Factors Affecting Passive Transfer in Neonatal Calves

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ABSTRACT

The objective of this literature review was to determine whether maternal colostrum or a colostrum replacer will provide adequate immunoglobulin concentrations to the calf, decreasing mortality and morbidity, and to determine which is more economical to dairy producers. Studies were reviewed and analyzed from various peer-reviewed journals, mainly from the Journal of Dairy Science. Articles were obtained from using library resources as well as government websites. AGRICOLA and Web of Science databases were used to search articles containing various phrases such as "factors affecting colostrum," "colostrum replacer," and "colostrum immunoglobulins." Many articles and studies were reviewed and declared as useful or not useful. Useful information and studies were then gathered and re-read and reviewed in order to be further analyzed. There were many factors affecting maternal colostrum quality and its effect of passive transfer including: age of the dam, breed, preparturient vaccination, health of the dam, maternal colostrum handling, dry period length, season of calving, time to colostrum collection, and method of feeding colostrum. Colostrum replacers were analyzed based on price, concentrations of immunoglobulins, and absorption levels in the calf. A third alternative feeding method was reviewed, colostrum supplements. Colostrum supplements were evaluated in terms of the calf's ability to absorb immunoglobulins and different product concentrations of proteins as well as related feeding cost per dose. Calves fed high quality maternal colostrum has high absorption rates and compared to colostrum supplements and replacers, had lower cost and management use. However, management practices on feeding calves and subsequent passive transfer are dependent on numerous factors and should ultimately be decided by

management. Further research and studies should be completed on the effect of immunoglobulin concentration in dairy calves when fed maternal colostrum, colostrum replacers, and colostrum supplements.

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INTRODUCTION

Effective colostrum management and administration is the single most important factor regarding calf health and survival. Because the calf is born deficient of antibodies, colostrum ingestion is essential for attaining antibodies and building immunity against diseases and pathogens. High quality colostrum contains immunoglobulins (Ig) which when absorbed through the intestinal tract of the calf, result in a passive transfer of immunity. Immunoglobulins can be broken into 5 categories: IgA, IgG, IgM, IgD, and IgE; all with different concentrations in colostrum (Table 1) (Anderson, 1985). IgG is the dominant immunoglobulin in the bovine and is linked to disease resistance. IgA is scarce because it protects against intestinal pathogens and would interfere with rumen flora development (Anderson). IgM is produced in smaller quantities compared to IgG but are more efficient at destroying viruses and is important in the initial exposure to antigens (Anderson). When a calf is first exposed to an antigen, a higher amount of IgM is produced but fades as IgG becomes the main immunoglobulin produced (Anderson).

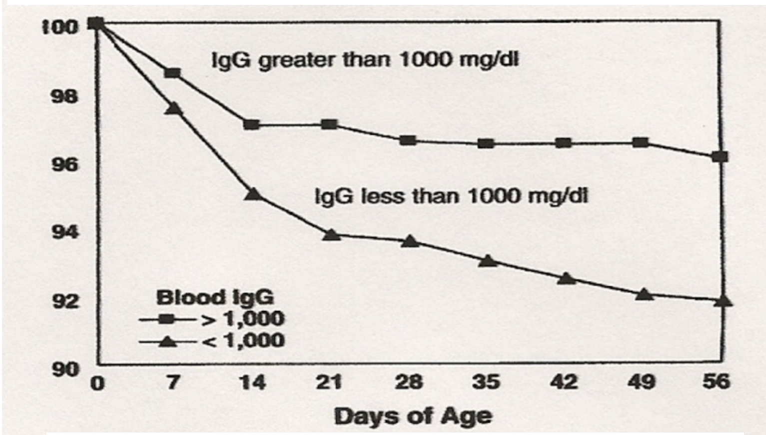
Table 1. Concentration and relative percentage of immunoglobulins in the serum and mammary secretions

Species	Immuno-globulin	Concentration (mg/ml)			% Total Immunoglobulins		
		Serum	Colostrum	Milk	Serum	Colostrum	Milk
Bovine	IgG1	11.0	47.6	0.59	50	81	73
	IgG2	7.9	2.9	0.2	36	5	2.5
	IgA	0.5	3.9	0.14	2	7	18
	IgM	2.6	4.2	0.05	12	7	6.5
	FSC		0.5	0.06			

Source: Anderson et. al., 1985

The amount of colostrum and immunoglobulin concentration is critical for passive transfer in neonatal calves. It is recommended that four quarts of colostrum should be fed between birth and 4 hours after the calf is born to ensure high absorption rates. Targeted blood Ig levels should be 10 g/l to achieve passive transfer (Kirk, 2011). As time increases, the percent of immunoglobulins absorbed decreases because the intestinal tract of the calf only temporarily allows absorption, ultimately resulting in a failure of passive transfer of immunity (Figure 1). Absorption sites in the intestine close and bacteria begin to colonize and grow in the intestine, making it critical for colostrum feeding to occur as soon as possible after birth (Kirk).

