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The Effect of Calcium and Protein Fed Pregnant Swine upon the Size, Vigor, Bone, Coat and Condition of the Offspring

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THE EFFECT OF CALCIUM AND PROTEIN FED PREGNANT SWINE UPON THE SIZE, VIGOR, BONE, COAT AND CONDITION OF THE OFFSPRING.[1]

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To determine the effect of adding calcium and protein to a corn ration fed the pregnant gilt upon the relative size and vigor of the offspring, a series of experiments has been conducted at this station. The results obtained during the year 1912-13 will be discussed briefly in the following pages.

The gilts under observation were divided into three lots of ten each. Lot I received whole corn grain (shelled) only, 1279.13 grams (reduced to 14 per cent moisture basis) per head daily; Lot II whole corn grain (shelled) the same amount as Lot I, plus calcium allowed in the form of chloride and carbonate (equivalent to approximately two and one-half grams of calcium daily); and Lot III corn grain (shelled) the same in amount as Lot I, plus protein fed as black albumen to the extent of 136.08 grams of the blood product per head daily. This black albumen analyzed 88.24[4] per cent protein and contained very little of the mineral elements, being especially low in calcium. All gilts received equal

[1]Written April 1, 1914, Preliminary Report.
[2]Animal Husbandry Section.
[3]Chemical Section.
[4]The black albumen and corn as analyzed contained in a hundred grams:

	Albumen	Corn
Protein	88.24	9.81
Ether extract	1.30	2.64
Ash (Total)	3.26	1.42
Nitrogen free extract	none	74.83
Crude fibre	none	2.38
Moisture	7.20	8.92
Calcium	.03	.01
Phosphorus	.19	.61

We used the black albumen because it was the best and purest form of commercial protein on the market. We preferred the blood derivative to the wheat gluten because of the much greater likelihood of its containing the complete series of amino acids.

The blood albumen runs higher than corn only in protein and ash. Fortunately the ash constituents of the corn exceed in potassium, magnesium, and phosphorus. The blood ash excels in sodium, chlorine, calcium and sulphur but the possible influence of the first two, sodium and chlorine, is negligible because we purposely fed a sufficiency of sodium chloride, the same to all lots. The calcium difference is so small as to be almost negligible. The results presented, wherein Lots I and II are contrasted, show plainly that calcium has some influence, and we must make some allowance for the extremely small but nevertheless constant difference. As regards the sulphur difference we attribute to it considerable possible influence,—but inasmuch as sulphur is to the protein much as "the tail is to the entire hide" we must charge the effects produced to the protein of the blood albumen. Summarizing, therefore, we find that the results secured by supplementing corn with black albumen are theoretically due almost entirely to its protein content.

quantity of sodium chloride daily, namely 7.26 grams per head. The daily gains for the three groups were as follows: Lot I, 107.95; Lot II, 154.68; Lot III, 237.23 grams.

The number of pigs farrowed per sow from these three lots was, respectively: Lot I, average 7.88; Lot II, 7.30; and Lot III, 8.22. Here we notice, as in our previous experiments, that the protein added to the corn ration during the breeding season influences favorably the number of young.

The weight of the total litters, as well as that of the individual pigs, shows clearly the influence of calcium and protein respectively upon the developing fetus. The table presented gives the number in litter, litter weight, and average weight per pig. The basis is grams.

WEIGHT OF OFFSPRING.

Lot No.	No. in litter	Litter weight—grams	Average per pig—grams[5]
I	7.88	6454.62	821.00
II	7.30	6695.02	916.26
III	8.22	7838.08	952.54

The litter of the lightest weight comes from the group receiving "corn alone," whereas the heaviest is to be found where corn was supplemented with protein, as in Lot III. Here we note a litter difference of 1383.46 grams in favor of the protein supplemented corn ration. The protein increased the weight of litter practically 29 per cent. The effect of the complex protein in black albumen is much more marked than that of the simple calcium fed as chloride and carbonate. The important deductions are such as to emphasize the importance of both of these constituents, namely calcium and protein, in feeding corn to bred swine; the addition of either one of these resulting in heavier litters and larger average pigs.

The vigor of the offspring was markedly affected by the ration. We have the following distribution of the pigs in the three lots according to their relative strength:

[5]On basis of all pigs farrowed.

VIGOR OF OFFSPRING.

(On basis of 100 pigs farrowed.)

Lot No.	Very strong	Strong	Medium	Weak	Very weak	Dead
I	9.52	34.92	17.46	12.71	20.63	4.76
II	23.29	24.66	24.66	**2.74**	**8.22**	**16.44**
III	39.19	32.43	17.57	5.41	1.35	4.05

Most assuredly, the addition of protein affected profoundly the vigor and stamina of the offspring. (See chart for distribution.) The addition of calcium was not without its effects. The protein, however, seems to be the more important constituent in balancing up the corn when compared to calcium.

The size of bone was likewise affected. When calcium and protein were added to the ration the bones were larger. This was determined by measuring the front and hind shins. The measurements are presented in centimeters:

SIZE OF BONE, CIRCUMFERENCE.

