Management of the Dairy Calf Prior to Weaning

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Introduction

The calf and heifer enterprise is an important component of most dairy operations. On average, 25 to 35% of the dairy herd is culled each year and must be replaced. In addition, 10 to 12% of calves born, die within the first two years of life (USDA:APHIS, 1992). Thus, a ready source of high quality heifers is necessary. Unfortunately, calf and heifer management is often overlooked in the dairy enterprise, which leads to increased mortality and morbidity followed by delays in growth, breeding and delayed age at calving.

Calves are born with a predetermined genetic potential, which may be permanently affected by environmental factors and management decisions implemented throughout the rearing period. A calf's genetic potential may be considered an upper limit that is expressed only if proper decisions are implemented at the appropriate time. Studies have shown that the level of management, estimated as herd milk production average, has a profound effect on calf morbidity and mortality (Curtis *et al.,* 1985; James *et al.*, 1984; Jenny *et al.*, 1981; Waltner-Toews *et al.*, 1986a, 1986b). Proper management of young stock, particularly during the neonatal period, can markedly reduce morbidity and mortality, whereas improper management will lead to economic losses from increased cost of veterinary intervention, death losses, growth retardation, and poor reproductive performance. Ultimately, poor management of calves and heifers can reduce the lifetime productivity of the individual cow and the herd as a whole.

Goals for Calf Rearing. A recent, informal, survey of veterinarians, extension personnel, dairy nutritionists, and other dairy professionals found a wide divergence of opinions in key areas of preweaning calf management. Some published goals (Quigley *et. al.*, 1996) for calf and heifer enterprise include:

1. Preweaning mortality ≤ 8%
2. Rates of body weight gain of 700 to 800 g/d from weaning to calving
3. Less than 20% scours in calves
4. Wean calves ≤ 6 weeks of age
5. Age at first breeding ≤ 15 months of age

Although the above goals can be used as a basis for a sound calf-rearing program, the actual goals of producers are markedly less quantitative and significantly more pragmatic. The primary goal of most producers is to keep calves alive during the all important period from birth to 2 months of age. Other goals include to keep the calf healthy (ie., minimize the incidence of scours) and for the calf to "look good" (ie., shiny hair coat with a reasonable amount of subcutaneous fat). The discrepancy among goals of producers and other dairy professionals suggests that improvements in the transfer of information and management techniques are needed to raise the overall level of management so producers may achieve these quantitative goals.

Successful management of preweaned calves is predicated on adequate transfer of passive immunity from the cow to calf during the first 24 hours of life. **Proper colostrum feeding is the single most important management practice that a producer can perform to successfully raise calves prior to weaning.** During the first 24 hours, calves have the opportunity to obtain passive immunity - the temporary immunity provided by the dam through colostrum. Many studies have shown that this immunity is critical to the life and health of the calf. A study was conducted recently by the National Animal Health Monitoring System (NAHMS) to find out how producers raise their dairy calves and the degree to which passive immunity influences calf survival.

The National Dairy Heifer Evaluation Project conducted by NAHMS (USDA:APHIS:VS) included 1,811 farms in 28 states which were selected to represent herds of 30 or more cows in those states. These operations represented 78% of all milking cows in the U.S. A total of 2,177 heifer calves (from 593 farms) was used to assess serum IgG. Blood from these calves was sampled between 24 and 48 hours of age and serum was measured for IgG.

Because serum IgG concentration is so closely related to the calf's overall resistance to infectious agents, it has been used as a measure of overall protection provided by the dam. Although the level of IgG that provides adequate protection will vary with the particular situation (pathogen load in the environment, stress, housing, feeding, etc.), a level of 1,000 mg/dl (10 g/L) has been suggested as a reasonable goal for IgG in the serum of calves by about 24 hours of age (Gay, 1984).

Over 40% of all calves sampled had IgG concentrations below the recommended level of 1,000 mg/dl (Figure 1). Worse still, over 25% of calves were below 620 mg/dl, which put them at a much greater risk of disease than calves with higher IgG levels. Mortality rates of calves with serum IgG less than 1,000 mg/dl was over twice that of calves with higher IgG levels (Figure 2). Of course, many other factors contribute to calfhood mortality, but this study indicated that over half of the death loss of calves with serum IgG levels < 1,000 mg/dl (≈ 40% of dairy heifer calves) can be attributed to a lack of IgG consumption.

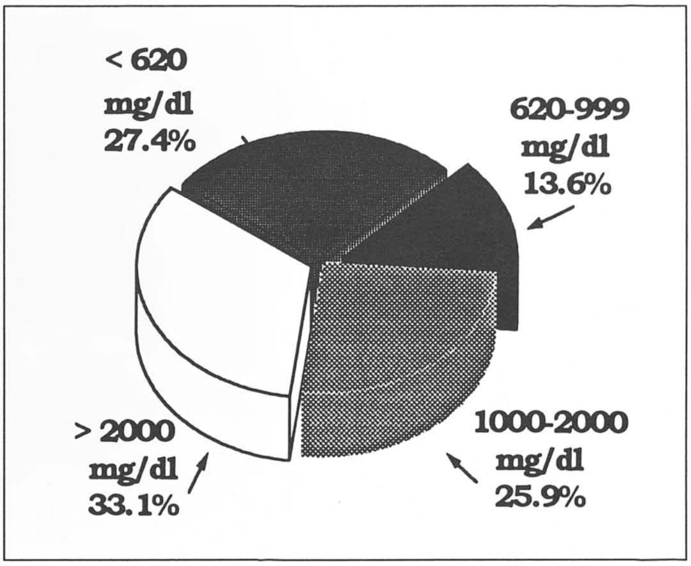

Figure 1. Distribution of IgG levels in the serum of calves (From: USDA:APHIS, 1992).

