THE VARIATION OF THE HEMOGLOBIN CONTENT OF THE BLOOD OF PIGS AND ITS EFFECT UPON SUBSEQUENT GROWTH

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By

MERRITT SAMUEL SWINBURNE

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Panhandle Agricultural and Mechanical College

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APPROVED:

Oliver L Willham
In Charge of Thesis

W. L. Blizzard by C.O.S.
Head of the Animal Husbandry Department

D. G. M. Scott
Dean of the Graduate School

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INTRODUCTION

A review of literature reveals a general agreement among research workers that pigs kept outdoors under normal conditions have a much higher hemoglobin content in their blood than pigs which are confined indoors for different length periods after farrowing.

It is also a reasonably well established fact that the addition of copper and iron to the soil on which pigs are living causes an increase in the hemoglobin content of their blood over that of pigs which are deprived of these minerals.

The purpose of this investigation was to study the variations in the hemoglobin levels of inbred and outbred pigs and to determine the effects of these variations upon the subsequent growth of the pigs.

REVIEW OF LITERATURE

The Effect of Environment on the Hemoglobin Content of the Blood of Pigs at Various Ages

The study of the hemoglobin content of the blood of pigs is relatively new, although as early as 1866 Muller (16) using a spectroscopic method reported 13.71 grams of hemoglobin per 100 cubic centimeters of blood in one pig three years of age, and 13.26 grams as the average for three pigs one year of age. However, very little work had been done on the blood of swine as late as 1900. In that year King and Wilson (11), using a Dare hemoglobinometer, made a comparative study from the blood of normal and diseased (cholera infected) swine, and found that the number of erythrocytes and hemoglobin content of the blood were decreased as the disease progressed.

Within the last few years several workers have made more extensive studies of the blood of baby and suckling pigs. Many of these include the findings at or near the time of birth and during intervals from birth until they reached the weaning age, which is generally fifty-six days.

The hemoglobin in grams per 100 cubic centimeters of blood at the time of birth in pigs that were farrowed indoors varied somewhat according to the records of several workers. Hart, Elvehjem, Steenbock, Bohstedt and Fargo (10) in Wisconsin, recorded an average of 8.7 grams of hemoglobin per 100 cubic centimeters of blood. Kernkamp (12), at the Minnesota

station, recorded 9.5 grams per 100 cubic centimeters of blood for a group of pigs that were farrowed on concrete and 11.7 grams for another group that was farrowed on loam soil indoors. Von Falk (23) in Germany reports the hemoglobin content at birth to be 15.6 grams. Craig (4), in Indiana, reports 9.5 grams; Craft and Moe (2) in Oklahoma, 9.7 grams; Hamilton, Hart, Mitchell and Doyle (5) in Indiana, 11.7 grams of hemoglobin per 100 cubic centimeters. In Ontario, Schofield (19) recorded an average of 67 percent hemoglobin according to the Dare method. This figure, when calculated on the basis of 100 percent on the Dare hemoglobinometer, equals 13.77 grams hemoglobin per 100 cubic centimeters of blood (manufacturers standard), and will be equivalent to 9.2 grams when compared in amount to that of the aforementioned workers. There are reports on recordings of different amounts of hemoglobin in the blood of pigs farrowed outdoors. Craig (4) found the average hemoglobin content of the blood to be 7.6 grams for a litter farrowed outside on a concrete floor. He also found 12.7 grams of hemoglobin per 100 cubic centimeters of blood at birth in a litter of pigs which had been farrowed outdoors on pasture.

Doyle, Mathews and Whiting (6) found the hemoglobin content for pigs farrowed indoors and kept in floored pens, or farrowed outdoors and kept in floored pens to be 8.0 grams per 100 cubic centimeters of blood.

In Saskatchewan, Fulton (7) found the average hemoglobin content for pigs three days old and kept in pens with concrete

floors, to be 46.5 percent. The method of estimation was not stated. For pigs the same age, but farrowed outdoors and kept in floored pens, the content was 43.7 percent.