Lot No.	Front shin	Hind shin
I	4.60	4.36
II	4.88	4.67
III	4.81	4.56

Peculiarly enough, where calcium was added to corn the size of bone was somewhat greater[6] than where the protein was added. Now this may be due in part to the fact that the Lot III farrowed a greater average number of pigs per litter, which would have a tendency, other things being equal, to decrease their relative size.

One is not surprised particularly to find that both calcium and protein had considerable effect upon the size, vigor, and bone of the offspring,

[6]Cf. Hart, Steenbock, and Fuller, Research Bulletin 30, Wisconsin Experiment Station. "High calcium rations, as compared with low calcium rations, had no effect whatever during a single gestation period on the size or calcium content of the skeleton of the fetus. The skeleton is not increased in any dimension by a wide variation in the amount of calcium fed the mother." According to these investigations the ration considered as a "low calcium" one is a much higher carrier of calcium than the basal ration of corn used in the Iowa experiments.

but the fact that the coat is likewise markedly affected is somewhat surprising. To determine the influence of the addition of the constituents above mentioned upon the quantity of coat produced in the offspring, observation being made at farrowing time, the relative coat covering upon all of the new-born pigs was carefully recorded. The table on "Coat Quantity of Offspring" gives the number of pigs of every hundred born showing the Very Heavy, Heavy, Medium, Light, Very Light and Absent coats. A chart showing the coat quantity distribution is also given.

COAT QUANTITY OF OFFSPRING.

(On basis of 100 pigs farrowed.)

Lot No.	Very heavy	Heavy	Medium	Light	Very light	Absent
I	3.23	29.03	41.94	24.19	1.61	none
II	8.33	34.72	40.28	9.72	6.94	none
III	21.62	40.54	42.43	5.41	none	none

The calcium addition was somewhat effectual in that the coats produced from this lot were a bit heavier. The difference between Lots I and II is, however, very slight. Marked effects are shown from the protein addition where the number having very heavy coats was increased from 3.23 to 21.62, or practically seven times as many, possessing the Very Heaviest, Densest coats where protein is allowed, as compared to where it was not. Dropping down to the next coat quantity, namely, Heavy, we find 29.03 in the check lot, as compared to 40.54 where the protein was added, or more than 40 per cent difference. The Very Light coated pigs are conspicuous in Lot III for their absence, thus further demonstrating the effects of protein additions in increasing the amount of hair covering.

That the coat of swine should vary according to the feed given is common experience. Just one month after these young gilts were placed on the experimental rations a marked contrast in the quantity and color of the coats was evident. The coats of hair in the order of their length and density are from Lots III, II, I, with II and I fairly close and III easily first. In color we have the same order, III, II, I, with III much the darkest. It is significant that the coat quantity and color should be affected by the ration—it is still more suggestive that the coats of the new-born should correspond somewhat with those of the dams from which they are farrowed.

What is the explanation of this difference? We know that keratin, a simple protein of albuminoid nature, is the chief constituent of hair. We find keratin in the epidermis, wool, nails, hoofs, horns, feathers, and so on. Keratin is peculiar in that it has a high sulphur content, the sulphur being present largely in the form of the complex amino acid cystine.

The keratin of human hair runs as high in cystine as 13 to 14½ per cent[7]. No other protein runs so high in cystine as the keratin of human hair. Swine hair, or bristles, contain about 7.2 per cent cystine. Most assuredly hair cannot be built unless the constituents of cystine are present in the feed, hence it is reasonable to suppose that if said sulphur compound, namely, the amino acid cystine, is absent from the feed, the development of hair may be retarded. In corn we find approximately .171[8] parts of sulphur in 100 parts of dry matter, whereas in black albumen we have .820[8] parts, or almost five times as much. Furthermore, it has been shown that of the sulphur present in zein, the amino acid that comprises 58 per cent of the proteins of corn, only 35 per cent[7] is present as cystine. On the other hand, a large proportion of the sulphur found in black albumen is supposedly present as cystine, hence it is not unreasonable to assume that the main reason why the addition of black albumen is efficient is because it furnishes the cystine, the basal constituent of hair growth.

The coat color of the offspring differs depending upon the dietetic treatment accorded the pregnant dam. The relative effects of the supplements upon the color is shown quite clearly in the following table showing the number of pigs out of a hundred farrowed classified as Very Dark, Dark, Medium, Very Light, and Absent coat colors:

COAT COLOR OF OFFSPRING.

(On basis of 100 pigs farrowed.)