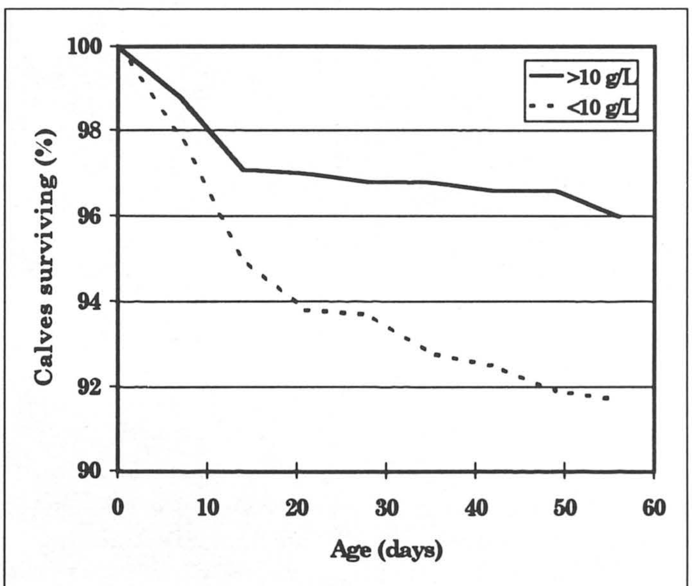

Figure 2. Survival of calves with serum IgG concentrations above and below 1,000 mg/dl (10 g/L; From: USDA:APHIS, 1992).

For many years researchers, extension specialists and dairy professionals have espoused early feeding of a large amount of colostrum to provide sufficient Ig prior to closure of the small intestine. Recent research has indicated the continued importance of feeding colostrum and has further refined our understanding of the importance of colostrum to the young calf. Healthy calves begin consuming starter at an earlier age, proceed more readily through the ruminal development period and can be weaned earlier than calves with health problems.

Rumen Development

Biological Impact of Weaning. Weaning following ruminal development is a key management practice and represents a significant metabolic adaptation by the animal. At weaning, the calf is forced to undergo several dramatic changes, including:

1. the primary source of nutrients changes from liquid to solid feed
2. the amount of dry matter the calf receives is cut dramatically at weaning. This often results in wide swings in post-weaning DM intake
3. the calf must adapt from a monogastric type of digestion to a ruminant type of fermentation and digestion
4. changes in housing and management often occur around weaning which can add to stress.

Assumptions regarding rumen development. Current methods of feeding management for young calves rely on early ruminal development and weaning to reduce the cost of feeding. These methods are based on several assumptions:

1. Sources of liquid feeds (whole milk, milk replacer) are more expensive than solid feeds (calf starter, hay)
2. A negative relationship exists between the amount of liquid and solid feed consumed
3. Rumen development can be achieved to allow early weaning (≤ 6 weeks of age) and results in acceptable rates of body weight gain with economic efficiency
4. Limited liquid feeding allows for rates of body weight gain that allow breeding at 14 to 15 months of age.

The negative relationship between liquid intake (milk/milk replacer) and intake of dry feed (starter and/or hay) occurs as long as the animal's energy requirement can be met by liquid (Figure 3). However, if energy intake is restricted to maintenance (or slightly above), the animal must seek other sources of energy to meet the energy needed for its genetically determined level of growth. This additional energy normally is supplied by feeding calf starter.

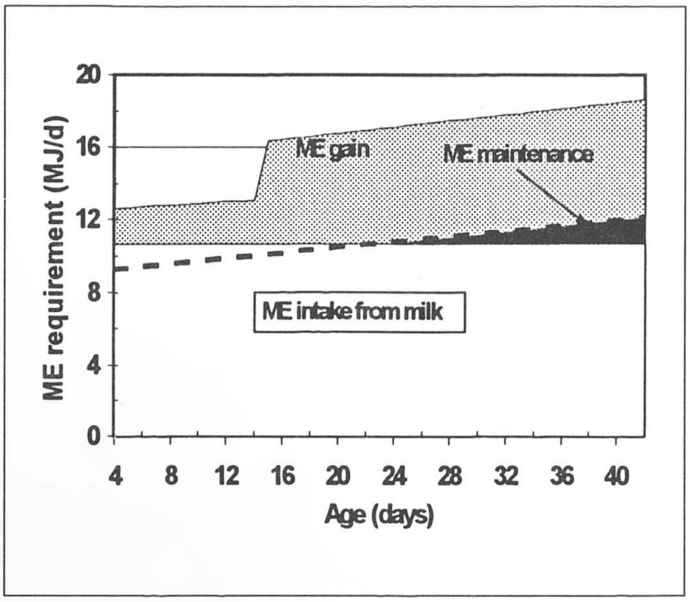

Figure 3. Metabolizable energy requirements for maintenance and gain for a calf weighing 40 kg at birth and gaining 250 g/d from d 4 to 14 and 500 g/d from d 15 to 42.