It was reported by Kernkamp (12) that the blood of pigs farrowed on concrete floors contained 5.7 grams of hemoglobin as compared to 8.1 grams for those farrowed on loam soil. Pigs one week old, kept indoors, vary in their hemoglobin content as shown by the following reports: Craig (4) 7.2 grams and Doyle (5) 8.2 grams per 100 cubic centimeters of blood. According to Doyle, the average for a group of seven day old pigs which were kept inside but had access to soil was 9.5 grams. Another group under the same conditions, except that they had access to green alfalfa pasture, averaged 6.6 grams of hemoglobin. Craig (4) records a group of seven day old pigs on pasture as having 8.9 grams of hemoglobin per 100 cubic centimeters of blood. Hamilton (9) reports 5.7 grams on a group kept under similar conditions.

Kernkamp (15) found a steady decrease in the hemoglobin content of pigs that were kept inside on concrete floors at twelve days of age. They had a mean hemoglobin content of 4.5 grams per 100 cubic centimeters of blood. The mean hemoglobin value for the group on loam soil was 9.1 grams per 100 cubic centimeters of blood which is an increase. Hart (10), Craig (4), and Doyle (5), found 4.0, 5.4, and 6.5 grams, respectively, as the average hemoglobin content for pigs kept inside in floored pens until they were 14 days of age. The average hemoglobin content of the blood of two weeks old pigs with

access to pasture is given by Hart (10) as 8 grams and by Craig (4) as 11.3 grams. Hart (10), Hamilton (9), Craig (4), and Doyle (5) found 3 grams, 3.3 grams, 4.8 grams and 5.4 grams of hemoglobin per 100 cubic centimeters, respectively, for twenty-one day old pigs kept indoors in floored pens. Doyle reported 9.6 grams for those kept indoors with access to alfalfa. For pigs of this same age that were outdoors and on pasture, Hamilton recorded 7.7 grams and Craig, 12.4 grams.

Craig (4) reported 5.0 grams per 100 cubic centimeters for thirty-five day old pigs which had been kept on floored pens and indoors from birth. He also recorded 6.1 grams of hemoglobin for those kept in floored pens but which could be outdoors. A reading as low as 2.8 grams is given by Hamilton (9), representing the average of a group of pigs thirty-nine days old that had been kept indoors. The corresponding group was living outdoors, and on pasture showed a content of 10.0 grams per 100 cubic centimeters. Kernkamp recorded 4.3 grams and 12.6 grams for pigs on concrete and loam respectively. These pigs were twenty-six days old.

From the foregoing work it can be concluded that pigs kept inside have a lower hemoglobin content in their blood than corresponding pigs which have access to outdoors. Doyle (5), Craig (4), and Hart and co-workers (10) all state definitely that outbreaks of anemia occur in pigs that are confined indoors. It is a general concensus of opinion among these investigators that pigs with low hemoglobin content are

generally more susceptible to the various diseases or secondary infections following anemia, and that they are weaker in other respects than those having high hemoglobin content, Doyle alone reports the effect of hemoglobin content upon the growth of the pigs. However, Craft and Moe (3) reported on correlations of weight and hemoglobin content run on different groups of pigs. They reported a negative relationship at birth and again at thirty days of -0.19 and that it was positive, +0.24, from thirty days to sixty days. The relationship dropped to negative, -0.09, again at ninety days of age. These changes were not highly significant.

Physiological Factors Influencing the Hemoglobin Content of the Blood of Pigs

Very few workers have reported on the relationship of sex to the hemoglobin content of the blood of pigs. Kernkamp (12) found no differences in the hemoglobin content of the blood due to sexes, while Welsch (25) and Palmer (17) reported a greater amount of hemoglobin in the blood of males than females in the groups of pigs used in their respective works.

Practically all workers agree that there is a decrease in the hemoglobin content of the blood during the first fourteen days after the birth of the pig. Doyle (5) found that the decrease was more marked during the first two weeks of age. Hamilton (9) reported similar results during the

the first days after birth. It was reported by Hart, Elvehjem, Steinbock, Bohstedt, and Fargo (10) that there was a decrease in the hemoglobin content of the blood during the first few weeks after birth. They also noted that at this time the pigs were often weaker, and in all appearances, more susceptible to various diseases.

