



COLOSTRUM -- The Key To Calf Survival

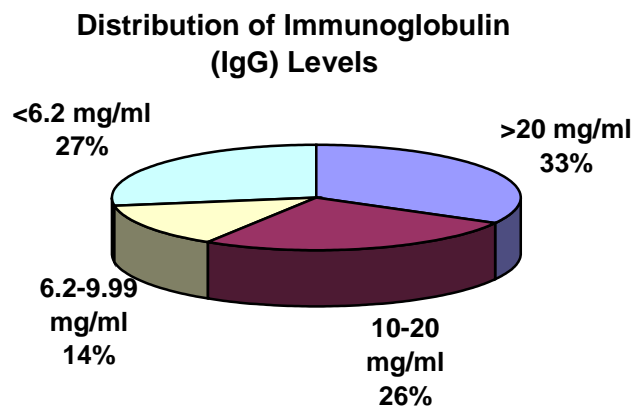
The most important factor in calf management is colostrum – it is the key to a calf's survival.

Because the physiology of the bovine placenta prevents transfer of maternal serum immunoglobulins to the calf before it is born, the neonatal calf is entirely dependent on colostrum immunoglobulins for protection from disease. The calf's acquisition of colostrum immunoglobulins through absorption in the intestine is called passive transfer or passive immunity. In addition to needed disease protection, colostrum also provides the neonatal calf with high quality nutrition and many growth factors and hormones that may be beneficial for initiating function and growth of the digestive tract.

When calves do not absorb adequate amounts of high quality colostrum, they are predisposed to disease and higher levels of mortality. Thus, it is vitally important that intensive management prevail during the first 24 hours of the calf's life in order to insure a healthy future for every animal.

The importance of feeding colostrum

In 1993, the National Animal Health Monitoring System (NAHMS) evaluated the degree to which calves in the United States were protected by colostrum immunity. Blood samples were collected between 24 and 48 hours of age to determine the level of serum IgG (which represents 90% of all immunoglobulins transferred to calves by colostrum) from 2,177 calves, which represented 598 farms. Of the calves tested, only 59% had absorbed sufficient immunoglobulins from colostrum to achieve adequate levels of serum IgG (defined as 10 mg/ml or more). This means that over 40% of calves on today's dairies have experienced failure of passive transfer (FPT) or, in other words, they have not received adequate amounts of immunoglobulins.



The importance of feeding colostrum to achieve 10 mg/ml of serum IgG was made clear when mortality rates of calves from the NAHMS study were evaluated. These researchers found that those calves with serum IgG levels <10 mg/ml experienced mortality rates over **twice** that of calves with serum IgG levels of ≥ 10 mg/ml! Numerous other researchers have studied the importance of serum immunoglobulin levels in neonatal calves. These studies indicated that not only are calves with low levels of serum immunoglobulins more susceptible to disease such as

pneumonia and scours but they are also at a greater risk for mortality (Nocek, et al., 1984; Donovan et al., 1998). Thus, feeding adequate levels of colostrum to obtain serum IgG levels of 10 mg/ml is necessary to ensure a healthy, productive calf.

What is colostrum?

Colostrum is a mixture of lacteal secretions and constituents of blood serum, such as immunoglobulins (Ig) and other serum proteins, that accumulate in the mammary gland during the pre-partum dry period and are collected via milking at parturition. The first six postpartum milkings, or the number of milkings it takes for the transition from colostrum to whole milk to occur, are considered colostrum. Of these six milkings, the first four reflect the majority of changes in composition. Table 1 illustrates the compositional changes of colostrum over the first five milkings compared to whole milk. During the transition from colostrum to whole milk, the level of total protein, fat, total solids, solids-not-fat and ash decreases, lactose increases and colostral Ig declines rapidly.

