.9205	67.15	67.06	9.33	9.47	1.74	1.76	21.78	21.71
Average			.7904	.7487	68.90	68.39	9.48	10.10	1.46	1.27	20.17	20.25
General average			0.7696		68.65		9.79		1.37		20.21	
36	M	Normal	1.2377	1.1913	54.05	51.88	17.06	17.49	8.61	9.26	20.28	21.37
50	M	"	1.1041	1.0456	55.62	53.54	17.72	18.69	6.01	5.83	20.65	21.94
56	M	"	1.4612	1.4222	55.85	56.39	16.35	16.65	6.72	5.58	21.08	21.38
9	M	"	1.2930	1.1168	54.30	55.02	16.02	18.42	7.29	5.72	20.79	21.56
61	F	"	1.1583	1.1118	56.42	55.02	16.01	17.23	6.44	6.56	21.13	21.19
68	F	"	1.0418	1.0448	52.85	53.30	15.91	16.14	10.13	9.52	21.11	21.04
61	F	"	1.1650	1.0760	56.47	55.03	17.59	18.50	3.71	4.03	22.33	22.44
6	F	"	1.0272	1.0142	54.93	50.90	17.48	17.97	6.20	9.00	21.39	22.13
54	F	"	1.0887	1.1769	55.32	55.54	16.12	17.53	8.23	5.07	20.33	21.86
13	F	"	.9543	.9933	53.45	53.97	18.42	18.25	6.68	6.75	21.45	21.03
Average			1.1531	1.1193	55.09	53.99	16.67	17.69	7.00	6.73	21.04	21.59
General average			1.1362		54.54		17.28		6.87		21.32	

TABLE 2C—Chick bones: Green weight and Composition of tibia

Chick No.	Sex	Ration	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
47	M	Rachitic	1.6439	1.5484	67.70	66.92	10.81	11.35	1.69	1.29	19.80	20.44
10	M	"	1.2602	1.1174	71.89	71.45	9.56	10.09	.29	.22	18.26	18.24
69	M	"	1.0556	1.0031	63.42	62.44	13.68	14.62	3.16	3.23	19.74	20.01
57	M	"	1.1609	1.1431	68.67	69.25	12.84	11.56	.41	.43	18.08	18.76
49	M	"	1.0876	1.0817	60.99	60.94	13.43	13.81	6.34	6.14	19.24	19.11
51	F	"	1.1277	1.0690	66.38	66.55	10.95	10.78	1.04	1.22	21.63	21.45
2	F	"	1.2873	1.2448	70.18	69.02	11.05	11.95	.62	.59	18.15	18.41
11	F	"	1.1340	1.1079	65.08	65.01	12.33	12.65	2.59	2.39	20.00	19.95
59	F	"	.8490	.8005	69.21	67.57	11.49	12.18	.31	.32	18.99	19.93
66	F	"	1.3886	1.3852	65.73	65.25	10.91	10.73	2.97	3.22	20.39	20.80
Average			1.2000	1.1501	66.93	66.44	11.71	11.97	1.94	1.91	19.43	19.71
General average			1.1751		66.69		11.84		1.93		19.57	
36	M	Normal	1.9981	1.7940	51.94	48.98	17.66	19.33	10.79	12.71	19.61	18.98
50	M	"	1.8344	1.7839	54.15	53.43	16.66	16.92	9.38	9.73	19.81	19.92
1	M	"	2.3763	2.3166	54.44	54.15	17.20	17.63	8.07	6.85	20.29	21.37
56	M	"	2.0613	1.9586	53.04	51.60	17.32	18.90	9.90	9.87	19.74	19.63
9	M	"	2.0326	1.9881	55.42	57.55	14.81	14.19	10.31	9.02	19.46	19.24
61	F	"	1.9375	1.9357	52.11	52.55	15.91	15.97	12.12	11.83	19.80	19.65
68	F	"	1.7700	1.8678	54.00	54.15	17.71	17.20	7.84	8.17	20.45	20.48
6	F	"	1.4703	1.5112	51.80	52.47	17.93	16.79	10.32	10.97	19.95	19.77
54	F	"	2.0844	2.1035	53.17	52.61	18.00	18.35	8.34	8.46	20.49	20.58
13	F	"	1.6278	1.5722	51.15	50.79	18.39	18.69	10.22	9.90	20.24	20.62
Average			1.9193	1.8832	53.12	52.83	17.16	17.40	9.73	9.75	19.98	20.02
General average			1.9013		52.98		17.28		9.74		20.00	

TABLE 2b—*Chick bones: Green weight and composition of ulna-radius*

Chick No.	Sex	Ration	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
47	M	Rachitic	0.8202	0.7895	65.39	65.08	10.90	11.27	.84	1.01	22.87	22.64
10	M	"	.5165	.5157	70.88	70.68	8.89	8.65	.31	.41	19.32	20.26
69	M	"	.5729	.5841	60.80	60.33	15.10	15.12	2.53	2.86	21.57	21.69
57	M	"	.5379	.5335	68.67	67.68	10.44	10.44	.63	.66	20.36	21.22
49	M	"	.5253	.5149	59.07	59.70	12.30	12.51	9.18	8.31	19.45	19.48
51	F	"	.5084	.4843	65.91	65.68	9.95	10.14	1.28	1.24	22.86	22.94
2	F	"	.5627	.5626	67.90	67.53	11.30	11.15	1.07	1.01	19.73	20.01
11	F	"	.5410	.5607	65.98	64.86	11.07	11.45	2.48	2.35	21.37	21.34
59	F	"	.4073	.3849	70.44	69.06	9.33	10.18	.32	.29	19.91	20.47
66	F	"	.6415	.6940	63.33	63.93	10.49	9.50	3.88	4.35	22.40	22.22
Average			.5684	.5624	65.75	65.45	10.98	11.07	2.25	2.25	21.03	21.23
General average			.5654		65.60		11.03		2.25		21.13	
36	M	Normal	0.9013	0.9040	46.23	46.07	18.01	18.19	15.16	15.35	20.60	20.39
50	M	"	.8753	.8065	48.35	46.57	17.88	19.19	12.46	12.73	20.71	21.51
1	M	"	1.0213	1.0274	49.38	49.09	17.23	17.75	12.74	12.83	20.75	20.33
56	M	"	.9198	.8618	49.38	47.45	17.56	18.79	12.37	12.24	20.69	21.52
9	M	"	.9397	.9275	49.44	47.91	16.49	17.59	13.79	13.89	20.28	20.61
61	F	"	.7558	.7001	44.23	41.89	17.27	17.61	17.87	20.31	20.63	20.16
68	F	"	.7907	.7980	50.59	51.64	19.67	19.32	7.53	7.37	22.21	21.67
6	F	"	.7243	.7223	45.69	43.71	19.27	19.36	13.79	14.26	21.55	22.07
54	F	"	.7244	.8263	47.79	47.86	21.27	18.87	10.92	11.50	20.02	21.77
13	F	"	.6961	.6696	45.61	44.09	19.54	20.25	13.60	14.29	21.55	21.37
Average			.8349	.8244	47.72	46.63	18.42	18.76	13.02	13.48	20.84	21.14
General average			0.8297		47.18		18.59		13.25		20.99	

