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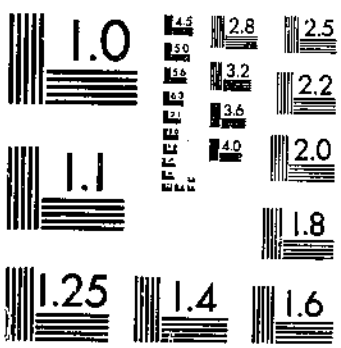

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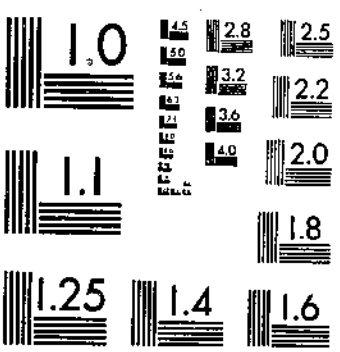

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REARING FOALS AND LAMBS BY THE USE OF COLOSTRUM, BLOOD SERUM, AND SUBSTITUTE MILKS[1]

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INTRODUCTION

Although inherited weaknesses, accidents, and diseases are important factors in early losses among foals and lambs, it appears that a considerable part of these losses is due to malnutrition arising from an insufficient supply of milk, from the death of the dams at parturition or shortly thereafter, or from the unsuitability of the colostrum and milk the dams provide.

The most economical procedure for the production of healthy weanling animals is undoubtedly the breeding of only such females as can deliver and properly nourish healthy offspring. It is usually uneconomical to have to provide for the care and artificial feeding of young animals whose dams are unable to nurture them. However, the attempt to breed such females does not always produce the desired results, and it is sometimes of considerable importance, especially if purebred stock are concerned, that the animal husbandman be able to feed young animals by hand. Since, in this country at least, milk production has played only a small part in the selective breeding of horses and of most types of sheep, there is seldom in either of these species a surplus of milk available for feeding an

[1] Submitted for publication May 10, 1938.
[2] J. A. Gamble left the Department May 31, 1935.

orphan. Hence, the hand-fed young must be fed on some substitute for the milk of its own kind.

The difficulty in raising orphaned foals on milk substitutes is apparently greater than that encountered with the young of other farm animals. How much of this difficulty may be attributed to an absence of the benefits of colostrum, how much to the unsuitability of the substituted milk, and how much to faults in the handling and management of the foal are as yet unsolved problems. Information in regard to suitable substitutes for homologous colostrum and milk for use with hand-fed foals probably promises more in the way of economic returns than with the young of other farm animals, since a young foal frequently represents a large investment in stud fee alone.

When a young animal is suckled by its dam it normally receives two rather distinctive products of mammary secretion, the first being colostrum from which there is a rapid transition to milk. After the first few days following parturition, the milk does not change radically during the remainder of the suckling period. Whether the colostrum is essential to the health of the young of the species and if so, what substance may perform the same functions, are questions which demand consideration in a program of hand-feeding of young animals from birth. Hence the studies reported in this bulletin included observations, (1) on the necessity for colostrum or a suitable substitute in rearing healthy animals (2) on the use of substitutes for homologous colostrum and (3) on the use of substitutes for homologous milk.

REVIEW OF LITERATURE

FUNCTIONS OF COLOSTRUM

The first product of the mammary gland after parturition differs markedly from the normal milk of the mammal in chemical composition and in biological properties. Perhaps the most significant difference in composition is in the quantity of globulins, which occur in high concentration in the colostrum and only in relatively small quantities in the milk. The concentration of total protein in colostrum is sometimes seven or eight times that in milk of the same animal, and the larger portion of this increased protein in the colostrum consists of globulins. It has been shown by Crowther and Raistrick (*6*)[3], Wells and Osborne (*36*), and Woodman (*37*) that the globulins in colostrum are identical in composition not only with those in milk but also with those in the blood serum from the same species. It has also been shown that the colostrum of the goat, sheep, cow, and horse may be richer in various types of antibodies that are closely associated with serum globulins than the blood serum of the same animals (*1*, *10*, *22*, *23*). Both globulin concentration and antibody concentration of colostrum diminish rapidly after the first few hours following parturition. It appears, therefore, that the colostrum globulins are probably serum globulins with their associated antibodies that either have been taken up by the glandular epithelium and excreted unchanged or else appear in the mammary secretion as the result of a leakage from the capillaries.

[3] Italic numbers in parentheses refer to Literature Cited, p. 32.

The particular benefits of colostrum to the newborn animal have been attributed by some observers—Bauer (*2*), Birk (*3*), and Hohlfeld (*13*)—to the high concentration of nutrients, namely, proteins, in a form most easily used by an organism in which the digestive functions have not yet become well developed. The extraordinarily high metabolic rate during the period immediately after birth, together with the known absence of or deficiency in digestive enzymes in the newborn animal, indicates that this possible function of colostrum should not be ignored.

Attention has been directed more recently by Dann (*7*) to the part played by colostrum in providing the newborn calf with vitamin A. Dann found colostrum from cows to be from 10 to 100 times richer in vitamin A than milk from the same animals. This concentration of the vitamin in the colostrum of the cow seems especially significant in view of the low concentration of the vitamin in the tissues of the newborn calf (*11*).

The function of colostrum most thoroughly investigated is the part that it plays in the passive immunization of the young. Since the classical researches of Ehrlich (*9*) on mice, in which he demonstrated the transfer of certain phytotoxins from dam to young by way of the milk, many other studies have been made on the transfer of immunity through milk and colostrum. Interpretation of results of these studies was confused until it was shown that in some species of animals there was transfer of passive immunity in utero, whereas in others there was no transfer, through the placenta, of the immune bodies investigated.

Famulener (*10*) was among the first to emphasize the peculiar value of colostrum in the immunization of the young. He immunized pregnant goats with sheep erythrocytes and demonstrated the absence of hemolysins in the serum of kids born of these immunized dams and the absorption by the kids during the first few days after birth of hemolysins from the colostrum. Reymann (*37*) made similar observations in regard to the transfer of agglutinins in goats.

In 1922 Smith and Little (*31*) published the first of a series of investigations that definitely established the importance of colostrum to the newborn calf. They showed that 9 of 12 calves that were deprived of colostrum succumbed to *Bacillus coli* septicemia, whereas all the control animals which received colostrum lived. These authors concluded (*31, p. 187*)—that the function of the colostrum is essentially protective against miscellaneous bacteria which are harmless later on when the protective functions of the calf have begun to operate and accumulate energy.

The same year Howe (*15*), an associate of Smith, found that the blood of the calf at birth contained neither euglobulin nor pseudoglobulin I in appreciable quantities, but that these protein fractions appeared in the blood soon after the ingestion of colostrum by the animal at any time within 2 days after birth. Little and Orcutt (*22*), also associates of Smith, stated that calves born of cows with a relatively high content of agglutinins toward *Brucella abortus* (referred to by these investigators as *Bacillus abortus*) are without agglutinins in their serum at birth. These antibodies appeared in the serum of the calves only after they had received colostrum from their dams. Further, Orcutt and Howe (*25*) furnished evidence of the association of agglutinins with certain globulin fractions in the colostrum. They

were also able to associate the appearance of these globulin fractions in the blood of the newborn animal with the simultaneous absorption of agglutinins.

Lewis and Wells (*20*) repeated the work of Howe, using the human infant. They found that in contrast to the calf the infant at birth has a quantity of pseudoglobulin per cubic centimeter of blood comparable to that of the adult, and lacks only euglobulin. These findings were confirmed by Boyd (*4*), who showed further that after the ingestion of colostrum there is a definite, although not great, increase in the quantity of euglobulin.

Kuttner and Ratner (*18*), in a study of the permeability to diphtheria antitoxin of the human placenta, found that the concentration of antitoxin in the blood from the umbilical cord of the infant corresponded to that in the blood of the mother. They observed no increase in antitoxin attributable to colostrum ingestion, and concluded that colostrum has no significance in the feeding of the human infant comparable to that shown by the work of Smith and his associates in the feeding of calves. They interpreted the differences in the globulin content of the blood of newborn infants and of newborn calves before the ingestion of colostrum, and the differences in placental transmission of immune substances in utero in the different species, as arising from differences in the histological structure of placentae of these species. A greater degree of permeability is found in animals in which the placenta interposes only one layer of cells between the maternal and the fetal blood, as in man, apes, and rodents, than in animals in which there are several cell layers between the maternal and the fetal blood, as in swine and cattle.

Transference of immunity from dam to offspring only through the colostrum has been demonstrated in the ewe for lamb dysentery by Mason, Dalling, and Gordon (*23*), in the mare for tetanus by Bardelli (*1*), and in the sow for vaccinia virus by Nelson (*24*).

Observations were made in this laboratory on the absorption of globulins from homologous colostrum by the newborn foal, kid, lamb, and pig (*8*). In the serum of the newborn of all four species studied, the euglobulin fraction was absent and the pseudoglobulin I fraction was present in much smaller quantities than in the adult of the same species. When the young animals were fed only milk there was no significant increase in either of these globulin fractions during the first few days, but in those animals that received colostrum from their respective dams there was a striking rise in the concentration of total serum proteins, which rise was occasioned by large increases in the euglobulin and pseudoglobulin I fractions. In view of the results obtained by other workers with calves, this investigator (Earle) concludes that young foals, kids, lambs, and pigs fed homologous colostrum during the period of extraordinary intestinal permeability, which apparently persists during the first 24 to 48 hours after birth, absorbed euglobulin and pseudoglobulin I as well as the immune substances that are associated with these fractions from the colostrum ingested.

Although it has been shown that lambs at birth lack both serum globulins and the immune substances present in the blood of the dams,

Smith and Ring (*34*) have published results which indicated that, under the conditions of their experiments—

> Ewe's colostrum was not necessary to protect the lamb against miscellaneous infections and that normal growth took place even when no colostrum was fed. * * * The freedom from early diseases * * * is to be assigned to the absence of infectious agents in the flock and to the general indifference of sheep to bacterial diseases such as those which afflict calves (*34, p.* [*260*]).

It appears, therefore, that although in the cow, horse, sheep, goat, and pig, the serum of the newborn is deficient in certain globulin fractions that are later absorbed from the colostrum ingested, and although colostrum is the sole channel for transfer of antibodies from dam to young, still the particular environmental conditions may be such that the protective action of colostrum against invasion of the young animal by miscellaneous bacteria is not so essential for some animals as for others. Further work seems to be necessary to establish the necessity for colostrum for the young of species other than the cow under the usual conditions.