Lot No.	Very dark	Dark	Medium	Light	Very light	Absent
I	1.61	19.35	30.65	37.10	11.29	none
II	2.78	29.17	38.89	12.50	16.67	none
III	14.86	44.59	32.43	8.11	none	none

Again we see the effects of the added black albumen in that it increases the general coat color of the offspring. The chart showing color

[7]Buchtala; Z. Physiol. Chem. Volume 52, page 474, 1907.
[8]Forbes; Bulletin No. 255, page 225, January, 1913, Ohio Experiment Station.

distribution plainly demonstrates the differences. The hogs which we used were Duroc Jerseys, having red coats. The coats designated as "Very Light" refer to those of little color, as compared to the "Very Dark" coats, which were of a bright cherry red. The calcium did not seem to affect the coat very much, although it shows a minor influence. The black albumen, with its high protein, and possibly its specific cystine content, seems to be the causative agent in the production of highly colored coats. It is to be understood that the coat color markings are affected by the amount of coat present, depending upon whether the hairs are densely studded on the surface of the body, as well as the length of the hair, and furthermore on the inherent color of the hair itself. As far as superficial observation goes, without entering into the details of microscopic technical examinations, we would give it as our judgment that the coats were not only denser and longer, but that the hairs themselves seemed to show a greater amount of pigment when corn was supplemented with the black albumen protein, as compared to corn fed alone.

The condition or degree of fatness of the new-born pigs is somewhat dependent upon the feed allowed the dam during the period of gestation. To demonstrate the effect of specific supplements to corn upon the relative condition of the offspring we append herewith table showing the degree of fatness of the various new-born pigs farrowed in the three lots:

CONDITION OF OFFSPRING.

(On basis of 100 pigs farrowed.)

Lot No.	Prime	Choice	Good	Medium	Fair	Common	Inferior
I	none	3.25	29.03	48.39	9.68	9.68	none
II	1.39	19.44	33.33	29.17	13.89	2.78	none
III	none	16.22	29.73	27.03	20.27	6.76	none

The condition or fatness of the new-born pigs was determined by sight and touch observations. Each pig was handled so that a fairly accurate estimate could be made of the fatty covering, special emphasis being placed upon the superficial layers over the ribs and back. Both the calcium and protein supplements to corn resulted in fatter offspring. The protein in this case had less effect than the calcium. Our estimates of the condition of the dams producing these pigs, placing the lots in order of fattest first, are thus: III, II, I, whereas the condition of the pigs farrowed by said dams, placing the fattest first, is II, III, I. In

other words, the condition of the resulting offspring does not compare as closely with that of the mother as does the coat character. There are obvious fundamental reasons for this.

To recapitulate so as to put the foregoing vigor, coat, and condition story on a comparative and more easily interpretable basis there are summarized the relative effects of the specific feed constituents in a grouped combination table chart.

The perpendicular columns denote the average on the assumption of the highest marking being perfect, or 100. The average is computed by placing a value on the various markings given the individual pigs—thus for vigor the Very Strong pig is credited with 100, Strong 80, Medium 60, Weak 40, Very Weak 20, and Dead 0. The Dead, with 0, and the Very Strong, with the 100 credit, makes the range from Absent vigor, the lowest, to Very Strong vigor, the highest marking. The total vigor credits are added and the average taken with results in Lots I, II and III, respectively of 57.14, 60.55 and 78.11. These values may be regarded as percentages of the maximum vigor marking, and so on.

The same general scheme was followed out in determining the average "Coat Quantity," "Coat Color," and "Condition." The gradations considered are identical with those on the tables and charts previously presented.

Withal, this method gives us a tangible, definite, interpretable average valuation quite in accord with the facts.

Uniformly the supplemental calcium and protein, respectively, produced improvement in specific characters of the offspring. Manifestly the influence of the complex nitrogenous organic constituents in protein is more marked than that of the more simple inorganic calcium (chloride and carbonate).

The relative influence of calcium and protein is more clearly appreciated on examination of the following table:

COMPARATIVE INFLUENCES OF CALCIUM AND PROTEIN FED THE PREGNANT DAM ON DEVELOPING FETUS.

Character of Offspring	Percentage Increase Over Corn Alone Attributable to	
	Calcium	Protein
Vigor	5.97	35.00
Coat quantity	6.38	24.42
Coat color	9.89	38.04
Condition	16.46	7.17

Perhaps the direct comparison of protein to calcium effectiveness would make the relation of these two constituents clearer.

The increase of the Protein-Corn-Lot III over the Calcium-Corn-Lot II shows for:

Vigor	29.00 per cent
Coat Quantity	16.96 per cent
Coat Color	26.74 per cent
Condition	—7.90 per cent

The protein is more effective than the calcium in the promotion of vigor, production of coat quantity and color, but less so in augmenting the condition.

Evidently the protein is the more efficacious when it comes to the production of those qualities which make for stamina and hardiness. The vigor and coat quantity are relatively more important in lessening the mortality of the suckling pigs than is the degree of fatness. If the new-born be strong, healthy, and well-coated, even though he come into existence under adverse conditions, he is much better adapted to live in the environment he finds than if he lacks vigor and coat but possesses a high degree of fatness. The strong, warmly coated pig will soon fatten on his mother's milk, hence the condition comes quickly. Not so, however, with the strength and coat; lost vitality and scant hair covering are replaced with comparative slowness.