TABLE 2E—*Chick bones: Green weight and composition of sternum*

Chick No.	Sex	Ration	Green weight (gms)	Moisture (%)	Ash (%)	Ether extract (%)	Organic non-fat (%)
47	M	Rachitic	2.8969	72.41	6.28	0.92	17.49
10	M	"	2.1514	76.26	4.99	.46	16.14
69	M	"	1.9210	69.15	8.60	1.56	18.77
57	M	"	2.1166	75.30	5.25	.50	16.83
49	M	"	1.8441	69.44	6.95	2.73	19.04
51	F	"	1.9278	68.38	5.89	.81	22.99
2	F	"	2.0872	73.07	6.33	.52	17.99
11	F	"	1.8599	71.19	6.77	.91	19.27
59	F	"	1.1055	67.12	7.18	.46	24.13
66	F	"	2.0642	69.63	5.89	1.70	20.72
		Average	1.9974	71.20	6.41	1.06	19.34
36	M	Normal	2.9735	58.64	12.38	6.24	19.77
50	M	"	2.7153	57.84	13.97	4.55	20.93
1	M	"	3.8840	62.00	10.99	3.70	19.43
56	M	"	3.0509	60.05	13.48	4.87	18.55
9	M	"	3.0163	59.69	11.71	5.88	19.70
61	F	"	3.2344	61.17	10.17	6.63	18.80
68	F	"	2.7714	62.39	12.52	2.20	20.12
6	F	"	2.2922	60.14	12.85	4.11	20.61
54	F	"	3.1145	61.64	12.37	3.74	19.14
13	F	"	2.5678	61.83	11.08	4.30	20.22
		Average	2.9620	60.54	12.15	4.62	19.73

TABLE 2F—*Chick bones: Iodine absorption number of extracted jets*

Sex	Femur			Tibia			Humerus			Ulna-radius			Sternum	
	Rachitic	Normal		Rachitic	Normal		Rachitic	Normal		Rachitic	Normal		Rachitic	Normal
	Left	Right		Left	Right		Left	Right		Left	Right		Left	Right
M	40.8	53.1	47.1	45.5	64.5	61.9	56.8	46.0	53.8	103.1	159.5	48.4	50.4	50.4
M	56.7	60.3	48.3	48.0	156.2	123.7	49.9	53.8	101.7	133.1	120.0	99.0	94.5	60.7
M	61.2	77.2	59.1	56.3	51.7	52.9	51.6	49.1	50.6	60.7	53.6	54.0	50.4	51.0
M	79.1	51.3	49.3	46.1	56.7	66.0	47.2	51.8	64.4	46.5	53.9	55.6	51.6	51.2
M	48.6	47.5	49.2	49.0	48.8	48.0	56.0	54.8	45.1	46.0	54.5	52.0	48.7	48.3
F	116.3	69.3	49.7	50.9	52.9	52.4	53.0	51.0	70.6	106.0	50.6	47.6	50.8	49.4
F	60.2	*	53.4	51.8	68.6	57.7	53.9	51.8	44.1	77.7	54.7	50.1	53.5	51.5
F	59.5	62.3	50.0	46.6	52.6	50.6	53.1	46.5	47.9	72.6	62.6	55.7	56.6	50.7
F	127.7	*	46.9	48.5	122.0	126.6	50.3	49.5	123.7	104.9	46.5	66.8	53.4	51.6
F	50.8	47.0	50.4	43.8	48.6	52.0	51.9	45.2	50.2	61.1	99.4	64.1	49.0	46.5
Ave.	70.1	58.5†	50.3	48.7	72.3	69.2	52.4	50.0	70.1	86.8	71.0	66.4	51.2	49.8
General Average	64.3†	49.5			70.8		51.2		78.5		68.7		50.5	

*Lost.

†Average of eight values for right, rachitic.

