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Breeding, Housing, and Feeding Management[1]

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Abstract

The rate of calf mortality increases with increasing herd size unless a specialist is involved in calf raising; then there is a drop in the death rate. Breeds of larger dairy cattle have more difficulty calving, and this appears to result in a high calf mortality rate at or soon after birth. Sires differ in respect to size of calf produced, and it behooves the dairyman to use care in selecting sires to mate with heifers. Calves from the breeds of smaller cattle appear to possess less antibody protection. They typically have a higher incidence of diarrhea.

Providing an acceptable relative humidity and adequate air movement is more important than ambient temperature in the colder climates. More research relative to environmental requirements of the calf, independent of human comfort, is needed. The importance of the mother's first colostrum soon after calving and mothering by the dam is emphasized.

Liquid diets including the advantages of high fat diets and the feeding of acidified colostrum are discussed. Recent research on liquid concentration, amount, temperature, and frequency of feeding is reviewed. Once daily feeding of 3.18 kg of liquid consisting of 12 to 18% solids, fed either cold or warm, is recommended for replacement Holstein calves weaned at 21 to 28 days.

Introduction

Despite the vast amount of information available on nutrition and management, calf death losses in the United States are excessive. Recent increases in herd sizes have accentuated calf health problems.

Reports published in the United States between 1904 and 1960 indicated that postnatal deaths from birth to 6 mo of age were at least 15% (6). More recent studies show little improvement in spite of the research and extension effort since 1960. Death losses continue to be greater in the larger herds (Table 1).

In a 1973 report of 379 Michigan herds, Speicher and Hepp (93) reported annual calf losses of 9.7% in herds of less than 25 cows and 16.6% in herds over 85 cows. When the herd operator cared for calves, losses approached 13%; but when hired labor assumed this reponsibility, losses increased to more than 20%. (Table 2). Losses were considerably

TABLE 1. Dairy calf losses in Michigan.[a]

Herd size	Farms	Calves per farm	Calf mortality (%)
< 30	48	26	12.1
30-49	119	39	13.7
50-69	69	58	13.4
70-99	32	80	15.3
> 100	13	115	18.4
Total or av.	281	50	14.2

[a] Speicher (92).

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TABLE 2. Relationship between person(s) caring for calves and calf mortality on 378 Michigan dairy farms.[a]

Person providing care	Farms	Calf mortality		
		Winter	Summer	Annual
		(%)		
Operator	171	16.2	10.0	12.8
Operator & others	158	16.5	10.6	13.3
Hired labor	25	28.1	12.4	20.1
Mother or wife	25	15.0	9.4	12.3

[a] Speicher and Hepp (93).

TABLE 3. Comparison of calf mortality in Illinois and blood plasma content of immune globulins (Ig) in England.

Breed	% Calf mortality[a]	Blood plasma Ig level[b]
Ayrshire	4.2	High
Brown Swiss	10.5	...
Holstein	13.1	Medium
Guernsey	18.2	Low
Jersey	16.9	Lowest

[a] Johnson and Harpestad (41).
[b] Penhale and Christie, cited by Roy (81).

higher in winter than in summer.

On too many farms, caring of calves is simply a nuisance job. As a herd becomes larger, it is easy to turn this chore over to the hired help. Only when the herd becomes so large that a specialist is involved in calf raising do we see a lowering in death rate. In a nationwide survey of 36 large dairies of 500 or more cows, calf death rates were 6.1, 6.8, 7.5, 8.9, and 10.1% in the East, Southwest, Southeast, Midwest, and West (94).

Illinois research (41) confirms earlier results that herd size is important. Herds of less than 60 cows had a calf death rate of 12.5%, and larger herds averaged 15.1%. Further, the death rate was 70% greater in herds with a herd production average of less than 182 kg fat (18%) compared to those over 226 kg (10.6%). Breed differences also were apparent (Table 3).

These statistics suggest that healthier calves and low mortality rates are related to good management. Attention to the probable size of the potential calf in mating the dam, adequate facilities, and improved feeding and management are essential in minimizing calf losses.

Calving Difficulty and Calf Size

Calving difficulty increases calf mortality for cattle of both dairy and beef origin (50). Of 298 Brown Swiss bred to Brown Swiss bulls, 13% had difficulty calving. Death rates of calves at or within 24 h of birth averaged 5.3% when the dam had no calving difficulty and 21.9% when there was difficulty.

Crossing of breeds differing in size of animal produces a higher incidence of calving difficulty. Iowa workers (10) reported a calving difficulty score of 3.2 for crossbred animals compared to 2.8 for straightbred animals (on a 1 to 17 point scale). Three-fourths of the cows calved without assistance, 10% required only manual help, chains were used on 8.7%, and 6.2% of the cows calving required a chain and jack. Difficulty scores in Holsteins increased nearly two-thirds unit for each additional kilogram of calf birth weight when the dam's pelvic depth and the calf's hip width were held constant. One extra centimeter of depth in the pelvic opening of Holstein cows reduced the calving score by nearly .5 unit when other variables were held constant.

Size of sire breed has considerable influence on calf size (10). Reduced size would decrease calving difficulty. Birth weights and calving difficulty scores on Holstein and Brown Swiss cows mated to Holstein, Brown Swiss, Angus, and Hereford bulls are in Table 4. Calving difficulty scores by Holstein cows mated to bulls of different breeds were reported. In comparison to Holstein sires, Angus lowered, Hereford maintained, and Brown Swiss bulls increased calving difficulty.

Monteiro (60) reported that Jersey cows had less calving difficulty than either Ayrshires or Holsteins in a study involving all possible crossbred combinations (Table 5). He concluded that the larger breeds of cows had more calving difficulty than the smaller breeds because their calves were larger in comparison to the size of the cow. Purebred Holstein, Ayrshire, and Jersey calves were 8.25, 7.89, and 6.86% of their dams' size.

According to Oxender et al. (74), calf mortality between birth and 60 days of age averaged 17.7%, accounted for by: calves born dead or dying during birth, 6.4%; calves dying between birth and 14 days of age, 8.5%; and calves dying between 2 wk and 2 mo, 2.8%. This means that 5 of 6 calves lost died before 2 wk of age. Both BreDahl (10) and Speicher and Hepp (93) reported that three-fourths of the calf deaths occurred before 10 days of age.

What proportion of these deaths may be attributed directly to calving difficulty is not known. Death prior to, or at, calving seems to occur more frequently in the breeds of larger

TABLE 4. Influence of breed on calf size and calving difficulty.[a]

Breed of dam	Trait	Sire breed			
		Angus	Hereford	Holstein	Brown Swiss
Holstein	Birth wt (kg)	37.8	38.9	39.5	42.6
	Calving score[b]	2.6	3.0	2.9	4.7
Brown Swiss	Birth wt (kg)	35.1	36 7	41.7	40.5
	Calving score[b]	1.9	1.8	2.4	2.6

[a] BreDahl (10).
[b] Avg scores, based on a 1 to 17 point scale.

animals, especially when the dams are first calf heifers. Other factors contribute to high mortality immediately after calving. According to a survey of dairymen (74), diarrhea (70% of the herds) and pneumonia (41% of the herds) are indicated as major health problems in young calves.

