

Ensuring optimal colostrum transfer to newborn dairy calves

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ABSTRACT

Ensuring adequate colostrum intake is a beneficial first step to rearing healthy calves. This article reviews best practice recommendations. Microorganisms multiply quickly, so colostrum must be collected hygienically and fed promptly (<1h) or stored using refrigeration, potassium sorbate as preservative, freezing and/or pasteurisation. All equipment must be scrupulously cleaned. A volume of 3-4L colostrum (approximately 10% body weight) should be fed within 2h and no later than 6h of birth. This should contain >50g/L immunoglobulin (Ig) with a bacterial count of <100,000 colony forming units/ml. Adequate intake cannot be assumed when calves suckle their dam. Pooling of colostrum between cows reduces quality and increases the risk of disease transfer. Feeding with a nipple bottle promotes oesophageal groove closure but if calves fail to suck then colostrum should be administered *via* oesophageal tube. Calves not receiving adequate IgG (<10g/L of IgG or <50g/L total protein measured in blood) have a reduced ability to fight disease. Risk of death and disease are also increased by facilities which are unhygienic, cold stress and/or inadequate feed intake. Mortality rates and disease incidence should be documented to enable early detection of problems and assist their future prevention.

KEYWORDS: Colostrum, calf, immunoglobulin, passive transfer

INTRODUCTION

The average mortality rates of liveborn dairy heifers in their first month in the UK was recently reported as 3.4%, ranging from 0% to 12% on different farms (Brickell and others 2009a). This indicates that, while losses on some farms are unacceptably high, they can be minimised when good management practices are in place. This article reviews the recent scientific literature on colostrum feeding and summarises the evidence to support best management practices. The aim is to assist all farmers working together with their veterinary surgeons to implement procedures which minimise their calf mortality.

Colostrum is one of several factors that play an important role in the health of new-born calves. It is most strongly associated with providing the calf with immunoglobulin (Ig) antibodies that form the main components of the calf's acquired immune system. There are several different types of immunoglobulins present in colostrum and milk, the most abundant being IgG₁, forming 81% of total Ig found in colostrum. In comparison, IgA and IgM are present at lower concentrations, (7% of total Ig) (Stelwagen and others 2009). After ingestion the IgG is transferred to the calf's circulation while the IgA acts locally within the intestinal mucosa (Sordillo and others 1997, Korhonen and others 2000). Calves receiving inadequate amounts of colostrum

are said to experience a failure of passive transfer (FPT). This is assessed by measuring total protein (TP) or IgG levels in blood. Values of >50g/L TP or >10g/L IgG have generally been defined as the cut off points for successful passive transfer (Weaver and others 2000, Calloway and others 2002, Trotz-Williams and others 2008, Elizondo-Salazar and Heinrichs 2009, Godden and others 2009). This is normally measured within the first 2-3 days of life but our own results indicate that measurements made within the first week give similar results (K.F. Johnson and D.C. Wathes, unpublished observations). Estimates of the incidence for FPT in two large-scale evaluation programmes of US dairies ranged from over 40% (Wells and others 1996) to 19% more recently (Beam and others 2009).

STORAGE OF COLOSTRUM

Microorganisms multiply quickly in colostrum, with total coliform counts (TCC) rising rapidly during the first 24 hours (Stewart and others 2005). It is therefore essential to collect it hygienically and then either feed it promptly after collection (<1h) or to store it appropriately within 1-2h by either refrigeration +/- preservative, or pasteurisation. Hygienic collection can be promoted by cleaning the teats in the parlour, using clean collection buckets, and keeping any collected colostrum covered.

A simple method to decrease the microbial load in colostrum is to use potassium sorbate at 0.5% together with refrigeration at 4°C. Potassium sorbate is a preservative (E202) widely used in human food and drink manufacture for its antibacterial and antifungal properties (Stopforth and others 2005). Tests in the USA showed that it was more effective at reducing bacterial proliferation in colostrum than refrigeration alone or leaving at ambient temperature (Stewart and others 2005). The total plate count (TPC) of bacteria in the samples stored using preservative and refrigeration dropped by 24h and stayed low and constant over the 96h study period. In contrast, refrigerated colostrum without preservative showed a steady increase in TPC over the 96h period, with the lowest TPC count at 24h. Refrigerated colostrum without preservative should therefore be used within 24h (Stewart and others 2005). This study also demonstrated that bacteria continue to multiply despite colostrum being stored correctly, so highlighting the importance of harvesting colostrum in a hygienic manner to minimise the initial bacterial load.

If colostrum is to be frozen, then this should be done in the quantities required for consumption, *i.e.* in 1 or 2L freezer bags. Zip-bags allow the colostrum to be stored as flat as possible. This is important when it comes to the thawing process, as a thin bag defrosts much more quickly than a block. Colostrum can be stored at -18 to -20°C for up to 1 year (Foley and Others 1978). It should be labelled with the cow ID and date, in case Johne's disease is later identified in the herd.

Pasteurising colostrum will reduce the bacterial load and has been shown to decrease or eliminate certain pathogens (*Mycobacterium bovis*, *Escherichia coli*, *Salmonella* Enteritidis) that can potentially cause scour in young calves (Godden and others 2006). Mean bacteria counts of colostrum were shown to be significantly lower immediately after heat-treatment compared with raw colostrum (Total Colony Count (TCC) 1.15 v 3.95; TPC 1.18 v 3.62 log₁₀cfu/ml respectively). Bacteria counts had already increased in both groups at the time of feeding between 1-2h of age, but remained significantly lower in heat-treated colostrum (TCC 2.81 v 2.92; log₁₀cfu/ml) (Johnson and others 2007).