It is vital to early development that the new-born pigs be vigorous, otherwise they will be compelled to suckle the teats discarded by the more active individuals in the litter. "That pig which suckles the hind teat" is at a disadvantage, but this is the consequence, usually, of being farrowed as the weakly member of the litter.

The protein in corn has been demonstrated to be deficient to a considerable extent in some of the essential amino acids. This is especially true of the zein, which comprises practically 58 per cent of the corn proteins, since zein does not contain in its amino acid makeup tryptophane, lysine, and glycine. Fortunately for corn, the glutelin, which furnishes most of the remaining protein, is quite complete in its amino acid constitution. However, the marked preponderance of zein in corn lessens greatly the general efficiency of the protein in toto. The tryptophane[9] is probably the limiting amino acid, hence it is reasonable to assume that the addition to the corn ration of a protein rich in tryptophane would show marked results. We are led to believe from

[9]Osborne, "The Nutritive Value of the Proteins of Maize," Science, N. S., Vol. XXXVII, No. 944, pages 185-191, January 31, 1913.

the work already done on the amino acid content of blood and its derivatives that the blood albumen used as the source of protein in our work carries the deficient tryptophane. Perhaps the possible deficiency of cystine in corn, as heretofore noted, may be a factor, the absence of which contributes to the general deficiency of the corn proteins. The balancing, therefore, of the protein present in corn by making it more complete, as well as an increase in the entire amount fed, should be a double reason for the greater efficiency observed.

We have some difficulty in the administration of our calcium. We first started out with calcium chloride, but found that where it accompanied protein, given in the form of black albumen, difficulty was experienced in that the mixture seemed to have antagonistic relations. We have supposed that this may possibly be due to acidosis caused by the liberation of the chlorine portion of the calcium chloride molecule, thus freeing hydrochloric acid. Along with a high protein ration the demand for calcium would necessarily be greater than where no extra protein was fed, hence we should expect a greater demand for calcium under these conditions, with a correspondingly greater liberation of chlorine, which would induce acidosis. This acidosis would, theoretically, be largely done away with by the feeding of a pure calcium limestone, such as calcium carbonate. We found when calcium chloride was replaced with calcium carbonate, feeding same between meals, that the ill effects heretofore noted were largely eliminated. Observation and trial showed, however, that calcium carbonate should not be mixed with the feeds as allowed, but that it should be fed, preferably, between meals. We are further investigating this problem in order to demonstrate the best way to feed the calcium.

It is reasonable to suppose that calcium will give results when added to the corn ration, as corn is especially lacking in this important mineral element, which comprises 40 per cent of the dry ash of bone. Calcium furnishes 70 per cent of the basal elements of bone, of the remainder, 29½ per cent being supplied by phosphorus and ½ per cent by magnesium. In the normal human body there is just about two-thirds as much calcium as nitrogen, that fundamental element of protein concerning which we hear so much and upon which a maximum of emphasis is invariably placed by feeding experts and dieticians. It is not to be gainsaid that the lack of protein is the more conspicuous deficiency in ordinary grain diets, but nevertheless the calcium deserves among the mineral nutrients considerably more attention than is now accorded.

Much of a conflicting nature has been said by obstetricians, dieticians, and the laity concerning the effect of different food constituents upon the development of the embryo and fetus.

The experience at the Iowa Station, involving over 2,000 new-born pigs, shows beyond all reasonable doubt that the addition of meat to the ordinary cereal diet of pregnant swine has very marked influence upon the size and vigor of the new-born.

All work heretofore done at the Iowa Station has plainly indicated that the addition of mineral elements as well as protein to the ration had its marked effects upon the development of the young in utero. We are led to believe that any feed, including water, added to or subtracted from the ration of pregnant swine which will tend to promote or discourage growth, thrift, and vigor of the dam will, within reasonable limits, have its effect upon the developing fetus.

SUMMARY.

1. Corn maize is markedly deficient in calcium and quite low in protein, the major part of which lacks certain important amino acids.

2. The addition of calcium (allowed as chloride and carbonate) to a fixed basal ration of corn and sodium chloride with pregnant gilts resulted in new-born pigs having greater size, more vigor, bigger bone, increased coat quantity, better coat color, and higher condition.

3. The addition of a high protein feed (black blood albumen) resulted in the new-born pigs having greater size, more vigor, bigger bone, increased coat quantity, better coat color and higher condition.

4. The influence of the complex organic protein is more marked generally than that of the more simple inorganic calcium.

5. The use of chloride as the source of calcium was not as satisfactory as the carbonate in a high protein ration presumably because of the undesirable liberation of chlorine causing a possible condition of acidosis.