Genetic Aspects

The genetic effect on susceptibility of calves to disease is not well documented. Roy (81) has indicated Jersey and Ayrshire calves have a higher incidence of diarrhea than Holstein. Moreover, these breeds have a lower protein digestibility and retention at the same intake per metabolic size than Holstein. On the other hand, Ayrshires seem to be less susceptible, when challenged, to respiratory infections (57%) than either Holsteins (81%) or Jerseys (86%).

Touchberry (98) showed that fewer Holstein than Guernsey calves die just after birth. Johnson and Harpestad (41), surveying Illinois DHI herds, found that calf mortality was higher in Guernsey (18.2%) and Jersey (16.9%) herds than in Holstein herds (13.1%). Brown Swiss herds lost 10.5% of their calves while Ayrshire herds lost only 4.2%.

TABLE 5. Relative size of calf and dam, and the frequency of calving difficulties.[a]

Breed of dam	Calves	Sire breed	Calving difficulty (%)	Relative size[b] (%)
Holstein	70	Holstein	40.0	8.25
	24	Ayrshire	12.5	7.85
	80	Jersey	1.3	6.97
		Mean[c]	17.9	
Ayrshire	35	Holstein	25.7	8.68
	82	Ayrshire	8.5	7.89
	33	Jersey	3.0	7.24
		Mean[c]	12.4	
Jersey	69	Holstein	15.9	8.91
	23	Ayrshire	.0	8.62
	42	Jersey	.0	6.86
		Mean[c]	5.3	

[a] Monteiro (60).
[b] Relative size = (100) av calf weight/av dam weight.
[c] Calculated from tabular data.

Several factors influence the content of immune globulin in colostrum and its effectiveness in disease prevention. Kruse (47) reported significant differences among breeds in the content of immune globulin in their first milk. Red Danish colostrum was lowest and Black and White Danish highest, with Jerseys intermediate. Mortality rates in Illinois and concentrations of blood plasma immune globulins in cows of these same breeds in England nearly parallel one another (Table 3).

Tennant et al. (97) found serum gamma globulins in 1-day-old Jerseys were twice as high as for Holstein calves. Since they found that losses due to neonatal diseases had been greater for Jerseys than Holsteins, they speculated that Jerseys may absorb more during the same period or that Holsteins had greater amounts of gamma globulins specifically related to immunity, or that absorption of gamma globulins may inhibit the ability of the calf to respond immunologically to various antigens.

When deprived of colostrum, British Friesian and Shorthorn calves did not differ in days of scours (2 to 3) and mean age at death (3 to 4) (7).

TABLE 6. Influence of breed of sire and dam on calf mortality.[a]

Breed of sire	Breed of dam	Calf mortality (%)
Holstein	Holstein	15
Holstein	Guernsey	11
Guernsey	Holstein	5
Guernsey	Guernsey	29

[a] Touchberry (98).

TABLE 7. Calving difficulty, by parity of dam and sex of calf.[a]

Dam	Sex of calf	Calving difficulty code[b] 1	2	3	4	5
		(%)				
Mature	M	81.3	8.3	6.5	2.8	1.1
	F	91.2	4.1	3.6	.8	.3
2nd calf	M	72.7	9.0	12.2	4.3	1.8
	F	87.9	6.9	3.6	1.3	.3
1st calf	M	52.4	10.4	20.8	10.4	6.0
	F	62.5	9.7	19.8	5.2	2.8

[a] Peissig (76).
[b] (1) = No problem, (2) = slight problem, (3) = needed assistance, (4) = required considerable force, and (5) = extreme difficulty.

Touchberry (98), from a 20-yr crossbreeding study of Holsteins and Guernseys, reported fewer crossbred than purebred calves dead at birth or within 24 h of birth (Table 6). The USMARC study (50) of Hereford and Angus cows yielded the same conclusion. Touchberry showed that fewer Holstein than Guernsey calves die just after birth. These results agree with an Illinois DHI survey (41).

Laster (50) demonstrated higher calf losses from 2-yr-old cows than from older cows receiving no assistance at calving. This suggests that a portion of the 2-yr-old cows not assisted may have needed assistance and that stress and injury of the calf may be responsible for increased calf mortality.

The sire of choice within a breed may contribute to the mate's difficulty in calving and to the offspring's livability, especially from a first parturition. Limited data to test the validity of this hypothesis follow.

Field study. The need for specific information on differences between bulls in their transmission of difficulty at calving and calf size is evident, particularly in deciding which bulls should be used on heifers. In 1971, Midwest Breeders Cooperative initiated a program to evaluate their bulls and to recommend to the membership those bulls that should or should not be used on heifers (76). An added benefit of this program may be a reduction in the use of beef sires on heifers, which materially reduces the potential for genetic improvement of the dairy herd.

TABLE 8. Calf size, by age of dam and sex of calf.[a]

Dam	Sex of calf	Calf size code[b] 1	2	3	4	5
		(%)				
Mature	M	.3	4.4	44.5	39.8	11.0
	F	1.3	8.0	62.8	25.1	2.8
2nd calf	M	.0	7.5	50.2	33.3	9.0
	F	2.0	13.2	62.3	21.5	1.0
1st calf	M	1.6	15.8	53.0	23.3	6.3
	F	3.5	22.2	55.2	16.3	2.8

[a] Peissig (76).
[b] (1) = Very small, (2) = small, (3) = average, (4) = large, and (5) = very large.

TABLE 9. Selected sample of bulls, with recommendations on mating to heifers.[a]

Sire group	Sire	Calves	% 3, 4&5 difficulty[b]	Average difficulty score[c]	Calf size ratio[d]
NO group	Ben	116	46	2.53	107
	Doall	319	52	2.52	104
	Image	128	53	2.43	108
	Joliam	110	48	2.16	108
	Matt	211	38	2.05	101
YES group	Maple	131	19	1.60	98
	Captain	155	20	1.60	97
	Burkgov	323	21	1.67	99
	Falcon	266	25	1.68	101
	Basil	221	22	1.69	96

[a] Peissig (76).
[b] See footnote, Table 7.
[c] First calf heifers only.
[d] Progeny means adjusted for variation in distribution of age of dam and sex of calf, then expressed as a percentage of the stud breed average.

A summary of the information collected on 5,958 calves by March 1, 1973 is in Tables 7, 8, and 9.

Calving difficulty is an important factor for younger cows, especially first calf heifers (Table 7). If a calving difficulty score of 4 or 5 represents serious problems, then mature cows with female calves have few problems (1.1%) whereas 16.4% of the first calf heifers with male calves encounter problems. Nearly a third of all first calf heifers had a calving difficulty score of 3 or higher.

The relationship of calf size to age of dam and sex of calf is illustrated in Table 8. Even though calf size was a subjective evaluation in this study, male calves were larger than females, and calves from heifers were appreciably smaller than calves from older cows, regardless of the sex of calf.