SUBSTITUTES FOR HOMOLOGOUS COLOSTRUM AND MILK

In the selection of a colostrum substitute the question arises as to which of the functions of colostrum is to be served primarily by the substitute. The part played by colostrum in the immunization of the newborn has been given most attention, and there is reason to believe that it is of greatest importance to the young of some species at least. To serve this function those products which are carriers of antibodies against bacteria, pathogenic to the newborn animal, can be used. After homologous colostrum, homologous serum suggests itself as the most practical source of immune substances in an easily absorbed medium.

Bauer (*2*) in 1909 concluded that colostrum owed its peculiar value, for the newborn, to the presence of certain blood constituents. Famulener (*10*) in 1912 attempted to replace colostrum by feeding these constituents as they occur in homologous serum. He presented experimental evidence that antibody absorption can take place when hemolytic serums are fed to newborn kids. Smith and Little (*32, 33*) showed that the administration of cow serum by feeding may replace colostrum as a conveyer of passive immunity from cow to calf. Mason, Dalling, and Gordon (*23*) went a step farther in showing that the lamb, calf, and foal absorb antitoxin from heterologous as well as from homologous serums when they are fed.

Milk is the natural food normally supplied by the dams to the young of all mammals. Although the dependence of the young on milk varies with the species, apparently in no mammalian species can the young do without milk entirely. Furthermore, results of studies on the feeding of milk of one species to the young of another species, as reviewed by Lane-Claypon (*19*), indicate that homologous milk is greatly superior to milk from another species in the nutrition of the young. The earlier the substitution of the foreign milk in the feeding of young animals the more unfavorable the results. The obvious conclusion is that the variations in the composition of the milks of different species are such that the nutritional requirements of the young of each species appear to be satisfied most successfully by the natural milk of its own kind.

Experimental work reported in the literature on the substitution of some product for the natural milk of the dam in the feeding of the suckling farm animal has been most often concerned with the feeding of calves. Interest in the artificial feeding of calves has been stimulated principally by the aim to reduce the cost of raising calves by substituting some food of less economic value than whole milk and, to a less extent, by the desire to raise disease-free calves which have been delivered by cows infected with some disease that may be transmitted through the milk.

In most of the experimental work directed toward the attainment of the ends just mentioned, the calves received colostrum for the first 1 to 4 days after delivery and whole milk for the next several days thereafter. At various ages of the animals, other feeds were substituted for varying proportions of the total quantity of milk ordinarily consumed. Numerous studies proved that skim milk with supplements is an excellent substitute for whole milk after the calf is from 2 to 3 weeks of age. Observations on the effect of further reducing the total quantity of milk used have been made in experiments in which calf meals of different kinds were used as milk substitutes. In all these studies, the milk substitutes replaced only a part of the homologous milk required by the young animals under normal conditions.

In feeding orphan foals, fresh cow's milk is often modified to approximate more or less the composition of mare's milk. Dimock,[4] of the University of Kentucky, advises the use of equal parts of cow's milk and boiled water with the addition of a tablespoonful of sugar (sucrose) to each pint of the mixture. As an alternative, he also suggests the use of one of the artificial foods that are on the market for human use.

A comparison of the average composition of cow's milk with mare's and ewe's milk showed that it contains less sugar, much more fat, and a little more protein than does mare's milk and considerably less protein and fat and a little more sugar than does ewe's milk.

In the composition of the milk of mares, Linton (*21*) reported no differences associated with breed, except in mineral content. He found that, in general, the heavier breeds produce milk with a higher ash content than do the lighter breeds. Linton's report also included observations on milk from mares whose foals appeared to be malnourished and unthrifty. As a result of his studies, he concluded that foals grow well on milk containing materially higher fat percentages than the average mare's milk. On the other hand, with an occasional exception, foals also do well on mare's milk containing less than 1 percent of fat. Milk having a sugar content higher than that of the average mare's milk is well tolerated by foals, whereas those receiving milk with a lower sugar content than the average mare's milk appear malnourished.

Hand-fed lambs usually receive whole cow's milk. There are, however, no data available for comparison of growth of such animals with that of animals suckled by their dams.

Ewe's milk, as compared with the milk of other species of farm animals, is very high in total solids. The concentration of total solids, however, appears to vary markedly with the stage of lactation.

[4] Personal communication.

Scheingraber (*30*) reviewed briefly previous studies illustrating increases in fat and in protein in ewe's milk with the advance in lactation. Steinacker (*35*) studied the composition of the milk of five different breeds of sheep during the period that the ewes normally suckle their lambs. He reported no significant differences due to breed and attributed the differences in the reports in the literature on the composition of ewe's milk to individual variations and to differences in stage of lactation.

Ritzman (*28*) made observations on the wide variations in the fat content of ewe's milk and the relation of these variations to the growth of the lambs. He found a range in milk fat of from 2.4 to 12.1 percent among 108 individuals. His observations indicate that there is considerable variation in the rate of growth of lambs, without any relationship to the percentage of fat in the milk of the dam. The growth of lambs receiving milk rich in fat was no greater than that of lambs receiving milk low in fat. Ritzman pointed out that milk fat is probably important in the nutrition of the growing lamb chiefly as a vehicle for the vitamins as growth stimulants and that milk which will satisfy the suckling's demands for protein and ash may be low in fat and still satisfy all nutritive requirements of the lamb.

REARING OF FOALS

EXPERIMENTAL PROCEDURE

Experiments reported in this bulletin on the feeding of foals involved the use of homologous serum as a constituent of a milk mixture used as a colostrum substitute and the use of two mixtures of dried cow's milk as substitutes for homologous milk. In these studies 13 newborn foals were used, consisting of three Thoroughbred-Morgans, one Thoroughbred-Percheron, one grade Clydesdale, two grade Percherons, three grade Thoroughbreds, one grade American Saddle, and two Thoroughbreds. At birth all animals were healthy and vigorous. The studies were made at the Agricultural Research Center, Beltsville, Md.

METHODS OF SERUM PREPARATION

Two healthy old horses were used for the purpose of providing serum. At each bleeding, from 2 to 3 liters of blood was drawn under aseptic conditions from a jugular vein of one of these animals into a sterile bottle which contained a handful of glass beads. The blood was defibrinated by shaking and then allowed to stand 6 to 12 hours for the cells to settle out. The serum was siphoned off into a sterile bottle and either stored until needed or dried, at room temperature, in a desiccator over sulphuric acid at reduced pressure. If for any reason the blood was suspected of having become contaminated during the drawing, the serum was filtered through a Seitz bacteriological filter before it was stored or dried.

The serum was prepared for feeding to foals by substituting the quantity of serum to be used for a similar volume of water, in making up a dried milk mixture. The proportions of dried milk and sugar used are given in table 1. When dried serum was used, it was first dissolved in water to make it up to its original volume and then mixed with the dried milk.

METHODS OF MILK PREPARATION

As a substitute for homologous milk two mixtures were made of dried whole cow's milk, dried skim milk, sugar, and limewater, approximating mare's milk in the relative proportions of protein, fat, and sugar. The total solids of these reconstructed milks, however, were considerably higher than those of the average mare's milk. It was considered that the higher concentration of nutrients was a distinct advantage in the handling and feeding of the milk and might conceivably be of further advantage to the foal in that it offered opportunity for increasing the total nutrients ingested without increasing the bulk.

The two mixtures differed from each other somewhat in the relative proportions of protein, fat, and sugar. The constituents and composition of these two milk mixtures are shown in table 1. The commercial dried whole milk and dried skim milk used in mixture 1, were both manufactured by the spray process. The skim milk used in mixture 2 was spray dried, but the whole milk was dried by the roller process. In order to increase the solubility or degree of dispersion of the roller-dried milk, the preparation, after being mixed, was heated to 100° C. and held at that temperature for 2 minutes before it was cooled and stored or fed.

TABLE 1.—*Constituents and composition of the dried-cow's-milk mixtures fed to foals*

Milk mixture No.	Constituents					Composition [1]					
	Dried whole milk	Dried skim milk	Sugar	Lime-water	Water	Protein	Fat	Sugar	Ash	Total solids	Water
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	9.7	2.4	2.8	6.0	79.1	3.5	2.8	7.5	0.8	14.6	85.4
2	8.6	5.1	3.1	6.0	77.2	4.1	2.6	8.7	.9	16.3	83.7

[1] Excluding lime added as limewater.

In preparing mixture 2, the proportions of the ingredients used in mixture 1 were changed so as to decrease the quantity of fat and increase the protein and sugar. The butterfat in the roller-dried milk had a tendency to separate out before the milk could be fed. Experience in feeding the roller-dried milk, made up in the proportions used in milk mixture 1, indicated that it produced in the young foal a diarrhea that was attributed to the physical condition of the fat; hence, the change in the formula with the change in kind of dried milk.

The percentage distribution of the total calories furnished by the protein, fat, and sugar in each mixture, as compared with that of cow's and mare's milk, is shown in table 2. The prepared milks fed to the experimental foals were more concentrated sources of calories than either cow's or mare's milk. However, the distribution of calories among fat and sugar in the prepared milks approached that in mare's milk more closely than that in unmodified cow's milk.

TABLE 2.—*Comparison of different milks with respect to percentage of total calories furnished by protein, fat, and sugar*

Kind of milk	Calories per 100 g of milk	Distribution of calories in—		
		Protein	Fat	Sugar
	Calories	*Percent*	*Percent*	*Percent*
Cow's	67.5	21.0	49.25	29.75
Mare's	49.6	21.7	28.6	49.7
Dried cow's-milk mixture 1	69.3	19.8	36.0	44.2
Dried cow's-milk mixture 2	74.3	22.0	31.0	47.0

The curd tension of the prepared milks was also more like that of mare's milk than of cow's milk. Results of curd-tension determinations made according to Hill's method (*12*) indicated that mare's milk has a curd tension of 0 g. Fresh cow's milk has an average curd tension of 60 to 80 g, whereas the prepared milks fed to the foals had a curd tension of 14 to 19 g. A curd tension of 20 g, according to Hill, is the most desirable standard for soft-curd milk recommended as a substitute in infant feeding for human milk which, like mare's milk, has a curd tension of 0 g.

METHODS OF FEEDING

For the first 3 to 10 days, the hand-fed animals were fed from bottles fitted with large rubber nipples. They were soon taught, however, to drink from pails. The milk was warmed to approximately 37° C. before it was fed. The same precautions were observed in handling this milk as are used in the handling of milk intended for human consumption.

During the early part of the experimental period, each foal was fed five or six times every 24 hours. The number of feedings was gradually decreased until at 6 weeks of age the foal received only three feedings per day, and at 20 weeks, only two. Milk feeding was discontinued at 24 weeks.

