



Revista MVZ Córdoba  
ISSN: 0122-0268  
ISSN: 1909-0544  
revistamvz@gmail.com  
Universidad de Córdoba  
Colombia

B. Schogor, Ana Luiza; Glombowsky, Patricia; Both, Fabiana; Danieli, Beatriz; Rigon, Fernanda; H. Reis, João; Da Silva, Aleksandro S  
Quality of bovine colostrum and its relation to genetics, management, physiology and its freezing  
Revista MVZ Córdoba, vol. 25, no. 1, 2020, -, p. 1465  
Universidad de Córdoba  
Colombia

DOI: <https://doi.org/10.21897/rmvz.1465>

Available in: <http://www.redalyc.org/articulo.oa?id=69361538021>

- ▶ How to cite
- ▶ Complete issue
- ▶ More information about this article
- ▶ Journal's webpage in redalyc.org










Scientific Information System Redalyc  
Network of Scientific Journals from Latin America and the Caribbean, Spain and Portugal

Project academic non-profit, developed under the open access initiative

Original

# Quality of bovine colostrum and its relation to genetics, management, physiology and its freezing

Ana Luiza B. Schogor<sup>1</sup>  Ph.D; Patricia Glombowsky<sup>1</sup>  M.Sc; Fabiana Both<sup>1</sup>  M.Sc;  
Beatriz Danieli<sup>1</sup>  M.Sc; Fernanda Rigon<sup>1</sup>  M.Sc; João H. Reis<sup>1</sup>  M.Sc;  
Aleksandro S. Da Silva<sup>1\*</sup>  Ph.D.

<sup>1</sup>Universidade do Estado de Santa Catarina (UDESC), Department of Animal Science, Chapecó, Santa Catarina (SC), Brazil.  
\*Correspondence: [aleksandro\\_ss@yahoo.com.br](mailto:aleksandro_ss@yahoo.com.br)

Received: December 2018; Accepted: November 2019; Published: January 2020.

## ABSTRACT

**Objective.** The aims of this study were to assess whether colostrum quality is modified by genetic, physiological and management characteristics in the pre-partum period, as well as evaluate whether quality and composition of colostrum is altered in the freezing process. **Material and methods.** In the experiment I, colostrum and blood samples of 35 cows (18 Holstein and 17 Jerseys) were collected. In the experiment II, six colostrum samples of Holstein cows were collected and frozen during 60 days. **Results.** The mean immunoglobulin (Ig) concentration was 77.65 mg/ml to Jersey and 82.77 mg/ml to Holstein. The genetic, parturition order, and the interaction between these factors were no significant on IgG concentration in the colostrum. Also, it was observed an effect genetic of cow in the weight on calf at birth and on three days of age ( $p < 0.0001$ ). Regarding transmission of calf passive immunity, no effects of cow breed and calving order were observed on plasma protein concentration of calf, as well as after three days of freezing. Calves of Holstein (83%) and Jersey (82%) breed showed total serum protein levels above 5.5 g/dL. Holstein cows housed in individual paddocks with diet supplementation provided better quality of colostrum (93.57 mg Ig/mL). Over time, the percentage of fat reduced at freezing, that reduced over time ( $p < 0.05$ ) in Experiment II. **Conclusions.** The pre-partum management exerts influence on colostrum quality, and the freezing not interfere on centesimal and immunological quality of colostrum, with exception the fat, that decrease along the time.