If a calf does not begin to consume calf starter by 14 to 21 days, significant depression in body weight gain may occur as energy consumed is directed toward maintenance rather than body weight gain. This situation may be exacerbated when maintenance energy requirement is increased, such as low ambient temperature or when a calf develops scours. Scours may also reduce digestibility of energy, further impairing growth rate. Conditions of emaciation may occur when calves cannot consume sufficient calf starter to provide energy for maintenance.

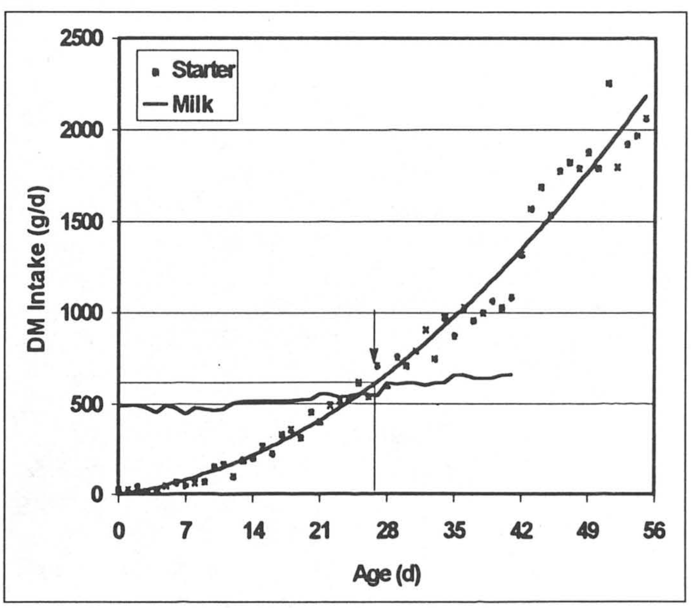

Figure 4. Voluntary intake of calf starter by calves fed whole milk to 42 days of age (From Quigley, 1994).

Voluntary consumption of calf starter appears to begin at 7 to 10 days of age (Figure 4), assuming proper management of starter, availability of water, and other factors to minimize stress and allow intake.

The process of rumen development. At birth, the rumen and reticulum are under-developed, sterile and nonfunctional. Liquid feeds are shunted past the reticulorumen by the esophageal groove. However, by the time the calf is weaned, the rumen is the **primary** compartment of the stomach. It has increased in size, metabolic activity, and blood flow to the rumen has increased. In a schematic diagram (Figure 5), the primary source of nutrients prior to weaning is liquid. During the transition period (in the gray box), both liquid and solid feeds provide nutrients to the calf. After weaning, only solid feeds (starter and hay) are available. Before solid feed is consumed, the abomasum is the primary compartment of the stomach and both energy (glucose and fat) and protein are derived from dietary sources. However, by weaning, the rumen has become an important compartment of the stomach, and all solid feed consumed is exposed to bacterial fermentation prior to reaching the abomasum. A net result of this fermentation is a change in the type of energy and protein available to the calf.

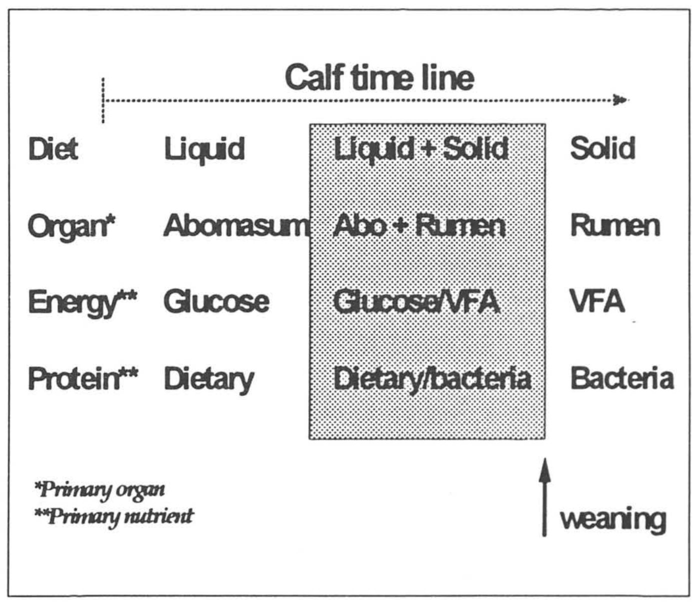

Figure 5. Calf time line and rumen development.

Not only does the activity of the stomach compartments change, but the size of each compartment changes as well. The percent of the stomach as reticulorumen increases from a low of 38% to a high of 67% by 16 weeks of age (Table 1). Note, however, that by 4 weeks of age, the reticulorumen has increased to 52% of the total stomach capacity. In contrast, the proportion of the stomach as abomasum declines from a high of 49% at birth to a low of 11% after 32 weeks of age.

Table 1. Changes in proportion of compartments of the ruminant stomach (From: Church, 1976).

	Age (weeks)						
	0	4	8	12	16	20-26	34-38
Reticulorumen	38	52	60	64	67	64	64
Omasum	13	12	13	14	18	22	25
Abomasum	49	36	27	22	15	14	11

Factors Required for Rumen Development

There are five factors associated with ruminal development. They are:

1. Establishment of bacteria in the rumen
2. Availability of liquid in the rumen
3. Outflow of material from the rumen (muscular activity)
4. Absorptive ability of the tissue
5. Substrate

A number of metabolic changes occur during ruminal development in the rumen and other tissues, but we will consider the above "ingredients" as requisite for the rumen to begin to function.