Variations in the Hemoglobin Content of the Blood in Relation to Copper, Iron and other Minerals in the ration

Moe, Craft, and Thompson (2) found that pigs having access to soil which had been supplemented with copper and iron in the proportions of 50 pounds of soil to 9 grams of iron and 1.5 grams of copper were significantly heavier at the third and fourth weeks than those on unsupplemented soil, or those that were kept entirely away from soil. These workers also report that there was a significant increase in the hemoglobin content of the blood of these pigs over the ones on unsupplemented soil and the other group which was kept in floored pens.

Mitchell (15) found that when milk was fed exclusively to albino rats that the hemoglobin content of their blood was lowered to as little as 2 grams, while normal rats from the stock colony showed a hemoglobin content of 15 to 16.5 grams of hemoglobin per 100 cubic centimeters of blood. He found that by the addition of copper sulfate and iron oxide the birth level of hemoglobin could be restored. Mitchell

also records a decrease in the hemoglobin content of the blood of mother rats during the later stages of gestation and the first stage of lactation. The ration at this time seemed to have no effect on the content of the blood, so apparently it was due wholly to some physiological factor or factors.

Hamilton (9) found that the birth level of pigs with a low hemoglobin content could be restored to normal by the administration of ferric citrate and copper sulfate either with a pipette or in daily doses equivalent to 25 milligrams of iron and 5 milligrams of copper per day.

It is generally agreed among research workers that copper is effective in the utilization of iron in the formation of hemoglobin in the blood of animals. Titus (21) reports evidence that not only copper, but manganese as well, was necessary in the utilization of iron in this respect.

In 100 pigs examined by McGowan, Pool and Crichton (14) in which they administered ferric oxide, they noted a marked increase in the amount of hemoglobin in the blood. The reports of these workers as well as many others substantiate the belief that iron and copper are essential to the production of hemoglobin in the blood of pigs.

Weaning Weights in Relation to the Hemoglobin Content of the Blood of Pigs

In the four experiments of Vestal and Doyle (22) 35

litters of 394 pigs that were removed from the central farrowing house within 7 days after birth, had a lower death rate and a higher hemoglobin content in their blood than the 41 litters of 341 pigs that were kept indoors for 28 days. The death loss from 4 days of age until weaning at 56 days in the outside group was 12.43 percent and 24.34 percent in the inside group.

In the following quotation Doyle (5) compares the two aforementioned groups:

> "The litters which were outside in contact with the soil from the time the litters were 4 days of age until weaned had an average weight of 154.4 pounds at weaning time, while those litters confined in the central farrowing house for 28 days after farrowing had an average weight of 107.1 pounds when weaned at 56 days of age. The outside litters averaged 6.31 pigs at weaning time as compared with an average of five pigs for the confined litters.
>
> Although the hemoglobin content of the blood of the pigs in the two groups was practically the same at birth, and again when they were 7 days old, marked differences were shown during the remainder of the 28 day period. The low point in the hemoglobin for the outside pigs was at about two weeks of age, after which there was considerable recovery in the amount of hemoglobin. On the other hand, the hemoglobin content of the blood of the confined pigs continued to decrease throughout the period of confinement. At the end of four weeks the outside pigs had more than twice as much hemoglobin per 100 cubic centimeters of blood as the confined pigs."

It is interesting to note that Doyle (5) of all the aforementioned workers experienced perhaps the most remarkable uniformity in the hemoglobin content of pig's blood, both between individuals within his groups and in the same individuals at weekly intervals from one to four weeks of age. The following table summarizes his findings.

Summary of Hemoglobin Content of the Blood of Pigs

Average of Experiments 1, 2, 3, and 4

Group 1 - 45 litters removed from central farrowing house when less than 7 days old.

Hemoglobin in 100 c.c. of blood (litter average)

Exp. No.	No. of litters	Age of pigs when tested				
		Birth	7 days	14 days	21 days	28 days
		Grams	Grams	Grams	Grams	Grams
1	9	....	9.1	8.2	9.9	10.4
2	11	13.7	9.6	10.0	10.3	12.4
3	11	10.7	6.5	5.6	6.8	8.2
4	14	9.5	5.9	5.8	7.6	8.9
Average		11.1*	7.5	7.2	8.4	9.8

Group 2 - 41 litters confined in central farrowing house until 28 days old.