**Keywords:** IgG, immunity, calf, pre-partum (*Source: CAB, MeSH*).

## RESUMEN

**Objetivo.** Los objetivos de este estudio fueron evaluar si la calidad del calostro se modifica por las características genéticas, fisiológicas y de manejo en el período pre-parto, así como evaluar si la calidad y composición del calostro se altera en el proceso de congelación. **Material y métodos.** En el experimento I, se recogieron muestras de calostro y sangre de 35 vacas (18 Holstein y 17 Jerseys). En el experimento II, se recolectaron seis muestras de calostro de vacas Holstein y se congelaron durante 60 días. **Resultados.** La concentración media de inmunoglobulina G (IgG) fue de 77.65 mg/ml en Jersey y de 82.77 mg/ml en Holstein. La genética, el orden de parto y la interacción entre estos

### How to cite (Vancouver).

Schogor BAL, Glombowsky P, Both F, Danieli B, Rigon F, Reis JH, Da Silva AS. Quality of bovine colostrum and its relation to genetics, management, physiology and its freezing. Rev MVZ Córdoba. 2020; 25(1):e1465. DOI: <https://doi.org/10.21897/rmvz.1465>



©The Author(s), Journal MVZ Córdoba 2020. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by-nc-sa/4.0/>), lets others remix, tweak, and build upon your work non-commercially, as long as they credit you and license their new creations under the identical terms.

factores no fueron significativos en la concentración de IgG en el calostro. Además, se observó un efecto genético de la vaca en el peso en la cría al nacer y en los tres días de edad ( $p < 0.0001$ ). Con respecto a la transmisión de inmunidad pasiva de terneros, no se observaron efectos de la raza de la vaca y el orden de parto en la concentración de proteínas plasmáticas de la ternera, así como después de tres días de congelación. Las razas de becerros Holstein (83%) y Jersey (82%) mostraron niveles de proteína sérica total por encima de 5.5 g/dL. Las vacas Holstein alojadas en potreros individuales con suplementos dietéticos, proporcionaron una mejor calidad de calostro (93.57 mg IgG/mL). Con el tiempo, el porcentaje de grasa cambió al congelarse, que se redujo con el tiempo ( $p < 0.05$ ) en el Experimento II. **Conclusiones.** El manejo previo al parto influye en la calidad del calostro, y la congelación no interfiere en la calidad centesimal e inmunológica del calostro, con excepción de la grasa, que disminuye a lo largo del tiempo.

**Palabras clave:** IgG, inmunidad, pantorrilla, pre-parto (*Fuente: CAB, MeSH*).

## INTRODUCTION

Consumption of colostrum is vital to augment the survival rate of dairy calf, and some articles have reported deficiencies on quality and quantity of colostrum produced by dairy cows (1), and the genetic group or birth order are factors that interfere on colostrum quality (2,3). Overall, colostrum is composed by essential nutrients to calves, and the immunoglobulins is present in high concentrations, followed by cytokines, maternal leukocytes, proteins, fat, lactose, minerals and vitamins; also, colostrum present epidermal growth factor and insulin-like growth factor (4). These nutrients can be measured to understand the quality of colostrum, being a colostrum with excellent quality when the concentration of immunoglobulin G (Ig) is superior to 50 mg/ml of milk (5).

According to researchers (6), the implantation of colostrum banks is considered a viable alternative to reduce problems linked to cows that produce colostrum with lower quality. Frozen samples supplied from colostrum banks may meet calf needs in possible mishaps, however, animals fed with frozen colostrum may have an innate slower response than those receiving fresh colostrum (7) since previous studies have identified that after the freezing process the cells were not viable (8). Thus, its storage is considered a valid alternative, but it is needed to know about the maintenance of the colostrum quality throughout its freezing. The aim of this study was to evaluate whether colostrum quality is modified by genetic, physiological and management characteristics in the pre-partum period, as well as evaluate whether quality and composition of colostrum is altered in the freezing process.

## MATERIAL AND METHODS

### Experiment I.

**Location and animals.** This experiment was carried out in dairy farms located in the municipality of Pinhalzinho, state of Santa Catarina, Brazil. Were evaluated colostrum samples from 35 dairy cows (18 Holstein and 17 Jersey), and the pre-partum management classified as follows: individual paddock with adequate diet to the pre-partum period; collective paddock (for dry cows, heifers and pre-partum cows) without provision of a pre-partum diet or without batch separation (kept with lactating cows). This experiment was initiated as soon as the calves birth, to avoid interference of managements. The 18 Holstein cow produced 17 Holstein calves and 1 Holstein x Jersey calf, while the 17 Jersey cows produced 12 Jersey calves and 5 Holstein x Jersey. Thus, the data regarding crossbreed calves were not collected in order to avoid interference on performance data.