Pasteurised colostrum can be given to the calf directly or alternatively frozen as above. The main concern with pasteurisation is the reduction in Ig that can occur. Several studies have shown, however, that by ensuring that the temperature does not exceed 60-63°C for more than 30 to 60 min, the potentially harmful pathogens were killed,

whilst maintaining an acceptable level of IgG in the colostrum (Godden and others 2006, McMartin and others 2006, Johnson and others 2007, Elizondo-Salazar and Heinrichs 2009). The volume of colostrum being pasteurised at one time is also crucial. A large volume (*e.g.* 95L) takes too long to heat to the required temperature, thereby causing a major reduction to the IgG concentration in addition to experiencing problems with coagulation (Godden and others 2003). A volume of 57L appears to be the maximum volume to batch pasteurise, but ideally 8-16L batches provided the highest amount of IgG to the calf (Godden and others 2003, Johnson and others 2007). For example, Elizondo-Salazar and Heinrichs (2009) found that heating colostrum to 60°C for 30 min using a steam vat pasteuriser caused little differences in IgG concentration: IgG₁ reduced by just 2.0g/L while the TCC was cut from 2.93 to 0.0 log₁₀cfu/ml. Similarly, Johnson and others (2007) reported that an IgG concentration of 72.6g/L in raw colostrum showed only a small decrease to 67.3g/L once heat treated at 60°C for 60 min using an on-farm batch pasteuriser.

There is evidence that use of pasteurised colostrum improves passive transfer. Elizondo-Salazar and Heinrichs (2009) gave calves control or heat-treated colostrum with the same mass of protein and 254g IgG. None of them experienced FPT but calves fed heat-treated colostrum subsequently had nearly 20% greater total circulating IgG concentrations than calves fed unheated colostrum (23.4 vs. 19.6g/L at 24h, and 23.9 vs. 20.2g/L at 48h, respectively). In the same study the apparent efficiency of Ig absorption (AEA) was greater for calves fed heat-treated colostrum. The AEA of IgG₁ from 4h to 48h of age ranged from 16.1% to 28.4% for calves fed unheated colostrum and from 19.2% to 33.4% for calves fed heat-treated colostrum. Several possible theories could explain the better absorption following heat treatment. Antibodies in colostrum can bind pathogens present in the gut before absorption can occur (Acres 1985, Saif and Smith 1985). So, by reducing the number of pathogens in colostrum, the number of pathogens reaching the gut is also reduced and more antibodies are potentially free for absorption. Additionally bacteria can bind to non-specific receptors on neonatal enterocytes, and so reduce the number of receptors available for IgG uptake (James and Polan 1978, James and others 1981).

PREPARATION

When frozen, colostrum should be warmed in a clean water bath at a maximum temperature

of 50°C replacing the water every 10 min until the colostrum has reached a temperature of 40-42°C. This temperature allows for cooling by the time the calf receives it and enables feeding at body temperature of 39°C. Alternatively it can be thawed in a refrigerator overnight. Once warmed it should be fed to the calf within 30 min (Leadley 2013). A thermometer should be used to check temperatures of both waterbath and colostrum as overheating will destroy the Igs as outlined above.

QUANTITY, QUALITY, QUICKLY (THE 3 Q'S)

One of the most debated aspects on colostrum management is how much should be fed and also how often. The ability of the gut to absorb IgG diminishes rapidly after birth, so ideally the earlier

the better is considered the standard advice. A summary of information from various organisations currently available on the internet is given in Table 1.

Quantity

The volumes suggested in Table 1 range from 1.5 to 3L for the first feed but many calves have the ability to consume 3-4L if provided with this amount. Several studies have examined the effect of different feed volumes on passive transfer. Godden and others (2009) compared two different feed amounts and two feeding methods (bottle or tube) to bull calves (n=24/25 per group) using colostrum with a concentration of 66.7g/L IgG, providing the calves with either 100g or 200g IgG.

Table 1. Current advice from the industry on colostrum feeding to calves[#].

Industry	Quantity	Quickly
Defra. Improving calf survival. http://archive.defra.gov.uk/foodfarm/farmanimal/welfare/onfarm/documents/calfsurv03.pdf	Maximum 1.5L, then 2-3 additional feeds of the same amount	As soon as possible after birth, then again within 24h
Defra. Cattle rearing to 10 months of age. http://archive.defra.gov.uk/foodfarm/farmanimal/welfare/documents/cattle-rearing10mon.pdf	5% BW or 2L	First <20 min and again after 6h
DairyCo. Feeding+ Chapter 10, Managing youngstock feeding. www.dairyco.org.uk/non_umbraco/download.aspx?media=3790	10% BW in 24h or 10-15 min continuous suckling time	At least half as soon as possible after birth, definitely at < 6h
EBLEX. Better management of bovine respiratory disease (BRD/pneumonia). http://www.eblex.org.uk/wp/wp-content/uploads/2013/09/BRPplus-Pneumonia040913.pdf	3-4L (approximately 10% BW) or 20 min continuous suckling time	As soon as possible, ideally <2h then again in 8-12h
Farmacy.co.uk. Colostrum. http://www.farmacy.co.uk/userfiles/file/factsheet_colostrum.pdf	6% BW	First <6h, then again within 12h
Mole Valley Farmers. Colostrum management and the new-born calf. http://www.molevalleyfarmers.com/mvf/info/farming/Colostrum_Management_and_the_New_Born_Calf	At least 3L or 20 min continuous suckling time.	First <6h, then again within 12h
NADIS. Calf nutrition and colostrum management. http://www.nadis.org.uk/bulletins/calf-nutrition-and-colostrum-management.aspx	2L followed by 2L, or 5% BW	First <20 min, then again after 6h
Volac. Colostrum management for calves. http://www.volac.com/news/agriculture-news/news176/colostrum-management-for-calves	At least 3L	First <6h

[#] All websites accessed December 11, 2013. BW, body weight

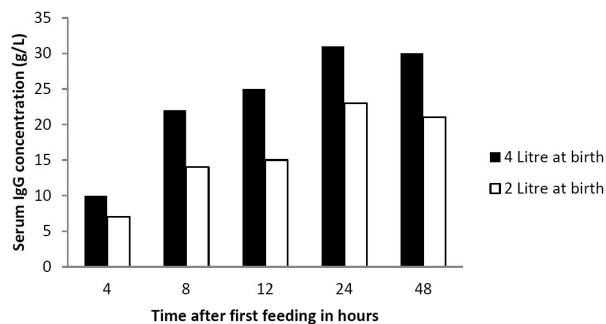
FPT was assessed as <10g/L circulating IgG after 24h (Table 2). Only 42% of those calves fed the smaller volume via tube achieved adequate passive transfer, whereas with the larger volume they were all deemed adequate. Morin and others (1997) found that calves fed 4L at birth acquired higher IgG concentrations than those fed 2L, although passive transfer was deemed adequate in both cases (Figure 1).

