THE PRODUCTION AND CURE OF NUTRITIONAL ANEMIA IN SUCKLING PIGS [1]

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INTRODUCTION

Although the investigation described in the preceding paper (*2*),[2] as well as contemporary work in this country (*1*), has not shown that good rations for young growing pigs are commonly deficient in iron even though they contain no feeds conspicuously high in this element, or that iron supplements to such rations will perform any useful purpose, the case of the suckling pig, subsisting largely or entirely upon the milk of the dam, may very well be in a different category. Although no record in the recent literature has been found of an iron analysis of the milk of the pig, the milk of cattle and of goats (*5*) contains only 0.0002 to 0.0003 per cent of iron, and human milk seems to contain but slightly more (*3*). As compared with other feeds (*17*), these milks, and presumably the milk of the pig also, are extremely poor in iron. Indeed, it has been found possible to induce severe nutritional anemia in rats (*19*), rabbits (*8*), and chickens [3] by the feeding of cow's milk. The probability of the occurrence of anemia in suckling pigs is thus not remote.

WORK OF OTHER INVESTIGATORS

The actual occurrence of anemia under farm and experimental conditions, and the symptoms by which it is accompanied, have been described by McGowan and his associates (*10*, *11*) in England, and by Doyle, Mathews, and Whiting (*4*) in this country. Its etiology, however, has been in doubt. McGowan claims that it is due to the feeding of iron-deficient rations to the sow, but Doyle and his associates were not able to confirm this belief. The latter investigators found that some factor in outdoor conditions tended to prevent anemia in suckling pigs. In a later communication (*13*) it was shown that sunlight was effective in preventing anemia, but that ultra-violet irradiation indoors was ineffective.

The remarkable finding of Hart and his associates (*9*), observed independently and less directly by McHargue and his coworkers (*12*), that the administration of copper salts to rats subsisting upon a milk diet prevented the appearance of the anemia that otherwise invariably occurred, afforded the first definite indication for the prevention and cure of nutritional anemia in suckling pigs. Hart himself was the first, in so far as the authors are aware, to apply this experimental finding to young pigs. In a talk given before the thirty-second annual meeting of the United States Livestock Sanitary Association in Chicago in December, 1928, Hart described his work on iron in nutrition,

[1] Received for publication Dec. 3, 1929; issued May, 1930.
[2] Reference is made by number (italic) to "Literature cited," p. 938.
[3] University of Illinois unpublished data.

and presented briefly the results of copper and iron medication of part of one litter of anemic pigs. The treatment was distinctly successful, but for some reason these results have not been included in the report of the paper appearing in the printed proceedings of the society.[4]

EXPERIMENTAL DATA

In a continuation of the work on the value of iron supplements in swine nutrition advantage was taken of this discovery of the function of copper in blood formation. Some preliminary observations on pigs farrowed from sows subsisting upon iron-poor rations (*14*) had not confirmed the belief of McGowan that anemia was a necessary sequel of such treatment. However, in the following year (spring of 1929) four Duroc-Jersey pigs from a litter of 13, raised under the usual routine at the swine barns, exhibited symptoms similar to those described by McGowan. Accordingly, samples of blood were taken from the tails of these pigs and analyzed for hemoglobin by the acid hematin method of Newcomer (*16*), the Newcomer plate being standardized by the Van Slyke oxygen capacity method (*18*).[5] The pigs were 11 days old, and the hemoglobin contents, expressed in grams per 100 c. c., was 5.05, 5.05, 5.57, and 5.05. Two of the pigs were then given daily by pipette a solution of copper sulphate containing 5 mgm. of copper daily and at the end of a week solutions of both ferric citrate and copper sulphate in amounts equivalent to 25 mgm. of iron and 5 mgm. of copper. One of these pigs died in about a week, but the hemoglobin in its blood had risen from 5.05 to 7.14 gm. per 100 c. c. The hemoglobin of the other treated pig remained at a low level for three weeks and then rapidly increased in the following three weeks to 10.1 gm. per 100 c. c., after which a slight drop occurred. The two untreated pigs showed a decrease in hemoglobin. At 25 days of age, one of them gave a sample of blood containing only 2.85 gm. of hemoglobin per 100 c. c. The iron and copper medication was started at this time, and the animal responded rapidly, so that at an age of 53 days the blood contained 9.62 gm. of hemoglobin per 100 c. c. The second untreated pig was kept in a distinctly anemic condition, with the hemoglobin varying from 2.5 to 3 gm. per 100 c. c., from the twenty-fifth to the sixtieth day of age. It was then given the usual daily dose of ferric citrate and copper sulphate. From a level of 2.96 gm. the hemoglobin increased in three weeks to 8 gm per 100 c. c. These pigs were all kept indoors.