**Sampling and analyzes.** Colostrum samples were collected individually using a mechanical milking sequential to birth. In births during the day, the colostrum was collected before calf suckling, while in the nocturnal births the colostrum was collected in the next day only from udder areas not sucked by the calf. An aliquot of 250 ml was used to evaluate the concentration of immunoglobulins using a specific colostrometer (Biogenics, Nascofarma & Ranch, EUA) at environmental temperature (25°C) according to the scale proposed by Fleener and Scot (9), being: until 21.8 mg/L: low quality colostrum; 22 to 49.8 mg/L: intermediate quality colostrum; superior to 49.9 mg/L: high quality colostrum. Estimation of birth weight was performed using measuring tape (Bovitec®), following the method described (10). Calves were fed with four liters

of colostrum within the 8-hour period after birth. At the third day of life, the calves were again weighed (11).

The fecal condition was observed following the methodology described by Larson et al. [12], which is based on fecal score and fluidity: (a) normal and solid; (b) pasty but with health aspect; (c) aqueous consistency and (d) fluid consistency. Blood samples of all calves (n=35) were collected from jugular vein in tubes without anticoagulant, that remained under refrigeration until serum separation. Thereafter, two samples of each animal were divided, as follow: the first samples were used to quantify the content of plasmatic proteins using refractometer (Model ITREF-200, Instrutemp, SP), and the second was stored at  $-4^{\circ}\text{C}$  during three days to verify whether freezing is capable to alter the serum protein concentration.

**Statistical analysis.** A complete randomized design (2x5 factorial scheme), comprised of the two breeds and the five orders of delivery, was used as statistical design. Data were submitted to analysis of variance and significance was given by the F test at 5% probability.

## Experiment II.

**Location, animals and sampling.** The results obtained in the experiment I stimulated the development of experiment II, since was verified the existence of elevated variation on immunological quality of bovine colostrum. Thus, 1 L of colostrum from 6 Holstein cow (multiparous) located in Xanxerê (Santa Catarina, Brazil) were collected and analyzed until 6 h postpartum, later, divided into two aliquots and submitted to freezing ( $-20^{\circ}\text{C}$ ). Thus, after 30 and 60 days of freezing, the samples were thawed in a water bath at  $25^{\circ}\text{C}$ , the ideal temperature for colostrum composition and quality analysis.

**Analyzes.** Fresh and frozen samples were homogenized to evaluate the levels of immunoglobulins using colostrometer following the method described by Silper and collaborators (2). Thereafter, the centesimal composition (fat, protein, lactose, density and minerals) was analyzed using infra-red (LactoStar Funke Gerber).

**Statistical analysis.** The data were submitted to the normality test (Shapiro-Wilk) and transformed to logarithm. Afterwards, the data were submitted to analysis of variance over time (day 1, 30 and 60), and the results were presented as mean and standard deviation.

## RESULTS

**Experiment I.** No significant difference was observed regarding genetics groups and birth order, as well as its interaction, on Ig concentration of colostrum ( $p>0.05$ ) (Table 1). The mean Ig concentration was 77.65 mg/ml to Jersey cows and 82.77 mg/ml to Holstein cows. Also, for Holsteins cows, 11.1 and 88.88% of samples were classified as average and high quality, respectively. On the other hand, 5.88 and 94.12% of samples of Jersey cows were classified as average and high quality, respectively.

