Feeding heat-treated colostrum or unheated colostrum with two different bacterial concentrations to neonatal dairy calves¹

J. A. Elizondo-Salazar and A. J. Heinrichs²

Department of Dairy and Animal Science, The Pennsylvania State University, University Park 16802

ABSTRACT

The objective of this study was to determine the effects of feeding heat-treated colostrum or unheated colostrum of different bacterial counts on passive transfer of immunity in neonatal dairy calves. First milking colostrum was collected from Holstein cows, frozen at -20°C , and then thawed and pooled into a single batch. One-third of the pooled colostrum was transferred into plastic containers and frozen at -20°C until needed for feeding (unheated-low bacteria). Another third was heat-treated at 60°C for 30 min and then frozen at -20°C until needed for feeding (heat-treated). The final third of colostrum was transferred into plastic containers, stored at 20°C for bacteria to grow for 24 h (unheated-high bacteria), and then frozen at -20°C until needed for feeding. A total of 30 Holstein bull calves weighing ≥ 30 kg at birth were systematically enrolled into 1 of the 3 treatment groups. Calves were separated from their dams at birth before suckling occurred. Before colostrum was fed, a jugular blood sample was collected from each calf. The first feeding consisted of 3.8 L of colostrum containing, on average, 68 g of IgG/L using an esophageal feeder between 1.5 and 2 h after birth. For the second and third feeding pasteurized whole milk at 5% of birth weight was fed. Blood samples were collected before colostrum feeding and at 24 and 48 h of age to determine serum total protein (STP) and IgG concentrations. Heat treatment of colostrum at 60°C for 30 min reduced colostrum bacteria concentration yet maintained colostrum IgG concentration and viscosity at similar levels to the control treatment. Calves fed heat-treated colostrum had significantly greater STP and IgG concentrations at 24 h and greater apparent efficiency of absorption (AEA) of IgG (STP = 62.5 g/L; IgG = 26.7 g/L; AEA = 43.9%) compared with calves fed unheated-low bacteria colostrum (STP = 57.0 g/L; IgG = 20.2 g/L; AEA = 35.4%) or unheated-

high bacteria colostrum (STP = 56.2 g/L; IgG = 20.1 g/L; AEA = 32.4%). High bacteria load in colostrum did not interfere with total protein or IgG absorption or AEA.

Key words: colostrum, IgG, serum protein, apparent efficiency of absorption

INTRODUCTION

Immunity is provided to neonatal calves by passive immunity derived from colostrum Ig ingested and absorbed during the first 24 h of life (Stott et al., 1979a). However, colostrum has been identified as a potential means of transmission of infectious diseases to newborn calves and heat treatment of colostrum has been suggested as a control measure to eliminate or reduce the transfer of colostrum-borne pathogens to dairy calves (Godden et al., 2006). Recent studies on heat treatment of colostrum using 60°C for 30 min have shown great advantage in reducing the number of bacteria (Godden et al., 2006; Johnson et al., 2007), and it has also been shown that feeding heat-treated colostrum to neonatal dairy calves increases IgG absorption and, as a result, serum IgG concentration (Johnson et al., 2007; Elizondo-Salazar and Heinrichs, 2009). The mechanism for this is unknown; however, Johnson et al. (2007) hypothesized that because antibodies in colostrum can bind pathogens present in the gut before absorption can occur, by reducing the number of pathogens in heat-treated colostrum, and consequently the number of pathogens in the gut, more antibodies are potentially free for absorption. In addition, bacteria may bind nonspecific receptors on neonatal enterocytes, thus decreasing the number of receptors available for IgG uptake; therefore, by reducing the number of pathogens in colostrum, there may be more receptors available for IgG binding (James and Polan, 1978; James et al., 1981; Staley and Bush, 1985).

On this basis, we hypothesized that feeding colostrum with a high bacterial load would decrease IgG absorption and serum IgG concentration in neonatal calves. The objective of this study was to determine effects of feeding heat-treated colostrum and unheated colostrum with 2 different bacterial concentrations on passive transfer of immunity in neonatal dairy calves.