Table 2. Influence of volume and method of feeding colostrum to calves on passive transfer*.

Volume	1.5L	1.5L	3.0L	3.0L
Method	Bottle	Tube	Bottle	Tube
Age at feeding (min)	45	44	42	42
Pre feeding IgG (g/L)	0.23	0.25	0.20	0.19
24h IgG (g/L)	12.5	9.8	19.7	18.6
% calves with FPT	0%	58%	0%	0%
Apparent efficiency of absorption of IgG	51%	40%	41%	39%

*Data are from Godden and others (2009). FPT, failure of passive transfer.

Figure 1. Time response to feeding calves (n=51) either 2L or 4L colostrum at birth followed by a further 2L at 12h. Data are from Morin and others (1997).



Chigerwe and others (2008) fed 1, 2, 3 or 4L colostrum at 7 different time points from 2-22h post-natally by oesophageal tube. They found that a minimum of 153g of IgG was needed for optimum colostrum transfer when feeding 3L at 2h after birth. Larger IgG intakes were required by calves fed later than 2h. Feeding only 100g of IgG caused FPT. From this study, it was recommended to feed 3L within 2h of birth. Kaske and others (2005) fed 2L by bottle or 4L by tube, both at 1h and obtained much higher IgG at 24h with the greater volume (14.1 v 25.2g/L

IgG). Finally, Russell Sakai and others (2012) found that the proportion of calves with FPT (IgG < 10g/L at 48h) was 12% more for those fed 3L compared with 4L respectively (57% v 45%). Median IgG concentrations at 48h were 86.3g/L and 102g/L for 3L and 4L respectively. This feed was given between 2-8h after birth, with a median of 4.5h for the 3L group and 2.0h for the 4L group. This is perhaps more representative of a typical farm situation. Although the IgG values were higher for the 3L calves these differences were not significant and the authors concluded that there was no added benefit of using the larger volume. However this study was only conducted on 28 calves.

In summary, calves acquire a higher serum IgG and so reduced risk of FPT when they are given a greater volume of colostrum at first feeding than that currently advised. Between 3-4L seems to be the optimum.

Quality

It is generally recommended that colostrum fed to calves has a minimum quality of 50g of IgG/L (Besser and others 1991, Pritchett and others 1994, Chigerwe and others 2008, Elizondo-Salazar and Heinrichs 2009). Quality is just as important as quantity, and should be measured. Insufficient Ig presented to the gut means the calf is at risk of FPT and increases its risk of both morbidity and mortality (Besser and Gay 1994). A study by Jaster (2005) found that serum IgG concentrations were four times higher in Jersey calves fed 2L of high quality colostrum at 0h and 12h compared to the same quantity of low quality colostrum given at identical time intervals (Table 3). Similarly, Morin and others (1997) found that colostrum high in IgG resulted in higher serum IgG concentrations at 48h in comparison with low quality colostrum and that

Table 3. Influence of volume and colostrum quality on passive transfer*.

Quality (IgG concentration)	84g/L	84g/L	31.2g/L	31.2g/L
Volume per feed	4L	2L	4L	2L
Time(s) fed after birth	0h	0 + 12h	0h	0 + 12h
Mean Serum IgG ₁ at 12h g/l	33	34	16	8
Mean Serum IgG ₁ at 24h g/L	40	46	16	11
Mean Serum IgG ₁ at 48h g/L	39	46	14	10
Absorption efficiency at 48h	25%	31%	26%	18%

*Data are from Jaster (2005)

the highest IgG values were obtained by doubling the amount of high quality colostrum fed to 4L.

Colostrum quality can be affected by many different factors: season, lactation number, breed, dry period length, prepartum nutrition, vaccination of dam, weight of first milking and time from calving to first milking (Pritchett and others 1991). Of these weight and timing of first milking are most important: if it is >8.5kg or obtained >6h after calving then quality is likely to be poor (Weaver and others 2000, Lorenz 2013). Multiparous cows will have a somewhat higher IgG concentration compared to primiparous cows (Pritchett and others 1991). Breed has also been shown to influence quality. Muller and others (1981) reported a range of 4.1% IgG (Holstein) to 6.6% IgG (Jersey) across five dairy breeds. Pooling between cows should be avoided as the poorer quality colostrum is generally present in a larger volume so will dilute the good quality colostrum (Weaver and others 2000). For example Beam and others (2009) found that use of pooled colostrum increased the risk of FPT by 2.2 fold.

Apart from the IgG concentration, another aspect of quality is the level of bacterial contamination. Evidence suggests that colostrum fed to calves should have a target bacterial count of <100,000 cfu/ml (McGuirk and Collins 2004, Stewart and others 2005). Contamination was shown to occur mainly during the harvesting period (Stewart and others 2005) and so collection should be done in a hygienic manner, using thoroughly cleaned equipment.

In summary, colostrum should be tested with the aim of feeding it to calves with a minimum of 50g/L of IgG. Failure to meet this standard could increase the risk of disease and mortality for that calf. Quality therefore needs to be checked before use.

Quickly

The Welfare of Farmed Animals (England) Regulations (2007) state that each calf shall receive bovine colostrum as soon as possible after it is born and in any case within the first 6h of life. Calves receiving their first feed at >12h are considered at a higher risk for death. Feeding immediately after birth is not always practical on farm, so industry members have often advised farmers to do the first feed within 6h. Several studies have, however, shown that this is too late, and increases the chance of that calf having FPT. Stott and others (1979) gave the first feed at 4h intervals from birth to 24h and showed that feeding at birth resulted in the highest mean IgG serum concentration. Feeding at each 4h increment caused decreasing levels of serum Ig

with time. The highest rates of absorption occurred in the first 4h after birth and several calves fed at 12h did not absorb any immunoglobulins. Other studies supported the finding that Ig transfer is optimal in the first 4h and declines rapidly after 12h (Bush and Staley 1980, Matte and others 1982). A more recent large scale survey of US dairies found that delaying first feeding after 4h increased the risk of FPT by 2.7 fold (Beam and others 2009).