6. The ration fed the pregnant mother affects in a marked degree the general development of the fetus.

Animal Husbandry and Chemical Sections,
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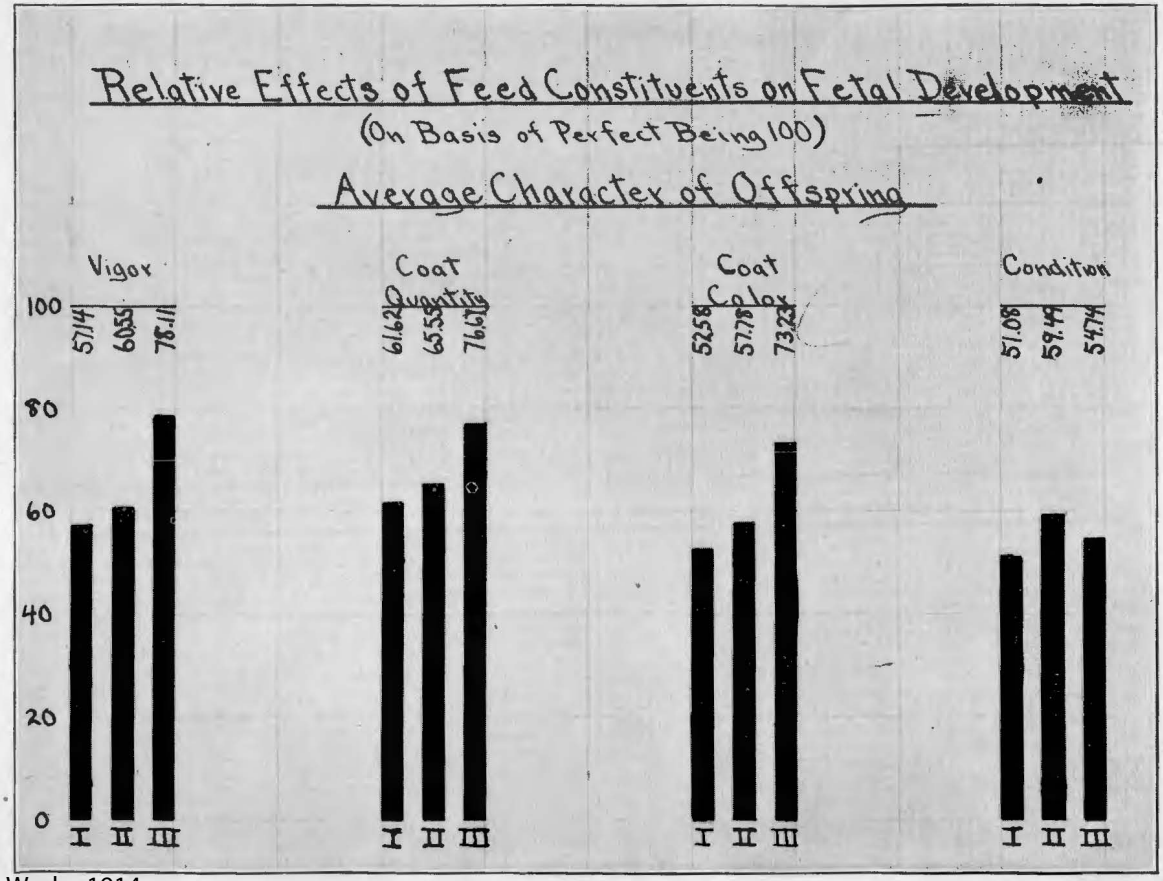
PLATE XXXI