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²Corresponding author: ajh@psu.edu

MATERIALS AND METHODS

Colostrum Management

First milking colostrum with IgG concentration >50 g/L as measured by colostrometer (Biogenics, Mapleton, OR) was collected from Holstein cows into new 1.89-L plastic containers and frozen immediately at -20°C to inhibit bacterial growth. Once 126 L was collected, colostrum was thawed at 4°C for 24 h, and then pooled and mixed for 20 min in a commercial batch pasteurizer (Girton Manufacturing Co., Millville, PA) to create a unique batch. Colostrum collected did not include dams of the calves used in the study. Subsamples were taken into sterile 15-mL screw-cap centrifuge tubes and stored at -20°C for later analysis. One third of the pooled colostrum was transferred into new 1.89-L plastic containers and frozen at -20°C until needed for feeding (unheated-low bacteria colostrum). Another third was divided into two 21-L batches, and each batch was placed into a stainless steel container. The 2 containers were placed in a steam vat pasteurizer (Girton Manufacturing Co.) equipped with agitators to allow even heating of colostrum during pasteurization. Water and colostrum temperatures were monitored every 5 min. Colostrum was heated to 60°C , held for 30 min, and then cooled using an ice water bath. Subsamples were collected from the 2 containers and pooled for later analysis. Heat-treated colostrum was then transferred into new 1.89-L plastic containers and frozen at -20°C until needed for feeding (heat-treated colostrum). The final third of colostrum was transferred into new 1.89-L plastic containers and stored at 20°C for 24 h, allowing naturally occurring bacteria to grow freely (unheated-high bacteria colostrum). Subsamples were taken from containers and pooled for further analysis. Colostrum was then placed into a freezer at -20°C until needed for feeding.

Colostrum Sample Analyses

Samples of all colostrum were thawed at 4°C and examined for standard plate count (SPC), CNS count, environmental streptococci count (ES), coliform count (CC), gram-negative noncoliform count (NC), *Streptococcus agalactiae* count (SAG), and *Staphylococcus aureus* count (SA) according to Jayarao et al. (2004). Colostrum samples were mixed thoroughly by inverting the tube 20 to 25 times; 50 μL was placed on selective and nonselective media using an inoculating loop. Plate count agar was used for enumeration of SPC. Numbers of ES and SAG in colostrum samples were estimated using modified Edward's agar supplemented with colistin sulfate and oxolinic acid (Sawant et al.,

2002). MacConkey's agar no. 3 (Oxoid, Basingstoke, UK) was used to determine CC and NC. Baird Parker's agar (Difco, LePont de Claix, France) was used to determine number of CNS and presence of SA. Plates for enumeration of SPC were incubated at 32°C for 48 h. Plates for enumeration of CNS, SA, ES, CC, SAG, and NC were incubated at 37°C for 48 h. Concentrations of IgG₁ and IgG₂ were determined by immunoprecipitation using single radial immunodiffusion (RID; VMRD, Pullman, WA). Serum samples (3 μL) were applied to serial RID plates containing agarose gel with anti-bovine IgG. Plates were left undisturbed for 20 h at room temperature after adding samples. Resulting ring diameters were measured with a monocular comparator (VMRD), and IgG content of samples was calculated by regression analysis. A standard curve was generated with reference sera supplied by the manufacturer.

Colostrum samples were also analyzed for ash, DM (AOAC, 1990), CP (Leco FP-528 Nitrogen Combustion Analyzer, Leco, St. Joseph, MI), and crude fat (AOAC, 2000) using a Tecator Soxtec System HT 1043 Extraction unit (Tecator, Foss NA, Eden Prairie, MN). Colostrum samples were sent to the Agricultural Analytical Services Laboratory at the Pennsylvania State University to be analyzed for Ca, P, Mg, Na, K, Zn, Fe, Cu, S, and Mn. Samples were also sent to the Diagnostic Center for Population and Animal Health (Michigan State University, East Lansing, MI) to be analyzed for fat-soluble vitamins. Compositional analyses and characteristics of colostrum samples before and after heat treatment are presented in Table 1. Colostrum composition was similar to values reported by Kehoe et al. (2007), with no effects of treatment. A reduction in pH for the unheated-high bacterial colostrum reflected the increased concentration of ES in that colostrum.