Hemoglobin in 100 c.c. of blood (litter average)

Exp. No.	No. of litters	Age of pigs when tested				
		Birth	7 days	14 days	21 days	28 days
		Grams	Grams	Grams	Grams	Grams
1	9	....	9.4	6.3	5.2	4.8
2	11	13.3	8.3	6.8	5.9	5.6
3	11	10.1	5.8	4.1	3.7	4.8
4	10	9.9	6.2	4.8	3.8	3.3
Average		11.1**	7.4	5.5	4.6	4.5

* 36 litters
** 32 litters

A variation in the hemoglobin content of the blood of pigs farrowed indoors and kept in confinement and those which were outdoors was recorded by Schwarte (18). He found that there was a variation between litters and between litter mates within the groups. Although there was an extremely low hemoglobin content in the blood of some of these pigs, there appeared to be no clinical avidence of a pathological condition or any serious delay in development.

EXPERIMENTAL

MATERIAL AND METHODS

Stock

The data used in this study were obtained from an experimental herd of Duroc Jersey swine which was maintained at the Oklahoma Agricultural Experiment Station from 1923 to 1937. This herd was used to study the consequences of inbreeding swine. An inbred and a control group were used.

The inbred descended from two unrelated Duroc Jersey sows which were mated to a Duroc Jersey boar. Half-brother X half-sister matings were used to maintain the inbred herd. The control group originated from the same foundation stock as the inbreds. This line was maintained by mating the sows to unrelated Duroc boars each generation.

Ration and Procedure

The breeding stock for the two groups in this experiment was fed and housed under identically similar conditions. The pigs were farrowed in a central barn which was equipped with brick floors inside and concrete floors outside. They were moved to small houses in yards with green pasture (rye, oats, wheat, sudan, or rape) at the age of one week. A creep in each lot or pen was provided with feed, so that the pigs could begin eating at any time after one week of age. The

pigs were weaned at sixty days of age and transferred to self-feeders supplied with shelled corn (yellow) wheat shorts; tankage (60 percent protein); and a mineral mixture consisting of bone meal--38 parts, calcium carbonate--39 parts, sodium chloride--20 parts, ferrous sulphate--2.5 parts, copper sulphate--0.25 parts and potassium iodide--0.03 parts. Each litter was lotted separately throughout the experimental period insofar as possible. When this procedure was not possible, the inbreds were fed as one group and the outbreds as another. When green pasture was not available, alfalfa meal was supplied at the rate of 5 pounds for each 100 pounds of feed.

Pigs were bled and weighed as nearly as possible twelve hours after birth, and weekly thereafter until they were four weeks old. Then they were bled at the sixth, eighth, twelfth, sixteenth and twentieth weeks, and finally at 180 days of age. Bleeding was accomplished by puncturing the vein in the margin of the ear. Special hemoglobin pipettes were used for individual pigs and the hemoglobin analyses were determined according to a method devised by Newcomer, using a Dubosq hemoglobinometer.

RESULTS

A Comparison of the Hemoglobin Value of Inbred and Outbred Litters at Various Periods

There was a significant difference between the hemoglobin level in the inbred and outbred groups at certain ages. For this reason it was deemed advisable to report the results for the two groups separately. The average hemoglobin level for each group at varying ages between birth and 180 days of age is given in Table I. The standard deviation and the coefficient of variability are also given for each group at each age.

The number of pigs within each group steadily decreased each succeeding period. Most of this decrease up to eight weeks can be attributed to death losses alone. Following the eight week period some of the pigs were not observed. Thus a large part of the decrease during the later periods was accounted for by this factor.

The hemoglobin content in both groups was relatively high at birth. In fact it approached that of the sows. There was a rapid decline in the hemoglobin content in both groups during the first week. This decline was continued during the second week in the inbred group, but arrested in the outbred group with a slight increase during the second week. By the fourth week the hemoglobin content was increasing in both groups, but more rapidly in the outbred group.

It apparently took the inbred pigs eight weeks to regain their normal hemoglobin level; whereas, the outbred group had practically regained theirs at four weeks.