The feeding data for each of the foals in the experiment are given in table 3. As shown in the table, foals 15, 16, and 17 received only dried-milk mixture 2. Beginning during the first 3 hours after birth, each foal received 450 cc of the mixture every 4 hours. At 18 hours after birth foal 18, which was received 16 hours after delivery, was fed 350 cc of mare's colostrum and every 4 hours thereafter 450 cc of dried-milk mixture 2. Foals 7 and 9 were fed, during the first 24 hours, colostrum which had been milked from their respective dams. They were then returned to their dams to suckle. During the first 14 hours after delivery foal 11 was fed 1,500 cc of fresh horse serum and thereafter 450 cc of dried-milk mixture 2 every 4 hours until it was returned to its dam at 48 hours after birth. Foals 6, 8, 10, 12, 13, and 14 were fed various quantities of horse serum as a colostrum substitute during the first 6 to 12 hours after delivery and were thereafter fed 450 cc of either dried-milk mixture 1 or 2.

TABLE 3.—*Breeding, birth weights, and feeding data of foals used in the experiments*

Colostrum or substitute fed and foal No.	Breeding	Birth weight	Quantity of mare's colostrum or substitute fed	Milk fed
No colostrum or substitute:		*Pounds*	*Cubic centimeters*	
15	Thoroughbred-Morgan	110	----------	Dried-milk mixture 2.
16	do	107	----------	Do.
17	Thoroughbred-Percheron	126	----------	Do.
Colostrum:				
18	Grade Percheron	125	350	Do.
7	Thoroughbred	92	3,900	Milk of dam.
9	do	123	4,900	Do.
Fresh horse serum:				
6	Grade Thoroughbred	97	1,000	Dried-milk mixture 1.
12	do	78	1,200	Dried-milk mixture 2.
11	Thoroughbred-Morgan	99	1,500	Dried-milk mixture 2 and milk of dam.
8	Grade Clydesdale	123	1,500	Dried-milk mixture 1.
Dried horse serum:				
13	Grade Percheron	112	[1] 1,170	Dried-milk mixture 2.
14	Grade American Saddle	111	[1] 1,170	Do.
10	Grade Thoroughbred	104	[1] 2,350	Dried-milk mixture 1.

[1] Volume given is in terms of fresh serum.

In estimating the quantities of milk required by the experimental foals during the first 12 weeks, during which milk was practically the sole source of energy, recourse was had to the data published by Brody and assistant (*5*) on the energy metabolism of Percheron foals. From these data the calculations shown in table 4 were made. Although it is recognized that the energy metabolism of foals of a draft breed, such as the Percheron, may be lower than that of the cross-bred animals used in these studies, it was considered that the data for Percheron foals could be used as an approximate basis for estimating the basal requirements of the experimental foals.

TABLE 4.—*Daily energy requirements of Percheron foals under resting conditions* [1]

Age of foals (weeks)	Calories per 100 pounds of body weight	Quantity of dried-milk mixture 1 per 100 pounds of body weight	Quantity of dried-milk mixture 2 per 100 pounds of body weight	Age of foals (weeks)	Calories per 100 pounds of body weight	Quantity of dried-milk mixture 1 per 100 pounds of body weight	Quantity of dried-milk mixture 2 per 100 pounds of body weight
	Calories	*Pounds*	*Pounds*		*Calories*	*Pounds*	*Pounds*
1	2,270	1.07	1.13	7	1,770	.83	.89
2	2,270	1.07	1.13	8	1,860	.87	.93
3	2,180	1.03	1.09	9	1,770	.83	.89
4	1,950	.92	.97	10	1,640	.77	.82
5	1,950	.92	.97	11	1,550	.73	.78
6	1,860	.87	.93	12	1,450	.68	.75

[1] Calculated from data on 6 Percheron foals published by Brody and assistant (*5*).

In order to avoid the possibilities of digestive disturbances due to overfeeding, only sufficient milk to maintain birth weight was fed during the first week. This quantity was gradually increased. The actual daily quantity of milk fed to any one foal from the second week until it began to eat an appreciable quantity of grain was the estimated quantity of milk necessary to furnish energy for normal

metabolism under resting conditions, taken from table 4, this quantity being increased until the foal appeared to be gaining at a rate approximately normal for Morgan foals of the same age. Table 5 shows the average quantities of milk consumed daily by the experimentally fed foals.

TABLE 5.—*Average daily consumption of dried-milk mixture 1 or 2 by experimental foals*

Age of foals (weeks)	Quantity of mixture 1 used per 100 pounds of body weight (average of 3 foals)	Quantity of mixture 2 used per 100 pounds of body weight (average of 3 foals)	Age of foals (weeks)	Quantity of mixture 1 used per 100 pounds of body weight (average of 3 foals)	Quantity of mixture 2 used per 100 pounds of body weight (average of 3 foals)	Age of foals (weeks)	Quantity of mixture 1 used per 100 pounds of body weight (average of 3 foals)	Quantity of mixture 2 used per 100 pounds of body weight (average of 3 foals)
	Pounds	*Pounds*		*Pounds*	*Pounds*		*Pounds*	*Pounds*
0	0.80	0.92	8	1.30	1.47	16	0.93	0.99
1	1.18	1.24	9	1.29	1.37	17	.90	.96
2	1.52	1.60	10	1.22	1.28	18	.88	.93
3	1.59	1.67	11	1.14	1.20	19	.78	.82
4	1.73	1.82	12	1.07	1.13	20	.77	.81
5	1.53	1.62	13	1.06	1.12	21	.55	.58
6	1.53	1.62	14	1.00	1.05	22	.51	.54
7	1.45	1.53	15	.98	1.04	23	.38	.40

At 3 to 4 weeks of age, the foals began nibbling grain and timothy hay. The grain mixture fed consisted of 1 part of cracked corn, 2 parts of ground oats, and 1 part of wheat bran. By the time each foal was 3 months old it was eating approximately 0.5 pound of grain mixture per 100 pounds of body weight. This quantity was increased as the quantity of milk was decreased.

MANAGEMENT OF ANIMALS

With the exception of foals 13, 14, and 18, each animal was delivered under the observation of some person connected with the experimental work and was removed from its dam before it had a chance to suck. With the exceptions indicated, each foal was born in a clean box stall and was removed at once to another clean stall. The stump of the umbilical cord was left untied but was washed well with tincture of iodine within a few minutes after delivery and at 24-hour intervals until the cord was fairly well dried. In the case of the foals (Nos. 15 16, and 17) which received no serum or colostrum, the additional precaution was taken to wash the stalls with a disinfecting solution before delivery.

Foals 13 and 14 were delivered unobserved in an open paddock, but it is believed that each was found before it had sucked. After removal from their dams these foals received the same care given to the others. Foal 18 was delivered by a mare which refused to suckle it and was received for experimental use when it was 16 hours old.

All foals were quartered in box stalls in the same barn and allowed to run in a paddock for about 4 hours a day during favorable weather. This paddock was kept closely cropped by the other animals confined therein during the remainder of the day and therefore furnished poor pasturage.

In view of the belief among horse husbandmen that colostrum serves as a necessary laxative for the young foal, all animals were watched closely for signs of constipation or diarrhea.

OBSERVATIONS ON SERUM PROTEINS

Observations were made on the serum proteins of 11 of these foals at birth and at one or more intervals after the ingestion of the first food, on the assumption that any increase in serum globulins occurring in the foals shortly after receiving serum would be indicative of an absorption of globulins from the serum ingested.

All blood samples were drawn from a jugular vein. As precautions against the introduction of any infection at the site of venepuncture, the skin area was clipped and scrubbed with iodine and alcohol and a sterile needle was used.

Blood samples were centrifugalized and the serum was removed. The proteins in the serum were fractioned by Howe's micromethod (*14*), using the modification later suggested by him in which volume molar concentrations of sodium sulphate were substituted for the percentage concentrations originally used (*17*). All nitrogen determinations were made by means of the technique of Pregl (*26*) for micro-Kjeldahls.

EXPERIMENTAL RESULTS

FEEDING OF COLOSTRUM

Table 6 shows that in foals 7 and 9, which were fed large quantities of colostrum during the first 24 hours, there were marked increases in the euglobulin and pseudoglobulin I fractions and, consequently, in the total globulins of their blood serum. These foals were in excellent health during the experimental period.

TABLE 6.—*Protein fractions in blood serums from experimental foals at birth and at varying periods after feeding* [1]

[Results are expressed as grams of nitrogen per 100 cc of serum]

Colostrum or substitute fed and foal No.	Time after delivery	Food ingested [2]	Nitrogen partition in blood serum						
			Globulin				Albumin	Nonprotein nitrogen	Total nitrogen
			Euglobulin	Pseudoglobulin I	Pseudoglobulin II	Total			
No colostrum or substitute:	*Hours*								
15	0.5	450 cc of dried-milk mixture every 4 hours.	0.063	0.019	0.008	0.090	0.559	0.042	0.691
	12		.021	.026	.052	.099	.522	.036	.657
	33		.022	.040	.051	.113	.414	.039	.566
16	0.5	do			.140	.230	.497	.028	.755
	12		.060		.208	.505	.022	.735	
	36				.159	.182	.534	.028	.744
17	0.5	do	.013	.024	.088	.125	.412	.035	.572
	12		.017	.007	.139	.163	.370	.036	.570

[1] No data were obtained from foals 12 and 13 until after the first feeding; consequently, blood-serum data for these animals are not reported.

[2] The serum fed was taken from 2 horses, the colostrum from mares, and dried cows's milk was used in making the dried-milk mixtures.