This preliminary experiment confirmed in every way the experiment reported orally by Hart.

Observations were then made upon three litters of pigs that were cared for in the normal manner, no metallic salts being given. The only difference in the treatment accorded the litters was the time from birth at which they were removed outdoors into cindered pens. The first litter, 9 PC, was a vigorous one of four Poland China pigs farrowed on February 25, to which one Duroc-Jersey pig was later added. This litter was removed outdoors to a cindered pen on March

[4] A popular bulletin describing these and other results of a similar nature on suckling pigs has since appeared (*7*).

[5] Five standardizations with pig blood of the Newcomer colored glass disk gave an average of 0.003085 as the disk factor instead of 0.0035 as furnished by the manufacturers of the disk. All acid hematin solutions were prepared in the manner described by Newcomer and all were allowed to stand overnight at room temperature before readings were made. Turbidities, such as those encountered when acid hematin solutions are prepared from avian blood by the Newcomer procedure, were not encountered with pig blood.

15. Very soon after this one of the pigs, 9–30–B, escaped from the pen. Litter 4 PC was also a normal healthy litter of Poland China pigs, which on account of the prevailing bad weather was not removed to the outside until April 11, when the pigs were over 3 weeks of age. Litter 3 DJ was a small litter of Duroc-Jersey pigs which, when 2 weeks of age, appeared to be anemic. Blood samples were therefore taken at this time and for three succeeding weeks. On March 30 this litter was removed to an outside pen. The observations on the blood, including hemoglobin content, and red-cell counts on the first litter, are summarized in Tables 1, 2, and 3. In this and all subsequent experiments, blood samples were taken from an ear vein.

TABLE 1.—*Hemoglobin content and erythrocyte count of the blood of a vigorous litter of pigs*

[Litter 9 PC; [a] farrowed Feb. 25 and moved outside Mar. 15, no medication]

HEMOGLOBIN (GRAMS PER 100 C. C. OF BLOOD)

Date of observation	Age of pigs	Pig No.				
		9–9–S	9–90–S	9–30–B	9–3–S	2–9–S
1929						
Mar. 6	1 week 2 days	6.37	8.03			6.78
Mar. 13	2 weeks 2 days	6.64	7.86	7.80		7.01
Mar. 20	3 weeks 2 days	8.39	10.68	11.99		9.53
Mar. 27	4 weeks 2 days	9.87	11.11		10.90	12.21
Apr. 3	5 weeks 2 days	11.03	9.74		10.74	10.33
Apr. 10	6 weeks 2 days	11.47	10.56		12.91	12.84
Apr. 17	7 weeks 2 days	11.45	11.90		12.45	10.37

ERYTHROCYTES (MILLIONS PER CUBIC MILLIMETER OF BLOOD)

Mar. 6	1 week 2 days	5.06	5.52			6.26
Mar. 13	2 weeks 2 days	5.54	5.15	5.16		5.39
Mar. 20	3 weeks 2 days	5.42	6.63	7.65		7.34
Mar. 27	4 weeks 2 days	7.09	7.78		11.70	10.12
Apr. 3	5 weeks 2 days	8.53	7.85		8.53	7.09
Apr. 10	6 weeks 2 days	8.35	9.23		8.53	9.65
Apr. 17	7 weeks 2 days	8.47	7.57		9.44	

[a] Blood of sow 9 PC contained 9.65 gm. hemoglobin per 100 c. c. when tested Apr. 3.

TABLE 2.—*Hemoglobin in grams per 100 c. c. of the blood of a normal litter of pigs*

[Litter 4 PC; kept inside till Apr. 11; no medication]

Date	Age of pigs	Pig No.			
		4–30–B	4–30–S	4–3–S	4–90–S
1929					
Mar. 20	2 hours	9.31	9.05	11.25	
Mar. 27	1 week	4.00	4.05	(a)	5.40
Apr. 3	2 weeks	3.20	3.69		3.63
Apr. 10	3 weeks	2.55	6.82		3.83
Apr. 17	4 weeks	(b)	9.53		6.82

[a] Killed by sow. [b] Died.

TABLE 3.—*Hemoglobin in grams per 100 c. c. of the blood of a small, apparently anemic, litter of pigs*

[Litter 3 DJ;[a] farrowed Mar. 13; apparently anemic when study started on Mar. 27; sow and litter placed in outside pens Mar. 30; no medication]

Date	Age of pigs	Pig No.		
		3-30-S	3-30-B	3-99-B
1929				
Mar. 27	2 weeks 1 day	3.34	3.42	
Apr. 3	3 weeks 1 day	2.33	2.26	2.47
Apr. 10	4 weeks 1 day	9.36	7.40	8.95
Apr. 17	5 weeks 1 day	12.95	8.16	10.64

[a] Blood of sow 56 DJ contained 10.30 gm. hemoglobin per 100 c. c. when tested Apr. 3.