The gut can absorb very little further Ig after 12h from birth. The epithelial cells decrease their ability to absorb intact macromolecules, ceasing completely by about 24h (referred to as gut closure), so little more can be contributed to the calf's blood immune system after this time (Bush and Staley 1980, Weaver and others 2000). The secretion of digestive enzymes also increases, so degrading IgG prior to absorption (Quigley and Drewry 1998). The gut is sterile at birth and delayed feeding also allows potentially pathogenic bacteria to colonise the gut first (James and others 1981). Nevertheless, continuing to feed colostrum over the next several days can still be beneficial as it provides local immunity within the gut. This could help prevent/reduce the severity of bacterial and viral infections that cause enteritis in the first few days of life (Van de Perre 2003, Berge and others 2009).

In summary, the earlier the colostrum is consumed by the calf, the higher the IgG concentration is in the serum. First feeding is most beneficial within 2h of birth.

FEEDING METHOD

Brignole and Stott (1980) looked at IgG absorption in 909 Holstein and 74 Guernsey calves which were left with the dam for between 12-26h after birth. Once removed, calves were given 1L of fresh pooled colostrum. A blood sample was taken before feeding and again at 24h. They found that 35% of calves had <2.0mg/ml IgG in serum at first blood sampling, with a range of 0 to 63g/L. These calves did not therefore obtain sufficient colostrum from their dam to provide any degree of passive immunity above that normally present at birth. Similarly Besser and others (1991) found that 61% of Holstein calves left with their dams had FPT at 48h. More recently Beam and others (2009) reported that calves left with their dams were at 2.4 times the risk of FPT in comparison with hand feeding. These workers did not investigate further why this high proportion of calves apparently failed to suckle adequately. Broom (1983) reported, however, that suckling attempts may be delayed by weakness of the cow or calf due to a difficult calving, injury, or disease. Calves may experience difficulty in finding

the teat when the udder is pendulous and may not be able to attach if the teats are too fat. First calving dams in particular may attack or avoid their calves. When cows calve in communal facilities the calf may also go to the wrong dam (K. Bond, personal communication).

This concern over insufficient natural intake from the dam has prompted the recommendation that colostrum should be fed to the calf by farm staff. Feeding a calf with a nipple bottle promotes closure of the oesophageal groove, which allows the colostrum to enter the abomasum or 'true' stomach where digestion takes place (Hegland and others 1957). In comparison, feeding with an oesophageal tube does not stimulate reflex closure of the oesophageal groove, so milk instead enters the rumen which at this age is not functioning to maximal capacity (Tamate and others 1962). This will increase the transit time to the small intestine by 2-4h (Lateur-Rowet and Breuink 1983). Therefore, feeding with a nipple bottle should be encouraged as the first choice method. Godden and others (2009) commented that when calves were fed 3L *via* bottle, then 62% of animals voluntarily consumed the full amount. They and others (Morin and others 1997, Jaster 2005) suggested that when calves did not consume the full amount by bottle then the extra volume required should be administered by tube, thus ensuring that every calf has received sufficient amounts. On the other hand, several others have reported little difference in passive transfer using tube feeding, suggesting that this is a useful method which ensures that the required amount is in the calf and that failure of the oesophageal groove reflex has little clinical consequence (Adams and others 1985, Besser and others 1991, Kaske and others 2005).

In summary, a nipple bottle is the first choice method but if the calf fails to take enough colostrum by this route then tubing can be used instead or as well. It is important, however, that all farm staff using this technique have been trained in the correct procedure to avoid damage to the calf.

CLEANLINESS

All equipment used to feed calves must be scrupulously clean. Buckets, bottles and feeding tubes should be free from any visual dirt and faeces, and be cleaned thoroughly with detergent and hot water after every use and left to air dry. This has shown to reduce the spread of pathogens such as *Cryptosporidium parvum* (Trotz-Williams and others 2008). Harvested colostrum can still have a high bacterial load, which is likely to be associated with the pre-harvest cleaning of the

udder, and the area that the milk is being collected should also be kept clean (Stewart and others 2005). Feeding equipment should not be in poor condition, especially anything that enters the calf, *i.e.* tube and nipple feeders. Oesophageal tubes must be smooth and free from any sharp edges as this can potentially lead to problems by damaging the mouth and oesophagus of the calf when tube feeding. Any tube used to feed colostrum that has previously been used to administer electrolytes to a sick calf must be cleaned and disinfected.

BENEFITS OF A GOOD START

Calves that do not receive adequate concentrations of immunoglobulins in the colostrum are at increased risk of FPT, reducing their ability to fight disease. For example, Virtala and others (1999) showed that calves receiving <12g/L of IgG were at 2.3 fold greater risk of developing bovine respiratory disease (BRD) while those achieving low serum total protein after feeding (<55g/L) were at greater risk of developing more than one ear tag infection. Brignole and Stott (1980) showed that calves which were agammaglobulinaemic had a greater risk of mortality, with a death rate of 13.3%. Another study showed that calves with a serum IgG >10g/L had a 96% survival rate compared to those with serum IgG <10g/L which had a somewhat lower 94% survival rate (Godden 2008). More recently 2,874 heifer calves from 19 commercial Canadian dairy farms were enrolled at 1-7 days of age and followed for approximately 3 months (Windeyer and others 2013). This study reported that a cut-off point of 57g/L TP was the most predictive of BRD before 5 weeks of age, with a high negative predictive value (NPV) of 87%. A somewhat lower cut off point of 52g/L was most predictive of death before 5 weeks of age (NPV=98%). Associations of serum total protein during the first week of life were, however, a poor predictor of diarrhoea.

The new born calf has little body fat, which means that it is highly dependent on the lipids and lactose in colostrum as a source of energy. This is used to maintain its body temperature, especially in cold weather and is also used for growth (NRC 2001). Colostrum feeding stimulates glucose absorption which in turn raises endogenous insulin levels. Insulin as well as glucose and cortisol act to stimulate the synthesis of insulin-like growth factor-1, which plays a role in promoting gut development (Hammon and others 2012). Insufficient energy supply at an early age can lead to hypothermia. The lower critical temperature for a newborn calf is about 15°C. Temperatures below this will increase the energy which the calf requires

for maintenance, thus reducing nutrient availability for growth (Webster and others 1978, NRC 2001). Calves born into an environment which induces cold stress have a reduced absorptive capacity for Ig (Olson and others 1980). Rectal temperatures drop to a greater extent in the first hour after a difficult birth, so such calves are particularly vulnerable (Vermorel and others 1983). Beam and others (2009) found that farms which did not provide a source of heat during cold weather to calves experiencing dystocia or which failed to seek veterinary assistance to correct a difficult delivery had more incidences of FPT. Feeding colostrum to calves at an environmental temperature of 10°C was able to stimulate an 18% increase in heat production in the following hour (Vermorel and others 1983). The protein content of colostrum also provides amino acids for protein synthesis (Quigley and Drewry 1998).