Protocols used for this study were approved by the Pennsylvania State University Institutional Animal Care and Use Committee. Holstein bull calves from the university herd were separated from their dams 20 to 30 min after birth, before suckling occurred, and placed into 1.0- $\times$ 1.0-m holding pens until fed colostrum and then were housed in 1.0- $\times$ 2.6-m naturally ventilated, individual calf condos bedded with straw. A total of 30 bull calves weighing ≥ 30 kg at birth were systematically enrolled into 1 of 3 treatment groups receiving unheated-low bacteria, unheated-high bacteria, or heat-treated colostrum for the first feeding. Calf numbers per group were based on specific previous data of this nature to achieve sufficient power to test the hypothesis. Information for each dam and calf was recorded, including cow identification, date and time of calving, calving ease score (Weigel, 2002), calf identification number, treatment allocation, and age at feeding. Before colostrum was fed, a jugular blood sample

Table 1. Compositional analysis of colostrum treatments

Item	Colostrum treatment		
	Unheated-low bacteria	Unheated-high bacteria	Heat-treated
Specific gravity, g/mL	1.071	1.071	1.072
pH	6.11	4.83	6.11
Fat, %	5.69	5.93	5.67
Protein, %	16.79	16.82	16.46
Lactose, %	9.47	8.51	9.51
Total solids, %	31.95	31.26	31.64
Ash, %	4.79	4.77	4.72
Ca, mg/kg	0.26	0.26	0.26
P, mg/kg	0.22	0.22	0.22
Mg, mg/kg	0.05	0.05	0.05
Na, mg/kg	0.07	0.07	0.06
K, mg/kg	0.15	0.17	0.15
Zn, mg/kg	23.96	23.36	23.51
Fe, mg/kg	<6.00	<6.00	<6.00
Cu, mg/kg	0.45	0.60	0.50
S, mg/kg	0.19	0.19	0.19
Mn, mg/kg	<1.00	<1.00	<1.00
Retinol, µg/g	1.95	1.07	1.08
β-Carotene, µg/g	<0.10	<0.10	<0.10
Vitamin E, µg/g	1.55	2.24	2.13

was collected from each calf. For the first feeding 3.8 L of colostrum was fed between 1.5 and 2 h of life. Colostrum at the first feeding was limited to 3.8 L, given that more acceptable serum IgG concentrations may be achieved when a greater total mass of IgG is presented to the gut early in the absorptive period (Johnson et al., 2007). Colostrum was warmed to approximately 38°C using a hot water bath heated to approximately 52°C and fed via esophageal feeder. For the second and third feeding, pasteurized whole milk at 5% of birth BW was fed. For remaining feedings, calves were fed milk replacer containing 20% CP (all milk protein) and 20% fat (North American Nutrition Company Inc., Lewisburg, OH) at 10% of birth BW, 5% fed in the morning and 5% fed in the afternoon, until 2 wk of age (no data reported). Blood samples were also collected from every calf at 24 and 48 h of age.

All blood samples were refrigerated overnight, centrifuged, and the serum separated from the clot within 24 h of collection (Johnson et al., 2007). Serum total protein concentrations (**STP**; g/L) were determined using a hand-held refractometer (VET 360, Reichert Inc., Depew, NY). Sera were then stored at -20°C until analyzed. Serum IgG concentrations (g/L) were determined via RID kit (VMRD) as described by Hadorn and Blum (1997). Apparent efficiency of absorption (**AEA**, %) of IgG, a calculated measure that estimates what proportion of the total IgG mass fed is actually absorbed into the calf's circulation, was calculated using the equation described by Quigley and Drewry (1998), assuming a plasma volume of 9.5% of birth weight.