TABLE 6.—*Protein fractions in blood serums from experimental foals at birth and at varying periods after feeding*—Continued

Colostrum or substitute fed and foal No.	Time after delivery	Food ingested	Nitrogen partition in blood serum						
			Globulin				Albumin	Nonprotein nitrogen	Total nitrogen
			Euglobulin	Pseudoglobulin I	Pseudoglobulin II	Total			
	Hours								
Colostrum:									
18	16	None	0.000	0.087	0.167	0.254	0.423	0.030	0.707
	31	350 cc of colostrum fed 18 hours after birth and dried-milk mixture thereafter.	.052	.081	.205	.338	.348	.036	.722
7	0	3,900 cc of colostrum during first 24 hours.	.000	.028	.059	.087	.552	.040	.679
	12		.115	.227	.095	.437	.499	.031	.967
	24		.037	.229	.069	.335	.471	.034	.840
9	0.5	4,900 cc of colostrum during first 24 hours.	.002	.054	.179	.235	.558	.034	.827
	12		.118	.108	.127	.353	.515	.034	.902
	24		.037	.204	.131	.372	.487	.031	.880
Fresh horse serum:									
6	0.5	1,000 cc of serum in dried-milk mixture during first 18 hours after delivery.	.000	.028	.031	.059	.608	.034	.701
	24		.040	.037	.059	.136	.543	.040	.719
11	0.5	1,000 cc of serum in dried-milk mixture during first 10 hours after delivery.	.031	.014	.019	.064	.439	.024	.527
	12	500 cc of serum in dried-milk mixture 14 hours after delivery.	.035	.063	.030	.128	.506	.021	.655
	24		.023	.061	.072	.156	.463	.024	.643
8	0.5	1,500 cc of serum in dried-milk mixture during first 6 hours after delivery.	.000	.002	.050	.118	.535	.035	.688
	24		.028	.008	.084	.180	.548	.019	.747
Dried horse serum:									
14	4	Dried serum equivalent to 1,170 cc of fresh serum in dried-milk mixture during first 12 hours after delivery.	.028	.086	.139	.253	.407	.031	.691
	12		.039	.112	.131	.282	.406	.031	.719
10	0.5	Dried serum equivalent to 2,350 cc of fresh serum in dried-milk mixture during first 12 hours after delivery.	.027	.044	.031	.102	.474	.022	.598
	18		.056	.068	.084	.208	.446	.031	.685
	24		.062	.009	.045	.176	.465	.019	.660

Results of analyses of serum from foal 18, which was not fed until 18 hours after birth, when it was given 350 cc of colostrum, indicate an increase in serum globulin 13 hours later but no increase in pseudoglobulin I. This foal, 52 hours after birth, developed a severe diarrhea. The hind legs appeared lame at this time and the left hock joint was beginning to swell. On the same day the animal received intravenously 100 cc of sterile serum drawn from a healthy mare and on the fourth day 75 cc of the same serum. On the fifth day the diarrhea had been checked and the animal appeared lively, had an excellent appetite, and its eyes were bright. Ten days later the foal contracted a cold as evidenced by running eyes, a nasal discharge, and diarrhea, which persisted for 2 weeks. At the end of this time the animal began to make good gains in weight, but at 7 weeks of age it became completely blind and was killed.

SUBSTITUTION OF DRIED-MILK MIXTURE FOR COLOSTRUM

Three foals, Nos. 15, 16, and 17, which were fed only dried-milk mixture 2 from birth, gave every indication of being vigorous and healthy animals at birth. Foals 15 and 17 lived only 42 and 57 hours, respectively. Each died of a bacteremia caused by the *Shigella equirulis* organism. Foal 16, under similar conditions and identical surroundings, lived 12 days and died of a septicopyemia caused by a strain of *Salmonella paratyphi*. The *Shigella equirulis* organism was also present in the tissues. Each of the animals gave definite evidence of illness within 40 hours after delivery.

Results of fractionation of serum proteins of these animals are included in table 6. In foal 15 there were very slight increases in euglobulin, in pseudoglobulin I, and in total globulins, within the first 33 hours. Data on globulin fractions in foal 16 are incomplete owing to the loss of samples during the analyses, but a decrease in total globulins was shown, whereas in foal 17 there was a slight increase in total globulins which was due to an increase in pseudoglobulin II.

SUBSTITUTION OF SERUM FOR COLOSTRUM

Seven foals (Nos. 6, 8, 10, 11, 12, 13, and 14) were fed horse serum as a constituent of a dried-milk mixture, instead of colostrum. The serum fed to foals 10, 13, and 14 had been dried. Foal 11 was returned to its dam 48 hours after delivery, by which time the milk of its dam had lost its colostrum characteristics. All these foals were healthy, thrifty animals from birth. In no case was there any evidence of constipation due to failure to receive colostrum and in only one instance was there any indication of diarrhea. Foal 12, on the third day, developed a mild diarrhea. This was attributed to the milk, since there had been used in the mixture a new lot of dried milk which, on examination, was found to be badly discolored and to contain appreciable quantities of foreign detritus. The diarrhea quickly disappeared when the milk was changed.

Results of fractionation of serum proteins from five of these animals are presented in table 6. Blood samples were not obtained from the other two foals until after the first feeding. In the foals which received the dried-milk mixture alone there was not sufficient increase in serum globulins to suggest an absorption of globulins from the milk. The results obtained from the foals that received serum indicate that there was a definite increase in the serum globulin fractions, which was presumably due to absorption of these fractions from the serum ingested. The absorption of globulins from serum, however, was much less than from colostrum.

SUBSTITUTION OF DRIED-MILK MIXTURES FOR MILK OF DAMS

Of the experimental animals that received a dried-milk mixture instead of their dams' milk, foals 8 and 13 were grade animals of draft type and grew at nearly the same rate. Their weights were averaged and plotted together on one line in figure 1. Foals 6, 10, 12, and 14 were grade animals from light-harness-type dams ranging in weight from 900 to 1,200 pounds. Their weights were averaged and plotted on another line in the same figure. All of these animals were fed the dried-milk mixture for 168 days. As shown previously, they received serum as a colostrum substitute.

For comparative purposes, the rate of growth of 10 normally fed Morgan foals is also shown in figure 1. The average suckling period of these animals was 165 days. The four experimental foals of light-harness type (Nos. 6, 10, 12, and 14) grew at a rate comparing favorably with that of the Morgan foals which had the same range of adult size as the experimental foals specified. The draft foals (Nos. 8 and 13), as was to be expected, grew more rapidly. In view of the fact that the foals available for use in this study were of more than one type, a close comparison of their rate of growth with that of the Morgan foals or with that of the Thoroughbred foals (Nos. 7 and 9) is of no great value.

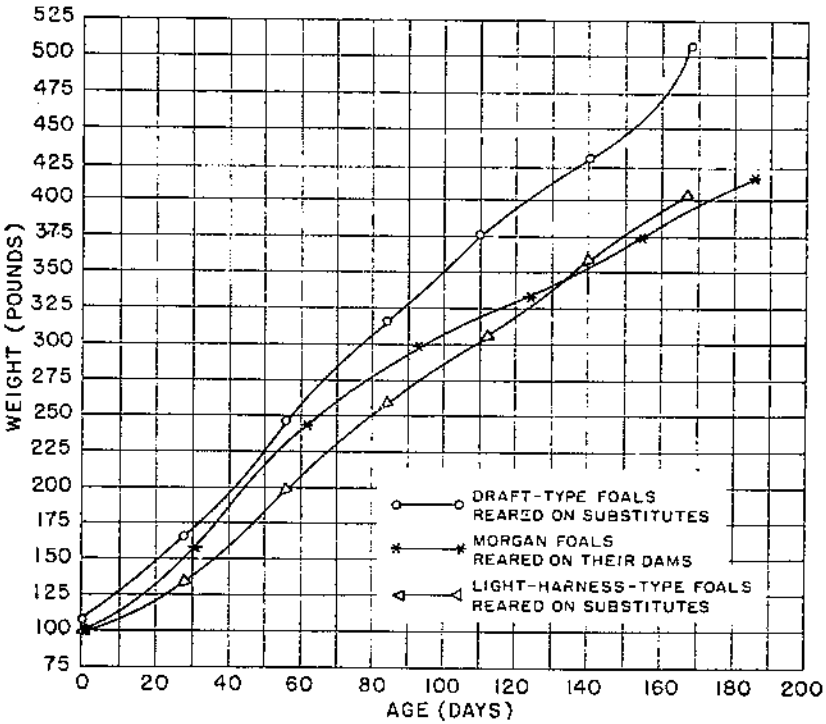

FIGURE 1.—Growth of draft and light-harness-type foals fed a mixture of horse serum and dried cow's milk as a substitute for mare's colostrum and a mixture of dried cow's milk as a substitute for mare's milk as compared with the growth of Morgan foals reared on their dams.

The significant observations on the foals that were fed serum as a colostrum substitute followed by mixtures of dried cow's milk are that, with minor exceptions, all foals so fed were thrifty and vigorous throughout the experimental period and that they gained in weight steadily.[5] The exceptions were as follows: Foal 6 received a leg injury in the barn from which she developed tetanus. She lost weight during the infection but recovered fully. During one period of about 2 weeks, all foals either lost a little weight or failed to gain.

[5] In the experiments, the growth of the foals fed the dried-milk mixtures was entirely satisfactory. However, in the practical feeding of foals the addition of cod-liver oil or some other concentrated source of vitamins A and D is generally advisable.

Examinations of feces at this time indicated in every foal an infestation of ascarids. The foals were treated for these parasites and after treatment they began gaining in weight.

DISCUSSION

The three foals which were fed, from birth, a dried-milk mixture without either serum or colostrum became ill within 40 hours after birth and died in 12 days or less. When handled under the same environmental conditions, the same system of management, and the same feeding schedule, except that they received a liter or more of horse serum within 12 hours after birth, five other foals suffered no illness during the first 3 months which could be attributed to the lack of colostrum and grew with every appearance of being healthy animals.

The foals that received no serum or colostrum developed symptoms commonly associated with the condition termed "joint ill." The chief symptoms observed were extreme lassitude, loss of appetite, swollen joints, and acute lameness. The fact that all three foals succumbed to infections can scarcely be considered accidental or due to surroundings especially favoring invasion of these animals by the pathogenic organisms. With the exception of these three foals, there had never been a case of joint ill in the barn in which they were kept although many healthy foals had been delivered and housed in the same stalls used for the experimental animals. As far as was determined, the dams of these three foals were healthy animals. The dams of Nos. 15 and 16 had each previously had two healthy foals, whereas foal 17 was the first offspring of its dam. Full sisters of foals 15 and 16, delivered the previous year, were thrifty, healthy animals. Although the possibility of infection before delivery is not ruled out, there seems to be no reason to assume such infection. It appears that the foals which received colostrum or serum had been exposed to the same hazards of infections to which foals 15, 16, and 17 succumbed but that they were supplied with protection which had been withheld from those that died.

In the light of the findings of Smith and Little (*31*) concerning the function of colostrum as a protective agency against invasion of the newborn calf by organisms to which the adult cow is immune, and against which the newborn has no resistance, it is to be expected that analogous conditions of susceptibility of the newborn are present in other animal species of similar placental structure or permeability. It has been shown that in the foal, as in the calf, there is an absence at birth of antibodies that are present in the blood of the dam. The results reported here suggest that there are organisms which are to the horse what the colon bacillus is to the cow; that is, pathogenic for the newborn animal but relatively harmless to the adult. In such case the adult horse has a resistance to these organisms which is transmitted under normal conditions to the foal through the colostrum. But when this passive immunization is not transmitted, the young animal when invaded by the organisms, appears unable to combat the infection.