TABLE 3A—*Swine bones: Green weight and composition of femur*

Breed	Sex	Lot	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Poland	M	1	244.7	242.6	30.89	30.79	29.33	29.70	19.69	19.60	20.09	19.91
Poland	M	1	302.6	303.4	28.12	27.62	28.30	28.89	24.76	24.88	18.82	18.61
Crossbred	F	1	264.9	252.7	28.24	27.82	30.70	31.84	21.74	20.42	19.32	19.92
Duroc	F	1	251.1	255.9	28.22	27.20	31.17	32.08	21.60	21.38	18.91	19.34
Berkshire	F	1	248.6	250.3	26.47	25.89	35.70	36.36	17.02	16.72	20.81	21.03
Average			262.4	261.0	28.41	27.86	31.04	31.77	20.96	20.60	19.59	19.76
General average			261.7		28.14		31.41		20.78		19.68	
Poland	M	2	291.3	298.9	31.31	31.58	28.36	27.52	21.07	20.73	19.26	20.17
Poland	M	2	265.0	258.8	30.94	30.72	28.10	28.55	22.95	22.68	18.01	18.05
Crossbred	M	2	246.3	251.5	29.92	29.94	29.98	29.97	19.74	20.14	20.36	19.95
Duroc	M	2	277.6	276.1	24.57	24.45	32.85	33.01	24.06	23.92	18.82	18.62
Berkshire	M	2	282.4	272.7	26.17	26.26	34.04	33.95	20.12	20.63	19.67	19.16
Average			272.5	271.6	28.58	28.59	30.66	30.60	21.59	21.62	19.16	19.19
General average			272.1		28.59		30.63		21.61		19.18	
Poland	M	3	305.7	307.2	26.36	27.53	34.28	33.61	19.95	20.60	19.41	18.26
Poland	F	3	248.3	240.0	27.67	27.79	31.65	31.91	21.33	21.00	19.35	19.30
Crossbred	M	3	273.2	268.8	31.33	28.87	32.38	32.16	14.62	17.88	21.09	21.09
Duroc	M	3	325.2	330.1	24.17	23.48	34.86	35.50	21.60	21.27	19.37	19.75
Average			288.1	286.5	27.38	26.92	33.29	33.29	19.38	20.19	19.95	19.60
General average			287.3		27.15		33.29		19.79		19.78	
Poland	M	4	264.5	262.1	27.86	26.97	30.33	30.96	23.13	23.33	18.68	18.74
Poland	F	4	282.5	280.9	24.14	23.60	34.12	34.83	22.75	22.51	18.99	19.06
Crossbred	M	4	293.2	289.0	29.43	28.62	31.94	32.45	19.33	19.35	19.70	19.58
Duroc	M	4	299.2	293.3	27.87	28.13	35.84	36.14	16.25	15.65	20.04	20.08
Berkshire	M	4	280.1	278.4	26.31	25.72	36.45	36.93	16.86	16.68	20.38	20.67
Average			283.9	280.7	27.12	26.61	33.74	34.26	19.58	19.50	19.56	19.63
General average			282.2		26.87		34.00		19.54		19.60	

TABLE 3b—*Swine bones: Green weight and composition of humerus*

Breed	Sex	Lot	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Poland	M	1	222.3	216.3	29.96	30.19	30.92	31.40	17.40	18.44	21.72	19.97
	M	1	263.2	264.5	27.66	27.86	29.88	29.53	23.08	23.53	19.38	19.08
	F	1	243.7	244.4	28.27	28.80	31.79	31.78	20.10	19.47	19.84	19.95
	F	1	238.8	237.1	27.47	27.58	32.30	32.96	20.96	20.82	19.27	19.01
	F	1	246.4	240.2	26.14	25.77	36.89	38.06	15.26	14.15	21.71	22.02
Average			242.9	240.5	27.90	28.05	32.36	32.67	19.36	19.28	20.38	20.00
General average			241.7		27.98		32.52		19.32		20.19	
Poland	M	2	259.0	253.8	32.62	33.29	28.22	27.56	19.70	20.05	19.46	19.10
	M	2	233.1	232.4	30.63	30.08	30.16	31.14	19.92	19.34	19.29	19.44
	M	2	226.7	220.5	28.85	27.12	31.98	32.40	17.24	19.41	21.93	21.07
	M	2	258.1	255.4	24.76	24.04	33.62	33.32	22.51	23.45	19.11	19.19
	M	2	253.6	261.0	26.62	25.86	35.40	36.25	17.58	17.28	20.40	20.61
Average			247.3	244.6	28.70	28.08	31.88	32.13	19.39	19.91	20.04	19.88
General average			246.0		28.39		32.01		19.65		19.96	
Poland	M	3	280.3	279.9	27.08	26.54	34.73	34.65	18.16	19.17	20.03	19.64
	F	3	222.3	229.4	26.59	27.77	33.29	32.79	20.52	20.22	19.60	19.25
	M	3	254.7	244.0	30.98	30.04	32.85	33.55	12.60	14.53	23.57	21.88
	M	3	308.5	302.6	23.73	23.43	35.85	35.35	20.60	21.26	19.82	19.96
Average			266.5	264.0	27.10	26.95	34.18	34.10	17.97	18.80	20.76	20.18
General average			265.3		27.03		34.14		18.39		20.47	
Poland	M	4	236.7	238.9	27.88	28.30	31.80	31.22	20.82	21.13	19.50	19.35
	F	4	267.8	269.7	25.32	24.51	34.62	35.40	20.13	20.28	19.93	19.81
	M	4	262.0	264.8	28.82	28.70	33.56	33.22	17.41	17.60	20.21	20.48
	M	4	274.2	270.5	27.49	27.91	36.75	36.45	14.79	14.96	20.67	20.68
Berkshire	M	4	276.9	270.3	26.18	26.19	37.92	37.79	14.50	14.58	21.40	21.44
	M	4										
Average			263.5	262.8	27.20	27.12	34.93	34.82	17.53	17.71	20.34	20.35
General average			263.2		27.16		34.88		17.62		20.35	