Descriptive statistics were generated to describe calf and dam characteristics for treatment groups. Blood

observations were analyzed using repeated measures analysis and the MIXED procedure of SAS 9.1 (SAS Institute, 2006). Calf was used as the random effect. The statistical model used for analysis was

$$Y_{ijk} = \mu + T_i + W_j + (TW)_{ij} + calf_k + e_{ijk},$$

where Y_{ijk} = dependent variables; μ = overall mean; T_i = fixed effect of treatment i , where i = unheated-low bacteria, unheated-high bacteria, or heat-treated; W_j = repeated measure of time j ; $(TW)_{ij}$ = effect of treatment by time interaction; $calf_k$ = random effect of calf k ; and e_{ijk} = residual.

The AR(1) covariance structure was used in the model. Initial measurements for blood parameters were offered as additional covariates into each model. However, none of these terms was significant and none interacted with the variable describing colostrum treatment group, so they were subsequently removed from final models. Significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

Mean birth weight was 48.9, 45.0, and 42.3 kg for calves in the untreated-low bacteria, unheated-high bacteria, and heat-treated colostrum groups, respectively. Age of calves at first feeding ranged from 90 to 120 min in all treatment groups. The median parity of dams was 2.5 for all groups. Calving score for dams in the study never exceeded 3 on a scale from 1 to 5.

There was no difference in the least squares means colostral IgG concentration for unheated and heat-treated colostrum. Total IgG concentration for calves

Table 2. Immunoglobulin G concentration (g/L) and bacterial counts in unheated-low bacteria, unheated-high bacteria, and heat-treated colostrum samples

Item ¹	Unheated-low bacteria	Unheated-high bacteria	Heat-treated	SEM
IgG, g/L	69.55	69.55	66.17	1.86
IgG ₁ , g/L	66.46	66.46	63.28	1.73
IgG ₂ , g/L	3.09	3.09	2.89	0.13
SPC, log ₁₀ cfu/mL	3.97 ^b	5.61 ^c	2.81 ^a	0.81
ES, log ₁₀ cfu/mL	1.86 ^b	5.59 ^c	0.90 ^a	1.43
CNS, log ₁₀ cfu/mL	0.00 ^a	0.90 ^b	0.00 ^a	0.30
CC, log ₁₀ cfu/mL	2.02 ^b	3.16 ^c	0.00 ^a	0.92
NC, log ₁₀ cfu/mL	3.37 ^b	5.39 ^c	1.83 ^a	1.03

^{a-c} $P < 0.05$, comparing least squares means for unheated-low bacteria, unheated-high bacteria, or heat-treated colostrum.

¹SPC = standard plate count; ES = environmental streptococci count; CC = coliform count; NC = noncoliform count.

fed unheated-low bacteria, unheated-high bacteria, and heat-treated colostrum was 69.6, 69.6, and 66.2 g/L, respectively (Table 2). Kehoe et al. (2007) surveyed, via sample and data collection, 55 dairy farms in Pennsylvania for colostrum composition and obtained an average colostrum total IgG of 41 g/L, whereas colostrum utilized by Johnson et al. (2007) had an average concentration of 73 g/L.

Early studies pasteurizing colostrum using methods and temperatures typically used to pasteurize milk yielded unacceptable results with reduction in colostrum IgG and increases in viscosity (Meylan et al., 1996; Green et al., 2003). However, more recent research has determined that problems with viscosity and possible problems with IgG denaturation can be avoided by using a lower pasteurization temperature (Godden et al., 2006; Johnson et al., 2007).