Item	<i>Colostrum (no. of postpartum milking)</i>					Milk
	1	2	3	4	5	
Specific Gravity	1.05	1.04	1.03	1.03	1.03	1.032
PH	6.32	6.32	6.33	6.34	6.33	6.50
Total Solids, %	23.9	17.9	14.1	13.9	13.6	12.9
Fat, %	6.7	5.4	3.9	4.4	4.3	4.0
Solids-not-fat, %	16.7	12.2	9.8	9.4	9.5	8.8
Total protein, %	14.0	8.4	5.1	4.2	4.1	3.1
Immunoglobulins, %	6.0	4.2	2.4			.09
IgG, g/dl	3.2	2.5	1.5			.06
Lactose, %	2.7	3.9	4.4	4.6	4.7	5.0

(Foley and Otterby, 1978)

Colostrum Quality

The first step to ensuring adequate levels of serum Ig in calves is to provide them with high quality colostrum. However, colostrum quality is influenced by a variety of factors including breed and lactation number.

The breed of cow from which colostrum is harvested plays an important role in the quality of colostrum. Jerseys have been reported to produce twice as much Ig in their colostrum as Holsteins! In 1981, a research study reported that the colostrum of Jerseys contained 9.0% Ig, Ayrshires 8.1%, Brown Swill 6.6%, Guernseys 6.3% and Holsteins 5.6% (Muller and Ellinger, 1981).

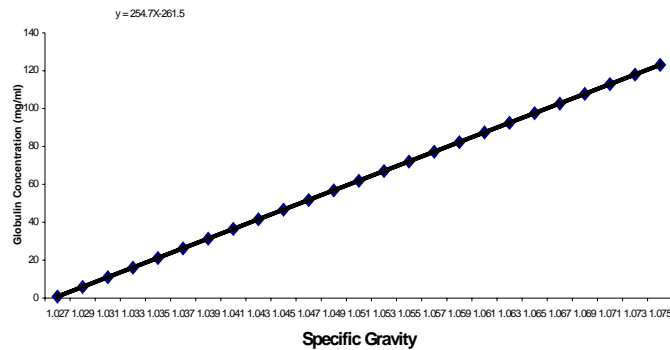
In addition to breed differences, the parity (or lactation number) of a cow will also influence colostrum quality. The concentration of Ig is lower in the colostrum of first calf heifers than

older cows. This is because first calf heifers have probably not been exposed to as many herd-specific pathogens as older cows which gives them a limited range of protective antibodies (Hunt, 1990). Across the major dairy breeds researchers found that the average total colostrum Ig concentration for first lactation to be 5.91%, second 6.26%, third 8.15%, and fourth and higher 7.49% (Muller and Ellinger, 1981). Another study (Corbett, 1991) measured the Ig concentration in the colostrum of first calf heifers to be 28 mg/ml. The level increased to 59 mg/ml in second lactation, 82 mg/ml in third and 73 mg/ml in fourth. Since the majority of dairy herds are 25 to 30% first calf heifers, a large proportion of calves that are fed the colostrum from their dam may not be well protected from disease.

Because the quality of colostrum plays a major role in the success of providing the calf protection from disease, it is necessary to be able to evaluate the quality of colostrum quickly and easily. Numerous methods are available to evaluate the quality of colostrum, the easiest of which is a device called a colostrometer.

The colostrometer is a calibrated hydrometer developed for practical use to determine the specific gravity of colostrum. The colostrometer works by measuring the specific gravity of colostrum and then taking advantage of the linear relationship between the specific gravity of colostrum and its Ig concentration (graph 1). This relationship provides an equation, through regression analysis, to estimate colostrum Ig concentration from the specific gravity of fresh, whole colostrum.

Graph 1. Colostral globulin concentration and quality based on colostrum specific gravity



Fleener and Stott, 1980

The colostrometer evaluates colostrum quality (or Ig concentration, mg/ml) as superior – 50 to 140 mg/ml, moderate – 20-50 mg/ml, or inferior - <20 mg/ml. These quality levels are also coded by color on the colostrometer as green yellow and red, respectively (Fleener and Stott, 1980).