Bacteria. When the calf is first born, the rumen is sterile - there are no bacteria present. However, by one day of age, a large concentration of bacteria can be found - mostly aerobic bacteria. Thereafter, the numbers and types of bacteria change as dry feed intake occurs and the substrate available for fermentation changes. As can be seen in Figure 6, the numbers of total bacteria (dashed lines) do not differ between calves fed only milk to 8 weeks of age or those fed milk and grain. However, there is a dramatic decrease in the number of aerobic bacteria (solids lines) that occurs approximately 2 weeks after calves begin to consume grain - at 1 week when calves were offered grain from birth, and at 9 weeks when calves fed only milk for 8 weeks were offered grain for the first time. The change in bacterial numbers and types is almost always a function of intake of substrate. Prior to consumption of dry feeds, bacteria in the rumen exist by fermenting ingested hair, bedding, and from milk backflow from the abomasum. The substrate ingested will also affect the types of ruminal bacteria that flourish in the young rumen. For example, calves fed mostly hay develop a different flora from those fed mostly grain.

Liquid in the Rumen. To ferment substrate (grain and hay), rumen bacteria require a water environment.

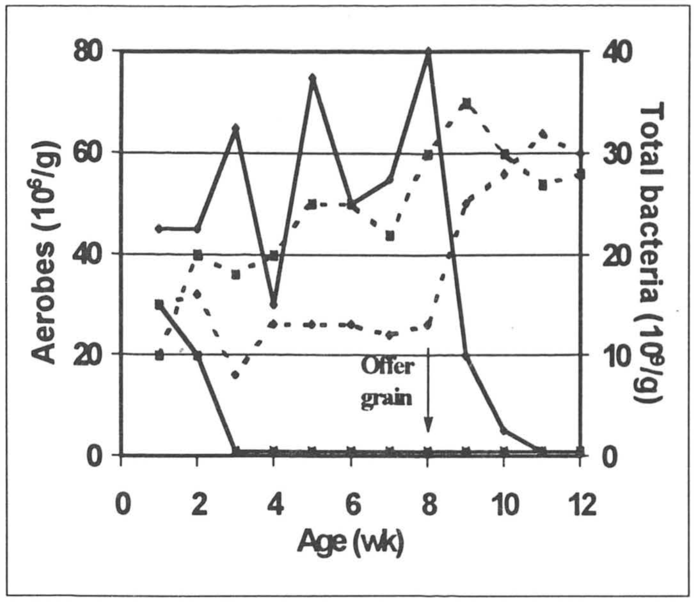

Figure 6. Numbers of bacteria in the rumen contents of calves fed milk or milk and grain (From: Lengemann and Allen, 1959).

Without sufficient water, bacterial fermentation is inhibited and ruminal development is slowed. Most of the water that enters the rumen comes from free water intake. If water is offered to calves from an early age, this is not usually a problem; unfortunately, many producers in the U.S. do not provide free water to their calves until calves reach 4 or more weeks of age (Figure 7).

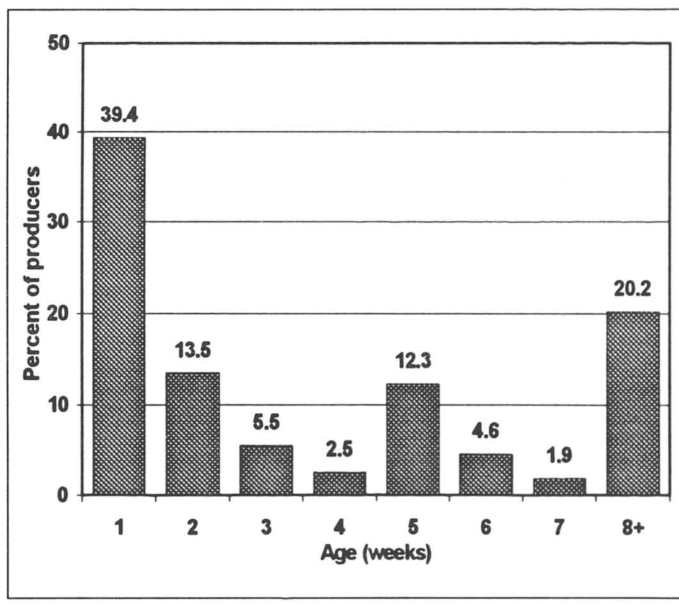

Figure 7. Proportion of producers offering water to calves. (From: USDA:APHIS, 1992).

Milk or milk replacer does not constitute "free water". When milk or milk replacer is fed to calves, it by-passes the rumen and reticulum by the action of the esophageal groove which is active in the calf until about 12 weeks of age. The groove closes in response to nervous stimulation and occurs whether calves are fed from buckets or bottles. Therefore, the feeding of milk replacer should not be construed as providing "enough water". Feeding water can increase body weight gain, starter intake, and reduce scours scores (Figure 8).

