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SOME EFFECTS OF COBALT
FEEDING WITH SHEEP

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE
Charles C. Chamberlain
1948



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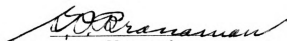
Some Effects of Cobalt Feeding With Sheep

presented by

Charles C. Chamberlain

has been accepted towards fulfillment
of the requirements for

M. S. degree in Animal Husbandry


Major professor

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SOME EFFECTS OF COBALT FEEDING WITH SHEEP

By

Charles C. Chamberlain

A THESIS

Submitted to the School of Graduate Studies of Michigan

State College of Agriculture and Applied Science

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Department of Animal Husbandry

1948

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SOME EFFECTS OF COBALT FEEDING WITH SHEEP

Interest in cobalt as one of the necessary trace elements stems from the New Zealand work on "bush sickness" done over a period of several years and reported in a series of articles in 1937. (1, 2, 3, 4) This work definitely established the need for cobalt by sheep under the conditions found in New Zealand. The symptoms as reported in this work were similar to symptoms reported in widely scattered areas all over the world.

One of the earliest pieces of work reporting the symptoms now generally recognized as those due to a cobalt deficiency was the result of work done in northwestern Michigan and reported in 1909. (5) Emaciation, loss of appetite, low water intake, depraved appetite, constipation, incoordination in gait, dry hard hair coat, and pale slimy stomach membranes on post mortem examination were the symptoms reported.

This work is largely of historical interest. Treatment consisted of dosages of raw linseed oil for three days followed thereafter by daily dosages of a thin linseed gruel. The suggestion was made at the time that the value of the treatment was due to a "softening effect on the feed ball in the omasum." It seems more logical, in light of the present analysis of linseed for cobalt, that the beneficial effect of the linseed was due to the cobalt present.

The Australian workers had reported that cobalt was effective in treating "coast disease" in 1935 (1) just as the New Zealand work was starting, which was an important factor in leading the New Zealand workers to study cobalt. Their work was of such a fundamental nature

that it deserves a brief summary here.

It was demonstrated that neither iron nor copper were beneficial in preventing or curing "bush sickness" in New Zealand. Certain types of soil if fed or given as a drench prevented or cured the disease while other soil types had no effect. A dilute HCl extract of the beneficial soils gave as good results as did the whole soil drench. If the soils were first ignited at low temperatures and then extracted with dilute HCl, the extract was still beneficial. These facts, plus the Australian reports on cobalt, led these workers to suspect a trace mineral and both nickel and cobalt were tried. In the group of 5 control sheep, 3 died, and the other 2 lost weight for 120 days before they leveled out and then started slight gains. In the nickel group, 1 died and the remaining 4 simply held their own. In the cobalt group, all the sheep made steady increases in weight so that at 230 days when slaughtered this weight was nearly double that of the control group. The controls showed the usual deficiency symptoms plus a low quantity of thin blood, liquid in the abdominal cavity, and soft bloodless breast bones. The nickel group had similar symptoms, but to a lesser degree; while the cobalt lambs showed none. Later, a careful analysis of the nickel salt used showed a 0.7% composition of cobalt, explaining the lessened symptoms.

These workers then checked the cobalt content of the soils that had been used as drenches and found almost perfect correlation between the cobalt content of the soil used as a drench and its success in preventing "bush sickness." However, when the soils were checked in non-afflicted areas as well as the afflicted ones, the soil picture was somewhat changed. Several of the non-afflicted areas had a cobalt soil

content much lower than the afflicted areas, but all the afflicted areas had soils with a low cobalt content. From this the workers concluded that the cobalt in the soil was not a reliable guide, but that there were other factors affecting availability. Unfortunately, this phase of the work was not continued.

A study was then made of the cobalt content of various internal organs of the experimental lambs. The "sick" lambs had very low cobalt content in the organs compared to those receiving a cobalt drench. This was found to be the case in spite of the fact that it had been found that nearly all the orally administered cobalt was excreted in 72 hours and that at the end of 120 hours cobalt excretion was back to pre-administration level.

The symptoms reported in New Zealand were similar to those found in Canada on a group of ewes that were originally on a wool growth and quality experiment. (6) The Canadian workers tried a number of supplements including pasture, calcium, phosphorus, cod liver oil, tankage, linseed meal, bran, and alfalfa meal to prevent and cure the unthrifty condition of the ewes. The best results were obtained with alfalfa and later with alfalfa ash. These facts, coupled with the New Zealand report, led them to use cobalt as a supplement to their basal ration of non-leguminous hay and oats. This entirely alleviated the unthriftiness and resulted in an immediate increase in appetite, gain in weight and stronger healthier lambs than with those continued on the basal diet.

This was followed by a later piece of work to determine types and levels of feeding. (7) The results from adding cobalt to the salt and in giving it in a solution as a drench were the same, as well as the

two levels of 0.73 milligram and 1.15 milligrams of elemental cobalt per ewe per day. This work established the fact that cobalt was needed in only minute quantities in the ration.

The interest in this problem in Michigan was revived about 1939 and 1940 and resulted in a report by Michigan State College in 1941 (8) on observed cobalt deficiencies in some Michigan dairy cattle. The symptoms reported were similar to those usually reported for ketosis and phosphorus deficiencies. A urine check for ketones and a plasma check for inorganic phosphorus eliminated these possibilities. Following the results of the Australian workers (9) which showed beneficial effects with 1 milligram per day per sheep, it was decided to use 13 milligrams of Co Cl_2 per day per cow. The visible results were almost immediate in increased appetite and milk production. However, hemoglobin regeneration was slow and in some cases even showed a decline for awhile after starting cobalt therapy. This is in line with the Wisconsin work with sheep. (10) The analysis of the hays of the afflicted farms in Michigan showed only one-third to one-half as much cobalt as those from non-afflicted farms. Similar conditions had been reported in New Hampshire (11) and Scotland. (12)

Since the availability of radio active cobalt for tracer work, considerable interest has been evidenced in excretion and tissue distribution. Much of this work has been reported by the Florida and Michigan groups. (13, 14) They found that cobalt solutions injected into the blood stream appeared in large quantities in the urine while that given orally was largely eliminated in the feces. In the latter case large concentrations were found in the small intestine and intestinal

lymph glands suggesting a possible absorption route. They seemed inclined to follow the postulation of McCance and Widdowson (15) that cobalt effects the microorganisms of the host rather than having a direct action on the host in light of the latter's work showing that cobalt injections with sheep were not curative. This postulation was extended by Thompson and Ellis (16) to the effect that the microorganisms effected were concerned with the synthesis of the B vitamins due to the fact that there was a great deal of similarity between the cobalt deficiency and experimental produced B vitamin deficiency symptoms.

All of the work thus far reported has concerned itself with definitely known cobalt deficiencies. The feeding levels to cure animals that showed the visible symptoms of cobalt deficiency had been established. (7) The excretion studies (4, 14) had shown that the greatest portion of the orally administered cobalt was excreted in less than 72 hours, but the organ studies (3) showed some storage especially in the liver. This storage level would not be sufficient to last for an extended time, however, on the basis of the lowest requirements of 0.73 milligrams per day per ewe to effect a cure as worked out in the Canadian work. (7)

There have been many cases in Michigan of growing and fattening lambs that had below average gains and appeared unthrifty, and yet showed no other visible symptoms of disease or deficiency. As a result, work was undertaken at this station to determine if there might be a so-called " twilight zone " where there were no pronounced effects of cobalt deficiency but where the use of cobalt therapy would give beneficial results.