The colostrometer does however, have its drawbacks. Because the temperature at which the colostrum is evaluated has a significant effect on colostrometer readings, it is very easy to evaluate colostrum and conclude it is superior when, in actuality, it is an inferior colostrum. Most colostrometer manufacturers recommend a temperature of 20 - 25°C (or about room temperature) for measurement of colostrum specific gravity. Studies using a colostrometer found that at temperatures lower than 20°C the colostrometer will over-estimate Ig content, while at temperatures higher than 20°C it will under-estimate Ig levels. For instance, colostrum measured as excellent quality at zero to 5°C (32 to 41°F) can be evaluated as poor quality at 35 to 40°C (95 to 104°F). Consistent temperatures for colostrum readings are the best to monitor quality. In general, the colostrometer allows for simple, rapid and low cost analysis of colostrum for selective feeding.

Colostrum quality has also been associated with the weight of the cow's first milking after parturition. In an evaluation of management and production factors influencing the IgG₁ concentration in colostrum, researcher found that there is a negative relationship between the weight of colostrum during the first milking and the concentration of IgG₁ in the colostrum (Pritchett et al., 1991). These researchers suggested that this decrease in IgG₁ concentration might be due to a dilution of the IgG₁ in the large volume of colostrum. Therefore, the more colostrum a cow milks during her first milking, the less likely it is that there will be a sufficient amount of IgG₁ in 2L of colostrum to provide adequate immunity to the calf. Researchers from this study concluded that when a cow milked over 8.5 kg (18 lbs.) of colostrum during her first milking the chances that the colostrum contained sufficient IgG₁ dropped from 77% to 64% of all samples (sufficient IgG₁ being defined as 35 g/L).

Colostrum consumption

Since calves' receive no placental transfer of immunoglobulins from the dam, the calf is totally dependent on the Ig in maternal colostrum for disease protection. Calves start producing their own Ig at approximately 10 days of age and reach normal levels by 8 weeks of age. During this time, the calf's essential dependence on maternal colostrum reinforces the need for the calf to consume colostrum as soon as possible after birth. To help maximize the calf's immune defense, only high quality first milking colostrum should be fed so that the calf has the opportunity to absorb adequate levels of Ig (Corbett, 1991; Roy, 1980).

To ensure the transfer of the highest possible quality of colostrum from each cow, all fresh cows should be milked out from a sanitized udder and then the quality of the colostrum should be verified using a colostrometer. Any bloody colostrum or colostrum containing mastitis should be discarded and frozen colostrum should be fed. Calves should consume a minimum of 2 liters of colostrum within the first hour after birth, preferably within the first 30 minutes. An additional 2 liters should be consumed by 6 to 12 hours of age. If the calf refuses to suck from a nipple bottle then he or she should be force-fed with an esophageal feeder. Depending on the cow and calf to accomplish the task of consuming colostrum in adequate amounts with proper timing usually isn't successful and leaves the calf at a greater risk for morbidity and mortality.

Although current industry standards suggest that a minimum amount of 2L of high quality colostrum be fed to obtain successful passive transfer of Ig (10 mg/ml), recent research has suggested that feeding larger quantities may be beneficial. Since the amount of Ig in colostrum is hard to determine and testing the serum Ig of the calf prior to 24 hours of life is not only expensive, but time-consuming, Davis and Drackley (1998) suggest that as a "rule of thumb" 100g of IgG should be consumed by the calf as soon as possible after birth to achieve 10 mg/ml of serum IgG.

The basis of this rule of thumb is as follows:

- The plasma volume of a newborn calf is about 6.5% of body weight, so for a 40 kg (88 lbs.) calf, the plasma (or serum) volume would be 2.6L
- To obtain 10 mg/ml of serum IgG, simply multiply 2.6L x 10 g of IgG/L = 26g of IgG

- However, apparent efficiency of absorption for IgG ranges from 20% to 48% depending on colostrum IgG content and the calf. We assume an average apparent efficiency of absorption of 25% for a calf fed within 1 hour of life and not under conditions of stress.
 - Thus the calf must consume a minimum of 104g of IgG ($26\text{g} \div 0.25 = 104\text{g}$)
- If a good quality colostrum (60 mg/ml of IgG), is fed, then feeding 1.73L (1.83qt) would be sufficient ($104\text{g} \div 60\text{g/L} = 1.73\text{L}$).
- However, if a lower quality colostrum (35 mg/ml of IgG) is fed, then a minimum of 2.97L (3.14qt) would be required ($104\text{g} \div 35\text{g/L} = 2.97\text{L}$).