Relative Effects of Feed Constituents on Fetal Development
(On Basis of Perfect Being 100)
Average Character of Offspring
Vigor
Coat
Coat
Condition
100
80
60
40
20
0
57.14
60.55
78.11
61.62
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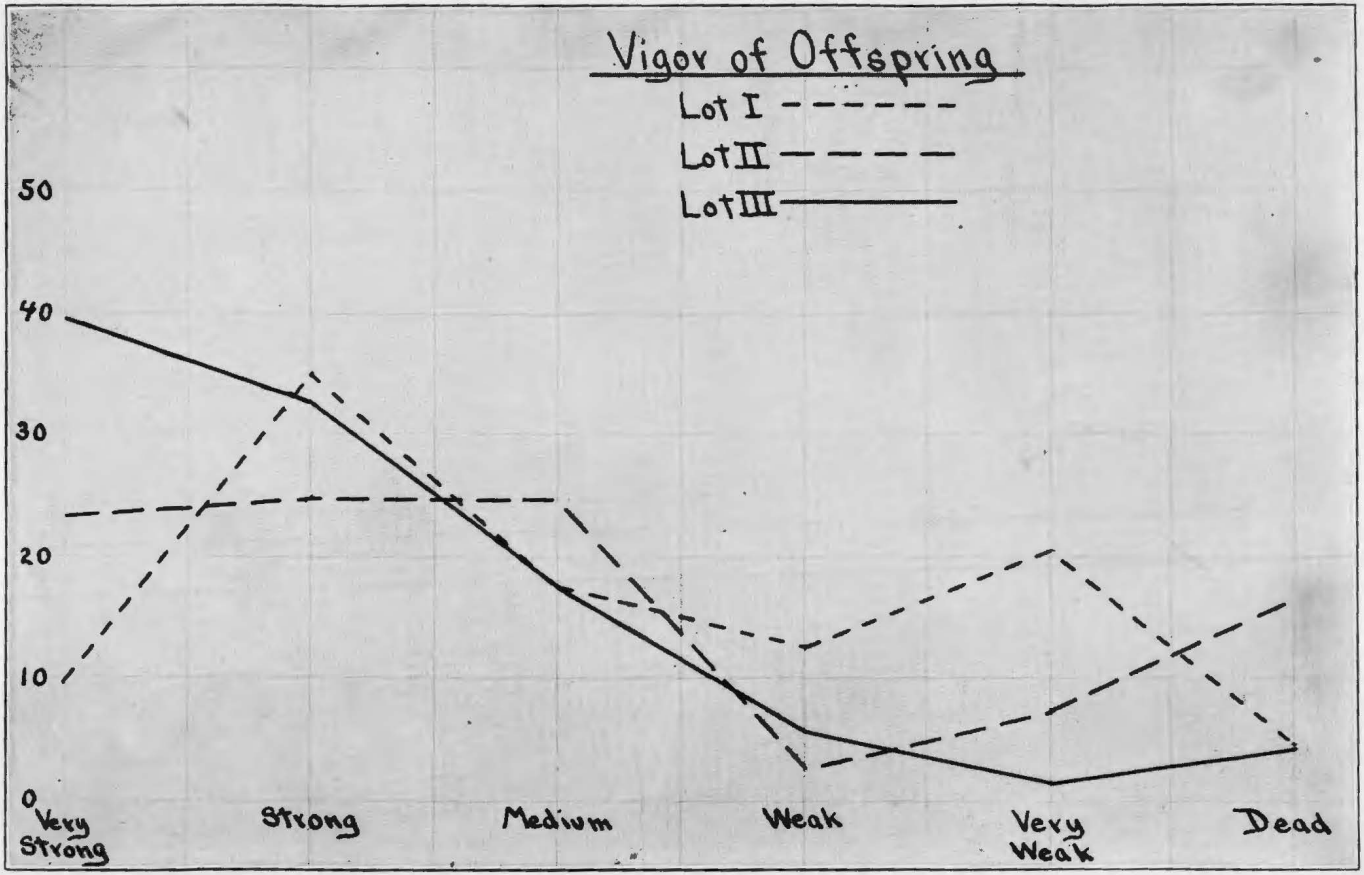