A selected sample of Holstein bulls is listed in Table 9, half of which are recommended for mating to heifers and half of which should be avoided. Only bulls having more than 100 calves reported were chosen for illustration. Note that from the avoided group of bulls, nearly half of the mates had a calving difficulty score of 3 or higher and that the mean calving difficulty score of first calf heifers averaged 2.34. Only a little more than a fifth of the cows mated to the recommended group had a calving difficulty of 3 or higher.

The calving size ratio was calculated by adjusting the calving size estimate for variation in the distribution of age of cow and sex of calf, and then dividing by the breed stud sire average and multiplying by 100. All except one of the bulls in the avoid group sired calves that were considerably above average size.

While not shown in tabular form here, there is little evidence that small cows experienced more difficulty in calving than large cows. Small cows appear to have smaller calves, indicating a direct correlation of reasonable magnitude between size of cow and size of calf.

To summarize this portion of the paper; calving difficulty does influence calf livability. Since sires differ in size of calves produced and difficulty of calving, it behooves the dairymen to use care in his selection of sires, especially when mating heifers.

Environmental Aspects

Appleman and Owen (6) reviewed research on the engineering aspects of raising young calves in 1971. Factors discussed included air temperature, humidity, ventilation, and animal space. The conclusions were that an air temperature between freezing and 21 C was satisfactory; that in warm weather, air movement up to 8 km/h was desirable, but that excessive wind concurrent with cold conditions should be avoided; and that a relative humidity in excess of 85% should be avoided. The latter is because condensation and damp bedding have deleterious effects on calf health.

Recent publications summarizing experimental studies of environmental aspects of calf raising are limited. The papers presented at the 1970 meeting of American Society of Agricultural Engineers and in the proceedings of the 1973 Dairy Housing Conference represent most of the recent research.

Hastings (32) believed that in winter conditions, relative humidity is more important to calf health than temperature. He cited previous work by Dunklin and Puck (24) which indicates that a relative humidity between 50 and 60% is more lethal than either the more humid or less humid atmosphere. Roy et al. (84) found that when calves were raised in a 15 C environment, incidence of lung lesions increased with increasing relative humidities. In a 23 C environment, lung lesions occurred less frequently with increasing relative humidities. They concluded that extremes in relative humidity have a minimal effect in predisposing lung lesions when calves are reared in a 17 C environment. Hastings (32) compared these laboratory results to field observations in which beef cattle on pasture naturally seek out areas of less humidity, thereby reducing the chance for chilling, even though there may be more wind. His experience with cold climates suggests that it is best to set the thermostat at just below 0 C, thereby allowing the humidity to crystallize out and not hinder the normal insulation of the animal's haircoat. He concluded that calf housing should be directed more toward the protection of the calf from severe extremes rather than from normal seasonal variations in which the animal's haircoat and natural instinct provide protection.

Hastings (32) emphasized the need for proper ventilation. Air movement is needed to remove moisture. Anderson (4) also stressed the need for positive ventilation with only tempered fresh air.

Smith (90) concluded that the air flow rate in barns for 45 to 136 kg calves should be .40 m^3/min per calf in winter conditions (< -7 C), .91 m^3/min in mild climates (-7 to 10 C), and 3.40 m^3/min in warm weather (> 10 C).

Boyd (9) recommended .0063 m^3/min per kg of animal for winter ventilation. This would be equivalent to the ventilation rate for a 64 kg calf in Smith's calculations. For summer ventilation where natural cross ventilation is not practical, Boyd recommended .125 m^3/min per kg of calf.

Ventilation rates indicated by both Smith and Boyd are for calves raised in enclosed insulated structures, presumably artificially heated. Willett et al. (104) have successfully reduced calf mortality by calving out-of-doors in the fall, raising calves in portable outdoor hutches, and arranging the calving schedule so that the calf raising facilities are vacant from 1 to 3 mo each year. Both Willett et al. (104) and Jorgenson et al. (42) indicated that the housing system (outdoor hutches versus conventional barns) was not an important factor influencing either calf growth or incidence of health disorders.

Research capability. More research is needed relative to ventilation and humidity requirements in enclosed housing, whether it be cold or warm. Too many reports are simply characterizations of operational conditions and the results thereof. There has been little controlled experimentation of facility needs, presumably because of the high cost in constructing multiple systems. Martin (58) has described a replacement animal research center at Fabius, N.Y. that incorporates a single heated and ventilated facility for small calves in elevated stalls. Cornell workers have recently constructed similar facilities (101). Larsen et al. (49) in Wisconsin built a cold barn utilizing ground level .61 × 1.22 m tie stalls.

The northern United States state agricultural experiment stations were surveyed to determine their capability to conduct comparative environmental studies at a single location whereby feeding and management practices could be standardized. Replies describing 28 different research facilities were received. Only five (Delaware, Indiana, Minnesota, New York, and Wisconsin) indicated a capability for replicated experimentation in which temperature, humidity, and/or ventilation could be controlled variables.

Pen construction. The size and style of pen used to control the small calf may vary from elaborate, expensive structures to improvised pens made from straw bales. The floor area requirement is dependent on (a) whether bedding is to be used, (b) frequency that bedding is added and removed, and (c) humanitarian considerations. Roy (82) found no difference in performance between calves kept on wooden slats or on bedding.

Boyd (9) stated that in a cold barn setting utilizing a manure pack, the pen should have three solid sides and contain 1.86 to 2.32 m^2 per calf. Solid sides prevent drafts and provide isolation.

Appleman and Owen (5) noted that calves kept in 1.86 m^2 metal pens had a higher scours index, consumed less starter feed, and grew at a slower rate, whether the growth standard be wither height or body weight, than those calves housed in 2.42 m^2 wooden pens. Calves in the larger pens spread their excreta over a larger area and have dry bedding for a longer period of time.

Dimensions of individual calf elevated stalls or free stalls for groups of small calves are frequently on the order of .61 × 1.22 m. Young et al. (110) found that when given a choice, 68 kg calves preferred 66 cm width stalls over 56 cm and that both were preferable to 46 cm stalls. Calves expressed no preference between slotted and steel screen stall floors. However, a difference in preference of bedding materials was significant. The descending order of preference was: sawdust (34.4% utilization), straw (19.4%), wood slats (18.1%), and steel screen (16.5%). Further, they indicated that in winter calves had a marked tendency to avoid areas under the ridge ventilator or near open doors.

Recommendations regarding calf pen construction frequently suggest that pen walls should be solid to prevent excessive drafts and to prevent suckling of one another. Roy (82) prefers mesh partitions, suggesting that calves are more contented when they see their neighbors.

Liquid feeding devices. Various methods have been devised for dispensing liquid diets to calves. The simpliest consists of open-pail feeding. Most other methods involve use of a nipple feeder.

Although devices with nipple attachments more closely simulate the natural method of calf feeding, research and field evidence has not shown this method is superior to open-bucket feeding of replacement calves on restricted liquid feeding programs.