**Table 1.** Immunoglobulin concentration (mg/ml) on colostrum of Holstein and Jersey cows.

Breed	Cow parity	CI	P-value		
			Breed (B)	Birth order (BP)	B x BP
Holstein	1	75.0 $\pm$ 30.41	0.727	0.910	0.238
	2	63.3 $\pm$ 5.77			
	3	97.5 $\pm$ 40.31			
	4	85.0 $\pm$ 23.80			
	5	86.2 $\pm$ 36.37			
Jersey	1	93.3 $\pm$ 27.53	0.727	0.910	0.238
	2	93.3 $\pm$ 11.54			
	3	74.0 $\pm$ 20.73			
	4	65.0 $\pm$ 7.07			
	5	65.0 $\pm$ 25.16			

CI= Concentration of immunoglobulins, Mean followed by standard deviation.

Was observed an effect of genetic of the cow in the weight on calf in the birth and on three days of age ( $p<0.0001$ ). At the birth, the calves of the Holstein and Jersey cows weighted 39.00 ( $\pm$  4.9) and 28.41 ( $\pm$ 2.6) kg, respectively, and on three day of age 38.55 ( $\pm$ 4.8) and 28.29 ( $\pm$ 2.8) kg, respectively.

Regarding transmission of passive immunity to calves, no significant effects of cow breed, birth order and its interaction were observed on plasma protein concentration of calves ( $p>0.05$ ). It was not observed significant difference on serum protein concentration after three days of freezing, since the values observed at the time of collection were exactly the same as those observed after three days. Due to this equality, the data were not presented. Is important highlight that 83 and 82% of Holstein and Jersey calves presented plasma total protein concentration above 5.5 g/dl, respectively, which suggest that colostrum administration was efficient in the transmission of immunity (Table 2).

**Table 2.** Plasma total protein concentration (g/dl) in calves of Holstein and Jersey cows, and its respective percentage found in each extract.

Calf bred	Extraction (g/dL)	Calves (%)
	>5.5	82
Jersey	5.4 – 5.0	6
	< 5.0	12
	>5.5	83
Holstein	5.4 – 5.0	11
	< 5.0	6

Observing the data regarding managements during the pre-partum, the cows allocated in individual paddocks with pre-partum diet supplementation presented colostrum with better quality compared to others managements collective paddocks and without batch separation (Table 3). Regardless of the breed of calves, 94% presented normal fecal condition and 6% semi-pasty.

**Table 3.** Quality of the colostrum (mg/ml) with different pre-partum management (individual and collective) and effect of the diet supply specific for this period in Holstein and Jersey cows evaluated in the municipality of Pinhalzinho, SC.

Pre-partum management	Jersey	Holstein
	mg/mL	
No feedlot separation	51.66	66.25
Collective paddock (dry cows, heifers, lactation)	82.50	81.42
Individual paddock with pre-partum diet	83.75	93.57

**Experiment II.** No significant difference was observed to colostrum IgG levels ( $p>0.05$ ), percentage of protein, lactose, minerals and density ( $p>0.05$ ) over the time. The percentage of fat in milk was the only factor that varied by colostrum freezing, which was reduced over time (Table 4).

**Table 4.** IgG levels and centesimal composition of colostrum from six cows of Holstein and Jersey cows after frozen at  $-20^{\circ}\text{C}$ .