57.78
73.23
51.08
59.49
54.74
I
II
III

PLATE XXXII


Vigor of Offspring
Lot I
Lot II
Lot III
50
40
30
20
10
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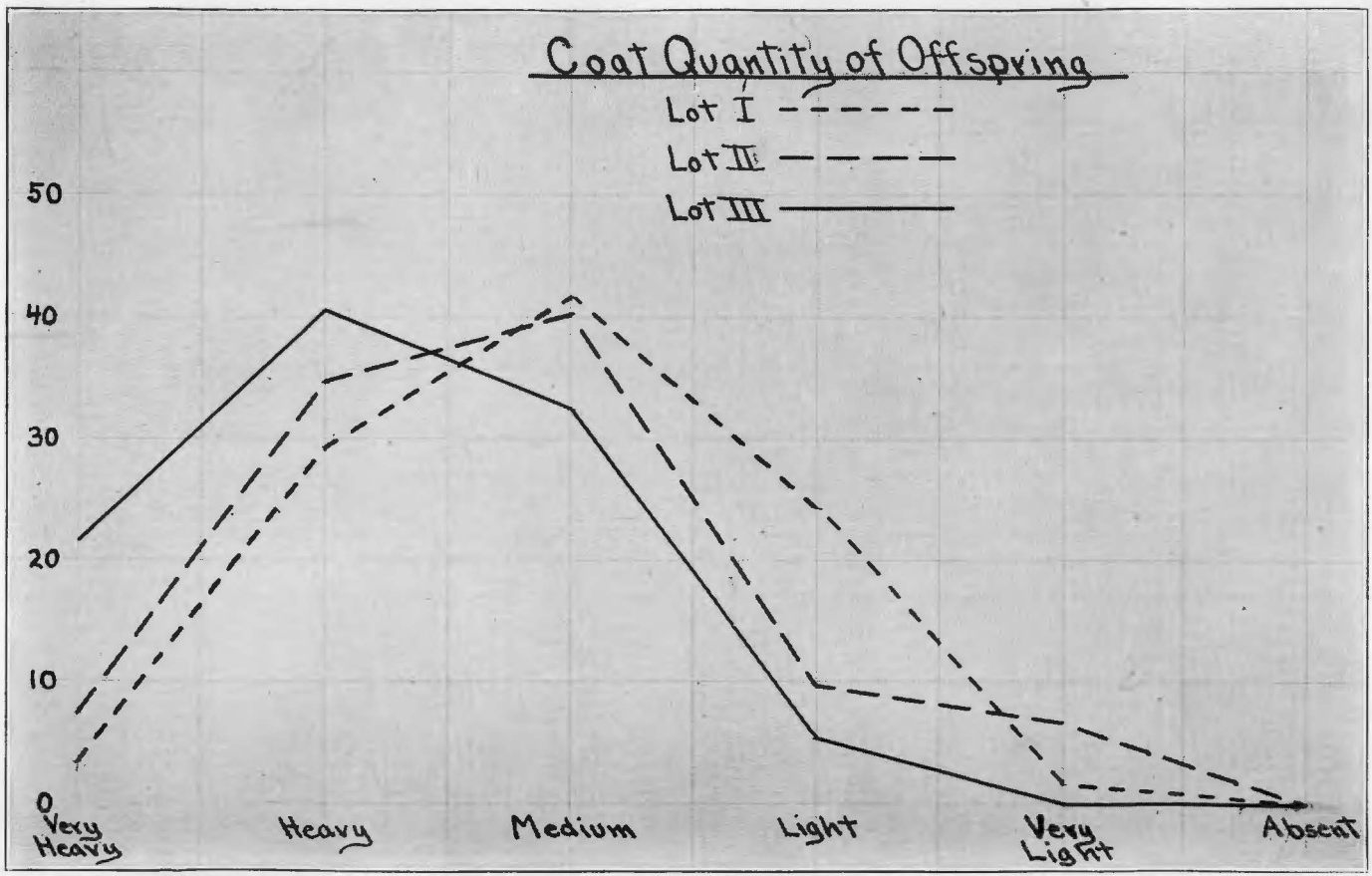
Very Strong
Strong
Medium
Weak
Very Weak
Dead