OBJECTIVES

The work was divided into two phases with the specific objectives listed below.

Phase one

Effect of cobalt supplement with fattening lambs
as measured by:

1. Rate of gain
2. Feed intake
3. Efficiency of feed utilization

Phase two

Effect of cobalt supplement with ewes and growing
lambs.

1. Possibility of increasing the cobalt
content of ewes milk
2. Effect of such an increase on lamb growth
3. Effect on the hemoglobin level in the
lambs blood

Other problems related to these objectives were studied
as they presented themselves

EXPERIMENTAL PROCEDURE

The experimental procedure consisted of using ten late
lambs from the college flock and two lambs from an outside flock.
They were paired as to breed, condition, sex, and weight as closely
as possible. The lambs were placed in individual pens, with those
to be fed a cobalt supplement placed to the east of the feed way,
and the control group to the west, to reduce the chances of any possible

errors in feeding. The ration used consisted of a mixture of 45% ground corn and 55% ground clover hay, which on analysis showed 0.12ppm of cobalt, 4.11% ash, 13.10% crude fiber, 3.36% ether extract, 11.75% crude protein, and 56.12% nitrogen free extract.

After placing these lambs in individual pens, they were given a light feed which was slowly increased as the lambs acclimated themselves to the individual pens and the change from whole to ground feed. The latter was used to enable a thorough mixing of the grain and hay and prevent any selection of feed. Fecal examinations taken during this period indicated that three lambs had a high degree of parasitic infestation, so all twelve were wormed just prior to starting the experiment. After fourteen days of gradually increasing the feed, it appeared that the lambs were on full feed.

The rations used for the lambs were based on Brody's formula for basal metabolic requirements in animals which is calories (or amount of feed) per 24 hours = a constant (70.5) times the body weight in kilograms raised to a power (0.73). (17) In this experiment we used the body weight in pounds raised to the 0.7 power based on Brody's statement, "While we employ the reference base $W^{0.73}$..., yet because of variations, we are inclined to drop the second decimal (which gives the impression of greater constancy or precision than is justified by the variability of the data) and suggest that $W^{0.7}$ be adopted for the reference base for basal metabolism." The lightest eating lamb within a pair was the controlling factor in determining the constant, which was equal to feed eaten per day. The daily ration for the pair mate was body wt. in pounds 0.7

found by using this constant in the formula times the body weight in pounds ^{0.7}. The previous week's feed consumption was used as a guide and the amount was increased as fast as the lambs would take it.

The lambs were fed twice daily at 6:30 A.M. and 4:30 P.M. and records kept of their feed consumption. The feed not consumed was not weighed back. If an animal did not clean up the feed from the previous feeding, then in the subsequent feeding the ration was reduced.

The cobalt was fed at the rate of one milligram of elemental cobalt per day as a solution of Co Cl_2 sprinkled on the afternoon feed. The solution was made up so that there would be one milligram of elemental cobalt per cc of solution.

Weights on the lambs were taken each Monday at 2:30 P.M. to reduce the error from shrink and fill to a minimum.

In an effort to see if the cobalt was having any effect on the rumen flora, rumen samples were taken weekly starting January 20, 1948, until the end of the experiment. On January 20 the lambs were fed as usual at 7:00 A.M. The feed was removed at 10:00 A.M. from pairs Nos. 1, 2 and 3 and the rumen samples taken at 2:00 P.M. This was repeated on pairs Nos. 4, 5 and 6 on January 27. On February 3 the technique was varied so that a sample was taken at 8:30 A.M., $1\frac{1}{2}$ hours after feeding, and again at 2:00 P.M. after the feed was removed at 10:00 A.M. on the first three pairs. This was repeated on the second three pairs February 10. On February 17 this latter technique was used on all six pairs. The first pair of lambs were not slaughtered, but were fistulated for further rumen work.

The remaining ten lambs were slaughtered. They were given a complete post-mortem check for any abnormalities or pathological conditions. None were found except for lamb 3 east that showed a few lung worms and also numerous small greenish colored abscesses. These often contained the lung worm Muellerius Canillaris.

Two lambs failed to respond to the conditions of the experiment. Lambs 4 east and 5 west refused to eat the amount of feed consumed by their pair mates. 4 east was a Southdown ewe lamb from the college flock receiving cobalt, while 5 west was a grade Shropshire from an outside flock used as a control. The 4 east lamb was eating just about enough for maintenance until the last four weeks of the experiment. 5 west was eating enough to put on some gains, but they were low.

Data for the individual lambs are given in the appendix including 4 east and 5 west. For the above reasons 4 east and 5 west are not included in the summary data. Their pair mates, 4 west and 5 east, consumed feed at a comparable level to the other four pair and showed similar gain and are included in the summary data.

DISCUSSION OF RESULTS

Table I is a summary in terms of averages per lamb. The average weekly gain of the cobalt lambs was 2.8 pounds as compared to 2.7 pounds for the controls. To make these gains the cobalt lambs required 17.6 pounds of feed and the controls 18.5 pounds of feed. These combined differences showed the cobalt lambs to be the more efficient. They required 0.7 less pound of feed for a pound of gain having an average feed intake of 6.2 pounds of feed per pound of gain as compared to 6.9

TABLE I

Average Data per Lamb

	Cobalt	Controls
Initial Weight per Lamb (Pounds)	44.9	51.7
Final Weight per Lamb (Pounds)	84.7	89.4
Average Gain per Lamb	39.8	37.7
Average Weekly Gain per Lamb	2.8	2.7
Average Feed Consumed per Lamb	246.8	258.6
Average Feed per Lamb per Week	17.6	18.5
Average Feed per Pound of Gain per Lamb	6.2	6.9

TABLE II

Data by Periods for 5 Pair of Lambs

Period	Pair No.	Gain		Pounds of Feed		Pounds of Feed per Pound of Gain	
		*E	*W	E	W	E	W
11/11 - 12/16 35 days	1	15.0	15.0	84.0	84.0	5.6	5.6
	2	14.5	13.5	91.8	103.9	6.3	7.1
	3	10.0	7.0	75.0	62.5	7.5	8.9
	4	13.0	12.0	64.2	84.0	4.9	7.0
	6	9.5	10.0	68.8	64.9	7.2	6.5
Total*		62.0	57.5	383.8	399.3	6.2	6.9
12/16 - 1/20 35 days	1	15.0	11.5	97.1	94.2	6.5	8.2
	2	13.5	19.0	77.6	130.4	5.7	6.9
	3	12.5	14.0	80.7	89.3	6.4	6.4
	4	16.0	11.5	77.2	90.0	4.9	7.9
	6	12.0	16.5	78.1	85.0	6.5	5.2
Total*		69.0	72.5	410.7	489.8	6.0	6.8
1/20 - 2/17 28 days	1	15.5	14.5	84.7	84.7	5.5	5.9
	2	16.5	18.0	120.5	120.6	7.6	7.0
	3	11.5	7.0	75.8	73.2	6.6	10.5
	4	14.0	10.5	77.2	83.3	5.5	7.3
	6	10.0	8.0	71.7	66.6	7.2	8.3
Total*		67.5	58.0	429.9	428.4	6.4	7.4

* E(ast) lambs received cobalt W(est) lambs served as controls.