If resources for measuring colostrum IgG are available (such as a colostrometer), these guidelines provide a good rule of thumb for the amount of colostrum necessary to achieve successful passive transfer of IgG. However, calves born under stressful condition (such as dystocia) may have lower rates of apparent efficiency of absorption and require even greater amounts of colostrum to achieve adequate passive transfer of Ig. Table 2 presents estimates of volumes of colostrum necessary to provide adequate Ig levels to calves of different weights.

Table 2. Quarts of colostrum necessary to achieve 10mg/ml of serum IgG										
Colostrum IgG g/L	Birth Weight(lbs.)									
	75	80	85	90	95	100	105	110	115	120
20	4.64	4.95	5.25	5.56	5.87	6.18	6.49	6.80	7.11	7.42
30	3.09	3.30	3.50	3.71	3.92	4.12	4.33	4.53	4.74	4.95
35	2.65	2.83	3.00	3.18	3.36	3.53	3.71	3.89	4.06	4.24
40	2.32	2.47	2.63	2.78	2.94	3.09	3.25	3.40	3.55	3.71
45	2.06	2.20	2.34	2.47	2.61	2.75	2.88	3.02	3.16	3.30
50	1.85	1.98	2.10	2.23	2.35	2.47	2.60	2.72	2.84	2.97
55	1.69	1.80	1.91	2.02	2.14	2.25	2.36	2.47	2.59	2.70
60	1.55	1.65	1.75	1.85	1.96	2.06	2.16	2.27	2.37	2.47
65	1.43	1.52	1.62	1.71	1.81	1.90	2.00	2.09	2.19	2.28
70	1.32	1.41	1.50	1.59	1.68	1.77	1.85	1.94	2.03	2.12
80	1.16	1.24	1.31	1.39	1.47	1.55	1.62	1.70	1.78	1.85

25% apparent efficiency of absorption
Equations taken from Davis and Drackley (1998)

Storing colostrum

Fresh, high quality colostrum may not always be available for the calf to consume within 30 minutes of birth. In these cases it is important to always have an adequate supply of high quality colostrum frozen in small quantities (1 liter bags). During freezing, nutrient content of colostrum can be preserved with little loss for up to 1 year. Frozen colostrum should be thawed slowly in warm water (38°C) or at room temperature in order to preserve its quality as rapid thawing denatures and reduces the active available Ig in colostrum. Colostrum can also be thawed in a microwave with little damage to the Ig. When thawing with a microwave, it is important to set

the power on low (60% of full power) and microwave the colostrum for short periods of time, pouring off the thawed portion in between. In addition, colostrum can be refrigerated up to 7 days without any appreciable loss in quality (Corbett, 1991; Hunt, 1990).

To avoid bacterial contamination of fresh colostrum that will not be fed immediately after milking, it is best to chill the colostrum to 40°F as soon as possible. Even under the best circumstances, most colostrum contains about 20,000 or more bacteria per milliliter (ml) immediately after milking. If colostrum remained un-refridgerated at 100°F with a bacteria such as *E. coli* (which doubles in number every 20 minutes) after just 1 hour the number of bacteria would be 8 times more numerous, after 2 hours, there will be 64 times more bacteria! Because of these high rates of bacterial growth, it is important to cool and store colostrum as quickly as possible.

Common methods to quickly cool colostrum and avoid bacterial contamination include refrigerating or freezing in small amounts, using a clean and well-sanitized ice pack (a 3L soda bottle or bag of ice works well), or keeping chilled nursing bottles in the freezer to immediately pour colostrum into (this has the added benefit of killing any *Cryptosporidium* that may have been present on the bottles).

COLOSTRAL IMMUNOGLOBULINS

Classes, production and function

Immunoglobulins present in the body are produced by plasma cells that were originally derived from bone marrow cells. These plasma cells are present in various locations in the body and secrete Ig that collects in the blood and then can be utilized by the calf for needed immune response.