The hemoglobin content was more variable in the inbred group during the earlier periods. The same thing was true in the control group only their variability was greater than the variability in the inbreds throughout the first sixteen weeks.

Table I

The Hemoglobin Content of the Blood of Pigs at Various Ages*

Age	Inbred				Outbred			
	No. of pigs	Aver. Hb.	s**	C.V.***	No. of pigs	Aver. Hb.	s	C.V.
Birth	197	9.8	1.65	17.5	228	9.7	2.1	21.3
1 week	163	7.9	1.57	19.9	183	7.0	1.68	24.1
2 weeks	149	7.8	1.68	21.5	168	8.1	1.50	18.6
4 weeks	134	8.5	1.49	17.6	161	9.0	2.11	22.9
8 weeks	117	9.8	1.55	15.9	147	10.7	2.36	22.1
12 weeks	78	9.2	1.38	15.9	116	9.5	2.36	24.8
16 weeks	65	9.7	1.52	15.7	112	9.6	2.09	21.8
20 weeks	62	10.2	1.18	11.6	98	11.2	1.17	10.4
180 days	55	9.9	1.43	14.4	77	9.5	1.32	13.8

* The Newcomer Method of analysis of hemoglobin was used in recording the amount of hemoglobin (Hb.).

** s - Standard Deviation

***C.V. - Coefficient of Variability

A comparison of average weight and hemoglobin content of the inbred and outbred pigs for the various periods from birth to 180 days is made in Table II.

Table II

Average Hemoglobin Content and Average Weight of the Inbred and Outbred Pigs

Age	Wt. in Pounds	Hemoglobin	Wt. in Pounds	Grams of Hemoglobin
Birth	2.2	9.8	2.39	9.74
1 week	4.5	7.9	4.9	7.0
2 weeks	7.13	7.83	8.28	8.07
4 weeks	12.02	8.49	13.13	9.2
8 weeks	24.01	9.78	24.61	10.67
12 weeks	31.13	9.23	35.21	9.51
16 weeks	49.49	9.7	54.00	9.58
20 weeks	75.6	10.2	80.53	11.24
180 days	108.9	9.9	134.05	9.53

Effect of Hemoglobin Content Upon Subsequent Growth

The average weights of the two groups of pigs are given in Table II for each period that the hemoglobin was determined. The average hemoglobin level has also been repeated in this table to facilitate comparisons.

There has been a steady increase in weights from one period to the next. These increases in weights are lower

than what would be expected. A low growth rate has been recorded throughout the inbreeding experiment from which these data have been collected. A part of this low growth rate has been attributed to heavy infestations of round worms and frequent outbreaks of necrotic enteritis.

The growth rates for the two groups of pigs are shown in Chart II. A comparison of Chart I and Chart II shows that the curves for growth and the curves for hemoglobin level are similar except for the first and second weeks after birth.