Several studies have evaluated nipple and open-pail feeding (17, 36, 43, 74, 108). A recent survey of Michigan herds revealed no significant difference in mortality of calves in 185 herds using open-pails versus 126 using nipple bottles (74).

Wise and LaMaster (108) compared these two systems. In the first trial, calves were fed milk at 7% of body weight to 14 days, then 10% to 56 days. No treatment effects on weight gains, health, or physical appearance were noted. The incidence of diarrhea was low but higher for nipple-fed calves.

The second trial involved a restricted group fed at 14 to 18% of body weight and another group fed unrestricted amounts of milk. Incidence and severity of diarrhea were greater for calves fed from the bucket, especially with unrestricted amounts of milk. Calves fed ad libitum consumed 20 to 21% of body weight during the first 2 wk.

Kesler et al. (43) also reported no benefits in growth or scours prevention from nipple feeding compared to feeding by open-pail. In one trial they found the open-pail was superior to a nipple bottle in promoting growth. Intake time averaged 3.82 min for the nipple fed calves and .87 min for pail fed calves.

Australian workers (36) compared nipple and pail feeding over several years. They used 10% of body weight of whole milk to 14 days of age at which time a shift was made to skim milk, and the amount gradually increased to 16% of body weight at 14 wk. They concluded that gains in weight and disease problems were not appreciably different for the two methods of feeding. Calves learned to drink in about the same time (three feedings) with the nipple or open-bucket. The only advantage for the nipple was in a reduction of calves suckling on other calves handled as groups. Disadvantages were increased time of feeding from 1 to 3 min to 9 to 14 min with .16 cm orifice nipple, frequent bloating from ingesting air via the nipple, and a more demanding job to clean and sanitize the nipple feeders. Occasionally milk may pass into the lungs and cause pneumonia if the feeder is too high (17).

Nipple feeding is, therefore, recommended only for veal calves which must consume large quantities of liquid diet and possibly for mechanized systems of feeding replacer calves.

Results from use of automatic liquid feeders have been reviewed by Roy (82). The two basic types of feeders are those designed for groups of calves and those for individually penned calves. Roy concluded that the advantage of the group feeders is saving labor, and major disadvantages are (1) weaker calves may get insufficient access to machine, (2) individual observation of intake is not possible, (3) greater possibility of cross infection, (4) inability to adjust intake of calves with diarrhea, and (5) extreme variation in performance, making this method unsuitable for veal production.

Individual automatic feeders offer more uniform performance through better control of intake and individual observation. However, due to complexity and cost, these systems may be practical only for the specialized, intensive calf grower.

Roy (81) pointed out that the psychological environment cannot be underestimated. For example, he reported that calves given colostrum artificially in the presence of the dam absorb more immunoglobulins than calves given the same amount of colostrum but raised in isolation. Albright and Alliston (1) pointed out that calf feeder and watering systems must be placed where the inexperienced animal can find them readily.

Gramling et al. (31) indicated that calves vary in their rate of learning, that younger animals seem to learn quicker, but older calves recover from an incorrect response more rapidly. Donaldson et al. (23) studied the effect of rearing experience (18 wk) of 36 calves on later behavior as cows. Groups 1 through 4 were (a) fed and raised separately, (b) fed separately and raised together, (c) fed and raised together, and (d) fed together and raised separately. They found that milking parlor behavior did not differ significantly but that Holstein cows which had been fed and raised separately as calves produced more milk. Calves raised together were more vocal as parturient cows, ignored and did not protect their young, only partially cleaned them, and failed to allow nursing.

Nutrition of the Dam

Calf mortality and health are influenced by the dam's nutrition during gestation (38, 64).

A recent summary published by the National Research Council (64) suggests that increased mortality and morbidity can result from deficiencies of energy, vitamins A and D, iodine, phosphorous, manganese, cobalt, molybdenum, and selenium. A prenatal deficiency of protein seems unlikely to be a factor in calf health. Raising dairy heifers on restricted energy from birth to first calving (65% of requirement) appears to increase dystocia at first parturition. In older cows a deficiency in late gestation could restrict calf size sufficiently to reduce postnatal survival.

Of most practical concern in the United States are deficiencies of vitamin A, and of phosphorus and iodine in the Midwest (64). A deficiency of any of these may result in birth of weak calves. Calves from dams with inadequate vitamin A diets may also be blind, have diarrhea, and muscular incoordination.

Attempts to reduce diarrhea and decrease calf mortality by feeding or injecting the gestating cow with vitamin A have not been successful (99).

Immunoglobulins. The vital importance of dams' colostrum as a factor in protecting calves from immediate disease hazards after birth is well documented. The protective value of colostrum is attributed mainly to its immune globulin content and its systemic effects. However, local protective effects within the intestine have also been reported (55, 59).

Immune globulin content of colostrum is highest in first drawn milk after parturition and declines to little by the fourth milking. If a cow is milked prepartum, her colostrum will be much lower in immune globulins than normal (83), and it will be higher in milk of older cows and cows with longer dry periods (91).

Selman et al. (86) showed that calves had higher serum immunoglobulins when receiving colostrum from their dams than from a bucket. Furthermore the 48 h immunoglobulin values were higher for calves that were mothered compared to those housed separately and simply reintroduced to suckle their dams twice daily (87, 88). It appeared that absorption was enhanced by the mothering effect.

In a farm survey Selman et al. (86) found that 76 calves bucket-fed colostrum <6 h after birth had higher immune globulin than 88 calves receiving first colostrum >6 h after birth.

A survey of 418 dairy herds in Michigan (74) revealed lower death losses (7.6% vs. 10.5%) during the first 2 wk for calves receiving colostrum within 6 h after birth compared to 6 to 12 h. Mortality was no greater, however, for herds feeding colostrum only 1 day compared to 2 or 3.

The amount of immunoglobulin absorbed is influenced by the amount fed, age of calf, and birth weight (14, 45). Bush et al. (15) reported that approximately 50% of the variation in blood immunoglobulin concentration was associated with the amount of colostral immunoglobulin consumed by the newborn calf.

The percent of ingested colostrum absorbed is mainly influenced by age. Absorption of ingested colostral antibodies declines sharply from birth to 24 h (29). Absorption of immunoglobulin is estimated at between 25 to 45% (14, 91) for the first feeding after birth. The importance of feeding the calf first milking colostrum soon after birth was pointed out by Smith et al. (91). He calculated that 10.89 kg of third milking colostrum would be needed to provide the same protection as 1.81 kg of first milking colostrum. This is based on an assumed 12.5% absorption (½ as much as for first colostrum [25%]) and a concentration of one-third as high an antibody level.

Recommended amounts and procedures for colostrum feeding vary. Kruse (46) suggested drying off the cow 4 wk prepartum and feeding 2 kg colostrum within 5 h after birth. Staub (95) found that at least 1000 ml colostrum must be fed during the first 12 h postpartum to attain maximum titers of antibodies specific for parainfluenza and IBR. Roy and Ternouth (85) suggested feeding under adverse conditions at least 7 kg colostrum collected during the first 24 h after parturition.