The main significance of these observations relates to the anemic condition developing in all pigs, no matter how healthy and vigorous they appeared to be, during indoor confinement, and the rapid alleviation of this condition upon removal to an outdoor cindered pen. According to the results obtained with litter 4 PC (Table 2), from which blood samples were taken two hours after birth, the pig is born with a fairly high level of hemoglobin, which is rapidly reduced during the first week of life.

The most striking illustration of the rapid decrease in the hemoglobin of pigs during the first few days after birth and of the rapid recovery that is effected by the change from indoor to outdoor conditions was obtained with litters 90 DJ and 93 DJ, farrowed from sisters bred to the same boar. These results are summarized in Tables 4 and 5. The hemoglobin measurements are presented graphically in Figure 1 A and B.

TABLE 4.—*Blood hemoglobin and erythrocyte count, and weights, of a litter of pigs kept outdoors*

[Litter 90 DJ;[a] sow and pigs moved outdoors in a cindered pen on the sixth day after farrowing; no medication]

HEMOGLOBIN (GRAMS PER 100 C. C. OF BLOOD)

Date	Age of pigs	Pig No.					
		90-3-B	90-3-S	90-30-S	90-9-S	90-99-S	Average
1929							
Apr. 5	6 to 10 hours	13.75	11.94	9.68	11.25	11.00	11.52
8	3 days	9.05	6.74	8.43	8.16	8.09	8.06
10	5 days	7.56	6.90	7.37	6.56	8.27	7.33
17	1 week 5 days	5.45	4.64	6.53	4.93	6.94	5.70
24	2 weeks 5 days	9.06	5.79	8.30	6.77	8.83	7.75
May 1	3 weeks 5 days	8.81	7.11	12.06	8.67	11.47	9.62
8	4 weeks 5 days	10.56	11.33	12.44	10.37	12.04	11.35
15	5 weeks 5 days	12.64	12.19	10.44	11.33	11.58	11.64
22	6 weeks 5 days	12.99	11.65	9.41	10.96	10.79	11.16

ERYTHROCYTES (MILLIONS PER CUBIC MILLIMETER OF BLOOD)

Apr. 5	6 to 10 hours	6.36	6.40	5.87	6.07		6.17
8	3 days	5.37	3.84	4.66	3.81	6.18	4.77
24	2 weeks 5 days		3.63	5.41	4.48	6.15	4.92
May 22	6 weeks 5 days	9.21	9.77			7.29	8.75

WEIGHTS OF PIGS (POUNDS)

Apr. 5	At birth	3.0	3.2	2.8	2.6	3.0	2.92
May 22	6 weeks 5 days	30.5	31.5		28.0	21.7	27.94

[a] Blood of sow 90 DJ contained 9.38 and 9.76 gm. hemoglobin per 100 c. c. when tested on Apr. 3 and Apr. 10, respectively.