Although colostrum immune factors are essential for calf health, bacterial contamination of colostrum may negate some of these benefits. A study to identify control points for bacterial contamination of bovine colostrum during the harvesting and feeding processes found that significant bacterial contamination occurred during the harvest process (Stewart et al., 2005). The SPC and CC present in the unheated-high bacteria colostrum are very similar to the values reported by Stewart et al. (2005) when the samples were taken from the floor bucket, which showed a significant increase when compared with samples collected directly from the mammary gland. Heat treatment resulted in a significant reduction of SPC, ES, CC, and NC (Table 2). Other laboratory studies have reported success in reducing or eliminating pathogens when colostrum has been treated by heat (Godden et al., 2006; McMartin et al., 2006; Trujillo et al., 2007). Undetectable levels of CNS before heating prevented a significant reduction of these bacteria due to heat treatment; however, more CNS were detected in unheated-high bacteria colostrum. In fact, populations of all bacteria types were

greatest in unheated-high bacteria colostrum and were well above acceptable levels. No samples contained measureable SAG or SA, so effects of pasteurization on these bacteria could not be determined in this experiment. Despite the fact that Johnson et al. (2007) heat treated colostrum at 60°C for 60 min and reported a significant reduction in SPC and CC, it appears that 60°C for 30 min is adequate for achieving a goal of bacterial reduction in heat-treated colostrum. An additional 30 min at 60°C would probably eliminate more pathogenic bacteria; however, a different response in calf IgG concentration or AEA would not be expected.

Measurement of STP by refractometer as an estimate of serum Ig concentration provides rapid and inexpensive test results and as such is a useful tool for monitoring passive transfer status (Tyler et al., 1998). One definition of failure of passive transfer is STP <50 g/L at 24 h of age (Donovan et al., 1998). Serum total protein increased after first feeding in all treatment groups due to absorption of colostrum IgG, as expected. When measured at 0 h (before colostrum feeding), there were no differences between treatments in STP (Table 3). However, 24- and 48-h STP concentrations were greater ($P < 0.01$) for calves fed heat-treated colostrum than for those fed unheated colostrum. Nonetheless, there were no differences ($P > 0.05$) in STP between calves fed unheated-low bacteria and unheated-high bacteria colostrum. Serum total protein concentrations for all treatments at 24 h of age were within normal ranges. Johnson et al. (2007) reported values very similar to those obtained in this experiment, and 24-h STP concentrations in their study were also greater for calves fed heat-treated colostrum when compared with calves fed unheated colostrum.

Serum IgG concentrations at birth were below detectable concentrations of the assay and did not produce rings on RID plates; therefore, they were assumed to be zero (Table 3). However, 24 and 48 h after birth calves fed heat-treated colostrum had higher ($P < 0.01$) serum

Table 3. Concentration of total protein and IgG in serum and apparent efficiency of IgG absorption (AEA) in bull calves fed unheated-low bacteria, unheated-high bacteria or heat-treated colostrum

Item	Unheated-low bacteria	Unheated-high bacteria	Heat-treated	SEM
Serum total protein, g/L				
0 h	43.1	41.8	43.7	0.23
24 h	57.0 ^b	56.2 ^b	62.5 ^a	0.23
48 h	56.8 ^b	54.5 ^b	61.4 ^a	0.23
IgG ₁ , g/L				
0 h	0.0	0.0	0.0	0.00
24 h	19.1 ^b	19.1 ^b	25.3 ^a	1.41
48 h	18.1 ^b	17.4 ^b	23.6 ^a	1.41
IgG ₂ , g/L				
0 h	0.0	0.0	0.0	0.00
24 h	1.1 ^b	1.0 ^b	1.4 ^a	0.08
48 h	1.0 ^b	1.0 ^b	1.3 ^a	0.08
Total IgG, g/L				
0 h	0.0	0.0	0.0	0.00
24 h	20.2 ^b	20.1 ^b	26.7 ^a	1.47
48 h	19.1 ^b	18.4 ^b	24.9 ^a	1.47
AEA of IgG ₁ , %				
24 h	34.9 ^b	32.1 ^b	43.4 ^a	2.90
48 h	32.7 ^b	29.4 ^b	40.4 ^a	2.90
AEA of IgG ₂ , %				
24 h	42.1 ^b	38.1 ^b	54.6 ^a	3.60
48 h	38.7 ^b	35.4 ^b	52.2 ^a	3.60
AEA of total IgG, %				
24 h	35.4 ^b	32.4 ^b	43.9 ^a	2.90
48 h	33.2 ^b	29.5 ^b	41.0 ^a	2.90

^{a,b} $P < 0.01$, comparing least squares means for treatments at each time point.