Liquid Diet

The calf can utilize effectively various types of liquid diets. Recommendable liquid feeds for the young calf include colostrum, milk, and properly formulated milk replacers. Skim milk, whey, and buttermilk, both fluid and dried, are sometimes used but require supplementation to be satisfactory for starting calves. Because of their deficiencies, they are more appropriate as ingredients in replacer formulas.

Colostrum. In addition to its value in protecting the calf against disease, colostrum is also a highly nutritious food for the baby calf. Colostrum is approximately twice as high in total nutrients and is especially high in protein, fat soluble vitamins, and certain minerals (82). The composition of colostrum shifts abruptly toward that of normal milk usually during the first 2 to 4 days.

Until recently much of this colostrum was discarded. However, during the last few years interest has developed in making more complete use of the available colostrum for calf feeding. It has been preserved by freezing or by allowing it to acidify through natural fermentation at room temperature.

Research reviewed earlier (82, 107) demonstrated that colostrum can successfully replace whole milk but may increase the incidence of scours. Although the resulting scours did not appear to be detrimental, several researchers believed the problem was minimized by diluting colostrum with water or skim milk.

Wing (107) combined 20% solids dried skim milk with colostrum (1:1) and increased gains 30% compared to 13% solids skim milk.

Whole milk and colostrum (preserved by freezing) was compared in Nebraska experiments. Colostrum improved growth rate and reduced scours (71). The benefits to gains were mainly for male calves. Colostrum fed calves averaged 52% greater gains in weight at 3 wk of age. Although the benefit to growth was evident several weeks beyond weaning, it appears unlikely that this effect, of itself, is of any ultimate value. However, increased growth during the first several weeks appears indicative of a more vigorous and healthy animal. Muller et al. (62) also found that colostrum greatly improved weight gains, percentage-wise, during the first 3 wk, but colostrum-fed calves consumed less starter during the milk feeding period, so total gains to 4 wk were only slightly higher for colostrum fed calves. Ad libitum feeding of a mixture of 1st and 2nd day colostrum resulted in less total intake and 30% less weight gain than for ad libitum whole milk (56). Neither caused diarrhea.

Swannack (96) reported the use of colostrum which was allowed to sour naturally for up to 25 days. He compared this colostrum (average age, 14 days) with a high fat (17%) milk replacer and a combination of colostrum and milk replacer alternating with colostrum. Calves were weaned when starter consumption reached .45 or .91 kg daily. All groups reached the same live weight at 84 days.

In a 1973 unpublished study (3) colostrum was collected and stored in plastic containers for 4 wk before feeding. Twenty Holstein calves were fed either colostrum or a commercial milk replacer twice daily to 40 days of age. In 4 wk the colostrum dropped in pH to 4.1; protein also declined markedly over several weeks of storage. The colostrum was mixed 1:1 with warm water and fed at a 2.27 kg per feeding. Calves fed colostrum had a lower incidence of scours and gained about twice as rapidly. Both males and females averaged about 454 g per day gain on the colostrum. However, compared to milk replacer, colostrum feeding improved male performance much more than female performance in both weight gain and scours prevention. This study with fermented colostrum confirms previous findings at Nebraska of colostrum stored by freezing (71).

Skim milk was soured with *Str. cremoris* or with *Str. durans* and Bulgarian sour milk and fed to calves from 21 to 150 days (89). Those receiving this soured milk scoured less and utilized their feed better, but weight gains were not different.

Recently the popular press has reported accounts of farmers who are feeding calves on fermented colostrum. Some apparently dilute the material with water before feeding.

If colostrum is utilized as the fermented product, it seems important to take certain precautions to minimize potential hazards. Molds may produce dangerous toxins in this method. Therefore, the dairyman should mix colostrum collected over only a few days and use an innoculum of fermented colostrum to aid in starting a fresh batch. He should plan to feed fermented colostrum within about a week and avoid extended holding of this material, especially in summer. Some dairymen report success with storing colostrum in plastic garbage cans or other containers with a plastic liner. Each cow's colostrum is kept separate or together with that of others calving within 2 to 3 days. Prior to feeding the colostrum is mixed, then fed at room temperature.

When colostrum was held for 21 days at 30 C, enterobacteriaceae and coliform counts were higher than when it was stored at 4 or 18 to 25 C (75). Lactobacilli numbers and titratable acidity were also greater. Various experiment stations, including Minnesota, Arizona, Louisiana, Indiana, and South Dakota, have experiments in progress with fermented colostrum.

A Russian report (100) indicates that feeding calves colostrum from cows with mastitis can be disastrous. Calves given colostrum from cows with staphylococcal mastitis had a morbidity of 71%; colostrum from cows with *Streptococcus agalactiae* mastitis produced 50% morbidity and 20% mortality. Those fed colostrum from healthy carriers of staphylococcus and streptococcus had 25% and 27% infection rates.

Milk replacers. Large amounts of reconstituted replacers with dry matter concentrations of 18% and above may produce diarrhea. Thorough reviews of the principal nutritional factors in maintenance of calf health have been made recently (79, 83, 85). Roy and Ternouth (85) gave special emphasis to the concept that incomplete digestion of proteins may be a basic cause of diarrhea in the calf associated with feeding of replacer formulas which minimize curd formation. Such diets are those with severely heat treated proteins or high soybean protein. Excessive heating may denature 60 to 72% of whey protein and cause a loss in the solubility of calcium making it unavailable to participate in the coagulation reaction.

In feeding tests, prevention of curd formation by citrate addition to the diet has not caused any increase in the incidence of diarrhea or affected feces consistency (13, 68, 69). Neither has precoagulated milks or sour colostrum caused digestive upsets (3, 96). Nevertheless, recent results show reconstituted dried skim milk produced by a low heat process was voluntarily consumed in less amount and produced a nonsignificant lower gain in body weight (57). Others (26) also reported that calves given filled skim milk plus 2% ethylenediamine tetraacetic acid and 1.48% sodium carbonate had scours, whereas calves fed milk replacers which supported coagulation tended to not have diarrhea. Weight gains were directly related to clotting ability.

Specially processed soybean protein, fish protein concentrate, and certain other ingredients which produce little or no coagulation in the stomach have proved satisfactory sources of protein for young calves (30). Therefore, coagulability, per se, appears not to be an absolute quality requirement for replacer protein sources.

For some years, it has been recognized that 10 to 15% fat in the dry replacer would give protection against diarrhea. Recently, Lister (54) showed that increasing fat content of the replacer from 18 to 20.9% improved both calf health and rate of gain. Antibiotic treatments of calves were reduced from 112 to 48 during the first 19 days.

Concentration of nutrients. It is frequently recommended to dilute colostrum, milk from high-testing cows, and milk for feeding calves with digestive problems. However, controlled studies summarized earlier (6) have revealed no observable benefits from routine dilution of colostrum or Jersey milk and that total amount of solids is more closely related to diarrhea than is volume of diet or concentration per se. In one experiment, addition of 25% water to Jersey milk reduced gains when the milk was warm but not when fed cold (68).