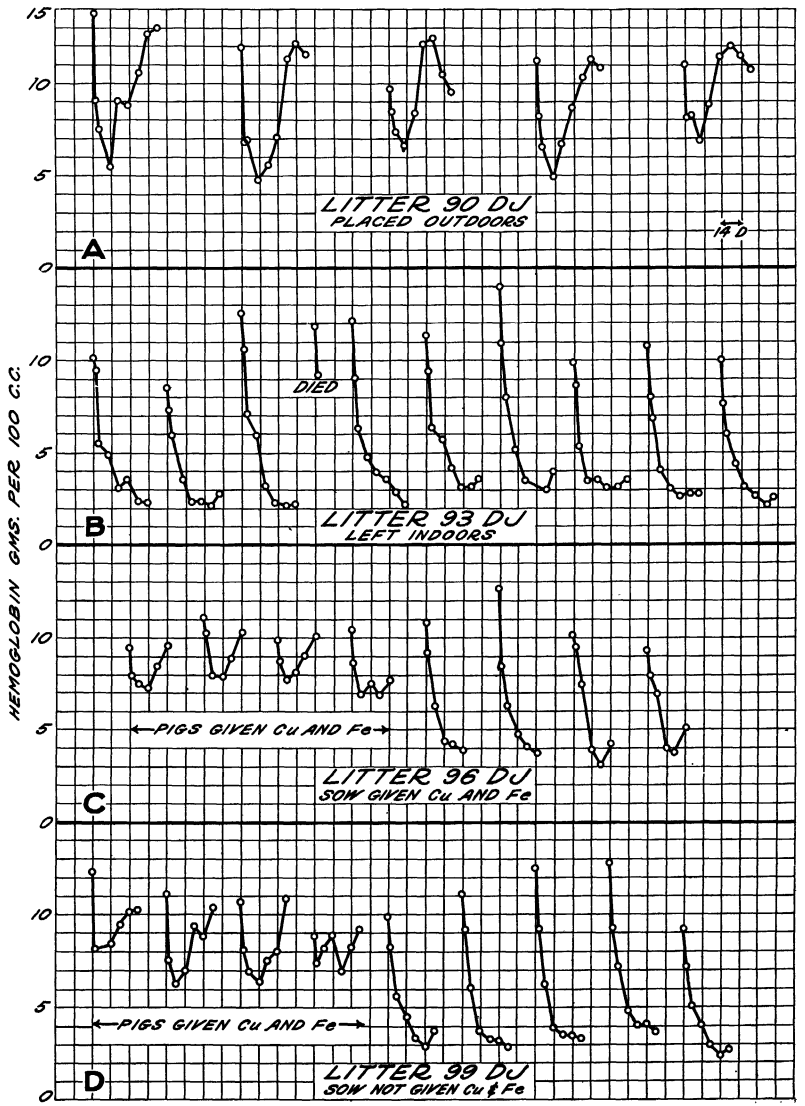

FIGURE 1.—The effect on the concentration of blood hemoglobin of suckling pigs of (A, B) outdoor as compared with indoor confinement; C, D, administration of iron and copper salts to the dam during gestation and lactation, and administration of iron and copper salts to the pigs themselves

TABLE 5.—*Blood hemoglobin and erythrocyte count, and weights, of a litter of pigs kept indoors*

[Litter 93 DJ[a]; sow and pigs kept inside; no medication]

HEMOGLOBIN (GRAMS PER 100 C. C. OF BLOOD)

Date	Age of pigs	Pig No.									Average
		93-90-B	93-9-B	93-90-B	93-39-B	93-30-B	93-60-B	93-90-S	93-9-S	93-3-S	93-39-S	
1929												
Apr. 13	2 hours	10.19	8.50	12.56	11.83	12.15	11.39	13.92	9.89	10.84	10.03	11.13
15	1 day	9.45	7.35	10.47	9.14	9.00	9.40	10.92	8.68	7.94	7.73	9.01
17	4 days	5.43	5.83	7.01	------	6.28	6.31	7.94	5.31	6.96	5.97	6.34
24	1 week 4 days	4.99	3.57	5.92	------	4.72	5.68	5.07	3.46	4.11	4.35	4.65
May 1	2 weeks 4 days	3.07	2.11	3.18	------	3.90	4.12	3.43	3.47	3.05	3.16	3.28
8	3 weeks 4 days	3.44	2.17	2.21	------	3.58	3.06	------	3.04	2.62	2.63	2.84
15	4 weeks 4 days	2.35	2.04	2.06	------	2.82	3.08	2.97	3.07	2.76	2.19	2.59
22	5 weeks and 4 days	2.27	2.79	2.19	------	2.09	3.53	3.97	3.51	2.75	2.55	2.85
ERYTHROCYTES (MILLIONS PER CUBIC MILLIMETER OF BLOOD)												
May 1	2 weeks 4 days	------	2.28	------	------	4.98	------	4.83	2.87	3.40	2.81	3.53
WEIGHTS OF PIGS (POUNDS)												
Apr. 13	At birth	2.3	2.4	2.7	2.4	2.6	2.5	2.5	2.2	2.5	2.4	2.45
May 22	5 weeks 4 days	7.2	8.0	13.0	------	12.2	15.5	17.0	14.0	15.5	12.0	12.71

[a] Blood of sow 93 DJ contained 11.67 and 11.58 gm. hemoglobin per 100 c. c. when tested on Apr. 3 and Apr. 13, respectively.

The first blood samples, taken from 2 to 10 hours after farrowing, indicate that the pig is born with a fairly high level of hemoglobin, averaging 11 to 11.5 gm. per 100 c. c. A rapid decrease occurs during the first week to a level but little more than half that at birth, and continues for four or five weeks if the pigs are left indoors (litter 93 DJ). Removal to an outside pen, with no access to soil or vegetation, brings about a prompt recovery (litter 90 DJ), both in blood picture and in physical condition. At 39 days of age the litter indoors averaged 17.71 pounds in weight, while at 47 days of age the outdoor litter averaged 27.94 pounds. While part of this difference in weight was due to age and part to a difference in size of litter, there can be little doubt that much of it was the result of the favorable influence of outside conditions. These two litters as they appeared at this time (May 29) are shown in Figure 2.