Variable	Animal	Birth order	Day 10	Day 30	Day 60	P-value
IgG (mg/mL)	1	1 <sup>a</sup>	100	105	93	* > 0.05
	2	3 <sup>a</sup>	140	140	140	
	3	1 <sup>a</sup>	45	45	40	
	4	2 <sup>a</sup>	92	95	95	
	5	1 <sup>a</sup>	93	100	100	
	6	2 <sup>a</sup>	81	81	81	
Mean and standard deviation (SD)			91.8 ( $\pm$ 30.6)	94.3 ( $\pm$ 31.1)	91.5 ( $\pm$ 32.2)	
Fat (%)	1	1 <sup>a</sup>	4.87	4.82	4.36	* < 0.05
	2	3 <sup>a</sup>	12.12	9.75	5.65	
	3	1 <sup>a</sup>	4.08	3.95	2.71	
	4	2 <sup>a</sup>	5.5	3.56	4.3	
	5	1 <sup>a</sup>	4.65	2.97	3.3	
	6	2 <sup>a</sup>	4.26	4.08	2.7	
Mean and standard deviation (SD)			5.91 ( $\pm$ 3.0) <sup>a</sup>	4.85 ( $\pm$ 2.4) <sup>ab</sup>	3.83 ( $\pm$ 1.15) <sup>b</sup>	
Protein (%)	1	1 <sup>a</sup>	8.65	8.89	8.73	* > 0.05
	2	3 <sup>a</sup>	12.2	10.6	9.73	
	3	1 <sup>a</sup>	5.13	8.59	5.36	
	4	2 <sup>a</sup>	7.99	7.04	6.8	
	5	1 <sup>a</sup>	7.86	8.19	7.6	
	6	2 <sup>a</sup>	7.97	8.04	8.0	
Mean and standard deviation (SD)			8.20 ( $\pm$ 2.2)	8.57 ( $\pm$ 1.19)	7.7 ( $\pm$ 1.52)	
Lactose (%)	1	1 <sup>a</sup>	12.6	13.1	12.8	* > 0.05
	2	3 <sup>a</sup>	17.8	15.4	14.2	
	3	1 <sup>a</sup>	7.5	8.5	7.8	
	4	2 <sup>a</sup>	11.6	10.3	10.4	
	5	1 <sup>a</sup>	11.5	12.0	12.4	
	6	2 <sup>a</sup>	11.6	11.8	13.3	
Mean and standard deviation (SD)			12.1 ( $\pm$ 3.3)	11.8 ( $\pm$ 2.36)	11.8 ( $\pm$ 2.32)	
Minerals	1	1 <sup>a</sup>	0.65	0.66	0.68	* > 0.05
	2	3 <sup>a</sup>	0.20	0.17	0.10	
	3	1 <sup>a</sup>	0.82	0.57	0.85	
	4	2 <sup>a</sup>	0.68	0.59	0.70	
	5	1 <sup>a</sup>	0.67	0.63	0.63	
	6	2 <sup>a</sup>	0.56	0.62	0.63	
Mean and standard deviation (SD)			0.59 ( $\pm$ 0.21)	0.54 ( $\pm$ 0.13)	0.59 ( $\pm$ 0.26)	
Density	1	1 <sup>a</sup>	1.082	1.034	1.082	* > 0.05
	2	3 <sup>a</sup>	1.112	1.090	1.092	
	3	1 <sup>a</sup>	1.046	1.052	1.048	
	4	2 <sup>a</sup>	1.073	1.064	1.070	
	5	1 <sup>a</sup>	1.072	1.079	1.500	
	6	2 <sup>a</sup>	1.074	1.075	1.065	
Mean and standard deviation (SD)			1.076 ( $\pm$ 0.020)	1.066 ( $\pm$ 0.02)	1.143 ( $\pm$ 0.17)	

## DISCUSSION

The bovine carry immunoglobulins (Ig) to colostrum via dependent-receptor (Fc-receptor), that is localized in the epithelial cells of mammary glands (13). The absolute number of receptors and its specificity can explain the difference on concentrations of Ig in colostrum samples (14). Colostrum quality is determined principally by Ig concentration (15). In this research, the concentration of Ig in colostrum samples can be considered at high quality, as recommended by literature (9). However, passage of Ig to colostrum is not absolutely dependent of receptors, and can be influenced by augmentation on performance rate, occurrence of metabolic problems, birth of preterm calves and hormonal factors (16).