Burt and Bell (12) found that feeding .17 kg or .26 kg of replacer in 1.14 instead of 1.70 liters of water twice daily reduced intake of concentrate and weight gain. Although free water intake was markedly increased by feeding 1.14 liters, total water intake was still below that for calves fed 1.70 liters. In both experiments 255 g replacer in 1.70 liters of water improved gains compared to 170 g in the same total liquid, especially when calves were weaned at 3 wk. Scours was no problem in these experiments.

Increasing replacer from 170 g to 425 g in 1.71 liters of water improved gains, decreased feces consistency and intake of concentrate ration (13). Diluting the 170 g of replacer in 2.85 liters of water had no beneficial effects compared to 1.71 liters of water but reduced concentrate intake and increased days of loose feces.

Hodgson (35) found that the amount of solid food eaten was not affected by differences in concentration of milk solids (10 or 20%), but dry feed intake was depressed by the amount of solids consumed in the liquid diet. Thus, certain combinations of replacer volume and concentration, which resulted in replacer solids intakes of 1.6% of body weight or more daily, restricted dry food consumption.

The concentration of solids in the liquid diet probably should range between 12 and 18% in milk replacers for early weaning programs. With lower concentrations such high intake is required to promote adequate growth that it may provoke diarrhea and depress starter intake. With low concentrations the calf would not consume enough to grow normally. If the concentration of solids is above 18 to 20%, limiting the amount sufficiently to avoid appreciable reduction in dry feed consumption may restrict water intake detrimentally.

Providing free access to water is a problem if young calves are to be raised in unheated barns or in outside hutches in a cold climate. More information is needed to determine the requirement for supplemental water under various conditions.

Albright et al. (2, 20) fed supplemental water to Group A calves for 40 days and to Group B calves only after the 30th day. Group A calves gained 2.45 kg more from birth to 40 days of age, consumed 19% more calf starter and 12% more hay. Group A calves on the average consumed just over 1.0 kg water per day during the first 30 days while receiving milk replacer. Calves from 4 to 10 days of age consumed more water daily (1.43 kg) than they did between 10 and 30 days (1.06 kg).

It is hypothesized that supplemental water may be advantageous in encouraging early intake of calf starter which is helpful if calves are to be weaned at 3 wk of age. Likewise, calves may require supplemental water if their liquid diet is undiluted colostrum. More research in this area of management would be desirable.

Temperature. A number of the early trials involving cold diets for calves were summarized by Roy (83). Consensus of these trials was that in moderate temperatures, cold liquid diets fed in restricted amounts were equally successful compared to warm diets. However, veal calves gained better and more efficiently on warm diets, especially in cold environments. The apparent reason for the lower rates of gain is the reduced acceptance of cold milk under conditions of ad libitum feeding.

Owen and Brown (68), using a factorial trial, evaluated warm (38 C) and cold (10 C) Jersey milk fed either diluted with 25% water or undiluted and with or without addition of sodium citrate to prevent curd formation in the abomasum. The overall effect of temperature on growth and health measures was nil; however, growth was superior for cold milk when the diet was diluted.

Radmall and Adams (78) found larger weight gains for Holstein calves fed cold (3 C) milk than for calves fed warm (33 C) milk when feeding both once or twice daily. However, during early weeks of the trial, calves fed cold milk had a greater incidence of scours.

In a recent Nebraska experiment (71) both colostrum and whole milk were compared warm (35 to 38 C) and cold (2 to 4 C) in a once-a-day feeding program. Results were generally equally good for the warm and cold diets. However, in terms of starter intake and gains, colostrum was superior when fed cold.

Clench (18) compared warm and cold milk substitutes in early weaning, once-a-day feeding programs and found them equally satisfactory. He reported that about 2.8 liters at one feeding was the upper limit for small calves. A report by Swannack (96) describes the successful use of cold fermented colostrum and a milk replacer in a once-a-day early weaning program. Shifting calves abruptly from the colostrum to the replacer several times was without apparent ill effects.

Flipot et al. (28) fed a milk replacer at 37, 18, and 1.5 C to Holstein veal calves at 10 to 15% of body weight or ad libitum. With limited intakes there was practically no effect on gains, but with ad libitum intakes, gains decreased at each lower temperature.

Frequency of feeding and amount of milk. Optimal liquid diets for early weaning programs have not been resolved completely. For reasons of economy and to induce early consumption of dry feed, whole milk equivalent of 8 to 10% of body weight has been used. This amount is sufficient to support a modest rate of gain (.3 to .4 kg per day) to 3 wk of age (39). Higher feeding is sometimes associated with increased problems from diarrhea, especially during the first 10 days of life and when milk replacers are utilized. Conversely, a number of researchers have given young calves high levels of nutrients during the early days of life without adverse effects (35, 56, 63, 108).

Although more milk in early weaning programs will produce faster initial gains, the effect will usually have dissipated by 12 to 16 wk of age (6, 16, 63).

Traditionally, calves have been fed their liquid diets on a twice-a-day schedule. To promote high intake, more frequent feeding is necessary. But, when feeding is restricted, as in conventional replacement calf raising programs, milk feeding only once daily has proved equally successful to twice-a-day feeding.

Initially, once-a-day feeding of the young calf was not successful whereas this system was satisfactory for older calves (82). This difference was apparently not due to health problems but to the lower milk consumption by the once-a-day calves.

In 1965, Owen et al. (72) found that feeding Holstein calves at a constant rate of 3.18 kg per day was equally successful to feeding 1.59 kg twice daily beginning at 2 days of age. Furthermore, by 84 days of age, calves fed by the once-a-day method and weaned at 3 wk of age had gained in weight and wither height at practically the same rate as calves fed twice daily to 6 wk of age. The main difference was a 40% higher starter consumption from birth to 42 days of age by the early weaned calves. Of 48 calves starting the experiment, only 2 were lost, 1 each on the 2 feeding frequencies. No differences in scours or other aspects of health were noted.

Since this study, numerous experiments and field observations on once-a-day milk feeding have been reported (18, 19, 27, 37, 40, 44, 53, 61, 73, 78, 109). Only one (109) has found the once-a-day system inferior. Wooden et al. reported reduced vigor, more pneumonia, and slightly more scours with the once daily program.

Khouri (44) fed 3 kg milk/day and weaned Friesian bulls at 5 wk of age in a comparison of a once versus twice daily feeding program. He noted equal starter intake during the milk feeding period and equivalent gains at 15 wk of age.

Johnson and Elliott (40) investigated effects of age at weaning on success of the once-a-day milk feeding program. They compared weaning at 24, 44, 64, and 84 days of age under once and twice-daily feeding regimes. Although preweaning total dry feed intake was only 3.6 kg for the calves weaned at 24 days, body weight changes with age were practically the same for all weaning age groups whether fed once or twice daily.