There are many beneficial ingredients found in colostrum in addition to immunoglobulins and energy/protein. These include bioactive proteins, oligosaccharides, lipids, minerals and vitamins (Wheeler and others 2012). A detailed description is not justified here but two categories are of particular note. Firstly the colostrum supplies vitamins A, D and E none of which cross the placenta in significant amounts (Quigley and Drewry 1998, Blum and Baumrucker 2002). These together with other proteins such as lactoferrin stimulate epithelial cell proliferation in the small intestine in neonatal calves (Schottstedt and others 2005). The amount of ingested colostrum corresponds with villus size of the small intestine, which will increase intestinal absorptive and digestive capacity of the gut (Blum and Baumrucker 2002). Secondly, colostrum contains a number of antimicrobial substances including lactoferrin, lactoperoxidase and lysozyme all of which suppress growth of certain bacteria. There is also a range of other antimicrobial peptides present including β -defensins, complement, cathelicidin, and calgranulins. Together these are likely to contribute to the local mucosal immune defence system and assist with pathogen recognition (Wheeler and others 2012).

USE OF COLOSTRUM REPLACER

Colostrum is the best feed for newborn calves, but if the dam is infected it can be a source of *Mycobacterium avium* spp. paratuberculosis for the calf. Additionally, if only low quality colostrum is available then an alternative may be sought. This is potentially where colostrum replacers (CR) may have a role. This is a difficult topic to review due

to the variability of ingredients between different products and the lack of information they provide as to the actual IgG content. In the UK market it is hard to source freeze dried colostrum to include in CRs. This follows a ban instigated by Defra (2010) working with the European Commission against the use of a particular brand of CR. This ban was introduced following the detection of antibodies against Enzootic Bovine Leukosis (EBL) in some calves which had received these *via* a CR containing colostrum derived from Canadian cows. EBL is a notifiable disease that has been eradicated from the UK but is still common in many parts of the world including Eastern Europe. Therefore within the UK the main role of CRs is as a source of basic nutrients rather than antibodies. While these can still have a beneficial effect, they are unlikely to prevent FPT.

Elsewhere Godden and others (2009) found that calves which were fed 3L of a CR containing 66.7g of IgG/L (2 packets) had very similar TP and IgG concentrations at 24h compared to calves which received 3.8L of maternal colostrum as a first feed (TP=55g/L, IgG=19g/L; TP=57g/L, IgG=21g/L respectively). In comparison another group of calves which received only one packet of CR in a total volume of 1.5L had significantly lower TP and IgG levels at 24h (TP=49g/L, IgG=10g/L). It was also calculated that only 54% of these calves achieved an acceptable passive transfer. Contrasting with these results, another study found that calves fed CR had significantly lower concentrations of TP and IgG (Smith and Foster 2007). In this study calves were fed either 2 or 3 packets of CR providing 41g/L of IgG and were compared to a control group which received 4.5L of maternal colostrum. Those fed 2 packets had less TP and IgG at 24h compared to those fed 3 packets (TP=44g/L, IgG=7.5g/L; TP=47g/L, IgG=9.1g/L) whereas those fed maternal colostrum achieved an average of 17.6g/L of IgG at 24h. It was calculated that FPT was 95% and 76% for those fed 2 or 3 packets of CR. Direct comparison between these two studies is, however, difficult as in the former study calves were fed within 2h of birth compared to 3h in the latter and each calf in the first study received more IgG/L. Morin and others (1997) investigated feeding 272g of a dried colostrum supplement together with low quality colostrum. This was not beneficial as it reduced the efficiency of IgG absorption from 33% to only 18%: five of the 10 calves given supplement developed umbilical infections whereas none of the 6 control calves did.

QUALITY CONTROL

Testing of the Ig content of colostrum should be performed before feeding. A refractometer (either optical or digital) has good accuracy in measuring Ig and is less sensitive to variations in temperature in comparison to a colostrometer (Bielmann and others 2010, Vandeputte and others 2011, Quigley and others 2013). Refractometers are also more robust. Failure of passive transfer in calves should be monitored by blood sampling some calves in their first week of life. This should be carried out by the veterinary practice. Testing a series of 12 animals with a requirement for an 80% pass rate has been suggested (McGuirk and Collins 2004). Values <10g/L of IgG or <50g/L TP indicate that the calf is at increased risk of disease and mortality. The odds of FPT were nearly 14 times higher in US dairies which did not routinely monitor serum proteins to assess passive transfer compared with those which did (Beam and others 2009). Bacterial contamination of fed colostrum must be minimised by being meticulous over the collection, storage and feeding of colostrum. On farms where a high bacterial load is suspected, laboratory tests to measure the contamination are justified (Leadley 2013).

MONITORING AND MANAGEMENT PLAN

To ensure avoidable losses of youngstock, mortality rates should be recorded along with the cause of death. In the UK 3.4% died in the first month with a further 11% of heifers from a month old and onwards not surviving until their first calving (Brickell and others 2009a). A recent French study reported 6.8% mortality within the first two days of life (Raboison and others 2013). In Norway, the mortality rate of calves in their first year was 7.8% showing that heifer mortality is not just a UK based problem. Disease incidence of young stock, regardless of whether it results in death, should be documented to enable early detection of possible problems and prevention of such incidences in the future (Johnson and others 2011).