TABLE 3C—Swine bones: Green weight and composition of tibia

Breed	Sex	Lot	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Poland	M	1	153.1	151.0	28.22	27.68	32.31	34.05	18.58	16.74	20.89	21.53
Poland	M	1	178.7	174.6	26.08	24.91	31.94	32.84	21.29	21.91	20.69	20.34
Crossbred	F	1	155.7	156.6	26.07	26.12	34.65	34.89	18.15	17.86	21.13	21.13
Duroc	F	1	158.0	159.6	26.20	25.50	33.78	35.12	19.78	18.53	20.24	20.85
Berkshire	F	1	151.6	152.2	25.20	25.29	33.89	33.93	11.33	12.38	23.58	23.40
Average			159.4	158.8	26.35	25.90	34.51	35.17	17.83	17.48	21.31	21.45
General average			159.1		26.13		34.84		17.66		21.38	
Poland	M	2	165.4	163.2	29.02	28.25	32.69	33.09	17.10	17.29	21.19	21.37
Poland	M	2	161.9	164.3	26.62	27.15	32.92	32.27	20.51	20.65	19.65	19.93
Crossbred	M	2	147.6	149.2	27.03	26.67	34.01	32.06	16.78	20.85	22.15	20.42
Duroc	M	2	190.0	190.4	22.52	22.01	37.66	37.98	18.72	18.71	21.10	21.30
Berkshire	M	2	170.7	167.4	23.43	23.30	38.16	38.34	16.93	16.63	21.48	21.73
Average			167.1	166.9	25.72	25.48	35.09	34.75	18.01	18.83	21.17	20.95
General average			167.0		25.60		34.92		18.42		21.08	
Poland	M	3	197.2	197.5	24.54	24.51	36.16	36.51	18.74	18.24	20.56	20.74
Poland	F	3	155.1	146.7	25.66	24.20	34.35	35.49	19.29	19.55	20.70	20.76
Crossbred	M	3	176.6	163.9	28.42	25.93	35.63	36.08	13.45	16.22	22.50	21.77
Duroc	M	3	207.5	210.3	21.83	21.45	38.48	38.54	18.20	18.49	21.49	21.52
Average			184.1	179.6	25.11	24.02	36.15	36.65	17.42	18.13	21.31	21.20
General average			181.9		24.57		36.40		17.78		21.26	
Poland	M	4	171.3	169.7	25.04	24.75	34.01	34.13	20.57	20.73	20.38	20.39
Poland	F	4	170.5	170.0	22.46	22.35	37.04	37.65	19.37	18.74	21.13	21.26
Crossbred	M	4	179.6	179.1	25.36	25.80	35.30	35.45	17.17	17.56	21.58	21.19
Duroc	M	4	188.5	185.1	25.20	24.42	39.01	40.27	13.88	13.86	21.91	21.75
Berkshire	M	4	174.0	174.8	24.25	23.40	40.20	41.36	12.75	12.53	22.80	22.71
Average			176.8	175.7	24.58	24.14	37.11	37.77	16.75	16.62	21.56	21.46
General average			176.3		24.36		37.44		16.69		21.51	

TABLE 3D—Swine bones: Green weight and composition of ulna radius

Breed	Sex	Lot	Green weight Left (gms)	Green weight Right (gms)	Moisture Left (%)	Moisture Right (%)	Ash Left (%)	Ash Right (%)	Ether extract Left (%)	Ether extract Right (%)	Organic non-fat Left (%)	Organic non-fat Right (%)
Poland	M	1	164.7	159.5	27.81	27.77	33.29	34.33	16.15	15.32	22.75	22.58
Poland	M	1	184.2	188.3	26.93	27.19	33.22	32.48	18.35	19.09	21.50	21.24
Crossbred	F	1	171.5	169.8	27.40	26.68	35.60	35.89	14.54	14.93	22.46	22.50
Duroc	F	1	178.7	169.5	26.64	25.54	35.42	35.54	16.22	17.31	21.72	21.58
Berkshire	F	1	159.3	161.7	25.55	25.42	39.48	39.98	11.58	10.82	23.39	23.78
Average			171.7	169.8	26.87	26.52	35.40	35.64	15.37	15.50	22.36	22.34
General average			170.8		26.70		35.52		15.44		22.35	
Poland	M	2	179.3	172.6	30.34	30.82	32.32	32.75	15.96	14.39	21.38	22.04
Poland	M	2	171.3	170.4	28.31	28.05	33.31	33.78	17.06	16.90	21.29	21.27
Crossbred	M	2	165.8	160.0	27.44	27.31	35.47	35.02	13.26	14.68	23.83	22.99
Duroc	M	2	197.3	194.5	23.82	23.24	36.30	36.27	18.55	19.33	21.33	21.16
Berkshire	M	2	190.7	191.3	25.80	24.99	38.53	38.31	12.93	14.20	22.74	22.50
Average			180.9	177.8	27.14	26.88	35.19	35.23	15.55	15.90	22.11	21.99
General average			179.4		27.01		35.21		15.73		22.05	
Poland	M	3	208.2	202.8	26.32	25.34	37.18	37.34	14.94	15.66	21.56	21.66
Poland	F	3	154.8	158.9	26.61	26.81	35.71	35.68	15.65	15.48	22.03	22.03
Crossbred	M	3	188.1	183.6	26.05	27.84	37.08	35.26	13.93	13.95	22.94	22.95
Duroc	M	3	221.5	221.3	23.30	23.00	37.97	38.54	16.51	16.14	22.22	22.32
Average			193.2	194.2	25.57	25.75	36.99	36.71	15.26	15.31	22.19	22.24
General average			193.7		25.66		36.85		15.29		22.22	
Poland	M	4	166.8	167.5	26.62	26.75	34.32	33.70	17.48	18.33	21.58	21.22
Poland	F	4	172.6	176.0	23.58	23.86	39.30	38.76	14.22	14.81	22.90	22.57
Crossbred	M	4	195.5	193.8	26.91	26.62	36.13	36.34	14.72	14.85	22.24	22.19
Duroc	M	4	204.5	202.8	24.89	25.79	40.16	38.77	11.87	13.24	23.08	23.20
Berkshire	M	4	201.0	199.9	24.88	24.26	40.09	40.60	11.52	11.72	23.51	23.42
Average			188.1	188.0	25.38	25.46	38.00	37.63	13.96	14.59	22.66	22.32
General average			188.1		25.42		37.82		14.28		22.49	