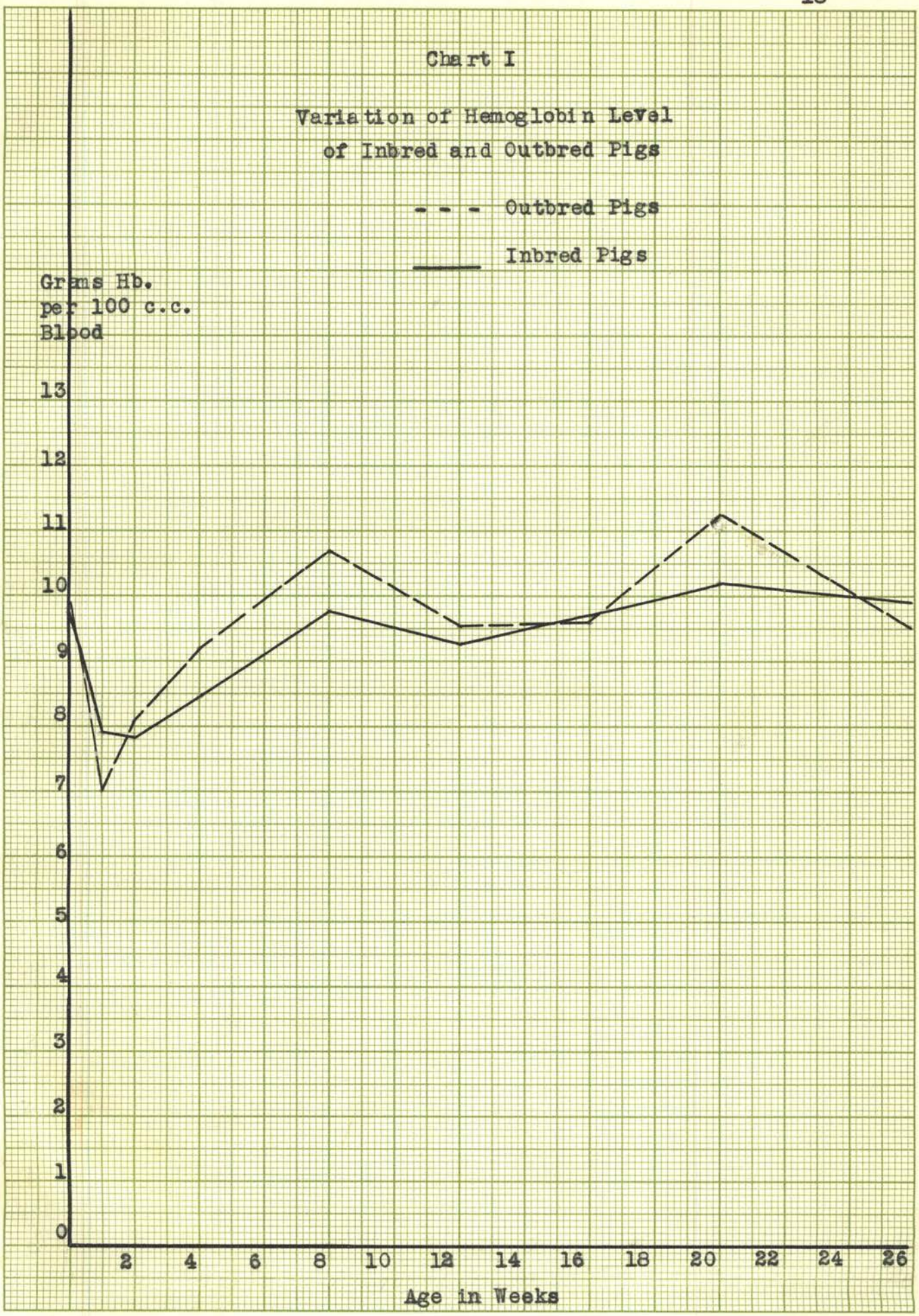
Chart I
Variation of Hemoglobin Level
of Inbred and Outbred Pigs
- - - Outbred Pigs
____ Inbred Pigs
Grams Hb.
per 100 c.c.
Blood
13
12
11
10
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Age in Weeks