In order to obtain more evidence concerning the effect of copper and iron medication of suckling pigs on the concentration of hemoglobin in the blood and to determine whether this effect can be secured by treatment of the sow with copper and iron salts preceding parturition and during the suckling period, two litter-mate Duroc-Jersey sows, 96 DJ and 99 DJ, were bred to the same boar. Two weeks before farrowing time sow 96 DJ was given daily doses of ferric citrate (4.0 gm.) and copper sulphate (0.75 gm.) equivalent to 750 mgm. of iron and 191 mgm. of copper daily. The former as a solid and the latter dissolved in 50 c. c. of distilled water, were mixed with the feed. This dose was continued until the litter, farrowed on April 16, 1929, was removed from observation. Sow 99 DJ

reeeived no iron or copper supplements at any time. Blood samples were taken from the individual pigs from two to five hours after birth, after which each litter was divided into two groups, containing four or five pigs each. One group in each litter received daily by mouth water solutions of ferric citrate and copper sulphate in amounts

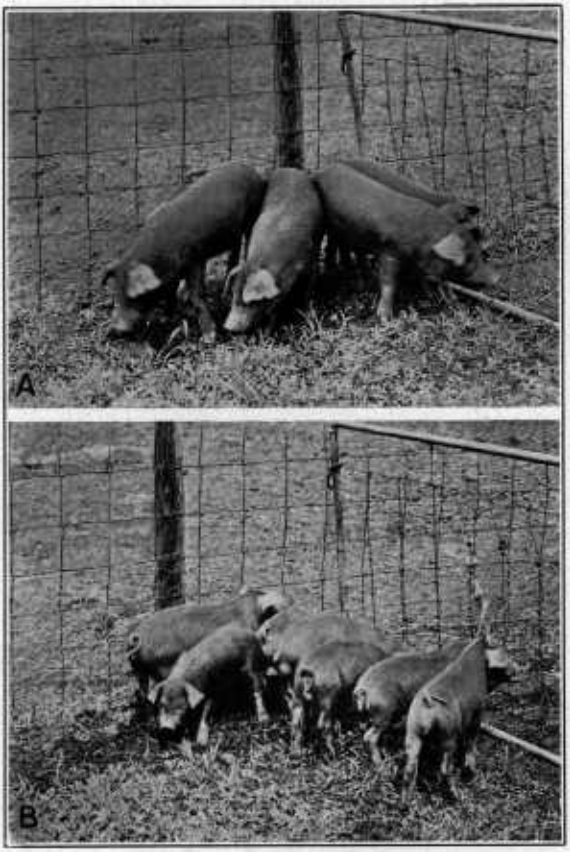

FIGURE 2.—The effect of indoor as compared with outdoor living conditions on the health and vigor of suckling pigs. The four pigs shown at A farrowed in the barn and were removed outdoors to cindered pens in about two weeks; their average weight was about 30 pounds each at the time the photograph was taken. The seven pigs shown at B farrowed in the barn and were kept there until a few days before this photograph was taken, at which time they were almost 2 months old. Long confinement indoors has reduced them to a distinctly anemic condition and at the time the photograph was taken their average weight was only about 14 pounds each. Although litter B was larger than litter A and eight days younger, the contrast in their size and condition must have been caused mainly by the difference between indoor and outdoor conditions of living

containing, respectively, 25 mgm. of iron and 5 mgm. of copper. During the observation of these two litters the little pigs were kept from the dam's feed and feces, either by putting them with the sow only at suckling time (every two or four hours) or, later, by cleaning the pen containing both sow and pigs every two or three hours and feeding the sow in another pen.

TABLE 6.—*Blood hemoglobin, erythrocyte count, and body weight of a litter of pigs half of which was given iron citrate and copper sulphate in individual doses; the sow had also been fed these salts*

[Litter 96 DJ[a]]

HEMOGLOBIN (GRAMS PER 100 C. C. OF BLOOD)

Date	Age of pigs	Pigs fed ferric citrate and copper sulphate				Control pigs				Average treated	Average controls
		96-99-S	96-9-S	96-90-B	96-9-B	96-30-B	96-39-S	96-30-S	96-90-S		
1929											
April 16	5 hours	9.38	11.16	9.82	10.42	10.79	12.61	10.19	9.34	10.19	10.73
17	30 hours	7.99	10.22	8.73	8.74	9.16	8.41	9.53	7.99	8.92	8.77
24	1 week, 1 day	7.42	7.91	7.68	6.88	6.29	6.28	7.46	6.90	7.47	6.73
May 1	2 weeks 1 day	7.24	7.90	8.06	7.58	4.37	4.71	3.99	4.00	7.69	4.27
8	3 weeks 1 day	8.41	8.82	9.00	6.93	4.24	4.01	3.12	3.78	8.29	3.79
15	4 weeks 1 day	9.56	10.33	10.11	[b]7.63	3.97	3.77	4.28	5.05	9.41	4.27

ERYTHROCYTES (MILLIONS PER CUBIC MILLIMETER OF BLOOD)