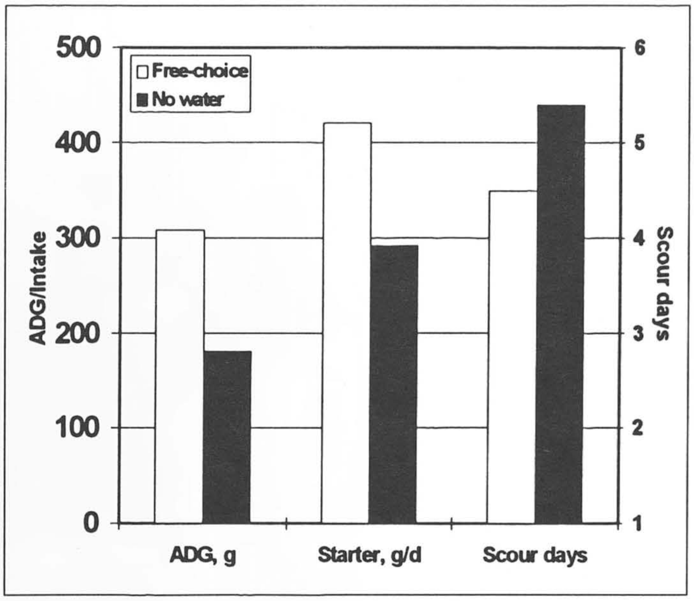

Figure 8. Effect of free water availability on intake of calf starter, body weight gain (ADG) and number of scour days (From: Kertz, 1984).

Offering water in the winter can be a significant challenge in many northern states. However, calves still need water, even when it is cold. Sometimes, it may be necessary to bring warm water at an additional feeding to ensure that calves have enough liquid water available.

Outflow of Material from the Rumen. Proper ruminal development requires that material entering the rumen must be able to leave it. Measures of ruminal activity include rumen contractions, rumen pressure, and regurgitation (cud chewing). At birth, the rumen has little muscular activity, and few rumen contractions can be measured. Similarly, no regurgitation occurs in the first week or so of life. With increasing intake of dry feed, rumen contractions begin. When calves are fed milk, hay, and grain from shortly after birth, rumen contractions can be measured as early as 3 weeks of age. However, when calves are fed only milk, rumen contractions may not be measurable for extended periods. Cud chewing has been observed as early as 7 days of age, and may not be related to ruminal development *per se*. However, calves will ruminate for increasing periods when dry feed (particularly hay) is fed.

Absorptive Ability of the Rumen Tissue. The absorption of end-products of fermentation is an important criterion of ruminal development. The end-products of fermentation, particularly the volatile fatty acids (**VFA**; acetate, propionate, and butyrate) are absorbed into the rumen epithelium, where propionate and butyrate are metabolized in mature ruminants. Then, the VFA or end-products of metabolism (lactate and β-hydroxybutyrate) are transported to the blood for use as energy substrates. However, there is little or no absorption or metabolism of VFA in neonatal calves. Therefore, the rumen must develop this ability prior to weaning.

The epithelial layer provides the absorptive surface for the rumen. At birth, ruminal papillae are small and non-functional. They absorb little and do not metabolize significant VFA. Many researchers have evaluated the effect of various compounds on the development of the epithelial tissue - in relation to size and number of papillae and their ability to absorb and metabolize VFA. Some results are summarized in Figure 9. Clearly, the results indicate that the primary stimulus to development of the epithelium are the VFAs - particularly propionate and butyrate. Milk, hay, and grain added to the rumen are all fermented by the resident bacteria; therefore, they contribute VFA for epithelial development. Plastic sponges and inert particles - both added to the rumen to provide "scratch" - did not promote development of the epithelium. These objects could not be fermented to VFA, and thus did not contribute any VFA to the rumen environment. Therefore, rumen development (defined as the development of the epithelium) is primarily controlled by **chemical**, not **physical** means. This is further support for the hypothesis that ruminal development is primarily driven by the availability of dry feed, but particularly starter, in the rumen. As can be seen in Figure 10, absorption of VFA increases dramatically to 14 weeks of age when calves were fed milk, hay, and grain. However, when calves are fed only milk to 14 weeks, there is little absorption by epithelium. When calves are given grain on week 15, the absorption of VFA begins shortly after consumption of grain begins. It appears that absorption by ruminal epithelium begins rapidly after consumption of dry feed begins.

Availability of Substrate. Bacteria, liquid, rumen motility, and absorptive ability are established prior to rumen development, or develop rapidly when the calf begins to consume dry feed. Thus, the primary factor determining ruminal development is dry feed intake. To promote early rumen development and allow early weaning, the key factor is early consumption of a diet to promote growth of the ruminal epithelium and ruminal motility. Because grains provide non-structural carbohydrates that are fermented to propionate and butyrate, they are a good choice to ensure early rumen development. On the other hand, the structural carbohydrates in forages tend to be fermented to a greater extent to acetate, which is less stimulatory to ruminal development.

Material	Effect
Milk	++
Acetate (Na salt)	++
Propionate (Na salt)	+++
Butyrate (Na salt)	++++
Grain	+++
Hay	++
Plastic sponges	-
Insert particles	-

Figure 9. Effect of various chemicals, feeds and objects on development of ruminal epithelium.