Figure 1. Calf survival by IgG concentration and age



Source: Godden, 2008

The United States Department of Agriculture recommends a minimum serum IgG concentration of 1,000 mg/dL and for more efficient passive transfer an IgG concentration of 1,500 mg/dL. Failure of passive transfer (FPT) in a calf exists if the IgG concentration is below 1,000 mg/dL (USDA, 2010). FPT increases mortality and morbidity 3 to 5 times (Kirk). The USDA conducted a Dairy 2007 study, which included 17 major dairy states in the United States, and found that 66.7 percent of heifer calves

attained excellent passive transfer and 19.2 percent had failure of passive transfer (USDA). By using good management protocols, FPT should be minimized and calf raisers should aim at a <5 percent calf loss. Ensuring calves receive an appropriate amount of high quality colostrum in a timely manner will be beneficial to calves survival rate and profitable to dairy producers. Reduced mortality in postweaning period, improved rate of gain and feed efficiency, reduced age at first calving, improved first and second lactation milk production, and reduced tendency for culling during first lactation are all expected outcomes of effecting passive Ig transfer (Godden, 2008).

The objective of this literature review is to determine whether maternal colostrum or a colostrum replacer will provide adequate immunoglobulin concentrations to the calf, decreasing mortality and morbidity, and to determine which is more economical to dairy producers.

METHODS AND PROCEDURES

Studies were reviewed and analyzed from various peer-reviewed journals, mainly from the Journal of Dairy Science. Articles were obtained from using library resources as well as government websites. AGRICOLA and Web of Science databases were used to search articles containing various phrases such as "factors affecting colostrum," "colostrum replacer," and "colostrum immunoglobulins." Many articles and studies were reviewed and declared as useful or not useful. Useful information and studies were then gathered and re-read and reviewed in order to be further analyzed.

REVIEW OF LITERATURE

Factors Affecting Maternal Colostrum Quality

Age of Dam. Cows that have had multiple lactations tend to have a higher quality of colostrum in regards to antigen level because they have been on the farm longer and had a greater period of exposure to various pathogens and antigens (Godden, 2008). Primiparous animals have not had the time to accumulate and build up resistance to the various herd-specific pathogens. Older cows build up a larger amount of antibodies because of a greater exposure time to pathogens. This exposure provides the calf with higher amounts of antibodies from the maternal colostrum. Although there have been conflicting studies, most studies show the age of the dam influences colostrum quality. A study from Iowa State University took 10 mL of jugular blood samples from Angus calves that were born from 2007-2009. Results showed that younger dams passed fewer maternal antibodies to their offspring compared to older dams that passed a larger amount of maternal antibodies to their calves (Downey et al.). Another study randomly selected 290 out of 1600 Holstein cows from China to determine important factors that affected IgG concentration in milk. Liu et al. (2009) found, by taking multiple samples of milk and blood, that there was a strong correlation between lactation number and IgG1 concentration. Immunoglobulin concentrations in primiparous cows significantly differed from older cows, with multiparous cows secreting 1.3-1.6 times higher antibody concentration (Liu et al., 2009). It was also noted that animals in 4^{th} lactation had the highest IgG1 concentration.

Merrick's article on "The Key To Calf Survival" (2005) noted that immunoglobulin concentration increases with parity until fourth lactation and above,

where it stays constant. First parity cows had an average Ig concentration of 5.91%, second lactation 6.26%, third 8.15%, and fourth lactation and greater had an average concentration of 7.49% (Merrick's, 2005).

Breed. Variations in immunoglobulin concentrations can be attributed in part to breed differences. Greater IgG1 concentrations were shown in beef cows compared to dairy cows. Holsteins produced lower amounts of IgG1 colostrum (5.6%) and Jerseys produced the highest (9.0%) according to Godden (2008). Other breed immunoglobulin concentrations included: Guernsey (6.3%), Brown Swiss (6.6%), and Ayrshire (8.1%) (Godden, 2008). Corke (2010) suggested compared to large breeds such as Holsteins, Jerseys have lower dilutions of immunoglobulins because they produce less milk, making them have higher concentrations of immunoglobulins.

A 2 year study performed by Murphy et al., (2005) examined the effect of breed on immunoglobulin concentration (Table 2). The study consisted of five breeds: LF (Limousin X Friesian), LLF (Limousin X (Limousin X Friesian)), L (Limousin), C (Charolais), and SLF (Simmental X (Limousin X Friesian)). During prepartum periods and 30 days postpartum, there was no significant effect on IgG1 concentrations with regards to the different breed types. However, at the time of calving, there was a significant effect of cow breed type on IgG1 concentrations (Table 2). Out of the five breed types, C has the highest serum IgG1 concentration at 9.3 mg/ml. LF contained a cow serum IgG1 concentration of 5.3 mg/ml, the lowest of the five breeds (Murphy et al., 2005). It is interesting to note that the two breeds with the highest immunoglobulin concentrations were purebred and the intermediate and low immunoglobulin producing

breeds were crossbred. The study also confirmed that there was no significant difference between breeds before calving and 30 days postpartum.