Historically the farm animal veterinarian has had fewer dealings with the youngstock than with the milking cows on dairy farms. They are often only called in following a major disease outbreak, by which time calves may have died. Even those which recover from respiratory disease have their later performance compromised. For example, Correa and others (1988) found that heifers experiencing BRD in their first 3 months of life took 6 months longer to reach first calving while Bach (2011) reported that heifers which experienced 4 or more cases of BRD were 1.87 times more likely

not to complete their first lactation. Severe BRD in calves during their first 3 months increased calving intervals by 12% in the mature cows (Svensson and Hultgren 2008). In another long-term study Heinrichs and Heinrichs (2011) found that the amount of illness as a calf affected first lactation milk production.

It is therefore appropriate for farmers and veterinary surgeons to develop a best practice management plan for youngstock. A first requirement is to start accurate monitoring of the timing and possible reasons for any mortalities and to try to identify likely causes when rates are too high. The plan should involve putting standard operating procedures in place and ensuring that all farm staff dealing with calves are properly trained in the relevant procedures and appreciate the importance of a good start for the subsequent health and performance of the animals in their care. It is, however, also important to appreciate that colostrum, even when administered appropriately, only contains a finite amount of antibodies and that the calf does not make significant amounts of its own IgGs until 2-4 weeks of age, not approaching adult levels until at least 4 months of age (Chase and others 2008). Placing young animals in a dirty environment will still put them at risk of becoming diseased. Furthermore, while a good colostrum intake protects against respiratory disease, it does not reduce the incidence of diarrhoea, particularly associated with *C. parvum* (Trotz-Williams and others 2007, Windeyer and others 2013). It is also important to ensure that sufficient milk is subsequently fed to enable calves to achieve growth rates on 0.7-0.8kg/d as this will provide adequate nutrients to assist in the fight against any disease outbreak (NRC 2001, Brickell and others 2009b).

CONFLICT OF INTEREST

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REFERENCES

- Acres, S.D.** (1985) Enterotoxigenic *Escherichia coli* infections in newborn calves: a review. *Journal of Dairy Science* **68**: 229-256
- Adams, G.D., Bush, L.J., Horner, J.L., Staley, T.E.** (1985) Two methods for administering colostrum to newborn calves. *Journal of Dairy Science* **68**: 773-775
- Bach, A.** (2011) Associations between several aspects of heifer development and dairy cow survivability to second lactation. *Journal of Dairy Science* **94**: 1052-1057
- Beam, A.L., Lombard, J.E., Kopral, C.A., Garber, L.P., Winter, A.L., Hicks J.A., Schlater, J.L.** (2009) Prevalence of failure of passive transfer of immunity in newborn heifer calves and