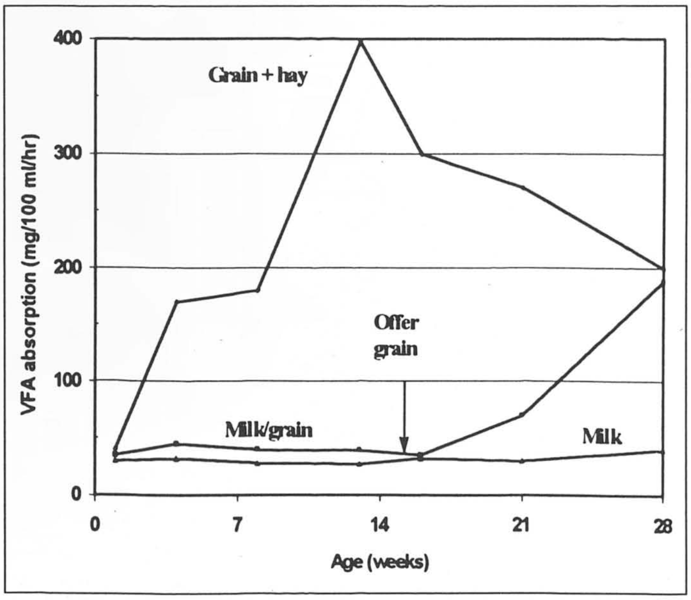

Figure 10. Absorption of VFA by ruminal epithelium in calves fed milk, hay, and grain (Grain+hay), milk for 2 wk, then milk+grain (milk/grain), or only milk (From: Sander *et al.*, 1959).

Changes in Nutrients with Dry Feed Intake

As the rumen develops, there is a change in the types and amounts of nutrients available to the calf. For example, the amount of glucose previously available from intestinal digestion of lactose from milk or milk replacer is replaced by VFA from ruminal fermentation. Consequently, the amount of glucose in the blood declines (Figure 11) and the amount of VFA and β-hydroxybutyrate increases (Figure 12). Since glucose is the major energy metabolite, the decreased availability of glucose requires a considerable shift in the concentration of enzyme systems in the liver, intestine, muscle, adipose and other tissues to reflect decreased availability of glucose and increased reliance on VFA and provision of glucose by gluconeogenesis. Most studies indicate that these enzyme systems shift rapidly after the intitiation of dry feed intake; the major enzymatic pathways will adjust by 30 days of age when substrate changes take place prior to weaning.

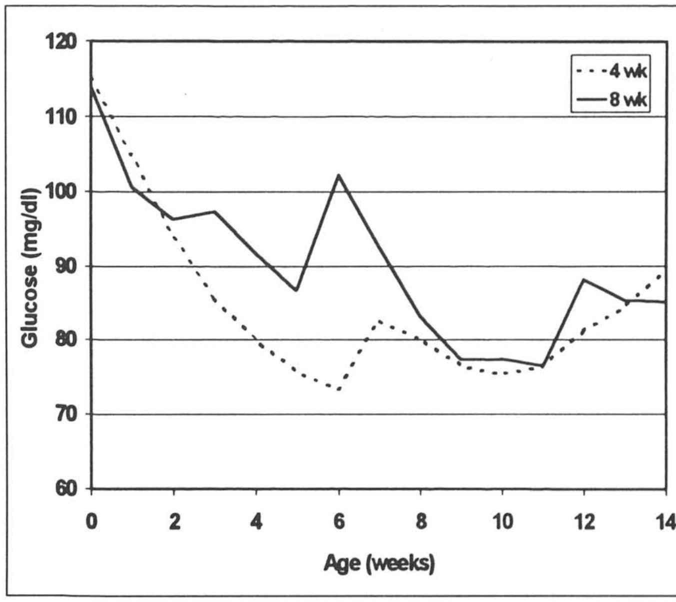

Figure 11. Concentration of glucose in calves weaned to calf starter at 4 or 8 weeks of age. Calves weaned at 8 weeks were offered starter from 4 weeks (From: Quigley *et al.*, 1991).

Increased concentrations of acetate and β-hydroxybutyrate in the blood as a consequence of ruminal development require peripheral tissues to utilize these compounds for energy. These changes are always closely associated with starter intake, which is further evidence of the relationship between intake and ruminal development.

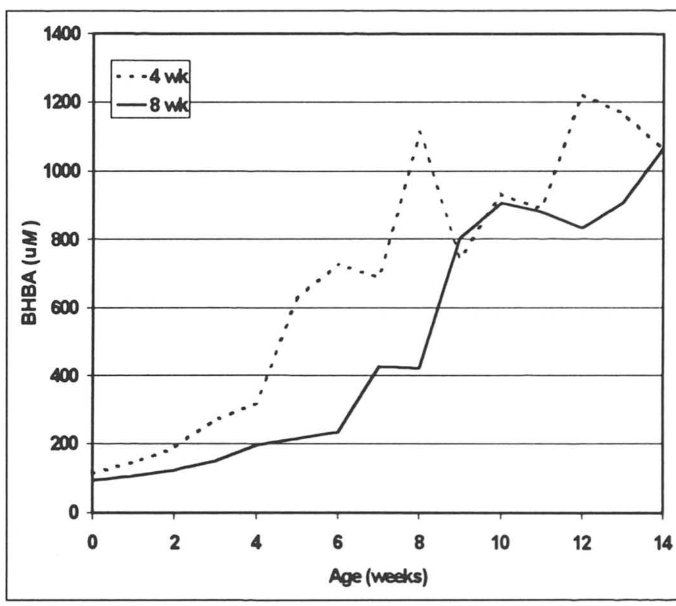

Figure 12. Blood β-hydroxybutyrate in calves weaned at 4 or 8 weeks of age. Calves weaned at 8 weeks were offered starter from 4 weeks (From: Quigley *et al.*, 1991).