There is probably a quantitative relationship among the gross quantity of immune substances absorbed from the colostrum by the

newborn animal, the size of the animal, and the degree and virulence of the infections. Even when foals suck their dams, the actual quantity of colostrum provided by the dam may be small in some cases. Observations made by the authors indicate that not infrequently mares "milk out" before the delivery of the foal. The mammary secretion available to the foal in such cases is then more like milk than colostrum, at least as far as its globulin content is concerned, and it seems probable that the antibody content is related to the globulin content. Again, if there is delay in the receipt of the first colostrum by the foal the proportion of globulins and antibodies absorbed to that ingested is greatly decreased. In such events, the quantity of antibodies absorbed may be insufficient to protect the foal against infection. The relationship between transference to the newborn animal of passive resistance by means of ingestion of colostrum or serum and the incidence of the infections which are associated with joint ill in foals appears to be a field which promises interesting and valuable returns for further work.

REARING OF LAMBS

EXPERIMENTAL PROCEDURE

In the feeding of lambs, use was made of ewe's or goat's milk, cow's colostrum, and sheep serum as substitutes for homologous colostrum. Dried cow's-milk mixtures also were used as substitutes for homologous colostrum and homologous milk. Some of the lambs in these studies were from Hampshire, Corriedale, Shropshire, and Karakul ewes at the Agricultural Research Center. Other lambs used were from grade ewes on farms nearby.

FEEDS USED AND METHODS OF PREPARATION

FRESH EWE'S OR GOAT'S MILK

Ewe's milk that was fed fresh to newborn lambs in place of colostrum was milked by hand from ewes with lambs that were 8 days or more old. It was not always possible to obtain sufficient quantity of such milk to feed the experimental lambs of this group. Hence, in certain instances, fresh goat's milk obtained from the mixed milk of the Beltsville herd of milking does was used.

COW'S COLOSTRUM

The fresh cow's colostrum that was fed as a substitute for ewe's colostrum was obtained from cows within 12 hours after parturition. Since a supply of fresh cow's colostrum was not always available when needed, part of the fresh colostrum was dried and stored. It was believed that the results obtained from the feeding of dried colostrum would not differ from those obtained from the fresh fluid, provided there was no denaturation of proteins nor destruction of antibodies during the process of drying.

In order to avoid the possibility of denaturation of the colostrum proteins by heat, an attempt was made to dry quantities of cow's colostrum at room temperature (20° to 30° C.) under reduced pressure over a suitable drying agent. The process, however, became

so laborious with only the usual laboratory facilities for that type of work that another means of drying the colostrum was sought. Use was made of a milk-drying machine of the dot-head type. In this machine the colostrum was blown as a fine mist into the top of a chamber and dried as it fell through 6 or 8 feet of hot air. The temperature of the chamber varied during the process from 93° to 104° C. As soon as the dried particles fell to the bottom, they passed through an opening into a flask in which the temperature was always below 37° C. Theoretically, the droplets of colostrum were dried instantly, thus making the exposure of the proteins while in solution to high temperatures extremely brief. The colostrum preparations were as follows:

No. 1, dried under reduced pressure; no analysis.
No. 2, dried by machine; 40.7 percent of protein.
No. 3, dried by machine; 40.1 percent of protein.
No. 3a, same colostrum as No. 3 but dried under reduced pressure.
No. 4, fresh colostrum; 9.0 percent of protein.
No. 4a, colostrum 4 fortified with dried colostrum 2; 13.0 percent of protein.
No. 31, fresh colostrum; 13.6 percent of protein.
No. 32, fresh colostrum; 8.5 percent of protein.

The dried product appeared to go into solution readily; however, in filtering such a solution, much of the apparently dissolved protein failed to pass through the filter paper. Nevertheless, fractionation of the filtrate by Howe's sodium sulphate method (*16*) indicated that the filtrate contained considerable quantities of globulin and albumin.

Nothing is known of the antibody content of the colostrum that was used either before or after drying. The colostrum that was dried in the milk-drying machine was obtained by milking fresh cows from 12 to 24 hours after calving; that dried under reduced pressure, within 12 hours after calving. This dried material was stored in tightly covered tins and was used within 3 months after drying.

For feeding to lambs, the dried colostrum was dissolved or suspended in warm water in the proportion of 25 parts by weight of colostrum to 75 parts of water.

SHEEP SERUM

The sheep serum that was fed to lambs in place of ewe's colostrum was obtained from blood drawn from healthy adult sheep by puncture of a jugular vein. The defibrinated blood was centrifugalized and the serum syphoned off. This serum was filtered through a Seitz bacteriological filter and either stored or dried in a desiccator at reduced pressure.

When fresh serum was used it was fed, within 72 hours after the blood had been drawn, as a mixture of serum and dried milk made up in the proportion of 85 to 15 parts by weight. When dried serum was fed it was first dissolved in sufficient water to make it up to its original volume and then combined with the milk in the proportion of 85 parts of serum to 15 parts of dried milk.

DRIED-COW'S-MILK MIXTURES

In most cases when dried cow's milk was fed in place of ewe's colostrum, a mixture of 15 parts by weight of dried whole milk and 85

parts of water was used. However, more concentrated mixtures of dried milk were fed during the first 3 days to lambs 19, 22, and 27. The quantities of dried milk protein fed to these lambs are shown in table 13.

Two different milk mixtures were fed as substitutes for ewe's milk. The percentage composition of each of these milk mixtures is recorded in table 7, together with the average composition of ewe's milk. The whole milk used was a mixture of dried whole milk and water in the proportions of 20 to 80 parts by weight. The skim milk used was a mixture of dried skim milk and water in the proportions of 29 to 71 parts by weight. As shown in table 7, although the two dried-milk mixtures had practically the same energy value as ewe's milk, the composition of the substitute milks was quite different. The dried-whole-milk mixture differed only slightly from ewe's milk in both protein and ash content. The fat content of the whole milk, however, was a little lower and the sugar content somewhat greater than those of ewe's milk. The skim-milk mixture, on the other hand, had approximately twice the protein content and three times the sugar content of ewe's milk, and, of course, an extremely low fat content.

TABLE 7.—*Comparison of composition of dried-cow's-milk mixtures fed to lambs with that of ewe's milk*

Milk analyzed	Proportion of total protein		Proportion of total fat		Proportion of total sugar		Proportion of total weight of ash	Total calories per 100 g of fluid milk
	Weight	Calories	Weight	Calories	Weight	Calories		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Calories*
Ewe's milk [1]	5.83	23.3	6.52	58.7	4.82	19.3	0.93	101
20-percent dried whole milk [2]	5.38	21.5	5.73	51.6	7.30	29.2	1.19	102
29-percent dried skim milk [2]	10.30	41.2	.51	4.6	14.10	56.4	2.34	102

[1] From associates of Rogers (*89*).
[2] Calculated from data taken from associates of Rogers (*89*).

HAY AND GRAIN MIXTURE

In accordance with the practice employed by the sheep husbandmen at the Agricultural Research Center, when the lambs were 2 weeks old alfalfa hay and a grain mixture were made available to them. The grain mixture consisted of corn, 4 parts; oats, 4 parts; bran, 2 parts; and linseed meal, 1 part.

METHODS OF FEEDING

Observations were made on groups of experimental lambs that were fed as follows:

Group 1. Seven lambs were fed fresh milk in place of colostrum for the first 3 days or 4 after birth and were thereafter allowed to suckle their dams. Three lambs in this groups were fed fresh ewe's milk; the other four were fed fresh goat's milk.

Group 2. Twelve lambs were fed a mixture of dried cow's milk from birth. During the first 3 days after birth this was a 15-percent mixture of dried whole milk and water; on the fourth day the concentration of milk was increased to 20 percent.

Group 3. Eleven lambs were fed cow's colostrum, either fresh or dried, in place of ewe's colostrum. Two of these lambs received dried

cow's milk for 1 or 2 days before receiving the colostrum. Since there was considerable variation among individuals in the method of feeding during the first 3 days, details of feeding for this period are summarized in table 8. Four of this group were suckled by their dams after the third day, and the other seven were fed a mixture of dried whole cow's milk thereafter.

TABLE 8.—*Bovine colostrums and milks fed to lambs in group 3 during the first 3 days after birth*

Lamb No.	Product and quantity of protein fed on—					
	First day		Second day		Third day	
	Product [1]	Quantity	Product	Quantity	Product	Quantity
		Grams		*Grams*		*Grams*
20	Dried colostrum 2	75	Dried colostrum 2	75	Ewe's milk	
21	Dried colostrum 3	90	Dried colostrum 3	90	90 percent dried milk	24
22	Dried milk	106	Dried milk Fresh colostrum 31	52 100	do	24
23	Dried colostrum 3a	55	Ewe's milk		Ewe's milk	
24	Fresh colostrum 4a	109	Fresh colostrum 4	81	Fresh cow's milk	21
25	Dried colostrum 3	60	Dried colostrum 3 15 percent dried milk	48 20	15 percent dried milk	20
26	do	90	Dried colostrum 3	90	do	24
27	Dried milk	106	15 percent dried milk	35	Fresh colostrum 31	122
28	Dried colostrum 1 Dried colostrum 3	[2] 15 72	Dried colostrum 3	90	Dried colostrum 3	118
29	Fresh colostrum 32	20	20 percent dried milk	48	20 percent dried milk	48
30	do	20	do	48	do	48

[1] For description of colostrums, see text.
[2] Approximately.

Group 4. Seven lambs were fed during the first 24 hours a mixture of sheep serum and dried cow's milk, and dried cow's milk thereafter.

Group 5. Eleven lambs received colostrum from their dams and were thereafter fed dried whole cow's milk. These lambs, as well as those in groups 6 and 7, were left with their respective dams for 6 to 48 hours after delivery and were then placed on experiment.

Group 6. Eleven lambs suckled colostrum from their dams and were thereafter fed dried skim milk.

Group 7. Nine lambs suckled colostrum from their dams and were thereafter fed dried skim milk. In addition, all animals in this group received 10 cc of cod-liver oil each day. Five of the group received each day a further addition of 75 mg of iron, 15 mg of copper, and 30 cc of tomato juice.