** Pair 5 not included in the totals. See page 9

Graph I

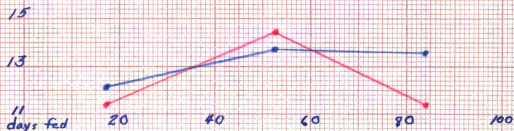
Pounds of
Feed

Average Feed Intake per Lamb per Period



Pound of
Gain

Average Gain per Lamb per Period



Pounds of
Feed per Pound
of Gain

Average Pounds of Feed per Pound
of Gain per Period

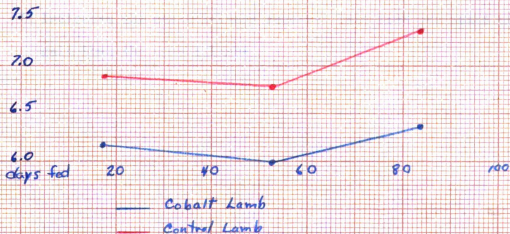


TABLE III

Weekly Data For 5 Pair of Lambs

Week Ending	Feed Intake		Gain		Pounds of Feed		Difference in Favor of Cobalt
	*E	*W	E	W	E	W	
11/18	68.1	76.7	14.5	11.0	4.7	7.0	2.3
11/25	79.0	74.7	13.5	11.5	5.9	6.5	0.6
12/2	73.6	78.1	11.5	8.0	6.4	9.8	3.4
12/9	80.6	84.4	12.0	17.0	6.7	5.0	-1.7**
12/16	82.5	85.3	9.5	10.0	8.7	8.5	-0.2**
12/23	83.2	90.4	15.0	15.5	5.5	5.8	0.3
12/30	84.5	92.9	19.0	17.0	4.4	5.5	1.1
1/6	97.3	103.6	6.5	11.5	15.0	9.0	-6.0**
1/13	90.8	101.3	17.0	16.5	5.3	6.1	0.8
1/20	91.9	101.7	12.0	12.0	7.7	8.5	0.8
1/27	102.7	109.6	17.5	17.0	5.9	6.4	0.5
2/3	103.8	111.6	16.0	15.5	6.5	7.2	0.7
2/10	101.5	109.1	14.0	13.0	7.3	8.4	1.1
2/17	94.7	73.5	20.0	13.0	4.7	5.7	1.0

* E(ast) lambs received cobalt W(est) lambs served as controls.

** Indicates the control-lambs required less feed per pound of gain than the cobalt lambs

TABLE IV

Cumulative Data For 5 Pairs of Lambs

Week Ending	Total Feed Consumption To Date		Total Gain To Date		Pounds of Feed per Pound of Gain		Difference in Favor of Cobalt
	*E	*W	E	W	E	W	
11/18	68.1	76.7	14.5	11.0	4.7	7.0	2.3
11/25	147.1	151.4	28.0	22.5	5.3	6.7	1.4
12/2	220.7	229.5	39.5	30.5	5.6	7.5	1.9
12/9	301.3	313.9	51.5	47.5	5.9	6.6	0.7
12/16	383.8	399.2	62.0	57.5	6.3	6.9	0.6
12/23	467.0	489.6	76.0	73.0	6.1	6.7	0.6
12/30	551.5	582.5	95.0	90.0	5.8	6.5	0.7
1/6	648.8	686.1	101.5	101.5	6.4	6.8	0.4
1/13	739.6	787.4	118.5	118.0	6.3	6.7	0.4
1/20	831.5	889.1	130.5	130.0	6.4	6.8	0.4
1/27	934.2	998.7	148.0	147.0	6.3	6.8	0.5
2/3	1038.0	1110.3	164.0	162.5	6.3	6.8	0.5
2/10	1139.5	1219.4	178.0	175.5	6.4	6.9	0.5
2/17	1234.2	1292.9	198.0	188.5	6.2	6.9	0.7

* E(ast) lambs received cobalt W(est) lambs served as controls

pounds of feed per pound of gain for the controls.

Table II shows the data for five pair of lambs broken down into three periods. The first two periods are thirty-five days long and the third is twenty-eight days long. In the first two periods the gains were nearly the same, while in the third the cobalt lambs gained a total of 9.5 pounds more than the controls. This considerable gain in the third period may be an indication that the body supplies of cobalt were nearly exhausted and that the long time effect of depletion is beginning to show.

The wide fluctuation in gains and in pounds of feed per pound of gain are shown in Table III. These tend to be consistent as between the two groups with both of them showing the fluctuations in any given week. In each case where there were low gains in one week the preceding or succeeding week there were heavy gains. This variation may be due to shrink, fill or water intake.

During seven of the fourteen weeks in the experiment the total gains of the five cobalt and five control lambs were the same or less than a pound apart. During five other weeks the cobalt lambs out-gained the controls while the latter made greater gains in two weeks as seen in Table II. It is seen in Table IV that there was an average difference of 1.9 pounds of gain per lamb or a total of 9.5 pounds for the five lambs during the entire experiment. This difference was accumulated in the last four weeks of the experiment.

It is entirely possible that during the first two periods the control lambs had adequate stores of the mineral for good gains, but that by the third period these stores were depleted to an extent to

effect the rate of gain.

The average weekly feed intake of the cobalt lambs was 0.9 pounds less than for the controls as shown in Table I. In Table II, the cobalt lambs show a lower level of feed intake in the first two periods and a nearly identical level in the third period. It was noted during the experiment that the control lambs appeared restless and were often observed chewing on their feed and water pails.

A study of Table III shows a gradual increase in the feed intake of both groups during the entire experiment. Table IV shows that the control lambs consumed 58.7 more pounds of feed than did those receiving a cobalt supplement. All of this increase in feed consumption was in the first two periods.

In the third period when the feed intake of the controls dropped to the level of the cobalt lambs a decrease in gain of the controls resulted. It is possible that the control lambs were starting to show the first signs of loss of appetite in the third period. This possibility is given support when one studies the number of times that it was necessary to reduce the feed to the lambs. The five cobalt lambs refused a total of 31.5 full feeds and the controls 32 full feeds over the fourteen weeks period. In the last four weeks, or the third period, the cobalt lambs refused a total of 7 feeds compared to 10.5 for the controls. The over-all picture shows little difference in appetite, which is not in agreement with work with steers at this station. (18) Broken down by periods, however, it too gives support to the possibility that the control lambs had

reduced their body reserves of cobalt to such a level that the first symptom of cobalt deficiency, loss of appetite, was starting to show.

The combination of slightly larger gains and lower feed intake combine to make the cobalt lambs more efficient. This shows up clearly in Table I. There were required 6.2 pounds of feed per pound of gain for the cobalt lambs as compared with 6.9 pounds for the controls. The cobalt lambs put on each pound of gain with 89.9% as much feed as was required by the controls.

Table II shows that the cobalt lambs were more efficient in each of the three periods. In the first period they required 0.7 less pound of feed per pound of gain, 0.8 pound less in the second period, and 1.0 pound less in the third period. This too supports the postulation that the cobalt reserves of the controls were nearing depletion.