Clench (18), in a brief report, compared the weaning of calves on once-a-day feeding at either .45 or .91 kg of daily starter consumption. Eight to 10 days of liquid feeding were saved by weaning at .45 kg starter intake. However, reservations were expressed about weaning at only 10 days of age when some calves were consuming .45 kg of starter daily.

Calves weaned on the basis of starter intake (.45 kg/day) or gain (5.44 kg from birth) showed less of a growth check at weaning time than calves abruptly weaned at 21 days (70). However, gains in body weight and wither height (at 6 and 12 wk of age) were not significantly different for these weaning criteria.

Little work has been done to determine optimal milk to feed on once-a-day feeding programs. Leaver and Yarrow (53) compared 2.4 kg and 3.0 kg of milk daily for Friesians weaned at .4 kg starter intake. Weaning age was exactly the same (18.9 days) for both feedings. Gains and starter intakes for these groups from birth to 56 days of age were similar and not significantly different from those of calves weaned at 28 days. Amounts of 3.18 and 3.63 kg per day are commonly used for Holsteins with consistently satisfactory results (19, 72, 73).

Although about 8% of body weight is frequently suggested for calves in the 1st wk of life, more may not be detrimental. Conrad and Hibbs (19) fed whole milk free choice beginning once daily at 3 days of age to 43 calves without notable differences in number or severity of digestive upsets compared to calves given restricted milk. Consumption ranged from 7.26 to 13.61 kg of milk per day.

Frequency of feeding and amount of replacer. Numerous experiments have been reported in the last several years on the feeding of milk replacers once daily (21, 22, 25, 27, 29, 30, 48, 51, 52, 53, 77, 80, 102, 105, 106). Generally, results have been good, but compared to whole milk and colostrum, additional attention must be given to replacer quality, amount of feeding, and concentration.

Davis and Woodward (21) obtained slightly lower average gains and a higher incidence of scours in one trial with a low-to-medium quality milk replacer. Ten of 20 Jersey and Guernsey calves starting on the replacer formula died with no deaths occurring in the control group of 10 milk fed calves. In a second trial with a higher quality replacer, gains were again lower for replacer-fed calves, but scours and death losses were greatly reduced. They concluded that a 20% solids replacer fed at 6% of body weight resulted in more scours and lower grain intake than when fed at 4%.

Leaver and Yarrow (51) using Friesian calves evaluated replacer formulas with two percents of fat (4.3 and 16.8%), each fed at three amounts (320, 480, and 640 g per day). Higher fat produced a lower incidence of scours and improved the rate of gain. On the low fat diet 24% of the calves scoured compared to only 9% on the high fat diet. Since higher replacer also increased scours and reduced early starter intake, the authors recommended a small amount of high-fat replacer for once-daily feeding systems.

In a summary of several trials, Clench (18) concluded that once-a-day feeding was equal to twice daily feeding for either high- or low-fat replacers, warm or cold water for reconstitution, and outside or inside housing. He suggested 340 to 454 g of dry powder in not more than 2.8 liters of water for small calves.

After 3 yr of tests involving over 500 calves, Wilson (106) recommended that the usual 2.8 to 4.0 liters per day offered in two feedings be reduced 30% for once-a-day feeding. To accommodate the reduced volume, he suggested increasing the replacer concentration from 100 to 150 g per liter. This would result in feeding 2.0 to 2.8 liters of replacer with 18% solids according to these recommendations. He also has received reports of excellence from users following introduction of the once-a-day system into commercial herds.

When calves were weaned at fixed starter intake, the total amount of dry milk replacer consumed (ranging from 5.9 kg to 18.0 kg in three experiments) had only a minor effect on rate of weight gain to 56 days (53). Most calves were weaned between 20 and 30 days of age. In one of these experiments (52) increasing the replacer fed from 320 to 480 g increased by 2 to 5 days the days to weaning. Starter intake the week following weaning increased about 550 g per day for calves fed both the high and low milk replacer. However, as a percent of maintenance, calves on high replacer dropped more in energy intake after weaning than did those on lower energy.

Perks et al. (77) conducted seven trials using 215 Friesian and Hereford x Friesian calves to compare 340 and 454 g of milk substitute reconstituted with 2.8 liters of warm water. In 6 of 7 trials, calves fed once daily had gains and starter intakes prior to weaning greater or equal to those fed twice daily.

Feeding Holstein calves once daily 680 g of milk replacer solids in 4.76 kg total mixture resulted in more scours and calf losses (5 of 12) than 454 g solids (1 of 12) in 3.18 kg of total mixture (67). When fed the same diets twice daily, more replacer was not detrimental.

For once daily feeding, dry replacer formula should be restricted to about 363 g per day in about 3.18 kg of total liquids for breeds of larger calves and proportionately less for the smaller breeds. Although calves fed high solids diets tend to drink more supplemental water, there is still some question relative to the possibility that the young calf's total water intake may be detrimentally limited by feeding more concentrated replacer formulas.

Beyond once-a-day feeding, several trials have assessed effects of eliminating additional feedings. The idea is to give the dairyman a day off, usually as a week-end break from calf feeding chores. Years ago Owen (66) reported no adverse effects on gains or health from a scheme in which feeding was omitted 1 day a week. A more recent unpublished University of Nebraska trial confirmed the initial results. However, these two trials involved only four and five calves per treatment.

Wilson (106) compared 6 days vs 7 days replacer feeding of 16 bull calves per treatment in a once-a-day program and found no significant differences in gains or dry feed intake.

Similar success was reported by others (8, 18, 29, 30, 48) when 1 or 1.5 days of liquid feeding were eliminated each week. Usually, calves were more than a week old before the first skip day. Early gains are reduced in some cases (8), but increased starter intake tends to compensate, and by 12 to 16 weeks of age, gains are essentially equivalent. Reducing the once daily feedings from 7 to 5 per week, skipping Sunday and Wednesday, reduced days to weaning (34 to 29) but increased starter intake and resulted in slightly higher gains at 12 wk of age (29). However, two calves were removed from experiment due to loss of appetite.

It appears that elimination of 1 day's feeding may be practical, especially for healthy calves beyond 10 days of age.

Calves fed once daily: method and criteria of weaning. The trend in recent years has been toward earlier weaning of replacement calves. Aside from labor and feed economics, reasons include the knowledge that pushing calves for rapid early growth offers no functional advantage. Furthermore, accumulated knowledge and developments in meeting the requirements for successful early weaning have additionally promoted the concept.

Although it is well accepted by nutritionists that healthy calves of breeds with larger calves can be satisfactorily weaned at 3 to 5 wk of age, there are numerous questions as to the appropriate practical procedures. What procedures of feeding and management best prepare the calf for early weaning? Should the calf be (1) weaned on age, body weight, body weight gain, or starter intake; (2) weaned gradually or abruptly; (3) should amount of milk or frequency of feeding be reduced before weaning, or (4) what combinations of these procedures should be employed?

The following findings relative to early weaning were evaluated under once daily liquid feeding regimes.