Chart II

Growth Rate of Outbred and Inbred Pigs

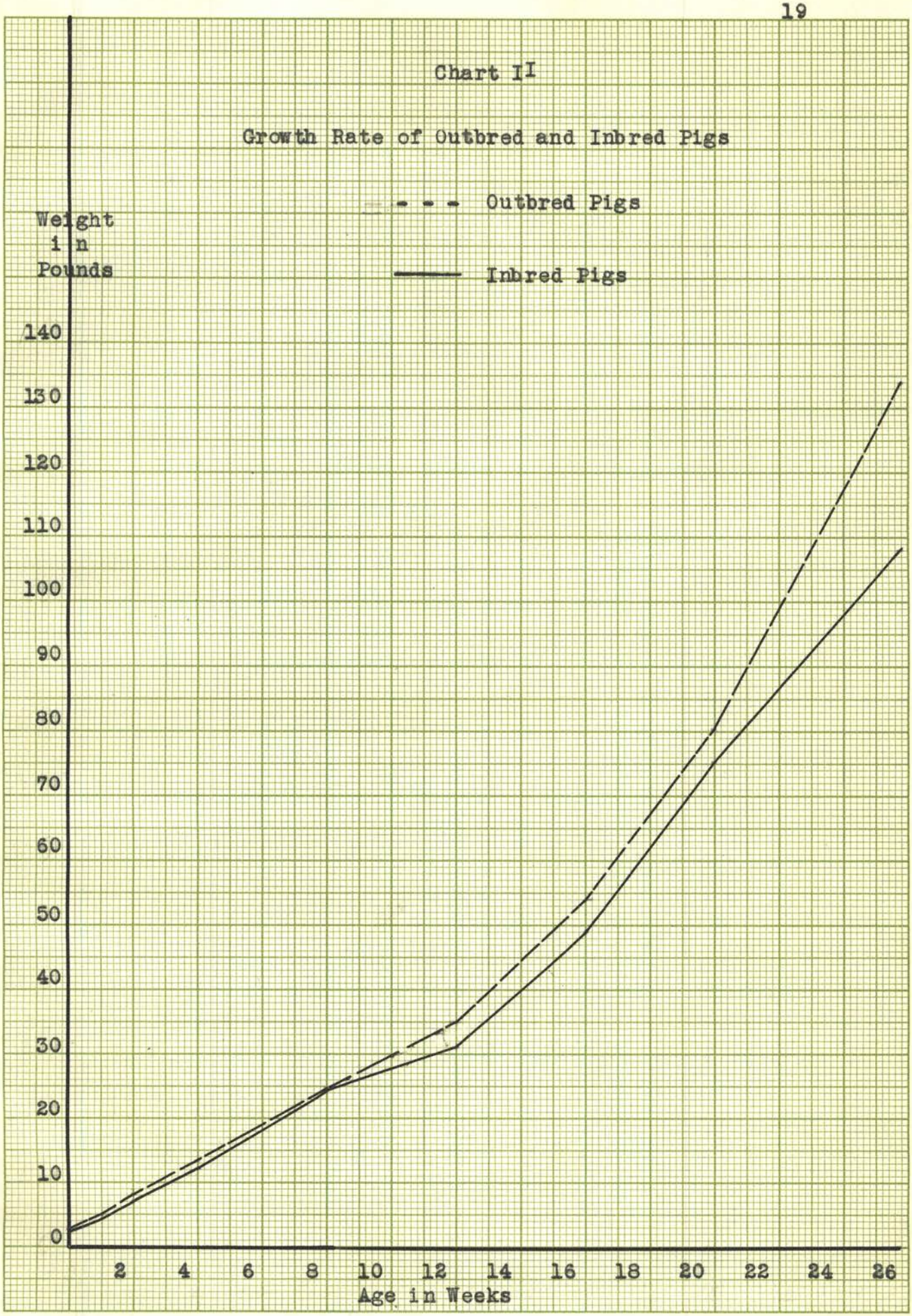

Table III

Coefficient of Correlation of Growth Rate and Hemoglobin Content of the Blood of Inbred and Outbred Pigs for Two Periods

Periods	No. of Pigs	Av. Daily Gains	Av. Hemo. Content Begin. of Period	Coefficient of Correlation
Birth to 56 days	284	.39	9.96	.0005
56 days to 120 days	201	.44	9.59	.0027

In Table III the growth rate and hemoglobin content of pigs are given for two periods. The first period from birth to 56 days and the second from 56 days to 120 days. The question naturally arises, will pigs whose hemoglobin content is low at birth gain as fast as pigs with a higher hemoglobin content. Data presented in this table reveals that there is no correlation between these two variables which indicates that there is no relationship between the variation in gains in weight and the variation in the hemoglobin content of the blood at the beginning of the period.

Table IV

Intra-class Correlation of the Hemoglobin Content of Pigs from the Same Sow for the Inbred and Outbred Groups

Age	Inbred	Outbred
Birth	.4354	.3370
1 week	.3220	.0416
2 weeks	.2879	.0166
4 weeks	.2491	.0493
8 weeks	.0267	.1716
12 weeks	.2075	.1421
16 weeks	.4031	.0553
20 weeks	.4387	.1607
180 days	.4586	.0192

* The correlations were tested according to the method set forth by Snedecor (20).