Table III shows wide variation from week to week in the pounds of feed required per pound of gain. Much of this variation is probably due to differences in shrink and fill. In only three weeks did the controls prove to be more efficient than the cobalt lambs. For the week ending December 9 the controls required only five pounds of feed per pound of gain. However, in the preceding week the controls required 9.8 pounds of feed to make a pound of gain. During the week ending January 6, there was a prolonged period of sub-zero weather; and also if we go to the preceding week, we note that both groups showed a high degree of efficiency.

After the week of January 6 the cobalt lambs made consistently more efficient gains than the controls until the close of the experiment. At time of slaughter the livers were removed and examined for cobalt. The cobalt content of the livers on analysis tends to confirm the postulation that the control lambs had severely depleted their body reserves by the end of the experiment. The control lambs had a range of 0.01 to 0.05 ppm of cobalt compared to a range of 0.08 to 0.17 ppm in the cobalt group, or an average of $33 \frac{1}{3}\%$ as much cobalt in the liver as had the cobalt lambs.

During the experiment the rumen samples obtained by the technique of using a tube and stomach pump at an isolated time, as indicated earlier, did not produce consistent results. Experience with cattle indicates that such factors as differences in feed intake, water consumption, and saliva dilution cause such great variations in the bacterial counts as to render them of little value. Noting this development in the lambs it was decided to save the pair 1 lambs for further bacteriological studies.

Although earlier fistulas with sheep had not proven satisfactory, new surgical techniques gave promise of success. The lambs of pair 1 were fistulated, held off feed for twenty-four hours, then started at one-third of a full feed with the east lamb receiving cobalt. This was gradually increased over a three week period until they were again back to a full feed. They were held at this level for a week and then two series of half hour interval samples were taken on March 24 and 26. These samples were taken by removing the plug from the fistula, and inserting a pipette

up to a marked point to get the sample from the same area each time. These samples were taken at half-hour intervals from 8:00 A.M. to 4:00 P.M. The lambs had access to feed immediately after the 8:00 A.M. sample and until 10:00 A.M. when it was removed. This may account for some of the irregularities noted in the forepart of the curves in Graphs II and III. The lambs had access to water during the entire sampling period. This probably caused a certain amount of dilution of the rumen contents explaining why some of the points lie well off the curve.

These curves show some differences between the two lambs. the cobalt lamb had a higher total and protozoa count, and lower iodophil and pseudo-yeast count. However, the differences were very small in most cases and the significance is not clear.

There was a consistent dilution effect during the time the lambs had access to feed as shown by the drop in total count in Graphs II and III. Then there was considerable rise in the total count from 10:30 until about 12:30 when the fermentation rate reached a maximum as indicated by the total count. After 12:30 the total count decreased until by 3:00 P.M. it was at or below the pre-feeding level.

Before any other conclusions can be drawn it is necessary to secure additional data in order to establish "regular" curves. It is felt that fistulated lambs can be used for bacteriological work over an extended period with the fistula techniques now used. These two lambs are still living, six months after being fistulated, and rumen samples have been secured on a variety of other feeds.

Counts in
Millions per cc

Graph II Bacteriological Counts March 24

30

20

10

0

Protozoa

800

600

400

200

Pseudo-yeast

30

20

10

0

Iodophils

Counts in
Billion per cc

40

30

20

10

0

Total Count

— Cobalt Lamb

— Control Lamb

Time 8:00 10:00 12:00 2:00 4:00

Counts in
Millions per cc

Graph III
Bacteriological Counts
March 26

30

20

10

0

Protozoa

800

600

400

200

Pseudo-yeast

30

20

10

0

Iodophils

Counts in
Billions per cc

40

30

20

10

0

Fatal Count

— Cobalt Lambs
— Control Lambs

Time 8:00 10:00 12:00 2:00 4:00

These include rations of regular long-cut hay, a mixture high in hay and low in grain, and grass.

EWES AND NURSING LAMBS

PROCEDURE

The second phase of the work, that with ewes and nursing lambs, was undertaken on the basis of Archibalds report (19) that oral administration of cobalt would increase the cobalt content of cows milk. Among nursing lambs there are usually those who fail to thrive and gain properly. On this basis it was decided to see if increased quantities of cobalt introduced through the milk would effect the rate of gain of the lamb.

The Hampshire ewe flock of the college was divided into two groups prior to lambing on the basis of their previous lambing records in an attempt to secure, as nearly as possible, the same number of lambs in each group. The cobalt was administered as a solution of CoCl_2 sprinkled on the grain at the rate of 100 milligrams daily per ewe. This level was used to insure, if possible, obtaining an increased cobalt content of the ewes milk.

The lambs were weighed every two weeks until put on pasture and then every three weeks until the first 120 day weights. They were bled each weigh date and determinations of the blood hemoglobin made in line with work showing some relationship between cobalt and hemoglobin. (8, 10)

At each weigh date composite samples of each group of ewes milk were obtained by taking 40 c.c. samples from each ewe and mixing. In this manner a sufficient quantity of milk for analysis

could be obtained.

DISCUSSION

The milk was analyzed for cobalt, copper and iron and the data presented in Table V. The ewes receiving cobalt had consistently higher quantities of cobalt in their milk. This difference ranged from four to fifteen times as much. The drop in the cobalt content of the milk was marked following the stopping of the cobalt supplement and the placing of the ewes on pasture on May 5. On May 11, six days after being placed on pasture, the cobalt ewes milk showed a drop from 0.21 to 0.04 ppm of cobalt, and the control ewes dropped from 0.05 to 0.01 ppm of cobalt. After another six days the cobalt content of the milk was 0.01 ppm in both groups. This shows the very rapid decline in the cobalt content of ewes milk once the cobalt is removed and the ewes placed on pasture.

There were few differences in the copper and iron content of the milk of the two groups with the one exception that the copper content of the cobalt ewes milk showed a marked drop after being placed on pasture.

The cobalt ewes gave birth to six pairs of twins, five of which were raised to 120 day weights. The control ewes gave birth to four pair of twins, one of which was raised to 120 day weight.

After the death of one lamb in a pair of twins the remaining lamb was placed in the single group. The cobalt ewes had three singles plus one remaining twin to give the four singles shown in Table VI. The control ewes gave birth to six singles, one of which died shortly after birth. The three remaining lambs from the twins

TABLE V

Analysis of Ewes Milk

Date of Sample	ppm Cobalt		ppm Copper		ppm Iron	
	Cobalt	Control	Cobalt	Control	Cobalt	Control
*3/15	0.30	0.02	3.0	3.0	3.0	3.0
4/5	0.10	0.02	2.0	2.0	2.0	3.0
4/19	0.20	0.02	2.0	2.0	1.0	2.0
5/3	0.21	0.05	2.0	2.0	2.0	3.0
**5/11	0.04	0.01	0.4	1.0	6.0	7.0
5/17	0.01	0.01	0.5	1.0	2.0	2.0