·um on IgG1 concentrations

Variable	Cow breed type[1]					s.e.[2]	F-test[3]
	LF	LLF	L	C	SLF		
IgG_1 in cow serum at (mg/ml)[4]							
Day 90 pre partum	11.9	11.2	12.6	12.6	11.4	0.69	
Day 60 pre partum	10.7	9.8	11.3	11.8	11.4	0.62	
Day 30 pre partum	9.3	8.5	10.5	11.5	9.6	0.68	
Parturition	5.3[a]	7.6[ab]	8.8[b]	9.3[b]	6.9[a]	0.61	**
Day 30 post partum	10.1	10.5	11.6	12.4	10.9	0.62	

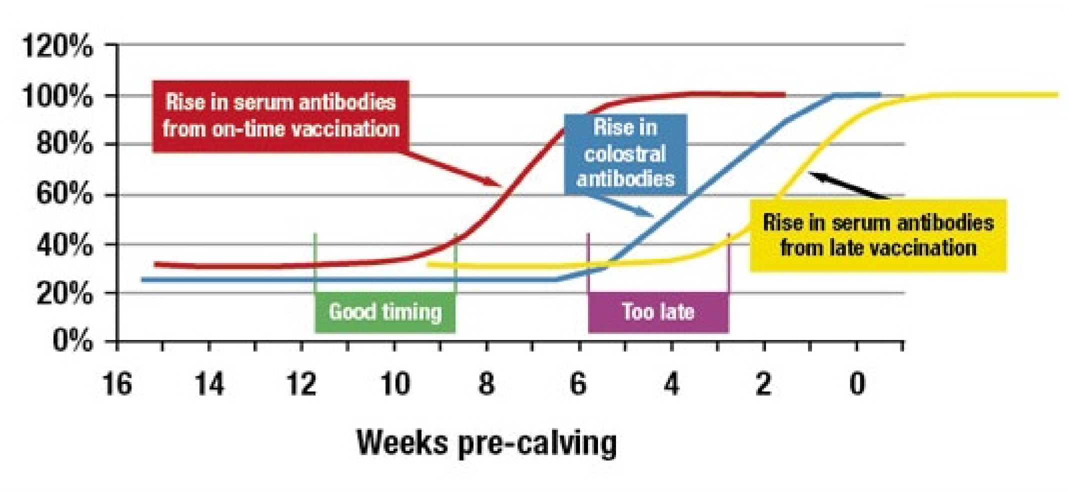
Source: Murphy et al., 2005

Murphy et al. (2005) explained that the findings are associated with the process of colostrogenesis. In the pregnant bovine, colostrum begins to form 3-4 weeks before parturition, mainly under the influence of progesterone. The mammary gland is lined with epithelial receptors that draw in antibodies and other material from the blood stream into colostrum (Murphy et al., 2005). The transferring of anibodies and other material to colostrum occurs about 2 weeks prepartum with the maximum concentration of immunoglobulins occurring about 5-10 days before parturition (Smith and Hogan).

Preparturient Vaccination. Colostrogenesis is also the reason why preparturient vaccination is effective in improving colostrum quality and aids in protecting calves against mortality and morbidity. Because antibodies are being transferred for the formation of colostrum before parturition, vaccinating cows at specific times may ultimately affect the immunoglobulin concentrations. An increase of maternal antibody production occurs approximately 10-14 days after vaccination of the dam, which provides colostrum with a higher Ig concentration (Hill, 2011). Vaccinating the dam at approximately week 6 before calving will allow enough time for antibody production and

transfer from serum to colostrum. This will result in higher antibodies in maternal colostrum at calving (Figure 2). Various vaccinations can be used and include protection from: rotaviruses, coronaviruses, clostridium, and *E. coli* (Heinrichs and Jones, 2003).

Figure 2. Relationship of vaccination timing to colostrum formation



Source: Hill, 2011.

Diseases/Health of Dam. Dam health is important with regards to immunoglobulin concentration and colostrum quality. Dams that have a persistent intramamary infection (IMI) tend to produce lower volumes of colostrum (Godden). As SCC increases in milk, IgG1 concentration also increases. Gulliksen et al., (2008) found that cows with a SCC >50,000 cells/mL had a higher tendency to produce colostrum with IgG levels of <30 g/L. Gulliksen et al., (2008) also concluded other conditions, including milk fever, prolonged pregnancy, retained placenta, dystocia, and mastitis did not have a correlation with IgG content in colostrum.

Pathogen exposure is crucial in regards to dam health and colostrum quality. Cows that have been exposed to higher amounts of pathogens are more likely to have higher immunoglobulin levels. Pathogen exposure and age are highly correlated due to

the fact that older cows tend to be exposed to greater number of pathogens (Bovine Alliance on Management and Nutrition). However, this is also a risk to feeding calves raw maternal colostrum because pathogen exposure occurring before calves have developed immunity can affect mortality and morbidity. *Mycobacterium avium* ssp. *paratuberculosis*, *Mycoplasma* spp, *Escherichia coli*, and *Salmonella* spp. are all infectious diseases that can cause scours and septicemia in calves by being shed from the udder or by mishandling and storing raw colostrum (Johnson, et al., 2007).