Newborn lambs fed by hand received daily for the first 3 days from 450 to 900 cc of fluid in five or six equal feedings. Small lambs, 5 to 7 pounds in weight, were fed 450 cc each 24 hours, and larger lambs received proportionately more. The average daily quantities of milk fed to the lambs after the first 3 days are indicated in table 9. Milk feeding was terminated at 12 weeks of age except in a few cases shown in later tables. No account was kept of the quantity of hay consumed by the lambs. The quantity of grain consumed daily per lamb was approximately one-fourth pound at 4 weeks of age, increased to one-half pound at 8 weeks of age. During the early weeks of life, the

young lambs were fed five times during each 24 hours as follows: 2 a. m., 8 a. m., 12 m., 4 p. m., and 10 p. m. At about 3 weeks of age, the 2 a. m. feeding was omitted and a few days later the 10 p. m. feeding also.

TABLE 9.—*Average daily consumption of whole or skim milk by experimental lambs per 100 pounds of body weight*

Age (weeks)	Dried whole milk	Dried skim milk	Age (weeks)	Dried whole milk	Dried skim milk	Age (weeks)	Dried whole milk	Dried skim milk
	Pounds	*Pounds*		*Pounds*	*Pounds*		*Pounds*	*Pounds*
0 to 1	3.6	5.0	2 to 4	2.5	3.6	8 to 10	1.3	1.9
1 to 2	2.6	3.8	4 to 8	2.1	3.1	10 to 12	.9	1.3

For the first 4 weeks the hand-fed lambs were fed from bottles fitted with large rubber nipples. At about 4 weeks of age they were taught to drink milk from pails. Due regard for cleanliness was exercised in mixing and handling the milk. All milk containers, nipples, and other feeding apparatus were sterilized every day. When the mixed milk was to be stored for several hours before being fed it was kept in a refrigerator. All milk was warmed to 37° C. for feeding.

MANAGEMENT OF ANIMALS

All animals fed milk or some other product instead of colostrum were delivered under observation and removed from their dams immediately. Each newborn lamb was rubbed with a cloth and the umbilical cord painted with tincture of iodine. Subsequent management of the animal varied somewhat with the experimental group to which it belonged and is described for each group separately.

The seven lambs (group 1) that were fed only fresh milk during the first 3 or 4 days after birth and were then placed with their dams were normal lambs delivered from healthy ewes at the Agricultural Research Center. Immediately after the birth of the lamb, an apron was tied around the ewe in such a fashion that the udder was inaccessible to the lamb. The ewe and lamb were then placed together in a small pen. The lamb was fed fresh milk from a bottle for the first 3 or 4 days. Each ewe was milked twice a day during the period that she wore the apron in order to remove all colostrum before the lamb suckled her. The apron was removed from the ewe on the third or fourth day, and the lamb allowed to suck. Lamb and ewe were then returned to the flock. When this procedure for handling ewes and their lambs was followed, there was no difficulty in getting a ewe to own her lamb and, furthermore, little trouble in persuading the lamb to suck its dam, even though it had been fed from a bottle for the first few days of its life.

In the first three cases so managed, the lamb and ewe were kept in a pen about 4 feet square in the same barn with other groups of experimentally fed lambs. Several of the experimental lambs in this barn died of pneumonia during the latter part of February. To avoid, as far as possible, infection by the agent producing the death of these lambs, the next four lambs which were to receive no colos-

trum were kept in the sheep barn in the "maternity" pens used throughout the lambing season for ewes during and immediately after delivery of lambs.

Of the 12 lambs (group 2) that were deprived of colostrum and fed a mixture of dried cow's milk throughout the suckling period, 2 were from healthy ewes at the Agricultural Research Center. The other 10 were from ewes of mixed breeding on farms a few miles distant from Beltsville. These ewes were brought to the center several days before lambing and kept until after delivery of the lambs. The ewes were of poor grade stock and appeared thin and in poor condition. After delivery the lambs were placed in individual pens in an unheated building where they were under cover and protected from the wind.

Of the 11 lambs (group 3) that were fed cow's colostrum in place of ewe's colostrum, 2 were from ewes brought to Beltsville just before delivery of the lambs. The other nine lambs were from the Research Center. The four lambs in this group that were suckled by their respective dams after the third day were managed in the same manner as the lambs that received ewe's or goat's milk instead of colostrum. The seven lambs that were fed the dried-milk mixture after the colostrum feeding were removed at once after delivery to individual pens in an unheated building.

The seven lambs (group 4) that were fed sheep serum in place of colostrum were also from the grade ewes that were borrowed from nearby farmers and kept at the Research Center until after delivery of the lambs. They were removed at birth to pens in the barn where the bottle-fed lambs were housed.

Lambs, not more than 2 days old, that were reported by their owners to have suckled their respective dams were obtained from farmers living in the vicinity of Beltsville. The lambs were collected in a covered truck in which they were kept from 4 to 10 hours before delivery at the station. All lambs were from ewes of mixed breeding. After being delivered at the Research Center, the lambs were divided into three groups—Nos. 5, 6, and 7. An effort was made to effect an equal distribution of weak and strong lambs among the three groups.

OBSERVATIONS ON SERUM PROTEINS

In order to determine whether there was a comparable absorption of globulins from cow's and ewe's colostrum, protein studies were made on blood serum from lambs that were fed cow's colostrum and on blood serum from lambs that were allowed to suckle colostrum from their dams. Similar studies were also made on serum from lambs that were fed dried milk instead of colostrum. All blood samples were drawn from a jugular vein with proper precautions against introduction of any infection at the site of venepuncture. Not more than 10 cc of blood was drawn from a lamb at any one time. Blood samples were handled and the serum protein fractions determined in the manner described for the determination of serum proteins of foals.

EXPERIMENTAL RESULTS

SUBSTITUTION OF FRESH MILK FOR COLOSTRUM

Of the seven lambs (group 1) fed fresh ewe's or goat's milk in place of colostrum, only three survived long enough to be placed on their dams to suck. One of these died 4 days later, and the other two, lambs 1 and 7, made good growth. Data in regard to the animals in this group are summarized in table 10. Autopsy of each of the five lambs that died revealed evidences of a lung infection, and in four cases additional evidence of a pericarditis also. However, bacteriological cultures were made in only one case. Although it appears that these five animals died of infections, there are no records to indicate whether one or several types were involved.

TABLE 10.—*Results obtained from feeding lambs (group 1) ewe's or goat's milk instead of colostrum for the first 3 or 4 days and allowing them to suck their dams thereafter*

Lamb No.	Breeding	Weight at birth	Source of milk fed instead of colostrum	Feeding results
		Pounds		
1	Hampshire	10.5	Sheep	Weekly rate of gain for first 4 weeks, 4.5 pounds; for second 4 weeks, 4.7 pounds; and for third 4 weeks, 6 pounds.
2	Corriedale	11.2	do	Died on fourth day.
3	do	5.6	do	Died on third day.
4	Hampshire	8.8	Goat	Do.
5	do	8.0	do	Died on second day.
6	Southdown	5.5	do	Died on seventh day.
7	do	5.6	do	Weekly rate of gain for first 4 weeks, 3.4 pounds; for second 4 weeks, 2.5 pounds.

FEEDING OF DRIED COW'S MILK FROM BIRTH

Of the 12 lambs (group 2) that were fed a mixture of dried cow's milk and water from birth, 7 survived to be slaughtered at approximately 16 weeks of age. Four died between 8 and 18 days after birth, each with a lung infection, and one, lamb 14, became partially paralyzed on the second day, dying 5 weeks later. The seven survivors made good growth, averaging 3.4 pounds of gain per week for 16 weeks. Data on growth of these animals are assembled in table 11. Results of fractionation of serum proteins of two of these animals are included in table 13. Lamb 18 which was fed a 15-percent mixture of dried milk sufficient to supply 30 g of protein during the first 24 hours, showed a decrease in serum globulins that was proportionally greater than the decrease in albumin. Lamb 19 was fed a much more concentrated dried-milk mixture sufficient to supply 113 g of protein during the first 24 hours and showed an increase in all globulin fractions that was proportionally much greater than the increase in albumin.

TABLE 11.—*Weekly gains of group 2 lambs, fed dried whole milk from birth*

Lamb No.	Breeding	Weight at birth	Average weekly gain during—			
			First 4 weeks	Second 4 weeks	Third 4 weeks	Fourth 4 weeks
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
8	Mixed	8.1	3.3	3.1	5.0	4.1
9	do	6.7	3.0	3.1	4.3	4.0
10	do	6.6	2.1	2.3	3.1	4.0
11	do	6.3	(1)			
12	do	5.9	(2)			
13	do	7.8	1.3	2.2	2.7	4.8
14	do	7.3	1.3	(3)		
15	do	5.0	2.0	1.8	3.2	3.1
16	do	12.5	2.0	3.0	4.0	3.1
17	do	9.5	(4)			
18	Shropshire	5.3	(5)			
19	Hampshire	10.7	4.5	4.5	6.5	5.5

[1] Died at 8 days of age.
[2] Died at 12 days of age.
[3] Died at 5 weeks of age.
[4] Died at 17 days of age.
[5] Died at 18 days of age.

SUBSTITUTION OF COW'S COLOSTRUM FOR EWE'S COLOSTRUM

The growth and feeding records of the group-3 lambs, which received cow's colostrum in place of ewe's colostrum, are summarized in table 12. Results of the fractionation of serum proteins in seven of these lambs are presented in table 13. Similar data from two lambs (Nos. 39–I and 47–I) that were allowed to suckle colostrum from their dams are included in the same table. Lambs 20, 21, 23, 24, and 26, which received cow's colostrum, either fresh or dried, on the first day after birth showed decided increases in serum globulins within 18 to 48 hours. These increases, however, are much less than those occurring in the two lambs that received ewe's colostrum.

TABLE 12.—*Weekly gains of group 3 lambs, fed cow's colostrum as a substitute for ewe's colostrum followed by the feeding of ewe's milk or of dried whole cow's milk*

Lamb No.	Breeding	Weight at birth	Days after birth on which colostrum was fed	Milk fed	Average weekly gain during—		
					First 4 weeks	Second 4 weeks	Third 4 weeks
		Pounds			*Pounds*	*Pounds*	*Pounds*
20	Hampshire	8.7	First and second	Ewe's	3.0	0.5	3.8
21	Southdown	6.3	do	do	3.2	1.8	1.8
22	Hampshire	11.0	Second	do	4.5	2.5	5.2
23	Shropshire	8.5	First	do	3.0	3.0	.5
24	Southdown	8.3	First and second	Dried whole cow's	2.5	(1)	
25	do	7.1	do	do	3.2	2.8	(2)
26	do	8.7	do	do	3.5	3.4	4.7
27	Hampshire	10.0	Third	do	2.8	4.0	5.0
28	Southdown	6.0	First, second, third	do	3.2	(3)	
29	Mixed	11.0	First [4]	do	1.6	2.5	2.6
30	do	8.0	do [4]	do	2.5	2.2	4.1

[1] Died of nephritis at 7.5 weeks of age.
[2] Died of nephritis at 8 weeks of age.
[3] Died of nephritis at 4.5 weeks of age.
[4] Only small quantity of colostrum proteins ingested.