* Ewes received first cobalt March 8

** Ewes placed on pasture May 5 and given no further cobalt supplement

TABLE VI

Nursing Lamb Weights

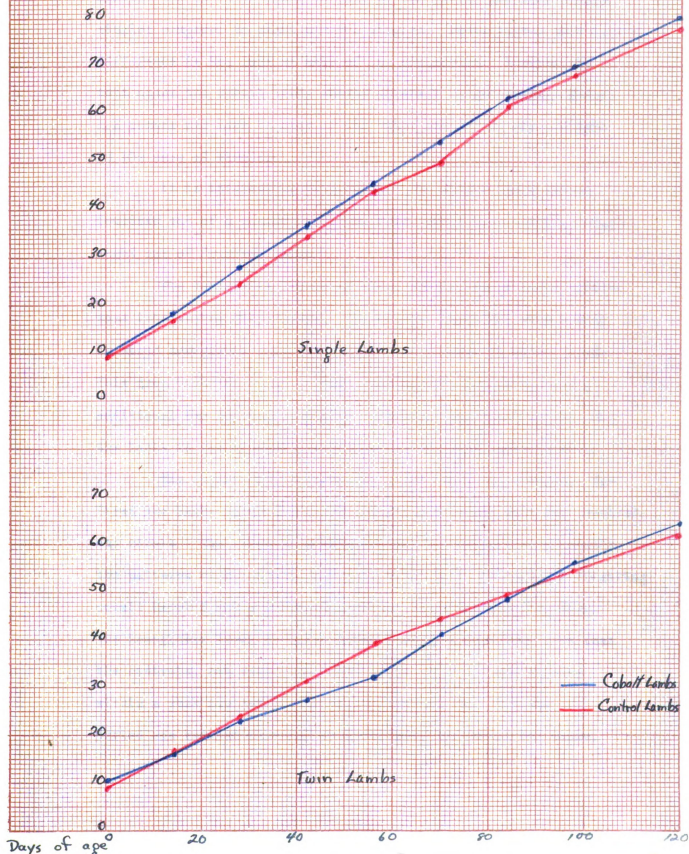
Twin Lambs- Cobalt

Lamb Number	Age in Days Birth	14	28	42	56	70	84	98	120
13	12.5	21.0	32.0	40.0	46.0	55.0	64.5	73.0	85.0
14	11.5	18.0	34.5	31.0	38.0	45.0	54.0	62.5	73.0
18	9.0	13.0	18.0	18.0	23.0	28.0	32.5	37.0	43.5
19	9.5	14.0	20.0	22.0	24.0	32.5	38.5	43.0	50.0
20	8.5	13.5	18.5	17.0	23.5	33.0	40.0	46.0	56.0
21	8.0	15.0	21.0	24.0	28.0	37.5	44.0	48.5	56.0
24	9.5	19.0	26.0	31.0	40.5	51.0	59.0	66.0	76.0
25	10.0	17.0	24.0	28.0	36.0	47.5	55.0	61.5	71.0
35	10.0	14.0	22.0	29.0	(Late Lambs)				
36	10.5	15.0	22.5	32.0					
Average Weight	9.9	16.0	22.9	27.2	32.4	41.2	48.5	54.7	63.7
Twin Lambs - Control									
27	9.5	17.0	24.0	30.5	37.5	43.0	48.0	53.5	62.0
28	8.5	17.0	24.5	32.0	40.0	48.0	52.0	56.5	63.0
Average Weight	8.0	17.0	24.3	31.2	38.8	45.5	50.0	55.0	62.5
Single Lambs - Cobalt									
7	11.0	18.0	29.5	40.5	49.5	59.5	70.0	79.0	86.0
*8	8.0	17.0	27.0	34.0	43.0	51.0	58.5	67.0	78.0
16	9.0	14.0	20.5	28.0	32.0	40.0	50.5	54.5	56.0
17	12.0	24.0	36.0	46.5	55.0	63.5	72.0	80.5	99.0
Average Weight	10.0	18.3	28.3	37.3	44.9	53.5	62.8	70.3	79.8
Single Lambs - Control									
1	7.0	10.0	14.5	22.0	28.0	33.0	(Lamb died)		
4	11.0	16.0	28.0	49.0	58.0	66.5	78.0	86.5	96.0
*5	6.0	18.5	29.5	38.0	45.0	53.5	63.0	70.0	84.0
15	12.5	20.0	25.5	29.0	35.0	45.0	54.0	62.0	74.0
23	7.0	14.0	20.0	26.0	36.0	45.5	53.0	61.5	72.0
26	9.0	19.0	26.0	35.5	46.0	54.0	57.5	60.0	63.0
*29	10.5	20.0	31.0	42.0	50.0	58.0	64.0	70.0	80.0
33	9.0	18.0	26.0	39.0	53.0	(Lamb died)			
Average Weight	9.0	17.0	25.1	35.1	43.9	50.8	61.6	68.3	78.1

*Remaining lambs from a pair of lambs

Graph IV

Growth Curves on Nursing Lambs

Weight in
Pounds

were added to give the total of eight singles.

Growth curves in Graph IV are plotted for ten cobalt lambs against two control lambs in case of the twins, and four cobalt singles compared to eight control singles. These curves show little difference in the rate of gain of the two groups. However, in both cases the cobalt lambs showed slightly larger average gains; 1.2 pounds per lamb in case of the twins and 1.7 pounds per lamb in the case of singles.

It is interesting to note that the cobalt lambs raised fourteen out of a possible fifteen lambs while the controls raised eight out of fourteen lambs.

The hemoglobin levels of these two groups of lambs present some interesting differences. The control lambs all show a drop in blood hemoglobin from the birth level of from 16.6% to 37.5%. This drop took two to four weeks to reach its low point, and an additional two to three weeks to recover to the birth level. All the lambs in the control group exhibited this drop and recovery.

The cobalt group presented a much different picture. The first two lambs in this group were born before the ewes had received any cobalt. The curve of hemoglobin levels followed very closely the patterns of the control group. The cobalt ewes started receiving cobalt March 8 and a different pattern was noted within a week. The hemoglobin level of these lambs dropped appreciably less than the controls, not exceeding 8.5%. This low point was reached within a week instead of two to four weeks. The recovery period was reduced from two to three weeks to one to two weeks.

In the case of the lambs born after the ewes had been receiving cobalt for three weeks, the lambs did not reach the low levels of the control lambs. It is unfortunate that most of the initial samples of blood on this latter group were not secured until they were eight to twelve days old. There may have been a slight initial drop that does not show. However, these first samples showed hemoglobin levels of 10 grams or better per 100 grams of blood which corresponds favorably with the levels taken within 24 to 48 hours after birth, in case of the other group of lambs.

In light of the Florida work with radioactive cobalt (14) it seems possible that at the high levels fed there was the possibility that some cobalt was passed across the placenta to the fetus. In light of the Wisconsin work (10) showing anemia to be one of the results of cobalt deficiency it seems possible that the cobalt passed across the placenta in some way affected the hematopoietic centers to stimulate the early production of red blood cells to prevent the early anemia of lambs.

SUMMARY AND CONCLUSIONS

On a ration of 45% corn and 55% hay, there was little difference in the rate of gain between lambs receiving one milligram of elemental cobalt daily and their paired controls. The cobalt lambs had a lower feed intake which resulted in a higher degree of efficiency of feed utilization. The differences in total gain in favor of the cobalt lambs were all accumulated in the last four weeks of the experiment. In this latter period the feed intake of the controls dropped appreciably. The differences in the pounds

of feed required per pound of gain increases throughout the experiment. During the early stages, the control lambs consumed equal or greater quantities of feed than the cobalt lambs. In the latter stages the feed intake of the controls declined. This lends support to the idea that the deficiency does not appear until most of the body reserves of cobalt are utilized. In short term feeding of less than ten weeks, one of the functions of cobalt was to increase the efficiency of feed utilization while in longer feeding work it not only aided in efficiency of feed utilization but helped to maintain the feed intake.