Immunoglobulins are divided into five classes (IgG, IgM, IgA, IgD and IgE). Each of these classes is then further divided into subclasses. Of these five classes, IgG, IgM and IgA are the three main classes. Although these classes differ in their structure and function (IgG and IgM function in systemic infections while IgA functions with internal body surfaces such as the intestine (Muller and Ellinger, 1981)), they all represent antibodies to specific foreign proteins to which the dam was previously exposed.

Immunoglobulins function is not however, limited to providing passive immunity in the blood, it has also been proven to work with a localized action especially against *E. coli*. The presence of Ig that protect the intestinal lining from *E. coli* suggest that there is a benefit to feeding first milking colostrum the first 3 days of the calf's life. Researchers have shown that there are substantial reductions in morbidity and mortality in calves exposed to *E. coli* (enteropathogenic) if they have consumed colostrum containing Ig against *E. coli* even after the gut is closed to absorption (Corbett, 1991).

Concentrations and sources of Ig in colostrum differ from those found in blood. For instance, the two subclasses of IgG: IgG₁ and IgG₂ are found in similar concentrations in the blood of the dam. However, in colostrum, the majority of IgG is in the form of IgG₁. In fact, in colostrum,

IgG₁ is seven times more concentrated than IgG₂ (Larson). Additionally, little, if any of the IgA and IgM in the blood is transferred to colostrum. Colostral IgA and IgM are produced by specific plasma cells that are adjacent to secretory cells in the mammary gland. These IgA and IgM producing plasma cells then transfer their Ig products directly to the secretory cells and into the colostrum (Larson).

Immunoglobulin concentrations in colostrum vary not only from those found in blood, as noted earlier, but also from those found in whole milk Table 3).

Table 3. Ig levels in colostrum and whole milk.

	<i>IgG₁</i> (g/L)	<i>IgG₂</i> (g/L)	<i>IgM</i> (g/L)	<i>IgA</i> (g/L)
Colostrum	75.00	1.90	4.90	4.40
Whole Milk	0.35	0.06	0.04	0.05

Larson; Roy, 1980

Absorption

The absorption of macromolecules (Ig) from the intestinal lumen to the blood occurs in two phases. The first phase is the internalization or uptake of Ig within the intestinal epithelium and the second is transport or subsequent expulsion of Ig into systemic circulation. Uptake and internalization of Ig stop when transport ceases; likewise, even when uptake and internalization result from active pinocytosis, transport and expulsion may not occur. Feeding colostrum stimulates pinocytosis followed by the termination of internalization although transport may continue. This would have significance in protecting the calf from prolonged exposure to the random absorption of pathogens (Stott et al., 1979a).

Rate of absorption

The interactions of three factors influence the rate and pattern of colostral Ig absorption. These are:

- The starting age at which colostrum is fed
- The quantity of colostrum fed
- The time after feeding colostrum

Ingested colostrum supplies Ig for uptake and stimulates pinocytosis (or absorption) of Ig by the intestinal epithelial cells. Efficiency of Ig absorption by intestinal cells decreases as the calf ages due to maturation of the intestinal cells. This decrease in Ig absorption over time emphasizes the importance of sufficient colostrum intake by the calf during its first feeding to activate all potential absorptive cells lining the walls of the small intestine. As the calf ages there is a progressive decrease in the rate of absorption in both the initial period after feeding and over subsequent time-periods. Evidence shows that declining rates of absorption are associated with the number of intestinal epithelial cells responsible for the transfer of Ig.

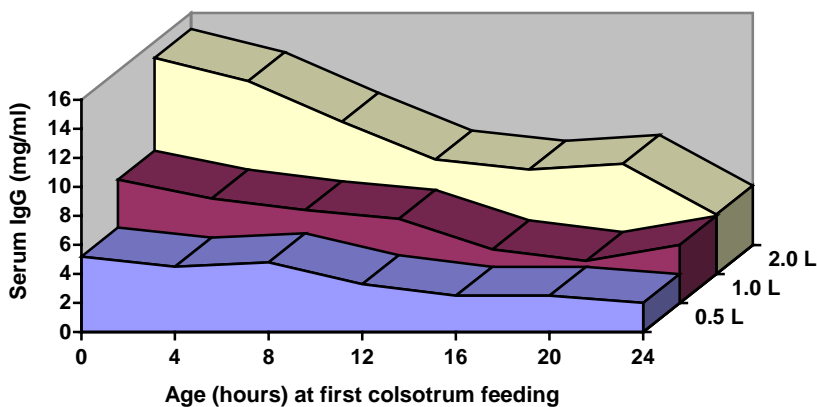
In order to determine how much colostrum was sufficient for maximum Ig absorption, researchers evaluated the effects of feeding different amounts of high quality colostrum at