When verified the effect of genetic group or birth order on colostrum quality, it was not observed difference, in disagree to observe by Silper et al (2). Also, the high weight to birth and on three days of age found in calves born of Holstein cows was attributed to another factors not directly associated to colostrum administration, since was observed an efficient colostrum administration at calves' births from both breed. It is believed that these factors are associated with cow's age and feeding during the gestation period

Neonatal diarrhea can be provoked by combination of infectious and non-infectious causes (17). The most common are caused by failure of passive antibody transfer, inadequate volume of colostrum and impairment on handling (17). Occurrence of diarrhea presents negative correlation with quantity of colostrum ingested by calf, i.e., lower intake of colostrum by the calf in the first hours of life augments the propensity to occurrence of diarrhea (15). In our preset study, it was not observed diarrhea in the animals with 3 days of age, but the diarrhea in calves is commonly caused by *Escherichia coli*, Rotavirus, Coronavirus and *Cryptosporidium parvum* (17,18).

The concentration of Ig found in colostrum of cows of 1<sup>o</sup> and 2<sup>o</sup> birth order are superior to found in the literature (61.98 mg/ml) (3). The order of lactation of cows can induce alterations on Ig levels, since multipara cows with 3 to 5 lactations present superior Ig levels, and cows with 1 and 2 parturition produce colostrum with lower Ig levels (3). This variation on Ig levels can be justified by the lower number of vaccinations received by young cows compared

to multiparous (3). Also, is important emphasize that individual evaluation of colostrum to evaluate its quality is considered primordial to colostrum administration management (2,3).

Ig concentration on colostrum is stable at environmental temperature until 4 h after the parturition, and after this period the IgG levels reduce significant (3), and in this way, the freezing process of colostrum does not promote a reduction in the immunological quality of colostrum. Colostrum is frequently preserved to future use by refrigeration for a limited period of time (9), and the freezing result in virtually no nutrient loss (protein, total solids, minerals and lactose) during storage, but requires extra handling and careful thawing for proper activity (9,19). Also, the content of IgG was not affected by the freezing process (9).

The freezing process aims to preserve the quality of colostrum to possible use in calves in critical moments, as: the quality of colostrum produced by mother is low, insufficient volume of colostrum and in severe cases due to the loss of the mother (20). In this sense, studies regarding colostrum preservation have been observed in the literature using different forms, as refrigeration, freezing, chemical additives, pasteurization and lyophilization (21,22,23,24). However, it was not possible to establish the time that the colostrum remains with the same quality without changing the composition.

The results found in the present study demonstrated that quantity of fat reduce with storage time (-20°C), and was similar to that found by Angulo et al (3), who reported 5.2% and Sobczuk-szul et al (23) who reported (5.7%) up to 1 h after delivery. In this study, colostrum freezing was performed until 6 h after the birth. Monthly for 3 months a sample of colostrum was thawed to perform the quality analyzes, which observed a reduction in the milk fat content explained by the literature by the continuous action of lipolysis during freezing and also by the adherence of the molecules in the flask (25,26,27).

The mean values of protein and lactose found in colostrum samples differs to found by Foley and Otter (28), that was 12.7% to protein and 2.9% to lactose. These authors related that difference on milking, feed, genetic group and hygiene degree promotes differences in the centesimal composition of colostrum. The mean mineral content is below that described by literature (28),

while the mean value of density is in agreement with the value presented by the same authors.

In conclusions the management during pre-partum influences the colostrum quality. The genetic group and cow parity do not influence the colostrum quality and in the transference of passive immunity to calf. The freezing process does not interfere with the immune and centesimal quality of colostrum, except for the fat that decreases over time.

**Ethics Committee.** The methodology used in the experiment was approved by the Ethical and Animal Welfare Committee of the Universidade do Estado de Santa Catarina (protocol 5320200317).