TABLE 3F—Swine bones: Green weight and composition of ribs 7 and 8

Breed	Sex	Lot	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
			(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Poland	M	1	59.6	56.2	33.89	33.45	32.60	34.08	10.32	9.46	23.19	23.01
	M	1	68.0	66.7	32.50	32.53	32.02	33.60	11.07	10.56	23.41	23.31
	F	1	72.9	74.4	32.65	33.06	33.38	32.48	11.20	11.81	22.77	22.65
	F	1	51.5	53.5	27.57	28.04	38.70	38.56	10.34	10.27	23.39	23.13
	F	1	61.0	62.6	29.34	29.23	38.88	39.16	6.98	7.08	24.80	24.53
Average			62.6	62.7	31.19	31.26	35.32	35.58	9.98	9.84	23.51	23.33
General average			62.7		31.23		35.45		9.91		23.42	
Poland	M	2	63.8	62.2	34.33	33.76	33.10	33.75	9.44	9.06	23.13	23.43
	M	2	65.2	64.1	34.66	35.10	33.42	32.83	9.28	9.82	22.64	22.25
	M	2	66.5	62.9	34.14	32.91	31.18	33.21	12.24	10.96	22.44	22.92
	Duroc	2	50.9	50.6	27.90	27.47	36.67	38.24	12.61	11.37	22.82	22.92
	M	2	75.3	78.5	29.08	30.06	36.86	36.42	11.38	11.41	22.68	22.11
Average			64.3	63.7	32.02	31.86	34.25	34.89	10.99	10.53	22.74	22.73
General average			64.0		31.94		34.57		10.76		22.74	
Poland	M	3	87.8	86.9	29.16	29.00	37.15	37.41	11.04	11.45	22.65	22.14
	F	3	63.5	58.5	31.18	31.11	35.33	34.93	10.58	11.34	22.91	22.62
	M	3	66.0	65.9	30.60	32.47	36.99	35.78	8.38	8.21	24.03	23.54
	M	3	76.9	70.4	27.57	26.84	37.07	37.80	12.67	12.55	22.69	22.81
	Average		73.5	70.4	29.63	29.55	36.64	36.48	10.67	10.89	23.07	22.78
General average			72.0		29.74		36.56		10.78		22.93	
Poland	M	4	58.8	61.7	30.95	30.31	34.74	36.28	11.79	10.41	22.52	23.00
	F	4	76.6	74.2	27.94	27.09	36.98	37.73	12.61	12.62	22.47	22.56
	M	4	78.7	79.6	32.15	32.03	34.67	34.49	10.59	11.54	22.59	21.94
	Duroc	4	64.5	64.0	27.45	27.81	39.83	40.54	8.58	8.11	23.84	23.54
	M	4	77.6	76.9	27.53	27.96	38.15	38.95	10.64	9.93	23.38	23.16
Average			71.2	71.3	29.32	29.04	36.87	37.60	10.84	10.52	22.96	22.84
General average			71.3		29.18		37.24		10.68		22.90	

TABLE 3F—Swine bones: Green weight and composition of lumbar vertebrae 2 and 3

Breed	Sex	Lot	Green weight (gms)	Moisture (%)	Ash (%)	Ether extract (%)	Organic non-fat (%)
Poland	M	1	97.1	34.71	31.84	9.58	23.87
Poland	M	1	119.1	34.34	31.08	10.96	23.62
Crossbred	F	1	110.9	32.64	32.00	10.76	23.60
Duroc	F	1	104.9	34.22	32.47	11.04	22.97
Berkshire	F	1	120.7	30.98	35.95	9.54	23.53
Average			110.5	33.38	32.87	10.38	23.37
Poland	M	2	108.4	39.02	27.01	12.10	21.87
Poland	M	2	100.6	40.56	25.59	12.98	20.87
Crossbred	M	2	99.8	36.17	28.86	12.37	22.60
Duroc	M	2	119.6	34.03	30.84	13.45	21.68
Berkshire	M	2	110.6	33.00	31.45	13.37	21.58
Average			107.8	36.56	28.75	12.97	21.72
Poland	M	3	121.2	31.68	33.93	12.34	22.05
Poland	F	3	105.4	36.05	30.04	12.13	21.78
Crossbred	M	3	118.7	35.21	31.09	10.82	22.88
Duroc	M	3	144.3	31.60	33.15	13.06	22.19
Average			122.4	33.63	32.05	12.09	22.23
Poland	M	4	104.1	34.20	30.45	13.45	21.90
Poland	F	4	121.0	30.50	33.75	13.75	22.00
Crossbred	M	4	120.8	33.61	32.41	11.49	22.49
Duroc	M	4	118.3	30.94	36.36	9.74	22.96
Berkshire	M	4	132.7	30.29	34.95	11.95	22.81
Average			119.4	31.91	33.58	12.08	22.43

TABLE 3G—Swine bones: Calcium and phosphorus in ash

Breed	Sex	Lot	Right femur			Right ribs 7 and 8			Lumbar vertebrae 2 and 3		
			Cal- cium (%)	Phos- phorus (%)	Mag- nesium (%)	Cal- cium (%)	Phos- phorus (%)	Mag- nesium (%)	Cal- cium (%)	Phos- phorus (%)	Mag- nesium (%)
Poland	M	1	38.56	18.05	0.87	38.25	18.64	0.81	37.71	18.19	...
Poland	M	1	38.58	17.74	.89	38.44	18.41	.89	37.83	18.18	...
Crossbred	F	1	38.56	17.98	.77	38.35	18.28	.88	38.31	18.24	0.88
Duroc	F	1	38.64	17.70	.91	38.54	17.91	.96	38.58	17.98	.93
Berkshire	F	1	38.93	17.85	.78	38.70	18.05	.81	38.98	17.95	.79
Average			38.65	17.86	.84	38.46	18.26	.87	38.28	18.11	.87
Poland	M	2	38.34	17.87	0.88	38.16	18.27	0.91	37.91	17.59	0.93
Poland	M	2	38.48	17.84	.77	38.42	17.86	.91	37.95	17.79	.91
Crossbred	M	2	38.68	17.96	.83	38.26	18.84	1.02	38.09	18.17	...
Duroc	M	2	38.62	17.80	.94	38.50	18.08	1.01	38.46	18.04	.97
Berkshire	M	2	38.64	17.93	.80	38.44	18.27	.85	38.66	18.15	.90
Average			38.55	17.88	.84	38.36	18.26	.94	38.21	17.95	.93
Poland	M	3	38.55	18.12	0.76	38.38	17.89	0.91	38.54	18.06	0.84
Poland	F	3	38.65	17.89	.79	38.64	18.30	.89	38.52	18.12	.85
Crossbred	M	3	38.64	17.83	.86	38.48	18.60	.86	37.75	18.19	...
Duroc	M	3	38.81	17.75	.90	38.59	18.15	.90	38.70	18.10	.97
Average			38.66	17.90	.83	38.52	18.23	.89	38.38	18.12	.89
Poland	M	4	38.55	17.89	0.77	38.52	18.39	0.83	38.32	17.64	0.89
Poland	F	4	38.63	17.96	.73	38.53	17.91	.70	38.75	17.92	.81
Crossbred	M	4	38.65	17.85	.89	38.29	18.41	.94	37.77	18.14	...
Duroc	M	4	38.27	17.91	.82	38.35	18.12	.95	38.53	18.11	.88
Berkshire	M	4	38.87	18.00	.79	38.58	18.14	.88	38.69	18.04	.84
Average			38.61	17.92	.80	38.47	18.19	.86	38.41	17.97	.85