different times after birth (Stott et al., 1979b). These researchers found that pinocytosis was not activated in all potential cells of calves fed ½L or 1L of colostrum after birth because a second feeding 12 hours later caused an increase in absorption of Ig. However, feeding 2L, versus feeding ½L or 1L, of colostrum greatly increased the rate of transfer of colostral Ig to Ig circulating in the blood during the first 4 hours after birth as well as successive time periods. Calves consuming 2L did not respond to a second feeding 12 hours later, which indicated that a 2L feeding supplied enough volume to completely contact and satiate potential absorptive cells in the intestine.

Amount of absorption

The two major factors that determine maximum serum Ig concentration for each Ig class in calves already fed colostrum are age at first feeding and the amount of colostrum fed. These

Graph 2. Serum IgG concentration in calves fed three amounts of colostrum



factors both exhibit a linear response such that as age at colostrum feeding increases, Ig concentration decreases and as the amount of colostrum fed increases, up to 2 liters, serum Ig concentration increases (Graph 2). Stott et al. (1979c) demonstrated that the greater the quantity of colostrum fed at the initial feeding age, the higher the serum Ig concentration in the calf. These factors interact so calves whose initial feeding of colostrum

is at progressively older ages need less colostrum to reach maximum absorption which is represented by a progressive decline in serum Ig concentration with increasing age.

However, the age at which colostrum is first fed and the amount fed, are not the only factors that affect Ig absorption from colostrum. Environmental factors such as heat stress, severe cold stress, and severe dystocia have also been shown to decrease Ig absorption from colostrum (Davis and Drackley, 1998). Unfortunately, even this list of factors does not explain why calves fed equal amounts of pooled colostrum at the same age do not always have similar levels of serum IgG (Davis and Drackley, 1998).

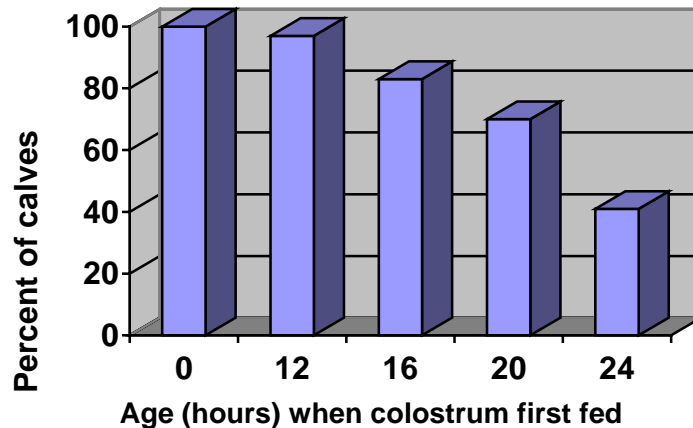
Period of absorption

The closure or termination of intestinal permeability to colostral Ig occurs spontaneously with age and the rate of closure progressively increases after 12 hours of age. When calves are not fed colostrum, mean closure time is approximately 24 hours after birth. Calves fed colostrum soon after birth have an earlier cessation of absorption. Thus, age at first feeding influences

closure time while the amount of colostrum fed has no effect. This period of intestinal permeability is crucial to the transfer of colostral Ig.