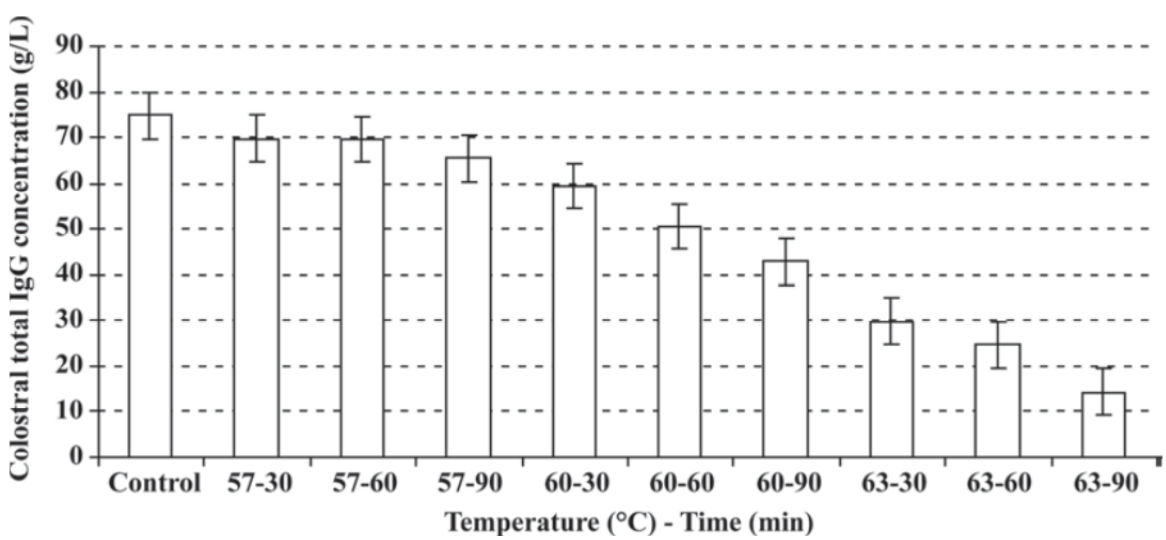
According to Quigley (2001), it is not recommended to feed colostrum that is infected with *M. paratuberculosis* even if it has been frozen or pasteurized. Because the organism is secreted from the udder, transmission of the disease to the calf will occur. Freezing at very low temperatures or pasteurizing at very high temperatures are not reliable for killing the pathogen because colostrum is thicker and denser than milk (Quigley, 2001). Quigley also suggests that pasteurizing is not effective at killing Johne's disease because the organism is contained in the white blood cells which make it harder to reach the organism. Also, pasteurization does not completely kill the organism; it simply reduces the number of organisms present. Commercial pasteurizers also differ from on-farm pasteurizers because of the standards and difference in effectiveness (Quigley, 2001).

Natural (Maternal) Colostrum Handling.

There are many management decisions when caring for colostrum and feeding it to calves. Often colostrum is collected and pooled, with many options on handling before feeding. Colostrum can be frozen and pasteurized with different effects attached to each. Pasteurizing colostrum can be a potential source for eliminating or reducing infectious

diseases in maternal colostrum. A recent study used 30 Holstein cows at the Pennsylvania State University dairy to determine the effects of time and temperature on heat-treated colostrum (Elizondo-Salazar et al., 2010). Methods for the study included collecting and mixing colostrum from each cow. Colostrum was then frozen at −20°C and thawed at the beginning of the experiment at 4°C. After the colostrum was thoroughly mixed, ten 15-mL centrifuge tubes were filled with 10-mL of equal parts of the 30 colostrum samples (total n = 300). Samples were heated in a water bath for 0, 30, 60, or 90 min at 57, 60, or 63°C (Elizondo-Salazar et al., 2010). Results showed that as both time and temperature increased, bacterial count in colostrum decreased as well as immunoglobulin concentration (Figure 3).

Figure 3. Changes in total IgG concentration in bovine colostrum samples after heat treatment at various time and temperature combinations (top of the bars represent SEM).



Source: Elizondo-Salazar et al., 2010

As temperature increases, organisms in colostrum are greatly reduced. Heating colostrum to 63°C had the greatest effect on decreasing bacterial groups and specifically the coliform count (Table 3).