Coat Quantity of Offspring
Lot I
Lot II
Lot III
50
40
30
20
10
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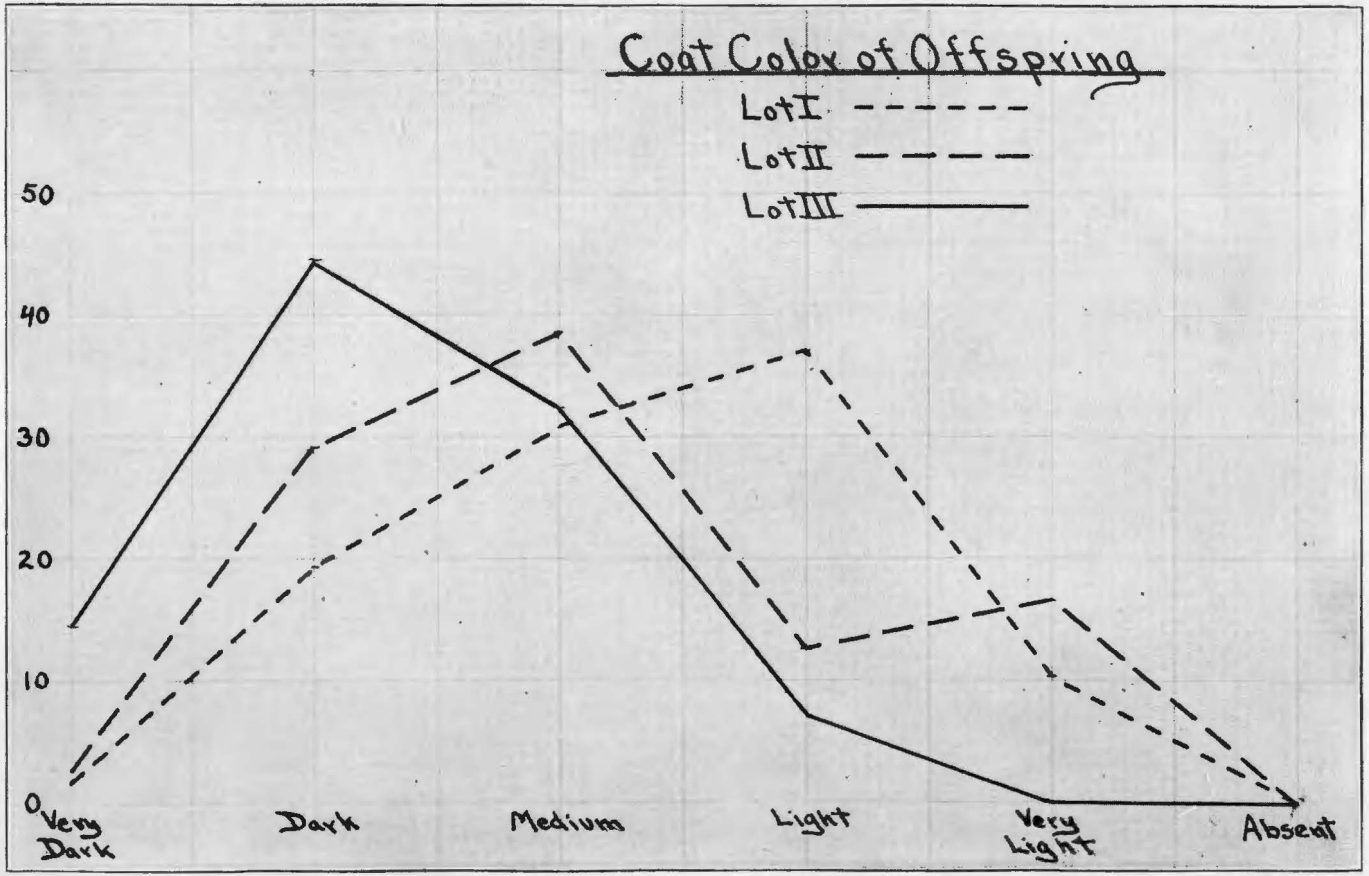
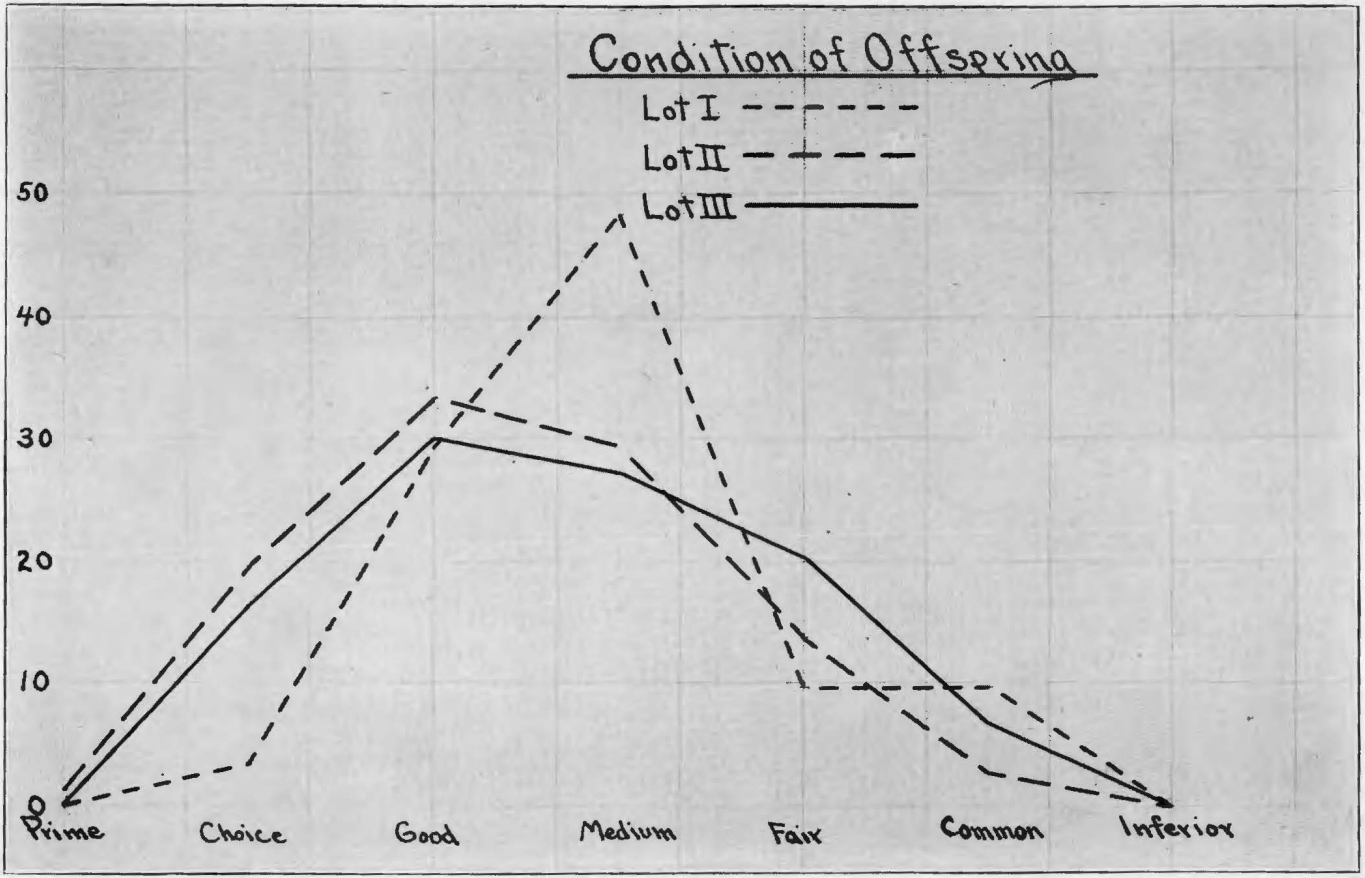
Very Heavy
Heavy
Medium
Light
Very Light
Absent


Coat Color of Offspring
Lot I
Lot II
Lot III
50
40
30
20
10
0
Very Dark
Dark
Medium
Light
Very Light
Absent


Condition of Offspring
Lot I
Lot II
Lot III
50
40
30
20
10
0
Prime
Choice
Good
Medium
Fair
Common
Inferior