Calves weaned at 21 days and 42 days of age were essentially equal in weight gains at 42 and 84 days but the later weaned calves were slightly superior at 84 days in wither height (72). Starter intake by 42 days was greatly increased by weaning early. No differences were noted in scours incidence or other health problems.

Weaning Friesian calves at 24, 44, 64, and 84 days was compared by Johnson and Elliott (40). Starter ration was fed ad libitum. Patterns of growth curves were similar for calves weaned at different ages. Weaning caused a marked sudden increase of 500 g in dry food intake in all groups but was not as immediate for those weaned at 24 days.

Three criteria for weaning were compared in a Nebraska experiment involving 48 Holstein calves (70): (1) age (21 days), (2) gain in weight (5.44 kg from birth), and (3) starter intake (3.18 kg in the week before weaning). Compared to other criteria, weaning abruptly at 21 days of age slightly depressed growth rate between the 3rd and 4th wk. However, differences in growth rate and health measures to 12 wk of age were not significant.

Weaning Friesians at an arbitrary 28 days was compared with weaning at 400 g daily starter intake (53). Calves averaged 18.9 days of age when weaned on intake. No health or scours problems were encountered by either treatment group and gains to 56 days of age were similar.

It is commonly recommended that calves not be weaned until they are eating 454 to 907 g of starter ration daily. Ironically, the strongest stimulus for inducing the young calf to eat dry feed is discontinuance of liquid feeding.

Accordingly, recent research data suggest that a specified amount of preweaning starter intake may not be a necessary prerequisite for successful weaning (40, 70). This is indicated by an experiment still in progress at Nebraska (unpublished data). The experiment was described earlier (5). Of 40 calves on the 21-day wean treatment, 47% were consuming less than 227 g of starter when weaned. Even so, during the 1st wk post-weaning, only 13% ate less than 227 g daily, and health data indicated no detrimental effects compared to those weaned at 42 days. By contrast, 92% of those weaned at 42 days were consuming over 454 g daily at weaning.

Clench (18) reported that weaning at 454 g rather than 907 g daily starter intake reduced the liquid feeding period by 8 to 10 days. Some (25, 77) found that once daily feeding resulted in earlier intake of starter. Calves fed replacer once daily and weaned at 907 g daily starter intake could be weaned 4 days earlier than calves fed twice daily (77).

Increasing the required starter intake before weaning from 400 to 900 g extended the number of days for milk replacer feeding of Friesian heifers from 22 to 32 days (52). However, the weight gain from 5 to 60 days of age was only 2.1 kg more for the high starter ration (28.9 vs. 31.0 kg), a difference which was not statistically significant. The authors recommended feeding only 320 g of milk replacer daily and weaning at 400 g starter intake. This program was in preference to feeding 480 g replacer and weaning at 900 g of starter intake even though gains from 5 days to weaning were only 3.5 kg for the smaller amount of replacer compared to 7.7 kg for the larger amount. Swannack (96) also found no advantage in weight gains to 84 days whether calves were weaned at 454 or 917 g starter intake.

In total, weaning of the breeds of larger calves can be accomplished safely at an earlier age than formerly thought. Furthermore, such calves will generally adjust to dry feed rapidly after weaning even when preweaning intakes are low, certainly less than 454 g per day.

Calves fed twice daily: method and criteria of weaning. The literature on early weaning programs of conventional twice daily feedings is extensive (39, 82). Weaning Holsteins on age has shown generally that a 21 to 28 day weaning age is equal in all respects to weaning later (11, 29, 33, 65, 103). Extending the liquid feeding period from 4 to 16 wk by the use of skim milk produced no benefit in weight gain or body measurements at 52 wk of age (103). Weaning from milk replacer at 25 days of age compared to 60 days resulted in similar weight gains by 90 days of age for calves receiving hay as roughage (11). When silage replaced the hay, gains were better for calves weaned later.

Opinions differ on whether weaning should be abrupt or gradual. The limited information does not indicate advantages for gradual withdrawal of liquids (33, 82).

Complete program. We have a long study underway to compare a new calf raising program developed at the University of Nebraska with a standard program similar to that on many dairy farms. Performance from birth through 18 mo of age was first presented in 1973 (5).

Forty standard plan calves were fed 1.59 kg warm (32 to 38 C) whole milk twice daily and weaned abruptly at 42 days of age. The 40 Nebraska plan calves were fed 3.18 kg frozen colostrum thawed overnight (2 to 7 C) once daily and weaned abruptly at 21 days of age.

Body weight and wither height differed significantly only at 42 and 57 days of age. At 57 days, the Nebraska plan calves weighed .95 kg less and were 1.1 cm shorter at the withers than their standard plan counterparts. However, by 6 mo of age, the early weaned calves were as heavy as standard raised calves.

Early weaning resulted in significantly more grain mixture being consumed between 21 and 42 days of age. There were no significant differences in the incidence of scours, and death losses were minimal. Later results will reveal whether this regime affects lactation performance.

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Treatment and Control of Neonatal Diarrhea in Calves

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Abstract

Treatment and control of acute neonatal diarrhea in calves are outlined and discussed. The difficulty in making a definitive etiological diagnosis makes effective treatment and control also difficult and largely empirical. Physiological events in calves with diarrhea are known, and fluid therapy is directed toward treating dehydration and acidosis. Whether affected calves should receive antibacterial agents orally is an open question. Principles of control of diarrhea in calves are outlined and discussed.

Introduction

Neonatal diarrhea of calves is a major cause of economic loss in rearing young calves (13). Treatment and control of the problem are usually difficult and unrewarding because often the cause of the diarrhea is difficult to determine quickly and accurately (7). Biochemical events in newborn calves affected with acute diarrhea are well known, and considerable progress has been made in the last 10 yr in treating physiological effects of the disease with such as fluid and electrolyte therapy for dehydration and acidosis (4, 22). Methods for control of the disease have been empirical and are usually based on the assumption that the disease is infectious and that the degree of colostral immunity in calves and certain environmental and nutritional factors each play a role in determining whether it will survive effects of diarrhea or die.

The purpose of this paper is to outline and discuss a rational basis for treatment and control of diarrhea in newborn calves based on our current understanding of the disease.

Etiology and Pathogenesis

Effective treatment and control of any disease are dependent on a clear understanding of the cause(s) of the disease and how the causative agent(s) produce the lesions in the animal. One of the major stumbling blocks in the development of effective methods of treatment and control has been the practical difficulty of making a definitive etiological diagnosis with a single calf or a group of calves affected with diarrhea. Diarrhea is only a clinical sign of alimentary tract dysfunction. One of the major mechanisms by which the intestinal tract of a newborn calf reacts to pathogenic bacteria or viruses or indigestible dietary nutrients is hypersecretion and a relative lack of intestinal absorption which results in a loss of fluids, electrolytes, and nutrients, and the net effect is diarrhea. Some of the common causes of diarrhea in newborn calves include enteropathogenic *E. coli* (7) and *Salmonellae spp.* (15), reo-like viruses (11), *Chlamydia spp.*

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