The rumen work showed rather consistent curves in terms of total count of the microorganisms. The peak number of organisms occur about two and one half hours after the feed was removed and it then takes another two and one half hours to return to the pre-feeding level. The variation in the protozoa, iodophil, and pseudo-yeast counts was not consistent and the significance was unknown.

The work with ewes and nursing lambs shows that the cobalt content of the ewes milk was increased from four to fifteen times over that of the controls in a weeks time. The ewe maintained this high cobalt level of the milk as long as she received supplemental cobalt. When the mineral was removed from the ration the cobalt level of the milk dropped to the control level in twelve days. This increase in the cobalt content of the ewes milk did not increase the rate of gain of their nursing lambs.

When the ewes received large quantities of cobalt for at least

thirty days prior to lambing, the early decline in the hemoglobin level of the lambs was materially reduced or even eliminated in some cases. In light of other recent work, it seems that sufficient cobalt can be passed across the placenta to cause a stimulation of the hematopoietic centers to prevent the early anemia of lambs.

The results of this experiment would indicate the need for further work to determine whether a control group of lambs, once they show signs of losing appetite, and a decreasing degree of efficiency, can have their appetites stimulated and their efficiency increased by adding cobalt to the ration. Further work with high cobalt levels to ewes for at least thirty days prior to lambing is indicated in order to study the possible effects on the nursing lamb by preventing early anemia.

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TABLE VII
Weekly Lamb Weights

Pair Number	1	1	2	3	4	5	6
Date	*E	*W	E	W	**5E	**4W	E
11/11	44.5	45.0	57.0	70.5	38.5	54.0	39.0
11/18	48.5	49.5	60.0	71.0	42.0	59.5	40.5
11/25	52.0	52.5	64.5	73.0	42.5	60.0	43.5
12/2	55.0	54.5	66.5	75.0	44.5	62.5	45.0
12/9	57.0	58.0	69.5	80.0	48.5	63.0	47.5
12/16	59.5	60.0	71.5	84.0	51.5	66.0	48.5
12/23	63.0	61.5	74.0	87.5	54.0	67.5	51.5
12/30	67.0	66.0	78.0	92.0	58.0	69.5	54.0
1/6	69.5	67.5	79.5	95.0	61.0	72.5	54.0
1/13	73.5	71.0	83.5	99.5	65.0	76.0	57.5
1/20	74.5	71.5	85.5	103.0	67.5	77.5	60.5
1/27	79.0	76.5	91.5	106.5	71.5	80.0	61.5
2/3	81.0	80.0	92.5	111.0	76.0	82.0	66.0
2/10	85.0	83.0	96.0	116.0	78.0	84.5	69.0
2/17	90.0	86.5	102.0	121.0	81.5	88.0	70.5

*E(est) lambs received cobalt W(est) lambs served as controls

**Pairs 4 and 5 were repaired in these tables as indicated on page 9

TABLE VIII

Pounds of Gain per Week

Pair Number	1	2	3	4	5	6
Date	E	E	E	W	W	E
11/18	4.0	3.0	2.5	3.5	2.5	1.5
11/25	3.5	4.5	2.0	.5	2.5	3.0
12/2	3.0	2.0	3.0	2.0	.5	1.5
12/9	2.0	2.0	1.5	4.0	.5	2.5
12/16	2.5	2.0	1.0	3.0	0.0	1.0
12/23	3.5	2.5	3.5	2.5	-1.5	3.0
12/30	4.0	4.0	4.5	4.0	3.0	2.5
1/6	2.5	1.5	-0.5	3.0	1.5	0.0
1/13	4.0	4.0	1.5	4.0	-0.5	3.5
1/20	1.0	2.0	3.5	2.5	1.0	3.0
1/27	4.5	6.0	2.0	4.0	2.0	3.0
2/3	2.0	1.0	4.0	4.5	1.5	2.5
2/10	4.0	3.5	1.5	2.0	2.5	2.0
2/17	5.0	6.0	4.0	3.5	.5	3.5
					2.5	2.5
						0.0

* E(ast) lambs received cobalt W(est) lambs served as controls

** Pairs 4 and 5 were repaired in these tables as indicated on page 9

TABLE IX
Pounds of Feed Consumed Per Week

Pair	1		2		3		4		5		6	
Date	*E	*W	E	W	E	W	**5E	**4W	**4E	**5W	E	W
11/18	15.4	15.4	16.1	19.5	12.0	11.0	11.9	18.2	5.8	9.6	12.7	12.6
11/25	15.9	15.9	16.7	19.0	12.0	10.9	11.3	16.5	4.1	10.2	13.1	11.9
12/2	16.7	16.7	18.1	20.2	13.0	12.0	11.9	16.8	8.5	11.1	13.9	12.6
12/9	18.2	18.2	20.0	22.0	13.7	14.2	14.0	16.0	10.6	13.0	15.0	14.0
12/16	17.8	17.8	21.0	23.2	14.4	14.4	15.2	16.2	9.2	10.4	14.1	13.9
12/23	18.6	18.6	19.0	24.1	15.2	16.5	15.3	16.4	5.7	10.4	15.1	14.8
12/30	19.0	19.0	20.1	24.5	15.6	16.8	13.9	17.4	13.2	11.5	15.9	15.1
1/6	18.9	17.4	23.2	27.0	17.9	16.8	16.8	19.0	11.4	10.9	13.0	16.8
1/13	20.3	20.3	21.6	27.4	15.0	19.6	16.8	19.0	8.8	12.4	16.7	16.8
1/20	20.3	18.9	20.8	27.4	16.6	19.6	16.8	19.0	10.0	10.3	17.4	16.8
1/27	21.7	21.7	25.5	29.9	19.2	20.8	18.9	20.3	9.0	11.9	17.4	16.8
2/3	21.7	21.7	24.6	31.0	19.3	19.4	19.9	21.7	12.4	12.4	18.4	17.8
2/10	21.7	21.7	21.2	31.3	19.3	17.9	19.9	21.7	14.9	11.9	19.4	16.2
2/17	19.6	19.6	22.2	28.1	18.0	15.0	18.5	19.6	13.1	13.0	16.6	15.8

*E(ast) lambs received cobalt W(est) lambs served as controls.