TABLE 3H—*Age and weight data on swine*

Breed	Sex	Lot	Age in days		Weight in pounds				
			When started	On experiment	When killed	When started	Gain during experiment	When killed	Gain per day
Poland China	M	1	57	136	193	46	174	220	1.28
Poland China	M	1	57	144	201	59	169	228	1.17
Crossbred	F	1	57	163	220	46	180	226	1.10
Duroc Jersey	F	1	56	207	263	36	188	224	0.91
Berkshire	F	1	60	228	288	35	187	222	0.82
Average			57.4	176	233	44.4	179.6	224	1.06
Poland China	M	2	57	151	208	46	160	206	1.06
Poland China	M	2	57	173	230	41	132	173	0.76
Crossbred	M	2	57	136	193	54	179	233	1.32
Duroc Jersey	M	2	56	208	264	39	135	174	0.65
Berkshire	M	2	60	191	251	44	154	198	0.81
Average			57.4	172	229	44.8	152	197	0.92
Poland China	M	3	57	200	257	34	159	193	0.80
Poland China	F	3	57	171	228	35	110	145	0.64
Crossbred	M	3	57	136	193	58	171	229	1.26
Duroc Jersey	M	3	56	228	284	56	153	209	0.67
Berkshire	M	3	Died during experiment						
Average			56.7	184	240	45.75	148.25	194	0.84
Poland China	M	4	57	171	228	40	125	165	0.73
Poland China	F	4	57	208	265	40	146	186	0.70
Crossbred	M	4	57	151	208	52	166	218	1.10
Duroc Jersey	M	4	56	191	247	52	184	236	0.96
Berkshire	M	4	60	191	251	40	188	228	0.90
Average			57.4	182	240	44.8	161.8	201	0.90

TABLE 4A—Cattle bones: Green weight and composition of whole bones

Heifer No.	Ration	Bone	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
			Left (gms)	Right (gms)	Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)	Left (%)	Right (%)
E 42	Rachitic	Metacarpus	242.6	254.5	28.52	30.38	26.93	26.70	25.25	23.51	19.32	19.43
		Ulna-Radius	568.8	572.3	31.65	30.58	23.58	23.45	26.06	27.38	18.64	18.60
		Humerus	729.0	710.1	39.53	38.40	18.26	18.55	25.09	26.85	17.06	16.19
		Femur	1021.2	1043.4	40.70	44.63	17.20	17.01	26.50	23.54	15.60	16.90
		Tibia	651.3	692.0	34.01	36.64	21.88	23.33	26.69	21.67	17.41	18.37
		Metatarsal	260.9	284.9	20.97	22.99	27.05	27.18	34.13	30.70	17.86	19.12
		Ribs 7 & 8	282.2	295.1	52.13	46.13	18.89	19.70	7.75	12.88	21.22	21.26
		Rib 13	64.2	64.3	44.58	42.29	26.01	26.10	3.38	5.61	26.06	26.00
Average		477.5	489.6	36.51	36.51	22.48	22.75	21.86	21.27	19.15	19.48	
General average		483.6		36.51		22.62		21.56		19.82		
E 48	Normal	Metacarpus	318.4	328.4	19.84	21.25	35.30	34.80	24.04	22.96	20.90	20.98
		Ulna-Radius	746.8	775.0	23.57	24.64	29.84	29.57	26.93	26.28	19.68	19.51
		Humerus	988.7	1014.2	27.34	28.14	25.40	24.94	28.41	28.21	18.82	18.74
		Femur	1371.1	1368.6	28.50	28.37	24.05	24.29	29.83	29.21	17.63	18.11
		Tibia	879.8	889.4	22.38	22.57	31.86	31.93	26.44	26.50	19.34	19.31
		Metatarsus	423.1	417.5	21.44	20.90	37.04	37.02	19.33	19.65	22.19	22.45
		Ribs 7 & 8	291.3	293.9	41.64	41.52	27.79	27.92	7.26	7.14	23.31	23.43
		Rib 13	38.4	37.9	36.20	34.83	32.50	33.73	6.58	5.73	24.74	25.69
Average		632.2	640.6	27.61	27.78	30.47	30.53	21.10	20.67	20.83	21.03	
General average		636.4		27.70		30.50		20.89		20.93		

TABLE 4B—*Cattle bones: Refractive indices and iodine absorption numbers of marrow fats**

Heifer Number and Ration	Refractive Index at 40° C											
	Metacarpus		Ulna-radius		Humerus		Femur		Tibia		Metatarsus	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
E42 Rachitic	1.46061	1.46044	1.45937	1.45933	1.45769	1.45787	1.45844	1.45804	1.45944	1.45951	1.46058	1.46124
Average	1.46053		1.45935		1.45778		1.45824		1.45948		1.46091	
E48 Normal	1.45965	1.45969	1.45787	1.45783	1.45715	1.45697	1.45658	1.45694	1.45804	1.45804	1.45983	1.45955
Average	1.45967		1.45785		1.45706		1.45676		1.45804		1.45969	
Iodine Absorption Number												
E42 Rachitic	64.5	64.8	54.4	54.0	46.0	45.4	45.4	48.0	54.7	53.5	65.3	63.3
Average	64.7		54.2		45.7		46.7		54.1		64.3	
E48 Normal	62.8	63.5	50.5	50.6	43.2	43.3	40.7	42.6	51.8	51.2	64.2	62.3
Average	63.2		50.6		43.3		41.7		51.5		63.3	

*E42 Rachitic—Marrow fats were light straw colored.