It is evident from Table IV that there is a high intra-class correlation between the hemoglobin content of the blood of pigs from the same inbred sows. This indicates that the hemoglobin contents of the pigs produced from the same sow were more alike than the hemoglobin contents for random pigs. This also indicates the possibility that the hemoglobin content of the blood is a hereditary factor and that some of the factors responsible for it must have been fixed in the inbred line. There is no correlation between the hemoglobin content of the blood of outbred pigs from the same sows. This would indicate that outbred sows must have been heterozygous for factors for hemoglobin content.

DISCUSSION

The cause for the drop in the hemoglobin content of the blood of pigs during the first week was not found. The pigs were farrowed indoors and kept on concrete and brick floors during the first week, but they had access to soil which had been supplemented with iron and copper, so it hardly seems possible that the decrease could be attributed to feed. It was not possible to compare these pigs with pigs farrowed outside.

It was found by Craft (3) that outbred pigs were more vigorous and resistant to disease and parasites than the inbred pigs. Since the outbred pigs in this experiment regained their hemoglobin content more rapidly the first week following birth it might be reasonable to attribute this added vigor and resistance to the higher hemoglobin content. If this were true it would seem reasonable to expect the pigs with high hemoglobin content to make the more rapid gains. The results did not bear this out for there was no correlation found between gains in weight and hemoglobin content for the two periods studied (birth to 56 days and 56 days to 120 days.

According to an intra-class correlation of the hemoglobin content of the blood of inbred pigs from the same sows and the blood of outbred pigs from the same sows there is more similarity of the hemoglobin of the blood of inbred pigs from the same sows. This tends to show that hemoglobin content

is an inherited character and that the inbred sows are more homozygous for the character. It also appears from this that as a result of the many generations of half-brother X half-sister matings of the inbred swine an increase of homozygosity also occurred for other characters.

The intra-class correlations found between the hemoglobin level of pigs produced by the same inbred sow are high. They are really higher than would be expected. Since the same correlation did not exist between the hemoglobin level of pigs produced by outbred sows, the hemoglobin level in pigs must be controlled to some extent by heredity. This suggests that it might be possible to use the hemoglobin level as one factor for which the swine breeder can afford to select.

There is no doubt but that anemia is a serious handicap to young pigs which have to be kept indoors for long periods. It may be possible to select and breed for a strain of swine which would have higher hemoglobin levels and thereby be more resistant to anemia.

It is suggested that it might be worth while to test the hemoglobin level of different inbred strains within a pure breed to see if the above resemblances will be found again.

SUMMARY

1. The data for this study were taken from a herd of inbred and a herd of outbred Duroc Jersey swine which were used to study the consequences of inbreeding.
2. The hemoglobin levels were observed at birth, 1 week, 2 weeks, 4 weeks, 8 weeks, 12 weeks, 16 weeks, 20 weeks, and 120 days.
3. The hemoglobin content of the blood of the pigs of both groups was relatively high at birth when it was an average of 9.8 grams per 100 cubic centimeters of blood.
4. The hemoglobin level decreased during the first week in both groups, being 7.9 grams for the inbreds and 7.0 grams for the outbreds at the end of the first week.
5. There was a decided increase in the hemoglobin of the outbreds and a further decrease for the inbreds the second week after birth.
6. The decrease or increase in the hemoglobin content of the outbred pigs was more marked than that of the inbred pigs at the different periods.
7. The high hemoglobin level, 11.24 grams, for the outbreds was reached at the sixteenth week and the high level for hemoglobin of the inbreds 10.2 grams per 100 cubic centimeters was reached the twentieth week.
8. No correlation between the hemoglobin level at birth and gains made during the suckling period (8 weeks) was observed.

9. There was no correlation between the hemoglobin level at weaning and gains made up to 120 days of age.
10. According to Craft (3) outbred pigs are less susceptible to diseases and parasites. This may be attributed to the higher hemoglobin content.
11. Inbred pigs produced by the same sows seemed to resemble each other in hemoglobin content more than outbred pigs produced by the same sows as indicated by the intra-class correlation at each period of observation. This is indicative that hemoglobin content is hereditary and that the inbred sows are more homozygous for this character.

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Typist:

Fern Petree