April 16	5 hours	6.67	8.07	6.73	5.71	7.09	8.71	7.09	5.76	6.80	7.16
May 8	3 weeks 1 day	6.84	7.43	8.73	5.29	3.76	3.59	4.88	4.13	7.07	4.09

WEIGHTS OF PIGS (POUNDS)

Apr. 16	At birth	2.5	2.5	2.6	2.6	2.5	2.4	2.8	2.5	2.55	2.55
May 8	3 weeks 1 day	9.5	8.5	10.0	11.0	7.5	8.0	11.0	9.0	9.75	8.87
15	4 weeks 1 day	9.0	8.5	10.0	10.5	8.5	10.0	14.0	9.0	9.50	10.37

[a] Blood of sow 96 DJ contained 12.06, 11.43, and 9.59 gm. hemoglobin per 100 c. c. when tested on Apr. 3, Apr. 15, and Apr. 17, respectively.
[b] Died May 16 of unknown cause.

TABLE 7.—*Blood hemoglobin, erythrocyte count, and body weight of a litter of pigs a part of which was given iron citrate and copper sulphate in individual doses, but when the sow had not been fed these salts*

[Litter 99 DJ[a]]

HEMOGLOBIN (GRAMS PER C. C. OF BLOOD)

Date	Age of pigs	Pigs fed ferric citrate and copper sulphate				Control pigs					Average treated	Average controls
		99-9-B	99-3-B	99-99-S	99-9-S	99-33-S	99-30-B	99-30-S	99-3-S	99-33-B		
1929												
Apr. 17	2 hours	12.39	11.14	10.61	8.89	9.86	11.10	12.48	12.73	9.24	10.76	11.08
18	40 hours	8.18	7.54	8.09	7.25	8.21	9.17	9.31	9.31	7.27	7.76	8.65
24	1 week	8.26	6.26	6.89	8.14	5.54	6.00	6.32	7.24	5.07	7.39	6.03
May 1	2 weeks	8.47	6.86	6.38	8.91	4.46	3.71	3.94	4.97	4.09	7.65	4.23
8	3 weeks	9.44	9.32	7.52	6.89	3.38	3.35	3.58	4.05	2.88	8.29	3.45
15	4 weeks	10.11	8.81	7.99	8.23	2.90	3.24	3.46	4.13	2.44	8.78	3.23
22	5 weeks	10.32	10.32	10.81	9.22	3.77	2.91	3.38	3.77	2.77	10.17	3.32

ERYTHROCYTES (MILLIONS PER CUBIC MILLIMETER OF BLOOD)

Apr. 17	2 hours	7.33	6.83	7.53	6.92	6.21	7.65	8.44	7.85	5.93	7.15	7.22
May 15	4 weeks	5.95	------	7.62	7.96	3.18	3.44	4.06	4.80	3.67	7.18	3.83

WEIGHTS OF PIGS (POUNDS)

Apr. 17	At birth	2.0	2.3	2.4	2.6	2.0	2.6	2.1	2.5	2.5	2.32	2.34
May 8	3 weeks	8.0	10.0	9.0	10.0	8.0	12.0	9.0	10.5	10.0	9.25	9.90
15	4 weeks	9.0	11.5	11.0	12.0	10.0	13.0	9.5	14.0	11.5	10.87	11.60
22	5 weeks	10.0	12.7	10.2	12.7	10.0	12.7	10.0	15.5	13.0	11.40	12.25

[a] Blood of sow 99 DJ contained 11.33 and 12.19 gm. hemoglobin per 100 c. c. when tested on Apr. 3 and Apr. 15, respectively.

All of the observations taken on these two litters are recorded in Tables 6 and 7. The hemoglobin results are shown graphically in Figure 1, C and D. The conclusions that may be drawn from these results seem clear cut. In both litters all of the pigs receiving copper and iron medication escaped anemic levels of hemoglobin. Although this treatment did not prevent a marked initial fall in hemoglobin concentration, in no case was a level of 6 gm. per 100 c. c. attained. For all but one pig (9–B in litter 96 DJ) a rapid recovery in hemoglobin occurred, so that at 4 or 5 weeks of age the birth level was again reached. The untreated pigs present an entirely different picture. The drop in hemoglobin concentration continued in every case until a level of 3 or 4 gm. or less per 100 c. c. was reached. It is noteworthy that the untreated pigs nursed by the sow receiving copper and iron medication were not appreciably benefited as judged by comparison with the pigs in the other litter. The effectiveness of the copper and iron treatment of suckling pigs in the prevention of nutritional anemia is clearly evident, as is the ineffectiveness of oral administration of these metals to the lactating sows.

It is interesting to note from Tables 6 and 7 that the body weights of the pigs were not favorably influenced by the copper and iron medication. Evidently the rigid restriction of the pigs to the milk of the dam prevented normal gains in weight.