Effect of Physical Form of the Ration

The Role of Forage. For many years, producers have fed forage - primarily hay - to calves to promote ruminal development. The common reason was to give the calf the "scratch" needed to start the workings of the rumen. **In fact, the development of rumen function is primarily chemical and is caused by VFA in the rumen.** Providing forage has less of an effect on ruminal epithelial development, thus on activity and function. The concept of "scratch" to develop the rumen is a myth. However, forage *is important* to promote the growth of the muscular layer of the rumen and to maintain the health of the epithelium. Rumen papillae can grow excessively in response to high levels of VFA - when this occurs, calves may suffer from hyperkeratosis. Also, some "scratch" *is* needed to keep the papillae from forming layers of keratin, which can also inhibit VFA absorption. Therefore, hay should be part of the diet - *after* weaning. A good recommendation is to wean at 4 to 5 weeks of age and offer hay from 6 to 7 weeks of age. If calves are not weaned until 8 to 10 weeks of age, it may be a good idea to feed a limited amount of hay (1 lb/day) from about 6 weeks of age. However, the amount of hay should be *limited* to ensure that calves will consume sufficient starter.

There are other reasons to limit the hay offered to preweaned calves. The first is voluntary intake. Most calves do not eat significant amounts of hay if grain is also offered (Figure 13). Therefore, producers feed calves the best quality hay available on the farm, only to have it turned into bedding. In Figure 13, it is clear that most of the intake of hay occurred only from 6 to 7 weeks of age. **This is a good time to put hay in front of calves.**

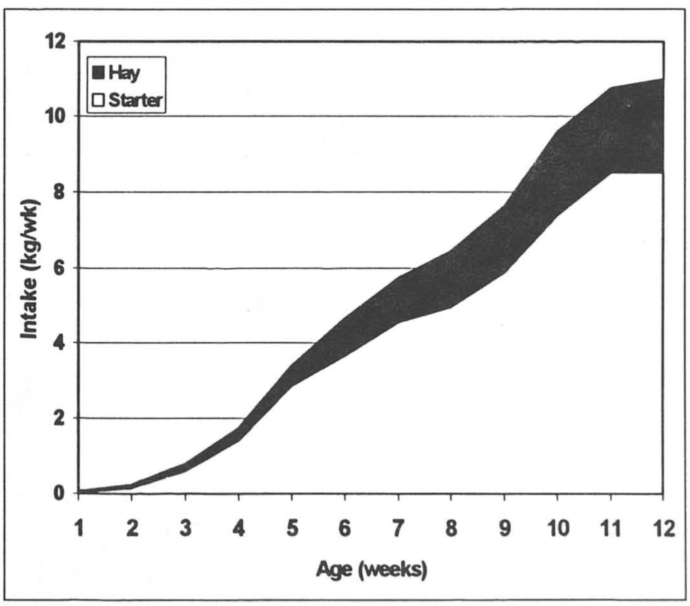

Figure 13. Intake of starter and hay in calves weaned at 12 weeks of age (From: Anderson *et al.*, 1982).

Another reason not to feed hay to calves prior to weaning is the energy requirement of young calves. Calves have a high energy requirement relative to their ability to consume dry feed. Therefore, if calves consume significant amounts of hay, their intake of other feeds (ie., starter) will be limited. This has the effect of limiting intake of starter, which can slow growth. Finally, most hay has too little energy for calves. The energy requirement for calves can usually be met only when calves are fed high quality milk replacer, waste milk and/or excess colostrum and calf starter. Even good quality legume hay generally has too little energy to support growth of preweaned calves.

Strategies that Affect Rumen Development

There are many ways to feed calves. The protocol described here is designed to optimize rumen development, allow early weaning, and reduce the costs of the calf rearing enterprise. It should be used in conjunction with good management and close daily evaluation of calves.

As described above, the key to rumen development is dry feed intake - especially calf starter intake. To maximize starter intake for preweaned calves:

1. *Feed limited milk or milk replacer.* Feed calves at 10% of birth body weight (a good rule of thumb is 10 lbs of milk or reconstituted milk replacer for a 100 lb calf) per day. Do not increase the amount of milk replacer offered as the calf gets older. However, the amount of replacer **should** be modified according to environmental conditions (added replacer should be fed in the winter in many locations). For economy, use only waste milk, excess colostrum, and milk replacer.
2. *Offer calf starter daily for ad libitum consumption.* Starter must be fresh and clean and calves must have access to starter at all times. Remove any refused starter **daily** so that spoiled feed won't accumulate. Offer starter refusals from younger calves to older ones already on feed to minimize feed wastage. Feed buckets or boxes should be kept clean and spoiled feed, manure, etc. should be removed promptly. Rumen development depends on intake - make the starter as appealing as possible!
3. *Water should be available to calves from 4 days of age.* It should be changed daily or water bowls should be used. Keep buckets or bowls clean, too.
4. *Hay should be offered 1-2 weeks after weaning, unless weaning occurs after 8 weeks of age.* If calves are not weaned until after 8 weeks, limited hay may be fed from 6 weeks of age.
5. *Wean early!* In most cases, weaning is possible by 4 to 5 weeks of age.

Weaning. Optimally, when large breed calves are consuming 1.5 lb of starter for 2 consecutive days, calves can be successfully weaned. When calves are offered starter *ad libitum* from 3 days of age, this usually occurs between 4 and 5 weeks of age (Figure 4). However, in some situations (e.g., very cold weather or during an outbreak of disease), intake of starter by calves may not reach 1.5 lb/day until after 6 weeks of age. Therefore, it is important that the recommendations of weaning at 4 to 5 weeks of age be tempered with common sense and good management to be sure that calves are not weaned before they are ready.