TABLE 13.—*Protein fractions of blood serum from lambs that received ewe's colostrum and from lambs that received cow's colostrum or dried-cow's-milk mixture in place of ewe's colostrum*

[Results expressed as grams of nitrogen per 100 cc of serum]

Lamb No.	Protein ingested			Nitrogen partition in blood serum							
	Time after birth	Kind [1]	Total protein	Time after birth	Euglobulin	Pseudoglobulin I	Pseudoglobulin II	Total globulin	Albumin	Nonprotein nitrogen	Total nitrogen
	Hours		*Grams*	*Hours*							
39–I	.....	Ewe's colostrum	.....	0	0.003	0.064	0.092	0.159	0.318	0.079	0.556
				24	.316	.218	.123	.657	.201	.064	1.002
				48	.201	.250	.077	.528	.292	.091	.911
47–I	.....	do	.....	0	.000	.054	.152	.206	.406	.040	.652
				24	.322	.248	.051	.621	.385	.071	1.077
				48	.295	.202	.099	.596	.381	.055	1.032
24	1 to 24	Colostrum 4a [2]	109	0	.006	.054	.193	.253	.457	.054	.747
	24 to 48	Fresh colostrum 4	81	24	.130	.140	.129	.399	.406	.045	.850
				48	.078	.111	.212	.401	.330	.033	.820
20	1 to 24	Dried colostrum 2	75	0	.001	[3].234		.235	.....	.....	.998
				24	.051	.098	.181	.340	.....	.....	1.002
21	1 to 24	Dried colostrum 3	90	0	.013	.031	.179	.223	.436	.042	.701
	24 to 48	do	90	48	.044	.124	.136	.304	.349	.083	.736
23	1 to 18	Dried colostrum 3a	53	0	.027	.008	.109	.204	.....	.....	.699
				18	.122	[3].223		.345	.440	.018	.824
26	1 to 24	Dried colostrum 3	90	0	.000	.100	.051	.151	.464	.042	.657
	24 to 48	do	90	48	.076	.140	.158	.374	.354	.063	.792
	1 to 24	Dried milk	106	0	.010	.056	.....	.....	.....	.....	.615
				24	.009	.044	.....	.....	.....	.077	.647
22	24 to 48	Fresh colostrum 31 and dried milk	109	48	.007	.075	.092	.174	.419	.081	.674
			52	0	.028	.019	.119	.166	.398	.054	.595
	1 to 24	Dried milk	106	24	.047	.023	.100	.170	.354	.081	.605
27	24 to 48	do	35	48	.012	.054	.122	.188	.438	.032	.658
	48 to 72	Fresh colostrum 31	122	72	.017	.040	.144	.207	.445	.027	.679
18	1 to 24	Dried milk	30	0	.008	.073	.116	.197	.450	.052	.699
				24	.000	.041	.089	.140	.408	.028	.572
19	1 to 24	do	113	0	.021	.024	.016	.161	.402	.049	.612
				24	.072	.092	.066	.229	.435	.041	.705

[1] Colostrum preparations are described on p. 18.
[2] Fresh colostrum fortified with dried colostrum.
[3] Of pseudoglobulins I and II.

Lambs 22 and 27 were fed on the first day dried milk sufficient to supply total protein in quantities equal to or exceeding that supplied by the cow's colostrum, which was fed to other lambs. In neither of these two lambs was there an appreciable increase in either the euglobulin or pseudoglobulin fractions. Furthermore, when cow's colostrum was fed on the second or third day to these animals, there was still no marked change in either of these two protein fractions.

In contrast to the results of protein determinations for lambs 22 and 27 are the results obtained for lamb 19. A greater quantity of dried-milk protein was ingested by this animal during the first 24 hours than of either dried-milk or colostrum protein by any other animal during the same time. In the case of lamb 19 there was a decided increase in globulins.

Of the lambs that were fed cow's colostrum, the four that were suckled by their respective dams after the first 3 days survived (table 12). Lamb 22, in which it was demonstrated that there was no gross absorption of foreign protein, made much better growth than Nos. 20, 21, and 23, in which marked increases in serum globulins occurred after the ingestion of the cow's colostrum. Of

the seven that were fed dried milk, three died of acute nephritis. The others grew very well.

Histological examination, at autopsy, of kidneys of all these animals that were fed cow's colostrum revealed in each case evidences of marked kidney damage. This damage varied in extent from a moderate distention of the convoluted tubules, with some degeneration of their epithelium in the regions near the capsule in lamb 22, to practically complete degeneration of most of the epithelium of the convoluted tubules in lamb 23. In those lambs that were fed ewe's milk after the first few days, the collecting tubules and glomeruli were relatively normal. However, in those animals that were fed dried cow's milk following cow's colostrum, in addition to the degeneration of the epithelium of the convoluted tubules, there was in each case some fibrosis of the cords of Bellini, degeneration of the cells of the collecting tubules, casts in the lumen of collecting tubules, and occasional hemorrhages in the parenchymal tissues.

FEEDING OF SHEEP SERUM OR COLOSTRUM FOLLOWED BY DRIED WHOLE COW'S MILK

Of the seven lambs (group 4) that were fed sheep serum and dried cow's milk, two died during the first 2 weeks. Under similar conditions of environment and management 5 lambs died out of a group of 12 that received neither serum nor colostrum but the same dried-milk mixture from birth (table 11). Growth records of the serum-fed lambs are assembled in table 14.

TABLE 14.—*Weekly gains of lambs of mixed breeding (group 4) fed sheep serum as a substitute for ewe's colostrum and dried whole milk as a substitute for ewe's milk*

Lamb No.	Weight at birth	Serum fed		Average weekly gain during—		
		Quantity	Condition	First 4 weeks	Second 4 weeks	Third 4 weeks
	Pounds	*Grams*		*Pounds*	*Pounds*	*Pounds*
31	12.9	50	Dried	1.9	3.7	3.7
		Cc				
32	6.9	360	Fresh	1.6	3.0	2.8
33	9.5	360	do	1.7	3.6	4.0
34	6.2	690	do	(1)		
35	5.5	360	do	(2)		
36	10.7	360	do	2.1	2.2	4.0
37	5.9	360	do	1.5	1.0	1.5

[1] Died at 34 hours of age.
[2] Very weak lamb; died at 2 weeks of age.

Data on 11 lambs (group 5) that were fed dried whole milk after having received ewe's colostrum are presented in table 15. Lambs in this group were 12 to 48 hours old when removed from their dams. Ten of these lambs survived and appeared to be thrifty and in excellent condition throughout the experimental period.

It appears that whereas lambs fed sheep serum as a substitute for colostrum have a better chance of survival than lambs that are fed only dried milk, they still may not have all the benefits supplied to those lambs that receive ewe's colostrum.

TABLE 15.—*Weekly gains of lambs of mixed breeding (group 5) that received ewe's colostrum and dried whole milk*

Lamb No.	Age and weight of lamb at end of colostrum feeding		Average weekly gain during—			Lamb No.	Age and weight of lamb at end of colostrum feeding		Average weekly gain during—		
	Age	Weight	First 4 weeks	Second 4 weeks	Third 4 weeks		Age	Weight	First 4 weeks	Second 4 weeks	Third 4 weeks
	Hours	*Pounds*	*Pounds*	*Pounds*	*Pounds*		*Hours*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
38	[1] 12	6.1	2.3	2.0	4.0	44	48	8.7	2.1	2.0	3.2
39	24	6.8	2.3	2.1	2.5	45	48	8.6	3.2	2.3	4.0
40	24	7.2	1.8	1.4	3.0	46	48	11.7	2.6	2.8	2.5
41	24	7.6	2.2	2.3	4.0	47	48	13.2	1.1	[2]	
42	24	7.3	2.2	3.0	3.4	48	12	8.1	3.3	2.8	5.2
43	48	8.5	2.0	2.6	2.8						

[1] Somewhat less than this age.
[2] Died at 7½ weeks of age.

FEEDING OF DRIED SKIM MILK AFTER EWE'S COLOSTRUM

Data on the 11 lambs (group 6) that received ewe's colostrum and were subsequently fed dried skim milk alone are assembled in table 16. All lambs in this group except No. 59 were with the ewe 24 hours or more. All survived for 3 weeks or more, but only 5 survived after the fourth week. Although three of these lambs (Nos. 50, 52, and 53) made good growth, they all suffered from frequent diarrhea and appeared to be in poor condition.

TABLE 16.—*Weekly gains of lambs (group 6) that received ewe's colostrum and dried skim milk*

Lamb No.	Breeding	Age and weight of lamb at end of colostrum feeding		Average weekly gain during—		
		Age	Weight	First 4 weeks	Second 4 weeks	Third 4 weeks
		Hours	*Pounds*	*Pounds*	*Pounds*	*Pounds*
49	Mixed	24	8.0	1.9	2.6	0.8
50	do	24	11.3	2.8	3.0	3.5
51	do	24	7.5	1.6	[1]	
52	do	48	5.9	2.9	3.3	3.7
53	do	24	10.2	3.1	2.4	3.5
54	do	48	11.2	2.0	[1]	
55	do	48	7.7	[2]		
56	do	48	11.6	2.1	2.1	2.1
57	do	48	10.0	[2]		
58	Corriedale	72	10.3	.2	[1]	
59 [3]	Mixed		8.3	1.0	[1]	

[1] Died at 28 days of age.
[2] Died at 21 days of age.
[3] Received 16 g of ewe's colostrum of first milking and dried skim milk thereafter.

Four lambs in group 7 were fed dried skim milk supplemented by 10 cc of cod-liver oil daily. Three animals of this group survived throughout the 3-month period of the experiment and made fair growth. Five lambs also in group 7 received, in addition to the cod-liver oil, further supplements of 30 cc of tomato juice, 75 mg of iron, and 15 mg of copper per day. Of these, four died within about 3 weeks of age and one lived to 3 months, unthrifty and ill-nourished.

The records of the lambs that were fed skim milk and supplements are presented in table 17.