IgG concentrations than the other 2 treatment groups. Serum total IgG concentrations at 24-h were 20.2, 20.1, and 26.7 g/L for calves fed unheated-low bacteria, unheated-high bacteria, and heat-treated colostrum, respectively. Calves are defined as having failure of passive transfer if serum IgG concentration is <10 g/L when sampled between 24 and 48 h of age (Weaver et al., 2000). Whether adequate serum IgG is actually obtained also depends on efficiency of absorption (Morin et al., 1997). Even though efficiency of Ig absorption declines somewhat as larger amounts are fed, feeding large volumes of colostrum results in higher serum IgG concentrations in the calf (Stott et al., 1979b; Bush and Staley, 1980). In the present trial, calves received an average of 254 g of total IgG, and none of the 30 calves experienced failure of passive transfer, regardless of treatment. Concentrations of total protein and IgG in serum at 24 h have been shown to be positively correlated (Stott and Fellah, 1983; Quigley et al., 2002; Foster et al., 2006). The relationship between circulating serum total IgG and STP in calves in different treatment groups is depicted in Figure 1. Calves in all treatment groups received the same mass of protein and IgG from colostrum; however, absorption of IgG varied, and relationship between STP and IgG was different ($P < 0.01$) between treatments. Calves fed heat-treated colostrum had greater serum total IgG concentration at 24 h than calves fed unheated-low bacteria or unheated-high bacteria colostrum at the same STP concentra-

tion. However, there were no differences between calves fed unheated-low bacteria and unheated-high bacteria colostrum. Considering the previous results, it could be speculated that 100% success in passive transfer of immunity, assuming 10 g of IgG/L as cut-off point, could be expected if calves receive a high volume of good quality colostrum within 2 h of life.

The regression equations obtained in this study for the different treatment groups were as follows:

$$\text{Unheated-low bacteria: Serum total IgG (g/L)} = 0.559 \times \text{STP (g/L)} - 11.0 \quad (R^2 = 0.563);$$

$$\text{Unheated-high bacteria: Serum total IgG (g/L)} = 0.548 \times \text{STP (g/L)} - 9.86 \quad (R^2 = 0.548);$$

$$\text{Heat-treated: Serum total IgG (g/L)} = 0.704 \times \text{STP (g/L)} - 16.7 \quad (R^2 = 0.518);$$

$$\text{All treatments: Serum total IgG (g/L)} = 0.719 \times \text{STP (g/L)} - 18.9 \quad (R^2 = 0.656).$$

When the cutoff value of 50 g/L of STP proposed by Donovan et al. (1998) is used in this study, estimates of passive transfer by measuring STP seriously under-

estimate the adequacy of passive transfer, especially in calves fed heat-treated colostrum. Tyler et al. (1996) demonstrated that an STP concentration of 52 g/L, measured by refractometry, was equivalent to an IgG concentration of 10 g/L. In the present study, when STP was near 52 g/L, serum IgG concentration was well above 10 g/L, and this was more evident for calves fed heat-treated colostrum. This may mean that refractometry is not an accurate means to estimate serum total IgG concentrations with standard reference values when calves are fed high volumes of colostrum or heat-treated colostrum.