E48 Normal—Marrow fats were deeper yellow and darker colored.

TABLE 5—Effect of ration on green weight and composition of bones
(Average of left and right for all animals in the groups indicated)

	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
	Rachitic	Normal	Rachitic	Normal	Rachitic	Normal	Rachitic	Normal	Rachitic	Normal
	(gms)	(gms)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Rat bones:										
F-T-F	0.4731	0.7496	58.65	41.46	12.75	32.10	3.55	4.19	25.10	22.30
H-U-R	.2002	.3083	55.55	38.55	15.74	35.49	2.05	2.17	26.66	23.79
Chick bones:										
Femur	0.9591	1.4550	67.47	53.86	10.98	17.09	1.10	7.65	20.46	21.41
Humerus	.7696	1.1362	68.65	54.54	9.79	17.33	1.37	6.90	20.21	21.34
Tibia	1.1751	1.9013	66.69	52.98	11.84	17.28	1.93	9.74	19.51	20.00
Ulna-radius	.8297	1.2927	65.60	47.18	11.03	18.59	2.25	13.25	21.13	20.99
Sternum	1.9974	2.9620	71.20	60.54	6.41	12.15	1.06	4.62	19.34	19.73
Cattle bones:										
Metacarpus	248.5	323.4	29.45	20.55	26.82	35.05	24.38	23.50	19.38	20.94
Ulna-radius	570.6	760.9	31.12	24.11	23.52	29.71	26.72	26.62	18.62	19.60
Humerus	719.6	1001.5	38.97	27.74	18.41	25.17	25.97	28.31	16.63	18.78
Femur	1032.3	1369.9	42.67	28.44	17.11	24.17	24.02	29.52	16.25	17.87
Tibia	671.7	884.6	35.33	22.48	22.62	31.90	24.18	26.32	17.89	19.32
Metatarsus	272.9	420.3	21.98	21.17	27.12	37.03	32.42	19.49	18.49	22.32
Ribs 7 & 8	288.7	292.6	49.13	41.58	19.30	27.86	10.32	7.20	21.24	23.37
Rib 13	64.3	38.2	43.44	35.52	26.06	33.17	4.50	6.16	26.03	25.22
Hog bones:										
Femur	272.1	261.7	28.59	28.14	30.63	30.41	21.61	20.78	19.18	19.68
Humerus	246.0	241.7	27.98	27.98	32.01	32.52	19.65	19.32	19.96	20.19
Tibia	167.0	159.1	25.60	26.13	34.92	34.84	18.42	17.66	21.38	21.38
Ulna-radius	179.4	170.8	27.01	26.70	35.21	35.52	15.13	15.44	22.05	22.35
Ribs 7 & 8	64.0	62.7	31.94	31.23	34.57	35.45	10.76	9.91	22.74	23.42
L. Vert. 2 & 3	107.8	110.5	36.56	33.38	28.75	32.87	12.97	10.38	21.12	23.37
	Lot 2	Lot 1	Lot 2	Lot 1	Lot 2	Lot 1	Lot 2	Lot 1	Lot 2	Lot 1
Femur	287.3	282.2	27.15	26.87	33.29	34.00	19.79	19.54	19.78	19.60
Humerus	265.3	263.2	27.03	27.16	34.14	34.88	20.17	17.62	20.35	20.35
Tibia	181.9	176.3	24.57	24.36	36.40	37.44	17.78	16.69	21.36	21.51
Ulna-radius	193.7	188.1	25.66	25.42	36.85	37.82	15.29	14.28	22.32	22.49
Ribs 7 & 8	72.0	71.3	29.74	29.18	36.56	37.24	10.78	10.68	22.93	22.90
L. Vert. 2 & 3	122.4	119.4	33.63	31.91	32.05	33.58	12.09	12.08	22.33	22.43
	Lot 3	Lot 4	Lot 3	Lot 4	Lot 3	Lot 4	Lot 3	Lot 4	Lot 3	Lot 4

TABLE 6—Moisture/ash ratios for bones from rachitic and normal rats
(Average of left and right) and relative changes in these ratios

	Rachitic	Normal	Rachitic/Normal ratio / ratio
Rat bones:			
F-T-F	4.601	1.290	3.57
H-U-R	3.530	1.086	3.25
Chick bones:			
Femur	6.145	3.135	1.95
Humerus	7.011	3.148	2.23
Tibia	5.632	3.067	1.84
Ulna-radius	5.948	2.537	2.34
Sternum	11.110	4.984	2.23
Cattle bones:			
Metacarpus	1.098	0.586	1.87
Ulna-radius	1.323	0.812	1.63
Humerus	2.116	1.103	1.92
Femur	2.494	1.117	2.23
Tibia	1.563	0.705	2.22
Metatarsus	0.810	0.572	1.42
Ribs 7 & 8	2.546	1.492	1.71
Rib 13	1.666	1.073	1.55
Swine bones:			
	Lot 2	Lot 1	
Femur	0.934	0.896	1.04
Humerus	0.887	0.860	1.03
Ulna-radius	0.767	0.752	1.02
Tibia	0.733	0.750	0.98
Ribs 7 & 8	0.924	0.881	1.05
L. Vert. 2 & 3	1.272	1.015	1.25
	Lot 3	Lot 4	
Femur	0.816	0.790	1.03
Humerus	0.792	0.779	1.02
Ulna-radius	0.696	0.672	1.04
Tibia	0.675	0.651	1.04
Ribs 7 & 8	0.814	0.784	1.04
L. Vert. 2 & 3	1.049	0.950	1.10