- associated management practices on US dairy operations. *Journal of Dairy Science* **92**: 3973-3980
- Berge, A.C., Besser, T.E., Moore, D.A., Sischo, W.M.** (2009) Evaluation of the effects of oral colostrum supplementation during the first fourteen days on the health and performance of preweaned calves. *Journal of Dairy Science* **92**: 286-295
- Besser, T.E., Gay, C.C.** (1994) The importance of colostrum to the health of the neonatal calf. *Veterinary Clinics of North America: Food Animal Practice* **10**: 107-117
- Besser, T.E., Gay, C.C., Pritchett, L.** (1991) Comparison of three methods of feeding colostrum to dairy calves. *Journal of the American Veterinary Medical Association* **198**: 419-422
- Bielmann, V., Gillan, J., Perkins, N.R., Skidmore, A.L., Godden, S., Leslie, K.E.** (2010) An evaluation of Brix refractometry instruments for measurement of colostrum quality in dairy cattle. *Journal of Dairy Science* **93**: 3713-3721
- Blum, J.W., Baumrucker, C.R.** (2002) Colostral and milk insulin-like growth factors and related substances: mammary gland and neonatal (intestinal and systemic) targets. *Domestic Animal Endocrinology* **23**: 101-110
- Brickell, J.S., McGowan, M.M., Pfeiffer, D.U., Wathes, D.C.** (2009a) Mortality in Holstein-Friesian calves and replacement heifers, in relation to body weight and IGF-I concentration, on 19 farms in England. *Animal* **3**: 1175-1182
- Brickell, J.S., Bourne, N., McGowan, M.M., Wathes, D.C.** (2009b) Effect of growth and development during the rearing period on the subsequent fertility of nulliparous Holstein-Friesian heifers. *Theriogenology* **72**: 408-416
- Brignole, T.J., Stott, G.H.** (1980) Effect of suckling followed by bottle feeding colostrum on immunoglobulin absorption and calf survival. *Journal of Dairy Science* **63**: 451-456
- Broom, D.M.** (1983) Cow-calf and sow-piglet behaviour in relation to colostrum ingestion. *Annales de Recherches Veterinaires* **14**: 342-348
- Bush, L.J., Staley, T.E.** (1980) Absorption of colostral immunoglobulins in newborn calves. *Journal of Dairy Science* **63**: 672-680
- Calloway, C.D., Tyler, J.W., Tessman, R.K., Hostetler, D., Holle, J.** (2002) Comparison of refractometers and test endpoints in the measurement of serum protein concentration to assess passive transfer status in calves. *Journal of the American Veterinary Medical Association* **221**: 1605-1608
- Chase, C.C., Hurley, D.J., Reber, A.J.** (2008) Neonatal immune development in the calf and its impact on vaccine response. *Veterinary Clinics of North America: Food Animal Practice* **24**: 87-104
- Chigerwe, M., Tyler, J.W., Schultz, L.G., Middleton, J.R., Steevens, B.J., Spain, J.N.** (2008) Effect of colostrum administration by use of oesophageal intubation on serum IgG concentrations in Holstein bull calves. *American Journal of Veterinary Research* **69**: 1158-1163
- Correa, M.T., Curtis, C.R., Erb, H.N., White, M.E.** (1988) Effect of calflhood morbidity on age at first calving in New York Holstein herds. *Preventive Veterinary Medicine* **6**: 253-262
- Defra** (2010) <http://archive.defra.gov.uk/foodfarm/farmanimal/diseases/atoz/ebi/colostrum.htm>. Accessed
- Elizondo-Salazar, J.A., Heinrichs, A.J.** (2009) Feeding heat-treated colostrum or unheated colostrum with two different bacterial concentrations to neonatal dairy calves. *Journal of Dairy Science* **92**: 4565-4571
- Foley, J.A., Hunter, A.G., Otterby, D.E.** (1978) Absorption of colostral proteins by newborn calves fed unfermented, fermented, or buffered colostrum. *Journal of Dairy Science* **61**: 1450-1456
- Godden, S., McMartin, S., Feirtag, J., Stabel, J., Bey, R., Goyal, S., Metzger, L., Fetrow, J., Wells, S., Chester-Jones, H.** (2006) Heat-treatment of bovine colostrum. II: effects of heating duration on pathogen viability and immunoglobulin G. *Journal of Dairy Science* **89**: 3476-3483
- Godden, S.M.** (2008) Colostrum management for dairy calves. *Veterinary Clinics of North America: Food Animal Practice* **24**: 19-39
- Godden, S.M., Smith, S., Feirtag, J.M., Green, L.R., Wells, S.J., Fetrow, J.P.** (2003) Effect of on-farm commercial batch pasteurization of colostrum on colostrum and serum immunoglobulin concentrations in dairy calves. *Journal of Dairy Science* **86**: 1503-1512
- Godden, S.M., McMartin, S., Feirtag, J., Stabel, J., Bey, R., Goyal, S., Metzger, L., Fetrow, J., Wells, S., Chester-Jones, H.** (2006) Heat-treatment of bovine colostrum. II: Effects of heating duration on pathogen viability and immunoglobulin G. *Journal of Dairy Science* **89**: 3476-3483
- Godden, S.M., Haines, D.M., Konkol, K., Peterson, J.** (2009) Improving passive transfer of immunoglobulins in calves. II: Interaction between feeding method and volume of colostrum fed. *Journal of Dairy Science* **92**: 1758-1764
- Hammon, H.M., Steinhoff-Wagner, J., Schönhusen, U., Metges, C.C., Blum, J.W.** (2012) Energy metabolism in the newborn farm animal with emphasis on the calf: endocrine changes and responses to milk-born and systemic hormones. *Domestic Animal Endocrinology* **43**: 171-185
- Hegland, R.B., Lambert, M.R., Jacobson, N.L., Payne, L.C.** (1957) Effect of dietary and management factors on reflex closure of the esophageal groove in the dairy calf. *Journal of Dairy Science* **40**: 1107-1113
- Heinrichs, A.J., Heinrichs, B.S.** (2011) A prospective study of calf factors affecting first-lactation and lifetime milk production and age of cows when removed from the herd. *Journal of Dairy Science* **94**: 336-341
- James, R.E., Polan, C.E.** (1978) Effect of orally administered duodenal fluid on serum proteins in neonatal calves. *Journal of Dairy Science* **61**: 1444-1449
- James, R.E., Polan, C.E., Cummins, K.A.** (1981) Influence of administered indigenous microorganisms on uptake of [iodine-125] gamma-globulin *in vivo* by intestinal segments of neonatal calves. *Journal of Dairy Science* **64**: 52-61
- Jaster, E.H.** (2005) Evaluation of quality, quantity, and timing of colostrum feeding on immunoglobulin G1 absorption in Jersey calves. *Journal of Dairy Science* **88**: 296-302
- Johnson, J.L., Godden, S.M., Molitor, T., Ames, T., Hagman, D.** (2007) Effects of feeding heat-treated colostrum on passive transfer of immune and nutritional parameters in neonatal dairy calves. *Journal of Dairy Science* **90**: 5189-5198
- Johnson, K.F., Burn, C.C., Wathes, D.C.** (2011) Rates and risk factors for contagious disease and mortality in young dairy heifers. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* **6** No. 059
- Kaske, M., Werner, A., Schuberth, H-J., Rehage, J., Kehler, W.** (2005) Colostrum management in calves: effects of drenching vs. bottle feeding. *Journal of Animal Physiology and Animal Nutrition* **89**: 151-157
- Korhonen, H., Marnila, P., Gill, H.S.** (2000) Milk immunoglobulins and complement factors. *British Journal of Nutrition* **84**(Suppl 1): S75-80
- Lateur-Rowet, H.J., Breukink, H.J.** (1983) The failure of the oesophageal groove reflex, when fluids are given with an oesophageal feeder to newborn and young calves. *Veterinary Quarterly* **5**: 68-74
- Leadley, S.** (2013) Points to check for reducing coliform counts in colostrum. <http://www.atticacows.com/documentView.asp?docID=4825>. Accessed December 11, 2013.
- Lorenz, I.** (2013) An update on research into factors affecting calf health. *Cattle Practice* **21**: 237-239
- Matte, J.J., Girard, C.L., Seoane, J.R., Brisson, G.J.** (1982)

Absorption of colostral immunoglobulin G in the newborn dairy calf. *Journal of Dairy Science* **65**: 1765-1770

McGuirk, S.M., Collins, M. (2004) Managing the production, storage, and delivery of colostrum. *Veterinary Clinics of North America: Food Animal Practice* **20**: 593-603

McMartin, S., Godden, S., Metzger, L., Feirtag, J., Bey, R., Stabel, J., Goyal, S., Fetrow, J., Wells, S., Chester-Jones, H. (2006) Heat treatment of bovine colostrum. I: effects of temperature on viscosity and immunoglobulin G level. *Journal of Dairy Science* **89**: 2110-2118

Morin, D.E., McCoy, G.C., Hurley, W.L. (1997) Effects of quality, quantity, and timing of colostrum feeding and addition of a dried colostrum supplement on immunoglobulin G1 absorption in Holstein bull calves. *Journal of Dairy Science* **80**: 747-753

Muller, L.D., Ellinger, D.K. (1981) Colostral immunoglobulin concentrations among breeds of dairy Cattle. *Journal of Dairy Science* **64**: 1727-1730

NRC (2001) *Nutrient Requirements of Dairy Cattle*. 7th ed. National Academy Press, Washington, D.C.