The individual dosing of anemic pigs under practical farm conditions would of course be out of the question. It is unfortunate that supplementing of the sow's ration with salts of iron and copper—a procedure that would be thoroughly practical—is ineffective in preventing anemia in pigs. In all probability this is due to the fact that the iron and copper content of milk is not readily, if at all, raised by administering iron and copper salts to the lactating female (*5*, *6*).[6] Another possible method of dosing the pigs was to spread a solution of the metallic salts over the udder of the sow several times a day, so that the little pigs would of necessity remove some copper and iron salts from the teats while suckling.

This expedient was tried in the case of a litter of nine Hampshire pigs, No. 23 Hamp. Two solutions were made up, the first containing 7.86 gm. of $CuSO_4.5H_2O$ per liter and the second 42.8 gm. of ferric citrate per liter. These solutions were applied by hand to the udder of the sow four, five, or more times daily. Starting on June 27 a mixed solution of the salts containing corn sirup in addition was substituted. This solution was made by dissolving 15.72 gm. of hydrated copper sulphate in 500 c. c. of water; the solution was brought to the boiling point, and 85.6 gm. of powdered ferric citrate was added slowly with shaking. To the mixture was then added about 1 pint of corn sirup. This was applied to the udder of the sow by hand. The sow and her litter were kept indoors throughout the experimental period. The observations on this litter comprise Table 8. The hemoglobin results are given graphically in Figure 3, A.

[6] In unpublished experiments in cooperation with W. B. Nevens, of the Department of Dairy Husbandry, it has been found that daily doses of 3.2 gm. of hydrated copper sulphate given to dairy cows do not appreciably alter the copper content of milk. For a brief description of these experiments, which will be continued and extended to iron salts during the coming year, see *15*, *p. 120–121*.

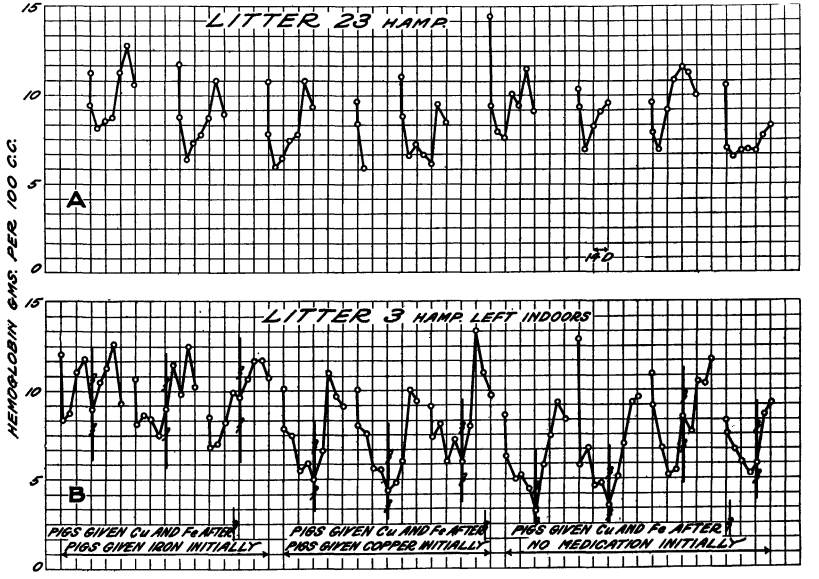

FIGURE 3.—The effect on the blood hemoglobin concentration of suckling pigs of (A) smearing a solution of iron and copper salts on the udder of the dam, and (B) of the separate and combined medication of the pigs with copper and iron salts

TABLE 8.—*Blood hemoglobin, erythrocyte count, and weights of a litter of pigs when the sow's udder was covered with a solution of iron citrate and copper sulphate*

[Litter 23 Hampshire; kept indoors]

HEMOGLOBIN (GRAMS PER 100 C. C. OF BLOOD)

Date	Age	Pig No. 23-30-B	23-9-B	23-90-B	23-99-B	23-30-S	23-9-S	23-90-S	23-99-S	23-60-S	Average
1929											
June 4	9 hours	11.26	11.74	10.73	9.66	11.06	14.40	10.33	9.62	10.51	11.03
5	1 day	9.45	8.72	7.73	8.36	8.59	9.38	9.27	7.82	6.92	8.47
12	1 week 1 day	8.10	6.22	5.87	5.87	6.50	7.92	6.89	6.86	6.50	6.75
19	2 weeks 1 day	8.53	7.35	6.43	[a]	7.17	7.60	8.18	9.12	6.82	7.65
26	3 weeks 1 day	8.74	7.78	7.38	------	6.55	10.10	9.02	10.78	6.87	8.40
July 3	4 weeks 1 day	11.32	8.65	7.81	------	6.03	9.32	9.50	11.57	6.81	8.88
10	5 weeks 1 day	12.62	10.99	10.76	------	9.44	11.48	------	11.23	7.66	10.60
15	6 weeks 1 day	10.68	8.89	9.22	------	8.50	9.10	------	9.93	8.27	9.23