Colostrum IgG concentration and volume of colostrum ingested determine the mass of IgG presented to the calf for absorption, the most important factor determining subsequent blood IgG concentration (Bush and Staley, 1980). The ability of the newborn calf to absorb colostrum Ig decreases rapidly following birth (Stott et al., 1979a). Mean AEA for IgG from maternal colostrum, calculated as grams of IgG in the blood at 24 h divided by grams of IgG intake is remarkably variable, ranging from 6 to 88%; however, most values are between 20 and 35% (Quigley and Drewry, 1998). Wide variation in reported AEA could be attributed in part to the value used to estimate plasma volume of animals and different methodologies used to determine IgG concentrations. The AEA was greater ($P < 0.01$) for calves fed heat-treated colostrum (Table 3). The AEA for total IgG ranged from 32.4 to 43.9% at 24 h and from 29.5 to 41.0% at 48 h for calves in all treatment groups. Johnson et al. (2007) also observed greater AEA for total IgG in calves fed heat-treated colostrum and did not find any detrimental effect on calf health.

Only 2 recent studies have reported that feeding heat-treated colostrum increased IgG absorption and, as a result, serum IgG concentrations in calves (Johnson et al., 2007; Elizondo-Salazar and Heinrichs, 2009). The first group hypothesized that bacteria in colostrum may bind free IgG in the gut lumen or directly block uptake and transport of IgG molecules across intestinal epithelial cells, thus interfering with passive absorption of colostrum Ig. Subsequently, by reducing the number of pathogens in heat-treated colostrum and, as a result, the number of pathogens in the gut, more antibodies are potentially free for absorption (James and Polan, 1978; James et al., 1981; Staley and Bush, 1985). However, in the current experiment, there were no significant differences in AEA or serum IgG concentrations between calves fed unheated-low bacteria or unheated-high bacteria colostrum. This suggests that the types of bacteria and high bacterial counts present in unheated-high bacteria colostrum used in this experiment did not interfere with IgG absorption and that other factors associated with thermal treatment

Figure 1. Regression of serum total IgG and serum total protein (STP) concentrations at 24 h of age in bull calves fed unheated-low bacteria [Δ ; serum total IgG (g/L) = $0.559 \times \text{STP (g/L)} - 11.0$; $R^2 = 0.563$; $P < 0.01$], unheated-high bacteria [$\diamond$; serum total IgG (g/L) = $0.548 \times \text{STP (g/L)} - 9.86$; $R^2 = 0.548$; $P < 0.01$], or heat-treated colostrum [$\square$; serum total IgG (g/L) = $0.704 \times \text{STP (g/L)} - 16.7$; $R^2 = 0.518$; $P < 0.01$].

of colostrum came into play. A possible explanation could be that heat treatment denatures some colostrum proteins that otherwise would interfere or compete for receptors on neonatal enterocytes, thus reducing the number of receptors available for IgG uptake; however, this hypothesis has to be further investigated. Elizondo-Salazar and Heinrichs (2009) reported that calves fed heat-treated colostrum had significantly greater IgG concentrations at 24 h, and greater apparent efficiency of IgG absorption compared with calves fed unheated colostrum. In that study, there was no difference between treatment groups when examining growth measurements, calf starter intake, lymphocyte counts, or health scores through weaning.

In the present study, dairy bull calves fed a high volume of heat-treated colostrum with high IgG concentration were able to absorb more IgG than calves fed unheated colostrum. It would be very important to investigate if the same effect could be seen by feeding calves similar volumes of colostrum with low IgG concentrations or lower volumes with varying IgG concentrations.

CONCLUSIONS

Based on the current study, batch heat treatment of colostrum at 60°C for 30 min reduced bacteria concentrations and preserved IgG concentration. Apparent efficiency of absorption of IgG was significantly greater for calves fed heat-treated versus unheated-low bacteria or unheated-high bacteria colostrum. All calves had successful passive transfer based on a cut point of 10 g of IgG/L and with a colostrum IgG concentration of

68 g/L fed within 2 h of life. Serum IgG concentrations were significantly higher for calves fed heat-treated colostrum. High bacterial load in colostrum did not interfere with IgG absorption. Although the precise mechanism for IgG absorption from colostrum is not yet known in the bovine, better understanding of this process could provide an improvement in practical feeding systems allowing higher blood IgG concentrations at 24 to 48 h of age. In addition, it is necessary to know if feeding different volumes of heat-treated colostrum with varying IgG concentrations would produce a similar increase in IgG absorption.

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