Stott et al. (1979a) evaluated the period of Ig absorption in the calf. Calves fed colostrum after birth had a closure time for IgG absorption at 21 hours, IgM 23 hours and IgA 23 hours. When feeding was delayed until 24 hours after birth the closure time was 33, 31, and 32 hours for IgG, IgM and IgA, respectively. Thus, length of absorption time is reduced with delayed feeding (for example, calves fed at birth had 24 hours to absorb Ig, while those not fed until 24 hours of age, had only 8 hours of absorption time). By increasing age of first feeding of colostrum and therefore decreasing the

Graph 3. Percent of Calves Absorbing Colostrum



length of absorption time, calves have increasingly less chances to absorb sufficient quantities of colostrum to achieve 10 mg/ml of serum IgG. In the same study by Stott et al. (1979c), age at first colostrum feeding resulted in over 59% of the calves fed colostrum at 24 hours of age were unable to absorb colostral Ig (graph 3). This proportion declined to 30% when fed at 20 hours, 17% at 16 hours and 3% at 12 hours. All of the calves fed colostrum prior to 12 hours of age absorbed all classes of Ig. This study concluded that calves not ingesting colostrum by 12 hours of age are subject to gut closure before any Ig absorption takes place.

The calf is physiologically limited by the mass of Ig that it can absorb from a specific volume of colostrum (Besser et al., 1985). Due to this physiological limitation, there is wide variation in the amount of Ig transfer in calves. This variability results in 10 to 30% of calves being hypogammaglobulinaemic or low in serum Ig concentration. The high frequency of hypogammaglobulinaemia can be assigned to a low concentration of colostral Ig, inadequate colostrum intake, colostrum being fed too late or an early loss of absorption capability (Stott et al., 1979a).

General

Several factors influence the passive transfer of Ig from colostrum to the calf. They include:

- Ig mass ingested
- Time of colostrum ingestion
- Method of feeding colostrum
- Genetic, physiological and environmental influences

The most important of these is Ig mass and time of ingestion. Colostral Ig are transferred across the intestinal epithelial cells during the first few hours of life and transported to the blood via the lymphatic system. Once in the blood the Ig are further distributed to body secretions and extra-vascular fluids depending on the Ig class. Absorbed Ig protects against septicemia disease and systemic invasion by microorganisms. The Ig that are not absorbed play an important role in protecting against intestinal disease (Gay and Besser, 1985).

There are herd to herd variations in serum Ig concentrations that are associated with the calf's resistance or susceptibility to disease. It is not possible to categorically state the serum Ig level that should be reached to insure neonatal disease resistance. Differences in infection pressure, infecting agents and calf management as well as colostrum quality can influence the level of Ig required for protection. Calves in herds considered to have low mortality rates may survive having serum Ig concentrations that are not associated with protection in herds with high mortality (Gay and Besser, 1985).

OTHER COMPONENTS OF COLOSTRUM

Nutrition components

The importance of colostrum as a source of Ig is a well-known fact for most dairy producers. Benefits from feeding colostrum are not however, limited to Ig. Colostrum also contains numerous nutrients such as protein, fat, carbohydrates, vitamins and minerals.

Colostrum is a good source of energy for the neonatal calf. The fat and the lactose, which provide energy in the colostrum, are necessary for the calf to begin thermogenesis (heat production) and maintain body temperature. Without the energy source that colostrum provides the calf would only have about 18 hours until its stores of body fat would be depleted (David and Drackley, 1998).

In addition to energy, the vitamins and minerals in colostrum are at much higher levels than those found in whole milk (David and Drackley, 1998). It has been suggested that these increased amounts may be a way to ensure that the calf receives adequate amounts of these vitamins and minerals to initiate its metabolism and possibly to assist in the development of its digestive system.

Non-nutritive components

In recent years, researchers have discovered that colostrum contains numerous growth hormones (insulinlike growth factor I and II, epidermal growth factor, transforming growth factor, and nerve growth factor) as well as insulin, cortisol, and thyroxine (Xu, 1996). Several research studies have suggested that these components of colostrum may be beneficial for development and maturation of the digestive system (Davis and Drackley, 1998).

General

Feeding high quality colostrum to calves as soon as possible after birth will provide them not only with immunoglobulins to help fight disease, but also with other nutritive values such as energy and high levels of vitamins and minerals and non-nutritive growth factors. With so many

obvious benefits to the calf from feeding colostrum, making the choice to have superior colostrum management protocols on their farm should be very easy. Not only will your calves be healthier, but they will also have the added benefits of high quality nutrition and beneficial digestive growth and maturation.

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