Table 3. Time required to destroy 90% of organisms (D-values, min) at each heating temperature for bacterial groups present in bovine colostrum samples

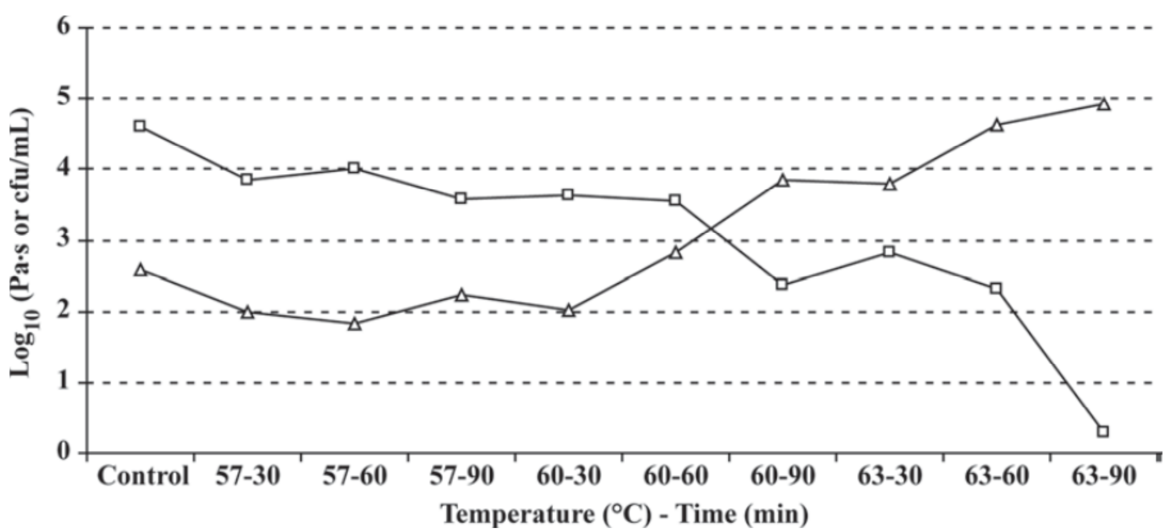
	D-value (min)				
Temperature (°C)	SPC	ES	CNS	CC	NC
57	34.09	65.22	40	37.04	30.93
60	25.64	54.55	36.14	32.26	10.00
63	23.50	45.92	23.08	10.75	10.00

SPC= Stanard Plate Count; ES= environmental streptococci; CNS= Coagulase-negative staphylococci; CC= coliform count; NC= non-coliform count

Source: Elizondo-Salazar et al., 2010

There was also no change in viscosity when colostrum was heated at 60°C for 30 or 60 minutes. However, colostrum viscosity increased when colostrum was heated 60°C for 90 minutes and 63°C (Figure 4).

Figure 4. Changes in viscosity (Δ) and standard plate count (□) in bovine colostrum samples after heat treatment at various time and temperature combinations



Source: Elizondo-Salazar et al., 2010

Johnson et al. (2007) conducted a study to determine the effect of feeding colostrum that has been heat-treated to calves at 60°C for 60 minutes. The authors found that the concentration of IgG was equivalent in heat-treated colostrum and raw colostrum. The authors also concluded that heat-treated colostrum contained a considerably lower amount of bacterial counts relative to the untreated product. Although bacterial counts slightly rose at the time of feeding raw colostrum and heat-treated colostrum, the counts were still significantly lower in the colostrum that was heat-treated (Johnson et al., 2007). There was also a difference in passive transfer in heat-treated colostrum and raw colostrum. Blood serum samples were taken at 24 h and calves fed heat-treated colostrum tested higher for total protein and immunoglobulin G, indicating that absorption rates for heat-treated colostrum proved to be higher (Johnson et al., 2007). However, Corke (2010) noted that there was a 23.6% reduction of IgG after pasteurization. Feeding heat-treated colostrum is a viable option for feeding calves and can yield positive results when done correctly.

Colostrum can be refrigerated or frozen to preserve quality in order to be fed at a later date. When refrigerating colostrum, temperature should be kept consistent at 33-35°F (Quigley, 2001). If colostrum collection and feeding interval is longer than an hour, colostrum should be cooled lower than 40°F to prevent rapid growth of bacteria (Heinrichs and Jones). However, colostrum should not be fed if it has been stored for longer than a week or if spoilage begins to occur (Quigley, 2001). Conversely, Penn State recommends not feeding colostrum that has been refrigerated for more than 24 hours due to high concentrations of bacteria.

Freezing colostrum is another option for storing high quality colostrum. Colostrum can be stored in 1 or 2 liter bottles or in 1 or 2 gallon zip-lock bags at -5°F (Quigley, 2001). It is not recommended for frost-free freezers to be used because the constant freeze-thaw cycles may allow colostrum to become slightly thawed, increasing the chance of bacterial contamination (Quigley, 2001). Frozen colostrum should not be used if it has been frozen more than one year due to loss of vital nutrients (Merrick's, 2005). Rapid thawing should be avoided because of the denaturing of proteins. It is recommended to thaw colostrum at 38°C or at room temperature to ensure high colostrum quality and immunoglobulin concentrations (Merrick's, 2005). However, colostrum can also be thawed by the use of a microwave although it is crucial the microwave is used on low power and to remove the thawed colostrum between intervals of warming (Merrick's, 2005).