TABLE 7—Moisture and ash content of swine and cattle bones
(Average of left and right)

	Moisture %	Ash %		Moisture %	Ash %
SWINE:			DAIRY CATTLE:		
L. Vert. 2 & 3	33.87	31.81	Ribs 7 & 8	45.36	23.58
Ribs 7 & 8	30.57	35.92	Rib 13	39.48	29.59
Femur	27.72	32.29	Femur	35.55	20.64
Humerus	27.67	33.34	Humerus	33.35	21.79
Ulna-radius	26.22	36.32	Ulna-radius	27.61	26.61
Tibia	25.25	35.88	Tibia	28.96	27.25
			Metacarpus	25.00	30.94
			Metatarsus	21.58	32.08

TABLE 8—Effect of age on composition of swine bones

Group	No. of animals	Bones analyzed	Age (days)	Moisture (%)	Ash (%)
1	3	33	201	30.43	31.36
2	3	33	229	29.15	32.61
3	2	22	261	25.99	36.06

TABLE 9—*Effect of breed on composition of swine bones*

Breed	No. of animals	Bones analyzed	Age (days)	Moisture (%)	Ash (%)	Ether extract (%)
Poland China	2	22	261	25.99	36.06	16.94
Duroc Jersey	4	44	264	26.14	36.10	16.59
Berkshire	3	33	263	26.55	37.60	13.64

TABLE 10—*Ash content of bones of various animals on "green" vs. "dry-extracted" basis*
(Average of left and right)

Bone	Green basis		Dry-extracted basis	
	Lot 2 (%)	Lot 1 (%)	Lot 2 (%)	Lot 1 (%)
Swine bones:				
Femur	30.63	30.41	61.62	61.41
Humerus	32.01	32.52	61.52	61.43
Tibia	34.92	34.84	62.31	61.97
Ulna-radius	35.21	35.52	61.46	61.30
Ribs 7 & 8	34.57	35.45	60.27	60.07
L. Vert. 2 & 3	28.75	32.87	56.88	58.40
	Lot 3 (%)	Lot 4 (%)	Lot 3 (%)	Lot 4 (%)
Femur	33.29	34.00	62.58	63.40
Humerus	34.14	34.88	62.53	63.11
Tibia	36.40	37.44	63.12	63.47
Ulna-radius	36.85	37.82	62.37	62.66
Ribs 7 & 8	36.56	37.24	61.46	62.39
L. Vert. 2 & 3	32.05	33.58	59.02	59.89
Rat bones:	Rachitic	Normal	Rachitic	Normal
F-T-F	12.75	32.10	33.80	58.84
H-U-R	15.74	35.49	37.11	59.76
Chick bones:				
Femur	10.98	17.09	34.89	44.26
Tibia	9.79	17.33	37.59	46.30
Humerus	11.84	17.28	32.18	44.85
Ulna-radius	11.03	18.59	34.16	46.93
Sternum	6.41	12.15	24.90	38.11
Cattle bones:				
Metacarpus	26.82	35.05	58.06	62.57
Ulna-radius	23.52	29.71	55.86	60.26
Humerus	18.41	25.17	52.57	57.28
Femur	17.11	24.17	51.32	57.47
Tibia	22.62	31.90	55.82	62.30
Metatarsus	27.12	37.03	59.46	62.40
Ribs 7 & 8	19.30	27.86	47.59	54.44
Rib 13	26.06	33.17	50.02	56.77

TABLE 11—Average weight of green bone and constituents determined

Bone	Green weight		Moisture		Ash		Ether extract		Organic non-fat	
	Left (gms)	Right (gms)	Left (gms)	Right (gms)	Left (gms)	Right (gms)	Left (gms)	Right (gms)	Left (gms)	Right (gms)
Chick bones:										
Ulna-radius	0.7016	0.6934	0.3861	0.3766	0.1077	0.1082	0.0607	0.0616	0.1470	0.1470
Humerus	0.9718	0.9340	0.5896	0.5574	0.1349	0.1363	0.0460	0.0422	0.2013	0.1981
Femur	1.2021	1.2119	0.7155	0.7188	0.1745	0.1776	0.0588	0.0614	0.2534	0.2540
Tibia	1.5594	1.5166	0.9126	0.8806	0.2337	0.2320	0.1045	0.1017	0.3085	0.3023
Swine bones:										
Ulna-radius	182.94	181.80	47.92	47.42	66.69	66.13	27.46	27.87	40.85	40.38
Humerus	254.43	252.40	70.41	69.37	84.98	84.49	47.26	47.80	51.78	50.74
Femur	276.12	274.35	76.85	75.35	88.89	89.13	56.45	56.29	53.94	53.58
Tibia	171.21	169.77	43.42	42.14	61.28	61.40	29.99	30.12	36.53	36.11
Ribs 7 & 8	67.64	66.83	20.67	20.39	24.17	24.14	7.20	7.01	15.59	15.30

TABLE 12—Approximate odds that bones from one side exceed those from the other side with respect to weight of a given constituent

Animal and bone	Analyses on each side		Total green weight		Moisture		Ash		Ether extract		Organic non-fat	
	L>R	R>L	L>R	R>L	L>R	R>L	L>R	R>L	L>R	R>L	L>R	R>L
Chick:												
Ulna-radius	20	4:1			15:1		3:1		3:1		1:1	
Humerus	20	500:1			2000:1		3:1		5:1		350:1	
Femur	20		4:1			2:1	48:1		7:1			1:1
Tibia	20	240:1			120:1		5:1		5:1		24:1	
Swine:												
Ulna-radius	19	7:1			5:1		16:1		6:1		25:1	
Humerus	19	32:1			18:1		7:1		9:1		55:1	
Femur	19	11:1			88:1		2:1		2:1		4:1	
Tibia	19	15:1			148:1		2:1		2:1		8:1	
Rib	19	9:1			5:1		1:1		12:1		53:1	
Combined values for all bones of:												
Chick	80	500:1			2500:1				2:1		61:1	
Swine	95	1000:1			5000:1		4:1				900:1	