**Pairs 4 and 5 were repaired in these tables as indicated on page 9.

TABLE X

Total Gain to Date

Pair Number	1	2	3	4	5	6						
Date	*E	*W	E	W	**4E	**4W	**5E	**5W	E	W		
11/18	4.0	4.5	3.0	.5	2.5	-1.5	3.5	5.5	-4.5	2.5	1.5	2.0
11/25	7.5	7.5	7.5	2.5	4.5	2.5	4.0	6.0	-3.5	5.0	4.5	4.0
12/2	10.5	9.5	9.5	4.5	7.5	3.0	6.0	8.5	-3.0	7.5	6.0	5.0
12/9	12.5	13.0	12.5	9.5	9.0	6.0	10.0	9.0	-2.5	7.5	8.5	10.0
12/16	15.0	15.0	14.5	13.5	10.0	7.0	13.0	12.0	-2.5	7.0	9.5	10.0
12/23	18.5	16.5	16.5	17.0	13.5	11.5	15.5	13.5	-4.0	10.5	12.5	14.5
12/30	22.5	21.0	20.5	21.5	18.0	14.5	19.5	15.5	-1.0	11.5	15.0	17.5
1/6	25.0	22.5	22.0	24.5	17.5	15.5	22.5	18.5	.5	13.5	15.0	20.5
1/13	29.0	26.0	26.0	29.0	19.0	17.0	26.5	22.0	0.0	15.5	18.5	24.0
1/20	30.0	26.5	28.0	32.5	22.5	21.0	29.0	23.5	1.0	15.5	21.5	26.5
1/27	34.5	31.5	34.0	36.0	24.5	25.0	33.0	26.0	.5	17.0	22.5	28.5
2/3	36.5	35.0	35.0	40.5	28.5	27.0	37.5	28.0	2.5	19.5	27.0	32.0
2/10	40.5	38.0	38.5	45.5	30.0	27.0	39.5	30.5	6.5	20.0	30.0	34.5
2/17	45.5	41.0	44.5	50.5	34.0	28.0	43.0	34.0	9.0	22.5	31.5	34.5

*E(ast) lambs received cobalt W(est) lambs served as controls.

**Pairs 4 and 5 were repaired in these tables as indicated on page 9.

TABLE XI

Total Feed Consumption to Date

Pair Number	1	2	3	4	5	6						
Date	*E	*W	E	W	**4E	**5W	E	W				
11/18	15.4	15.4	16.1	19.5	12.0	11.0	11.9	18.2	5.8	9.6	12.7	12.6
11/25	31.3	31.3	32.8	38.5	24.0	22.0	23.2	34.7	9.9	19.8	25.8	24.5
12/2	48.0	48.0	50.9	58.7	37.0	33.9	35.1	51.5	18.3	30.9	39.7	37.1
12/9	66.2	66.2	70.8	80.7	50.7	48.1	49.0	67.5	28.9	43.9	54.7	51.1
12/16	84.0	84.0	91.9	103.9	65.1	62.5	64.3	83.7	38.1	54.4	68.8	65.0
12/23	102.6	102.6	110.9	128.0	80.3	79.0	79.6	100.1	43.8	64.8	83.9	79.8
12/30	121.6	121.6	131.0	152.5	95.9	95.8	93.5	117.5	56.9	76.3	99.8	94.9
1/6	140.5	139.0	154.2	179.5	113.8	112.6	110.3	136.5	68.4	87.2	112.8	110.0
1/13	160.8	159.0	175.8	206.9	128.8	132.2	127.1	155.5	77.2	99.6	129.6	126.8
1/20	180.1	178.2	196.6	234.3	145.4	151.8	143.9	174.5	87.2	110.0	146.9	143.6
1/27	202.8	199.9	222.1	246.2	164.6	172.6	162.8	194.8	96.2	121.9	164.3	160.4
2/3	224.5	221.6	246.7	295.2	183.9	192.0	182.7	216.5	108.6	134.3	182.6	178.2
2/10	246.2	243.3	267.9	376.5	203.2	209.0	202.6	238.2	123.4	146.2	202.1	194.4
2/17	264.8	262.9	290.1	354.6	221.2	224.9	221.1	257.8	136.5	159.1	218.7	210.2

*E(ast) lambs received cobalt W(est) lambs served as controls.

**Pairs 4 and 5 were repaired in these tables as indicated on page 9.

TABLE XII

Cumulative Pounds of Feed per Pound of Gain

Pair Number	1		2		3		4		5		6	
Date	**E	*W	E	W	E	W	**5E	**4W	**4E	**5W	E	W
11/18	3.9	3.4	5.4	3.9	4.8	(1)	3.4	3.3	(2)	3.8	8.5	6.3
11/25	4.2	4.2	4.4	15.4	5.3	8.8	5.8	5.8		3.9	5.7	6.1
12/2	4.6	5.1	5.4	13.0	4.9	11.3	5.8	6.1		4.1	6.6	7.4
12/9	5.3	5.1	5.7	8.5	5.6	8.0	4.9	7.5		5.9	6.4	5.1
12/16	5.6	5.6	6.3	7.6	6.5	8.9	4.9	7.0		7.8	7.2	6.5
12/23	5.5	6.2	6.7	7.5	5.9	6.9	5.1	7.4		6.2	6.7	5.5
12/30	5.4	5.8	6.4	7.1	5.3	6.6	4.8	7.6		6.6	6.7	5.4
1/6	5.6	6.2	7.0	7.3	6.5	7.3	4.9	7.4		6.5	7.5	5.4
1/13	5.5	6.1	6.8	7.1	6.8	7.8	4.8	7.1		6.5	7.0	5.3
1/20	6.0	6.7	7.0	7.2	6.4	7.2	5.0	7.4		7.1	6.8	5.4
1/27	5.9	6.3	6.5	7.3	6.7	6.9	4.9	7.5		7.2	7.3	5.6
2/3	6.1	6.3	7.0	7.3	6.5	7.1	4.9	7.8		6.9	6.8	5.6
2/10	6.1	6.4	6.9	7.2	6.8	7.9	5.1	7.8		7.3	6.7	5.6
2/17	5.8	6.3	6.5	7.0	6.5	8.0	5.1	7.6		7.0	6.9	6.1

*E(ast) lambs received cobalt W(est) lambs served as controls.