Fermenting colostrum is a method used to preserve colostrum in order to feed to calves at a later date. Temperature for fermentation should be between 50°F and 70°F (Morter). The lid on the container should be left loose so air is able to circulate and new colostrum should added every day to prevent spoilage bacteria from ruining the colostrum (Morter). Soured colostrum is fed to calves in two parts of fermented colostrum to one part of warm water (Meinershagen, 1993). It is important that the mixture of soured colostrum and water is fed at or below 8% of the calves body weight (Meinershagen, 1993). However, neonatal calves should not be fed fermented colostrum at first feeding and for 3 days after, but may be fed as a partial milk replacer (Meinershagen, 1993). The reason for not wanting to feed fermented colostrum is

because the bacteria involved in the fermenting process will degrade the protein in the colostrum, affecting passive transfer (Quigley, 2001).

Dry Period Length. Watters et al., (2008) studied the effects of shortening the dry period length from 55 days to 34 days on milk production, colostrum quality, and overall animal health. 781 Holstein cows were used in the experiment and results showed that there was no difference in colostrum quality between the two groups (Watters et al., 2008). Penn State suggests a dry period length of at least 3 to 4 weeks in order to provide an adequate amount of time for antibodies to concentrate in the colostrum from the blood. During the dry period, nutrition can have an effect on colostrum quality. Dams that are fed low amounts of protein or energy have a tendency to produce colostrum that will result in a failure of passive transfer (Heinrichs and Jones).

Season of Calving. Depending on certain climates and locations, calving season may affect immunoglobulin levels in maternal colostrum (Figure 5). Gulliksen et al., (2008) conducted a study in Norway and experienced cows calving during the months of August, September, and October produced higher quality colostrum. There are many factors combined with the season that might be affecting the results. In Norway, cows usually spend 8 weeks on pasture from May to September, which inhibits change in feeding routine and could possibly affect immunoglobulin levels (Gulliksen et al., 2008).

It has also been suggested that season affects colostrum quality due to temperatures. High temperatures during late pregnancy are associated with increased heat stress, decreased dry matter intake resulting in reduced amounts of nutrients the udder received (Godden, 2008).

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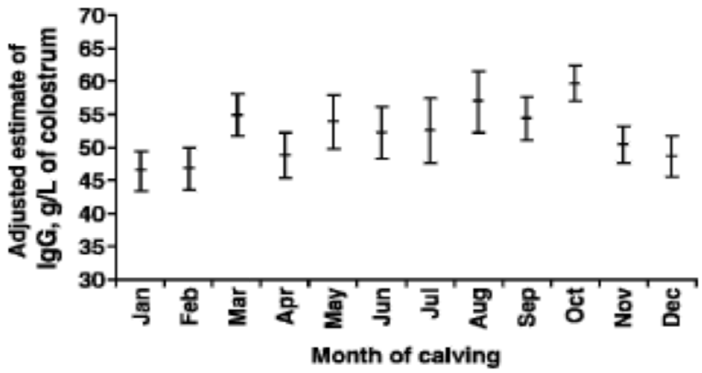

ulliksen et al., 2008

Time to Colostrum Collection. Colostrum is the highest quality at the first milking after parturition and decreases with time (Table 4). Also, as time to colostrum collection from the dam increases, the concentration of immunoglobulins change. An increase in time results in a decrease of Ig concentration, which makes it important to collect colostrum as soon as possible from the dam. Postponing first colostrum collection for 14 hours resulted in a 33% decrease in IgG concentration (Godden, 2008).

Table 4. Composition of bovine colostrum and transition milk

	1st milking	2nd milking	3rd milking	Milk
Spec. Grav.	1.056	1.04	1.035	1.032
Solids	23.9	17.9	14.1	12.9
Protein %	14	8.4	5.1	3.1
Fat %	6.7	5.4	3.9	3.5
Lactose %	2.7	3.9	4.4	5
IgG, g/ℓ	48	25	15	0.6
Casein	4.8	4.3	3.8	2.5

Source: Foley and Otterby (1978).

Method of Feeding. Leaving calves to nurse from their mothers can cause extreme problems with colostrum and immunoglobulin consumption. Calves that are left to nurse tend to experience a higher rate of morbidity and mortality because they do not receive a sufficient amount of colostrum (Quigley, 2001). The United States Department of Agriculture (2007) found 25.8% of calves left to nurse the dam experienced failure of passive transfer and 16.9% of calves that did not nurse from the dam experienced FPT. Approximately 25-40% of calves that nurse from the dam do not consume an adequate amount of high quality colostrum because calves tend to drink small quantities after birth (Quigley, 2001). This inadequate consumption allows bacteria to enter and multiply in the intestine, causing mortality that may lead to death (Quigley, 2001).