TABLE 17.—*Weekly gains of lambs (group 7) that received ewe's colostrum and dried skim milk with supplements*

Lamb No.	Breeding	Age and weight of lamb at end of colostrum feeding		Supplement	Average weekly gain during—		
		Age	Weight		First 4 weeks	Second 4 weeks	Third 4 weeks
		Hours	*Pounds*				
60	Mixed	24	7.5	Cod-liver oil	2.6	2.1	2.6
61	do	24	10.0	do	2.5	2.3	3.8
62	do	24	12.1	do	1.4	(1)	
63	do	48	8.6	do	3.2	3.1	.8
64	Corriedale	48	6.5	Cod-liver oil, iron, copper, and tomato juice.	(2)		
65	Mixed	48	10.1	do	(3)		
66	do	72	11.7	do	.5	2.1	.5
67	do	48	8.7	do	(4)		
68	Corriedale	48	10.3	do	(5)		

[1] Died at 30 days of age.
[2] Died at 22 days of age.
[3] Died at 19 days of age.
[4] Died at 15 days of age
[5] Died at 8 days of age.

The addition of cod-liver oil alone to the skim-milk diet appeared to effect a larger percentage of survivals, but the lambs were no thriftier in appearance than those without cod-liver oil and evidenced the same diarrhea. Tomato juice, iron, and copper supplements appeared to be harmful rather than beneficial.

Examination of the digestive tracts of the lambs that died revealed large, very firm curds of undigested milk in the stomach and highly inflamed intestines.

DISCUSSION

Results of observations indicated that when a sufficient quantity of fresh cow's colostrum was ingested by the lamb during the first 24 hours after birth, there was an increased concentration of globulins in the serum of the lamb. The same quantity of fresh colostrum ingested during the second 24 hours after birth was ineffective in this respect, as determined by ordinary chemical methods of determining proteins. Furthermore, colostrum dried under reduced pressure at room temperature appeared to be as easily absorbed as fresh colostrum during the first 24 hours. Colostrum dried by heat, however, produced much smaller increases in serum-globulin fractions than the same colostrum, fresh or dried under reduced pressure, when each was fed in equivalent quantities. That this increase in serum globulins was not a phenomenon occurring independently of the ingested colostrum was shown by the fact that it did not occur when a dried-milk mixture of a protein concentration equivalent to that of the colostrum was fed. However, it appears possible to produce increases in serum globulins by feeding dried milk if the concentration and total quantity fed during the first 24 hours after birth are sufficiently great. This was demonstrated by the results obtained from serum from lamb 19 (table 13).

When the ingestion by the newborn animal of large quantities of homologous globulins, which are known to be identical with the serum globulins, results in increases in certain globulin fractions of the circulating blood, the phenomenon is explained as being the result of absorption of these undigested globulins from the intestinal tract. This absorption may be due to an unusual and rapidly diminishing selective permeability of the intestinal mucosa during the early hours of life or to a deficiency of proteolytic enzymes in the newborn animal and a selective permeability which persists but does not operate extensively after the proteolytic enzymes begin to function. When, however, similar increases occur in the serum-globulin fractions following the ingestion of heterologous proteins, the question arises as to whether these increases are due to direct absorption of the heterologous globulins or to a stimulation of the organism to the production of homologous globulins. A few unpublished experiments by the authors on the precipitin reaction of serum drawn from lambs following the ingestion of bovine colostrum strongly suggest the presence, in the blood serum, of bovine globulins that were directly absorbed from the colostrum. However, it is difficult to explain the increases in serum globulins in lamb 19, following the ingestion of a high concentration of dried milk, as the result solely of absorption, since the globulin concentration of the dried milk is shown to be low.

If the absorption of globulins and their associated antibodies from heterologous serum and colostrum ingested by the newborn lamb can take place, such serum or colostrum would serve as a substitute for homologous colostrum in the transference of passive immunity to the young animals, provided the antibodies needed by the lamb were present in the substituted serum or colostrum. Mason, Dalling, and Gordon (*23*) have already shown that lambs absorb tetanus antitoxin from horse serum injected subcutaneously, and less readily from horse serum administered per os during the early hours of life. For any such substitution to become of practical use in the transference of immunity to lambs, it should be known what immunity is needed by the young animal in its particular environment, what medium will supply the needed immune substances and further, what, if any, deleterious effects may result in the normal development of the young animal from the administration of the foreign protein.

Under the conditions of the experimental work reported here, the use of cow's colostrum in place of ewe's colostrum was of no value in the production of healthy lambs, although there was considerable absorption of globulins from the colostrum fed during the first 24 hours and conceivably absorption of antibodies also. A larger percentage of lambs fed cow's colostrum survived during the first few weeks than of those receiving no colostrum. But the autopsies indicate that the survivors of the latter group appear to have a better chance to make a good rate of growth than those of the group fed cow's colostrum. Results of histological study of the kidneys of lambs fed cow's colostrum suggest that there was a sensitization of the newborn lamb to the foreign protein that was absorbed in appreciable quantities and a subsequent resulting kidney damage especially marked when the feeding of the foreign protein in the form of cow's milk was continued.

In the group of lambs that received either ewe's milk or goat's milk instead of colostrum and their dams' milk after the third day, five of seven died within 7 days after birth. In the same environment and the same season, only 9.6 percent of the lambs delivered and fed by the ewes in the flocks at the Research Center died during the first 2 weeks of life. In the group of lambs fed dried whole milk from birth (table 11) 5 of 12 died between the eighth and thirty-fifth days whereas in a group of 11 lambs similarly fed and housed except that they received ewe's colostrum (table 15), only 1 died during the suckling or milk-feeding period.

Although in each group of lambs there are uncontrolled factors such as breeding, the results warrant the conclusion that, at least under the conditions and environment that prevailed during these experiments, lambs need homologous colostrum or its equivalent. Since, in a group of 7 lambs that were fed sheep serum as a colostrum substitute and dried milk thereafter, only 2 died as compared with 5 in a group of 12 that received dried milk alone, it may be concluded that sheep serum is at least partially successful as a substitute for colostrum.

Losses in the groups of hand-fed lambs seem somewhat high until they are compared with the total losses among lambs in the flocks at the Research Center during the same season. The latter losses amounted to 9.6 percent during the first 2 weeks after birth and to an additional 6.2 percent from 2 weeks to 4 months of age. These losses were greater than usual and suggest during this particular season the presence of some unfavorable factor, probably bacterial, among all lambs.

SUMMARY AND CONCLUSIONS

Studies were made on 13 newborn foals and 68 lambs with respect to the importance of colostrum in their development, the use of certain substitutes for homologous colostrum, and the use of mixtures of dried cow's milk as substitutes for homologous milk. These studies were carried on at the Agricultural Research Center, Beltsville, Md.

During the first 18 hours after birth, seven of the foals were fed, as a substitute for mare's colostrum, 1,000 cc or more of horse serum incorporated in a mixture of dried whole cow's milk, dried skim milk, sugar, and water. These foals suffered no apparent ill effects from failure to receive colostrum. Four of these foals received fresh serum, and the other three received serum that had been dried at room temperature under atmospheric pressure. Both serums appeared to give equally good results.

Three foals fed only the dried-milk mixtures as a substitute for dam's colostrum developed symptoms commonly associated with joint ill and died within 2 weeks after birth.

Three foals were fed known quantities of mare's colostrum. Studies were made of the changes in protein fractions of the blood serum of these three foals, of the three that received the dried-milk mixtures, and of five that received horse serum incorporated in the dried-milk mixtures. These studies indicated that when 1,000 cc or more of horse serum was ingested by a foal during the first 18 hours after birth, sufficient globulins were absorbed to produce an increase in

serum globulins that was easily demonstrated by the ordinary methods of protein fractionation. In the foals receiving no colostrum or substitute, there was either a decrease or only a slight increase in total serum globulins.

Six of the foals that received the colostrum substitute of horse serum incorporated in a dried-milk mixture also received the dried-milk mixture as a substitute for mare's milk during the first 24 weeks. These six foals were healthy and vigorous and grew at a rate that compared favorably with that of foals suckling their dams.

Because of the small number of foals used and the differences in breeding, no definite conclusions can be made regarding the comparative rates of growth of colts suckled by their dams and of colts fed the dried milk mixtures. However, the studies show that the use of colostrum or a suitable substitute is essential to the animal, that horse serum incorporated in a dried-milk mixture can be used successfully as such a substitute, and that a cow's-milk mixture such as the one used in the experiments is a satisfactory substitute for dam's milk. In the practical feeding of foals, the addition, to the milk mixture, of cod-liver oil or some other concentrated source of vitamins A and D is considered advisable.

Of the 68 lambs used in the experiments, 7 were fed fresh sheep's or goat's milk as a substitute for colostrum. Only two of this group survived beyond the seventh day.

Seven of twelve lambs fed from birth a mixture of dried whole cow's milk and water survived and made a good rate of growth.

A third group, containing 11 lambs, was fed cow's colostrum as a substitute for ewe's colostrum. Four of these lambs were fed ewe's milk after the second day and all survived. Seven of them were fed the mixture of dried whole cow's milk and water after the second day. Three of these died of nephritis at 8 weeks of age or less. The kidneys of all animals that were fed cow's colostrum showed marked damage at autopsy.

Studies made on serum-protein fractions of nine of the lambs fed either cow's colostrum or the dried-milk mixture in place of their dams' colostrum indicate that cow's colostrum, when ingested in sufficient quantities by the newborn lamb during the first 24 hours after birth, effects a marked increase in the serum globulins of the lamb. It is suggested that the absorption of the foreign protein from cow's colostrum may be a factor in the kidney damage observed in the animals fed such colostrum. This damage was most marked in those animals subsequently fed dried cow's milk.

In a fourth group, consisting of seven lambs, that were fed during the first 24 hours a sheep serum incorporated in the whole-milk mixture, followed by the milk mixture in place of dam's milk, only two died during the first 2 weeks. The percentage of survivals was larger than was obtained with the substitution of cow's colostrum for ewe's colostrum and the use of a similar dried-milk mixture thereafter.

Thirty-one lambs, after being allowed to suckle colostrum from their dams, were fed mixtures of dried cow's milk and water. Of 11 of these lambs fed a mixture of dried whole milk and water, 10 remained healthy and made excellent growth. Of 11 fed a dried-skim-milk mixture, only 5 survived for the entire feeding period and these suffered from frequent diarrhea. In a group of nine lambs,

neither the addition of cod-liver oil to a skim-milk mixture nor the further addition of tomato juice, iron, and copper appeared to effect a marked improvement in the condition of the animals over that observed in those fed skim milk alone.

The experiments indicate, therefore, that lambs, as well as foals, need homologous colostrum or its substitute. In the feeding of lambs, sheep serum appears to be at least a partly successful substitute for colostrum. The experiments also indicate that lambs and foals grow well on a mixture of dried whole cow's milk and water fed in place of the milk of the dam.

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