Olson, D.P., Papsian C.J., Ritter, R.C. (1980) The effects of cold stress on neonatal calves. II. Absorption of colostral immunoglobulins. *Canadian Journal of Comparative Medicine* **44**: 19-23

Pritchett, L.C., Gay, C.C., Besser, T.E., Hancock, D.D. (1991) Management and production factors influencing immunoglobulin G1 concentration in colostrum from Holstein cows. *Journal of Dairy Science* **74**: 2336-2241

Pritchett, L.C., Gay, C.C., Hancock, D.D., Besser, T.E. (1994) Evaluation of the hydrometer for testing immunoglobulin G1 concentrations in Holstein colostrum. *Journal of Dairy Science* **77**: 1761-1767

Quigley, J.D., Drewry, J.J. (1998) Nutrient and immunity transfer from cow to calf pre- and postcalving. *Journal of Dairy Science* **81**: 2779-2790

Quigley, J.D., Lago, A., Chapman, C., Erickson, P., Polo, J. (2013) Evaluation of the Brix refractometer to estimate immunoglobulin G concentration in bovine colostrum. *Journal of Dairy Science* **96**: 1148-1155

Raboisson, D., Delor, F., Cahuzac, E., Gendre, C., Sans, P., Allaire, G. (2013) Perinatal, neonatal, and rearing period mortality of dairy calves and replacement heifers in France. *Journal of Dairy Science* **96**: 2913-2924

Russell Sakai, R., Coons, D.M., Chigerwe, M. (2012) Effect of single oroesophageal feeding of 3 L versus 4 L of colostrum on absorption of colostral IgG in Holstein bull calves. *Livestock Science* **148**: 296-299

Saif, L.J., Smith, K.L. (1985) Enteric viral infections of calves and passive immunity. *Journal of Dairy Science* **68**: 206-228

Schottstedt, T., Muri, C., Morel, C., Philipona, C., Hammon, H.M., Blum, J.W. (2005) Effects of feeding vitamin A and lactoferrin on epithelium of lymphoid tissues of intestine of neonatal calves. *Journal of Dairy Science* **88**: 1050-1061

Sordillo, L.M., Shafer-Weaver, K., DeRosa, D. (1997) Immunobiology of the mammary gland. *Journal of Dairy Science* **80**: 1851-1865

Smith, G.W., Foster, D.M. (2007) Short communication: Absorption of protein and immunoglobulin g in calves fed a colostrum replacer. *Journal of Dairy Science* **90**: 2905-2908

Stelwagen, K., Carpenter, E., Haigh, B., Hodgkinson, A., Wheeler, T.T. (2009) Immune components of bovine colostrum and milk. *Journal of Animal Science* **87**(13 Suppl): 3-9

Stewart, S., Godden, S., Bey, R., Rapnicki, P., Fetrow, J., Farnsworth, R., Scanlon, M., Arnold, Y., Clow, L., Mueller, K., Ferrouillet, C. (2005) Preventing bacterial contamination and proliferation during the harvest, storage, and feeding of fresh

bovine colostrum. *Journal of Dairy Science* **88**: 2571-2578

Stopforth, J.D., Sofos, J.N., Busta, F.F. (2005) Sorbic acid and sorbates. In *Antimicrobials in food*, 3rd edition. Ed P.M. Davvidson, J.N. Sofos, L. Brown. CRC Press, Boca Raton, Florida, USA. pp 49-92

Stott, G.H., Marx, D.B., Menefee, B.E., Nightengale, G.T. (1979) Colostral immunoglobulin transfer in calves. III. Amount of absorption. *Journal of Dairy Science* **62**: 1902-1907

Svensson, C., Hultgren, J. (2008) Associations between housing, management, and morbidity during rearing and subsequent first-lactation milk production of dairy cows in southwest Sweden. *Journal of Dairy Science* **91**: 1510-1518

Tamate, H., McGilliard, A.D., Jacobson, N.L., Getty, R. (1962) Effect of various dietaries on the anatomical development of the stomach of the calf. *Journal of Dairy Science* **45**: 408-420

Trotz-Williams, L.A., Wayne Martin, S., Leslie, K.E., Duffield, T., Nydam, D.V., Peregrine, A.S. (2007) Calf-level risk factors for neonatal diarrhea and shedding of *Cryptosporidium parvum* in Ontario dairy calves. *Preventive Veterinary Medicine* **82**: 12-28

Trotz-Williams, L.A., Leslie, K.E., Peregrine, A.S. (2008) Passive immunity in Ontario dairy calves and investigation of its association with calf management practices. *Journal of Dairy Science* **91**: 3840-3849

Van de Perre, P. (2003) Transfer of antibody via mother's milk. *Vaccine* **21**: 3374-3376

Vandeputte, S., Detilleux, J., Rollin, F. (2011) Comparison of four refractometers for the investigation of the passive transfer in beef calves. *Journal of Veterinary Internal Medicine* **25**: 1465-1469

Vermorel, M., Dardillat, C., Vernet, J., Saïdo, T., Demigne, C. (1983) Energy metabolism and thermoregulation in the newborn calf. *Annales de Recherches Veterinaires* **14**: 382-389

Virtala, A-M., Gröhn, Y.T., Mechor, G.D., Erb, H.N. (1999) The effect of maternally derived immunoglobulin G on the risk of respiratory disease in heifers during the first 3 months of life. *Preventative Veterinary Medicine* **39**: 25-37

Weaver, D.M., Tyler, J.W., VanMetre, D.C., Hostetler, D.E., Barrington, G.M. (2000) Passive transfer of colostral immunoglobulins in calves. *Journal of Veterinary Internal Medicine* **14**: 569-577

Webster, A.J.F., Gordon, J.G., McGregor, R. (1978) The cold tolerance of beef and dairy type calves in the first weeks of Life. *Animal Science* **26**: 85-92

Wells, S.J., Dargatz, D.A., Ott, S.L. (1996) Factors associated with mortality to 21 days of life in dairy heifers in the United States. *Preventive Veterinary Medicine* **29**: 9-19

Wheeler, T.T., Smolenski, G.A., Harris, D.P., Gupta, S.K., Haigh, B.J., Broadhurst, M.K., Molenaar, A.J., Stelwagen, K. (2012) Host-defence-related proteins in cows' milk. *Animal* **6**: 415-422

Windeyer, M.C., Leslie, K.E., Godden, S.M., Hodgins, D.C., Lissemore, K.D., Leblanc, S.J. (2013) Factors associated with morbidity, mortality, and growth of dairy heifer calves up to 3 months of age. *Preventive Veterinary Medicine*. doi:pil: S0167-5877(13)00329-2. 10.1016/j.prevetmed.2013.10.019. [Epub ahead of print]