Many times, calves do not want to consume the recommended amount of colostrum right after birth because they do not have a strong drive to nurse (Morter). Another reason calves might be reluctant could be because the calf might not physically be able to consume colostrum because of the birthing process (Quigley, 2002). Sometimes calves suffer from internal bruising to the organs or broken bones (Quigley, 2002). When this occurs, esophageal feeders can be used to ensure calves receive an appropriate amount of quality colostrum. It is recommended that calves be removed from their dam no longer than 2 hours after parturition when fed via bottle or esophageal feeder (Godden, 2008). Feeding calves by the use of an esophageal feeder or “tube” doesn’t come without risk. Calves should be fed appropriately according to their body weight, Holsteins at 4 L, or the calves may not be able to hold the amount (Quigley,

2002). Inserting the tube can cause damage to the oral tract of the calf so it should be inserted and taken out very carefully (Quigley, 2002).

Factors Affecting use of Colostrum Replacers

There are times when a producer has to decide what form of feed will yield the best results on their individual operation. When waste milk is scarce or unavailable and colostrum is poor quality and not useful, a producer needs to use an alternative nutrient source. If there is a problem with infectious diseases on the farm, a dairy producer may opt to discard all colostrum from infected cows instead of using a heat-treatment method in order to prevent disease transmission (Godden, 2008). In such cases, high quality colostrum replacers can serve as a viable alternative to natural colostrum.

The amount of immunoglobulins absorbed by the calf is vital and must be acceptable whether using maternal colostrum or colostrum replacer. There are many studies on the subject, some with conflicting results. Godden et al., (2009) compared the effects of feeding commercial colostrum replacer and 3.8 L of maternal colostrum. Absorption rates were all equivalent among groups. Of the three treatment groups, FPT occurred in almost half of the calves that were fed 1 dose (1.5 L) of colostrum replacer. Although the results showed that total Ig concentrations tended to be higher in calves fed maternal colostrum versus calves fed 2 doses (3 L) of colostrum replacer, the difference was not statistically significant. The results also showed that the percentage of IgG was higher in calves fed 2 doses of colostrum replacer versus calves fed maternal colostrum. However, IgA and IgM percentages were higher in calves fed maternal colostrum compared to calves fed 2 doses of colostrum replacer. The study concluded that feeding 2 doses of colostrum replacer was comparable to feeding 3.8 L of maternal colostrum

(Godden et al., 2009). Attaining passive transfer using colostrum replacer is also dependent on the type of colostrum replacer that is used. Because there are many different types available commercially, it is important to combine label directions and management protocols to obtain the greatest result.

In 2009, an experiment conducted by Godden et al. found similar results to Swan et al. (2007). Calves that were fed a single dose colostrum replacer, containing 100 g/dose of IgG were likely to have a failure of passive transfer. The study noted that when calves were fed a higher dose of IgG, passive transfer rates improved. The authors concluded that calves fed maternal colostrum contained significantly higher serum immunoglobulin levels mostly due to the fact that there was a higher concentration of IgG consumed (Swan et al., 2007). Multiple feedings of colostrum replacer are required to achieve an acceptable level of proteins received by the calf.

Jones et al. (2004) performed a study that used Holstein and Jersey calves to evaluate immunoglobulin absorption. Calves were fed 2 feedings of maternal colostrum as well as 2 feedings of colostrum replacer. When blood samples were taken at d 8 and 15, calves that were fed a colostrum replacer had a higher serum IgG concentrations than calves fed maternal colostrum. There was also no difference in morbidity and mortality between calves fed maternal colostrum and calves fed colostrum replacer. Although the study concluded colostrum replacer provided acceptable levels of immunoglobulins and adequate health, the authors still had doubts about using colostrum replacers over maternal colostrum (Jones et al., 2004).

It is important for producers to make sound management decisions regarding the use or maternal colostrum and colostrum replacers. Because colostrum replacers cost $25-$30/dose, it may not be feasible (Godden, 2008).

Although most colostrum replacers are currently derived from bovine colostrum, it is conceivable that calves may not receive specific antibodies for on-farm pathogens and, in turn, may not be provided with adequate protection. However, colostrum replacer is a plausible alternative when maternal colostrum is questionable in terms of quality. If maternal colostrum becomes unavailable or the dam is infected with a disease, it is crucial to use an alternative form of colostrum. Early exposure to pathogens can be harmful to the newborn calf and easily shed from the dam which may result in poor calf health and economic losses. If high quality maternal colostrum is available, it is the best form of colostrum to use to provide the calf with an excellent source of nutrients and proteins and to achieve passive transfer.

Cost of Commercial Colostrum Replacer. A disadvantage in using colostrum replacers over maternal colostrum is the cost. Colostrum replacers are approximately $25-$30/dose (Godden, 2008). If high quality maternal colostrum is available but discarded, it may ultimately result in an economic loss.