Most producers in the U.S. wean their calves at 8 weeks of age (Figure 14). This could easily be reduced to 6 weeks of age with improvements in management, and to 4 to 5 weeks of age with careful management. Calves require less labor after weaning, and feed costs and costs of veterinary treatments are often lower. Therefore, it is usually less costly to wean calves early.

What type of starter?

There are many types of starters and other feeds available for calves. These include:

1. Commercial textured calf starters
2. Commercial pelleted starters (with or without roughage products)
3. Commercial lactation feeds
4. Home-made grind and mix starters.

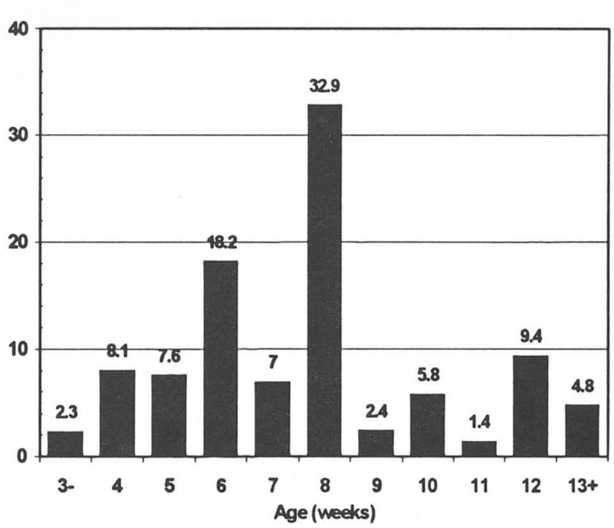

Figure 14. Percent of producers that wean calves at various ages (From: USDA:APHIS, 1992).

There are many commercial calf starters on the market. In general, these high quality feeds are very palatable and provide nutrients required for rumen development and acceptable calf growth. In addition, many starters contain ingredients that are not normally available in lactation feeds or in home-made grind and mix starters. Unfortunately, some commercial starters may contain low-quality by-products and fillers that cannot support adequate growth. Many commercial feed companies and cooperatives include some B-vitamin supplementation to provide calves with a source of B-vitamins before the rumen begins to produce large amounts of B-vitamins on its own. Also, many commercial calf starters contain a coccidiostat (Bovatec®, Deccox® and Rumensin® are examples) that provide protection against coccidial infection. **Protection provided by a coccidiostat is inexpensive and very important, so a coccidiostat should be part of all starters in most parts of the US.**

Palatability is generally highest with textured feeds, followed by complete pellets. Calves generally do not like mash feeds and palatability and intake are usually lower than with other types of feeds. Fines in pelleted calf starters can also depress intake. Look for a starter with pellets that will not break into fines.

Lactation feeds generally should not be fed to calves. In many cases, lactation complete feeds do not contain sufficient energy to support good calf growth. Also, lactation feeds may contain added fat, animal by-products, or other additives that reduce palatability. Finally, lactation complete feeds do not contain added B-vitamins or coccidiostat.

Summary

Proper management of the dairy calf prior to weaning requires adequate transfer of passive immunity to ensure the calf can utilize ingested nutrients for growth. Current methods of feeding require limited liquid feeding and maximal ruminal development. Early weaning (≤ 6 weeks of age) and limited hay feeding prior to weaning can improve rates of gain and economy of the replacement enterprise. Current management practices often limit availability and/or intake of starter, thereby slowing ruminal development and delaying weaning.

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Abstract

Concurrent bovine viral diarrhoea virus and *Salmonella typhimurium* DT104 infection in a group of pregnant dairy heifers

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Two days after being imported into the United Kingdom one of a group of 30 pregnant dairy heifers showed clinical signs of bovine viral diarrhoea virus (BVDV) infection and subsequently died. Before it died the heifer was BVDV antigen-positive and antibody-negative. The gross post mortem findings were suggestive of mucosal disease but in addition to *noncytopathic* BVD virus, *Salmonella typhimurium* DT104 was cultured from tissues and gut contents. The other heifers were screened for *S typhimurium* by culturing faeces, and serology showed that 13 (45 per cent) of the group seroconverted to BVDV in the three weeks between samplings and the remainder were seropositive, indicating previous exposure. During this period four heifers showed clinical signs of acute BVDV infection but recovered uneventfully. Four animals (14 per cent) were positive for *S typhimurium* DT104 on faecal culture, and three of these excretors concurrently seroconverted to BVDV. Of the 29 heifers remaining in the group, one aborted in late gestation, 26 bore live calves and two delivered stillborn calves. Pre-colostral blood samples from the calves showed that their dams' pre-existing antibody titres correlated well with in utero fetal protection. In non-immune dams, exposure to BVDV between 69 and 120 days of gestation led to the birth of live persistently viraemic calves. Infection between 120 and 140 days of gestation led to the birth of live calves with evidence of congenital damage to the central nervous system, and infection later than 140 days of gestation led to the birth of live, normal calves with high pre-colostral antibody titres to BVDV. One calf which sucked colostrum was antibody and virus antigen-positive when sampled at 12 hours old but regular blood sampling failed to detect viraemia again until the calf was seven weeks old when it became persistently viraemic.