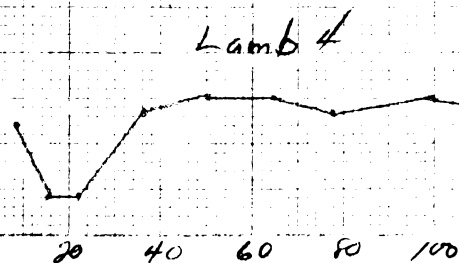
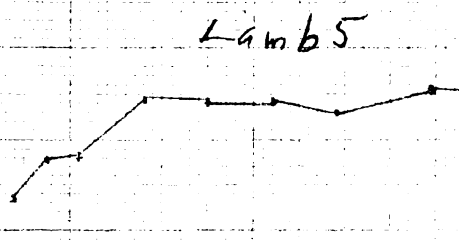
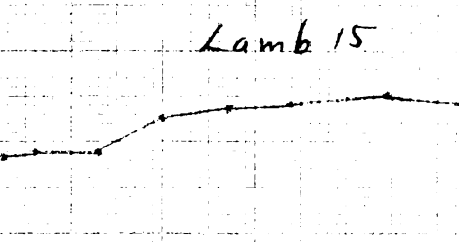
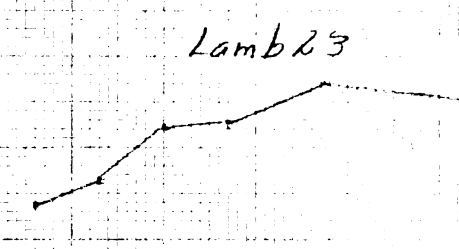
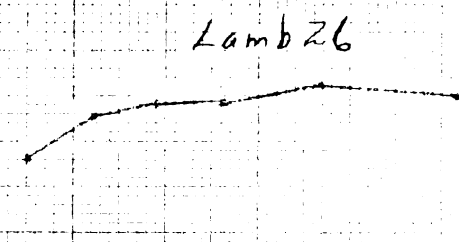
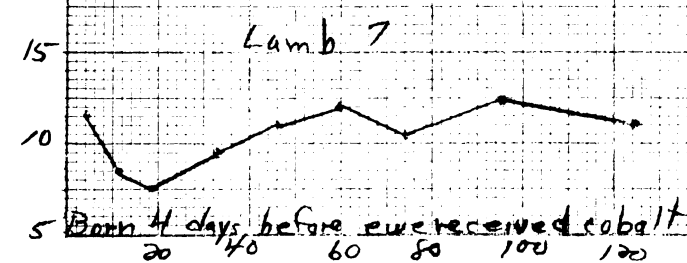
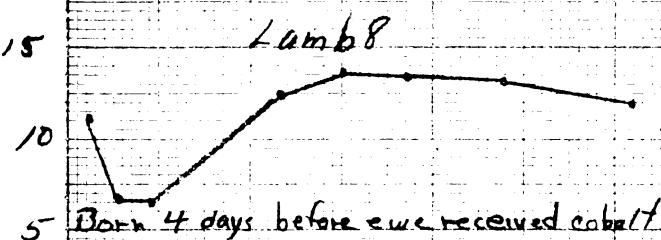
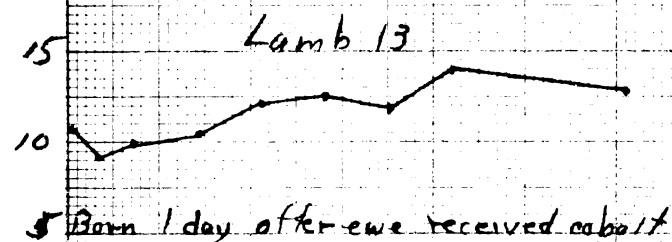
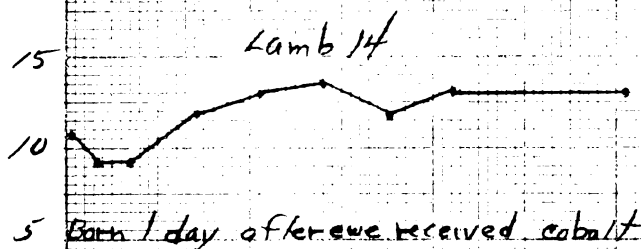
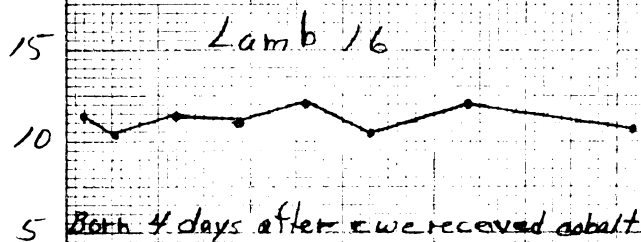
**Pairs 4 and 5 were repaired in these tables as indicated on page 9.

(1) Lamb lost weight the first week.

(2) Lamb did not recover starting weight until 1/6.

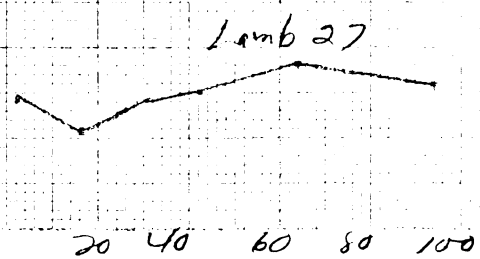
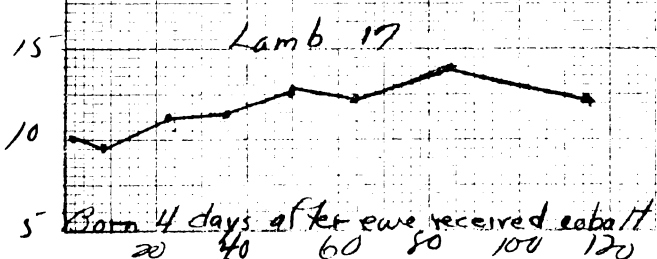
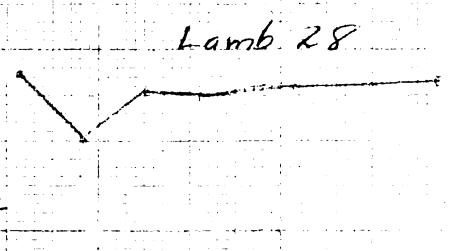
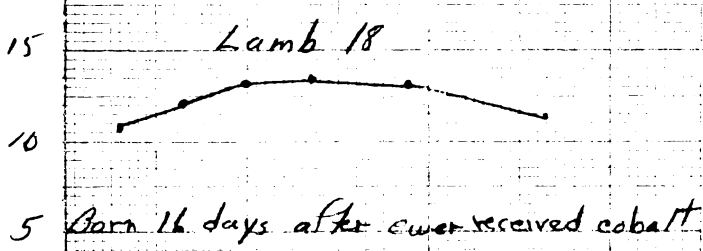
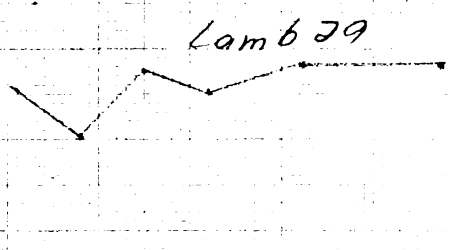
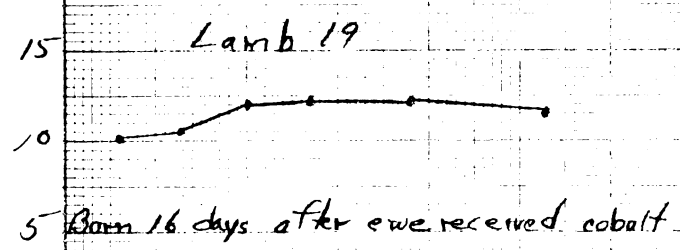
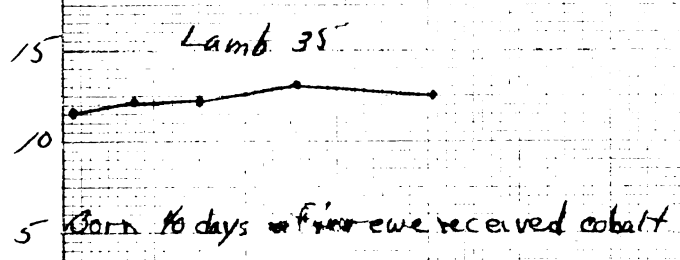
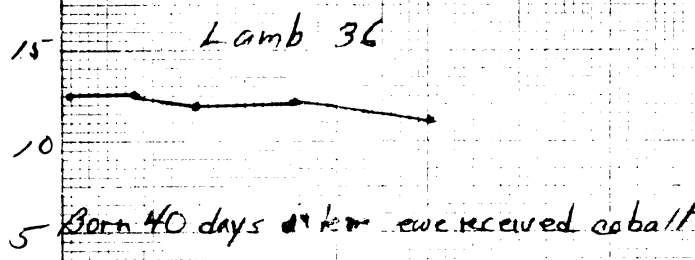
Hemoglobin
in plasma per
100 cc. of blood.

Graph V
Hemoglobin Values for Lambs



Graph IV

Neuroglobin
in plasma per
100 cc of blood



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