Colostrum Supplements

A third alternative to using maternal colostrum and colostrum replacers is to use a combination of maternal colostrum and colostrum supplements in order to achieve passive transfer of immunity. Quigley et al. (2002) determined whether a colostrum replacer or a colostrum supplement was more successful in transferring immunoglobulins to calves. There were 2 doses of colostrum supplement given to one group of calves and

2 doses of colostrum replacer given to the 2nd group of calves at approximately 0.5 h and at 24 h of age (Quigley et al., 2002). Both treatment groups efficiently absorbed immunoglobulins, however, the treatment group that was fed colostrum replacer achieved passive transfer and the group fed the colostrum supplement had FPT (Quigley et al., 2002). The authors discussed that the colostrum replacer contained more nutrients, forming a complete diet and the colostrum supplement should be fed in union with maternal colostrum to aid in achieving appropriate nutrient levels (Quigley et al., 2002).

Most colostrum supplements are derived from cheese whey, colostrum from cows at selected herds, or bovine serum (Quigley, 2001). Serum-derived supplements in combination with maternal colostrum had higher IgG absorption rates when fed at the suggested amount compared to maternal colostrum fed without supplementation, according to a study conducted at the University of Tennessee (Quigley, 2001). Supplements made from maternal colostrum had lower absorption rates and does not provide assistance to the calf. Quigley (2001) concluded that colostrum supplements should only be used when maternal colostrum is not available, poor quality, or contaminated with infectious diseases.

It is important that supplements are not used as replacers because supplements do not contain the same amount of immunoglobulins and do not contain a complete source of protein, energy, vitamins, and minerals (Godden, 2008). Quigley et al. (2002) tested the composition of the colostrum replacer and colostrum supplement used in his experiment and found the colostrum supplement contained 11.08% IgG and the colostrum replacer contained 21.20% IgG. The amount of immunoglobulins in colostrum

supplements is not adequate and can lead to a poor transfer of immunity in neonatal calves.

DISCUSSION AND CONCLUSIONS

There are many factors that influence protein absorption rates in neonatal calves, making it difficult to determine the most effective protocol to use when feeding colostrum. Feeding an adequate amount of high quality colostrum as soon as possible after birth that will greatly influence passive transfer in the calf. It is critical that maternal colostrum contain a minimum of 50 g/L of immunoglubulins. High quality maternal colostrum is the most wholesome, nutrient rich colostrum when the dam is free from disease. Additionally, it is crucial to use the first milking of the dam due to the increased antibody levels. Colostrum should be collected from the dam as soon as possible to prevent a decreased immunoglobulin concentration. After 6 hours postpartum, there is a 17% Ig concentration and after 14 hours post-calving, there is a 33% reduction in immunoglobulin concentration (Godden, 2008).

Managing the collection of colostrum is very important in protecting the maternal colostrum from contaminants. The cow’s udder should be cleaned well and dried before harvesting. Collection canisters or buckets and milking equipment should always be sanitized before use (Heinrichs and Jones). Although management protocols are very important in protecting calves from the spread of disease, there are other ways calves can be infected with harmful bacteria and pathogens. Cows can shed diseases and pathogens from their udder into their colostrum which will affect calf mortality and morbidity. If the dam is infected with disease, it is best to discard the maternal colostrum and opt to use a high quality colostrum replacer. Using a colostrum replacer will greatly reduce the transmission of Johne’s, BVD, leucosis, and mycoplasma resulting in healthier calves

(Heinrichs and Jones). Table 5 describes both positive and negative associations with using a colostrum replacer.

Table 5. Colostrum replacer advantages and disadvantages

Positive Attributes	Negative Attributes
· Aids in passive transfer providing higher Ig concentrations compared to poor quality maternal colostrum · Reduced transmission of disease · Convenient feeding method	· Variability of protein in products · Cost

When deciding on a colostrum replacer to use, it is important to read the labels and determine the amount of immunoglobulins per dose of feeding. There are many products sold on the market with various ranges of protein and price making it difficult to determine which one will result in the highest passive transfer rates (Table 6).

Table 6. Colostrum replacer products and associated protein levels and price

Colostrum Replacer	Protein per feeding	Price
Product A	150 g	$29.95
Product B	130 g	$28.65
Product C	75 g	$14.36

Although colostrum supplements have varying protein levels and corresponding price, there are many benefits that can result with proper use (Table 7). If maternal colostrum is of moderate quality, using a high Ig colostrum supplement can aid in passive transfer of immunity. Using a colostrum supplement in combination with maternal colostrum is the best alternative when maternal colostrum does not meet the minimum protein levels.

Table 7. Colostrum supplement products and associated protein levels and price

Colostrum Supplement	Protein per feeding	Price
Product A	100 g IgG	$22.99
Product B	45 g	$11.95
Product C	20 g	$9.49

With a passive transfer of immunity being the ultimate goal for reducing mortality and morbidity in calves, colostrum conception is crucial. If available, high quality maternal colostrum should be used because it contains herd specific antibodies and offers the calf the most complete form of nutrition. If maternal colostrum does not meet minimum protein standards, a high quality colostrum supplement can be used with maternal colostrum to assist in passive transfer. If maternal colostrum is such poor quality where the bacterial load is very high or the dam suffers from infectious diseases, select a high quality colostrum supplement to promote the health of the calf.

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