ERYTHROCYTES (MILLIONS PER CUBIC MILLIMETER OF BLOOD)

June 4	9 hours	6.84	7.34	7.08	6.23	6.25	7.55	5.51	5.44	4.69	------
12	1 week 1 day	------	------	------	------	------	------	------	------	3.95	------

WEIGHTS OF PIGS (POUNDS)

June 4	At birth	3.5	3.4	3.1	3.1	3.4	4.0	3.5	3.0	3.1	------
5	1 day	4.0	4.1	3.9	3.2	4.0	4.5	4.0	3.5	3.9	------
12	1 week 1 day	6.5	6.5	6.5	6.0	7.0	7.5	7.0	6.0	6.5	------
19	2 weeks 1 day	9.5	9.5	10.0	[b]	11.0	11.0	11.0	8.5	11.5	------
26	3 weeks 1 day	10.5	12.0	14.0	------	13.5	13.5	14.0	10.0	13.0	------
July 3	4 weeks 1 day	12.0	14.0	17.0	------	16.0	16.0	18.0	13.5	16.0	------
10	5 weeks 1 day	14.0	19.0	18.5	------	19.5	20.5	------	16.0	18.5	------
15	6 weeks 1 day	16.5	24.0	24.5	------	24.0	26.0	------	21.0	23.5	------

[a] Dead. [b] Killed by sow.

The pigs in this litter increased in body weight at a rate that was not far from normal. The hemoglobin concentration of the blood decreased, as usual, for the first week or so, after which it increased

up to the fifth week of age, sometimes to a value higher than that initially observed. A comparison of the hemoglobin curves of this litter with those of litter 93 DJ (fig. 1, B) seems to indicate clearly that the method of administering copper and iron salts to suckling pigs by spreading a solution of the salts over the udder of the dam is an effective as well as a practical method of preventing milk anemia when, because of inclement weather, the pigs must be kept indoors. The experiment unfortunately did not continue long enough to evaluate the significance of the decrease in hemoglobin concentration, generally slight, that occurred in six of the eight surviving pigs from the fifth to the sixth weeks of age.

In the last experiment a litter of 10 Hampshire pigs was divided into three groups in order to determine the effect on the concentration of hemoglobin of the separate administration of ferric citrate and copper sulphate. Three of the pigs received ferric citrate in the ordinary dosage (equivalent to 25 mgm. of iron daily) three received copper sulphate (equivalent to 5 mgm. of copper daily) and four were untreated. At 4 weeks of age all pigs received the combined treatment of iron and copper. The experiment is not particularly conclusive, except in showing again the markedly favorable effect of the combined dosage. The hemoglobin changes are presented in Figure 3, B. All of the pigs receiving iron showed the initial drop in hemoglobin, but all of them showed some response to the iron medication. In two cases the response was marked. The sample of ferric citrate used contained 0.73 mgm.[7] of copper per gram, so that in this group each pig received 0.01 mgm. of copper daily in its dose of ferric citrate. The three pigs receiving copper sulphate only were not benefited appreciably by this treatment. All pigs responded promptly to the combined dosage of iron and copper.

SUMMARY

A few hours after birth the hemoglobin concentration in the blood of pigs was found to range from less than 9 to almost 15 gm. per 100 c. c., averaging 10.75 gm. in the 54 pigs tested. There is a rapid decrease in hemoglobin during the first few days, a decrease which starts at or soon after birth.

In the case of litters remaining indoors, this decrease in the level of hemoglobin in the blood continued until concentrations of 4, 3, or even 2 gm. per 100 c. c. of blood were reached. In the case of litters removed outdoors to cindered pens, this decrease was stopped and an increase was induced until the birth level of hemoglobin was again reached.

The birth level of hemoglobin could be restored also by administering ferric citrate and copper sulphate to the pigs, either by pipette in daily doses equivalent to 25 mgm. of iron and 5 mgm. of copper, or by spreading a solution of these metallic salts over the udder of the lactating sow. However, the administration of copper and iron salts to the dam during the last two weeks of gestation and the period of lactation had no appreciable effect on the blood hemoglobin concentration of the suckling pigs.

The administration of copper sulphate alone to the suckling pigs was ineffective in promoting the regeneration of hemoglobin. Ferric citrate alone, contaminated with a very small amount of copper, was

[7] Determined by the potassium ethyl xanthate method.

appreciably effective, but much less so than a combination of copper sulphate and ferric citrate.

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