### Conflict of interest

The author (s) declared no potential conflicts of interest

## REFERENCES

- Gavin K, Neiberghs H, Hoffman A, Kiser JN, Cornmesser MA, Haredasht S, et al. Low colostrum yield in Jersey cattle and potential risk factors. *J Dairy Sci.* 2017; 101(7):1-11. DOI: <https://doi.org/10.3168/jds.2017-14308>
- Silper BF, Coelho SG, Madeira MMF, Ruas JRM, Lana AMQ, Reis RB, Saturnino HM. Avaliação da qualidade do colostro e transferência de imunidade passiva em animais mestiços Holandês Zebu. *Arq Bras Med Vet Zootec.* 2012; 64(2):281-285. DOI: <https://doi.org/10.1590/S0102-09352012000200005>
- Angulo J, Gómez LM, Mahecha L, Mejía E, Henao J, Mesa C. Calf's sex, parity and the hour of harvest after calving affect colostrum quality of dairy cows grazing under high tropical conditions. *Trop. anim. health prod.* 2015; 47(4):699-705. DOI: <https://doi.org/10.1007/s11250-015-0781-z>
- Santos GT, Massuda EM, Kazama DCS, Jobim CC, Branco AF. Bovinocultura leiteira: Bases zootécnicas, fisiológicas e de produção. Maringá-Brasil: Editora da Universidade Estadual de Maringá - Eduem; 2010: 381. <http://www.bdpa.cnptia.embrapa.br/consulta/busca?b=ad&id=860278&biblioteca=vazio&busca=autoria:%22BRANCO,%20A.%22&qFacets=autoria:%22BRANCO,%20A.%22&sort=&paginacao=t&paginaAtual=1>
- Pritchett LC, Gay CC, Hancock DD, Besser TE. Evaluation of the hydrometer for testing immunoglobulin G1 concentrations in Holstein colostrum. *J Dairy Sci.* 1994; 77(8):1761-1767. DOI: [https://doi.org/10.3168/jds.S0022-0302\(94\)77117-4](https://doi.org/10.3168/jds.S0022-0302(94)77117-4)
- Quigley JD, Lago A, Chapman C, Erickson P, Polo J. Evaluation of the Brix refractometer to estimate immunoglobulin G concentration in bovine colostrum. *J Dairy Sci.* 2013; 96(9):1148-1155. DOI: <https://doi.org/10.3168/jds.2012-5823>
- Costa JFDR, Novo SMF, Baccili CC, Sobreira NM, Hurley DJ, Gomes V. Innate immune response in neonate Holstein heifer calves fed fresh or frozen colostrum. *Res Vet Sci.* 2017; 115(1):54-60. DOI: <https://doi.org/10.1016/j.rvsc.2017.01.008>
- Reber AJ, Donovan DC, Gabbard J, Galland K, Aceves-Avila M, Holbert KA, Marshall L, Hurley DJ. Transfer of maternal colostrum leukocytes promotes development of the neonatal immune system Part II: Effects on neonatal lymphocytes. *Vet Immunol Immunopathol.* 2008; 123:305-313. DOI: <https://doi.org/10.1016/j.vetimm.2008.02.009>

9. Fleenor WA, Stott GH. Hydrometer Test for Estimation of Immunoglobulin Concentration in Bovine Colostrum. *J Dairy Sci.* 1980; 63(6):973-977. DOI: [https://doi.org/10.3168/jds.S0022-0302\(80\)83034-7](https://doi.org/10.3168/jds.S0022-0302(80)83034-7)
10. Reis GL, Albuquerque FHMR, Valente BD, Martins GA, Teodoro RL, Ferreira MBD, Monteiro JBN, Silva MA. Prediction of live weight based on body measurements in crossbred animals Holstein/Gir. *Ciênc Rural* 2008; 38(3):778-783. DOI: <http://dx.doi.org/10.1590/S0103-84782008000300029>
11. Ferreira SF, Guimarães TP, Moreira KKG, Alves VA, Lemos BJM, Souza FM. Caracterização fecal de bovinos. *Rev Cien Med Vet.* 2013; 11(20):1-22. [http://faef.revista.inf.br/imagens\\_arquivos/arquivos\\_destaque/gxBqUaQtId7aE3R\\_2013-6-21-15-54-36.pdf](http://faef.revista.inf.br/imagens_arquivos/arquivos_destaque/gxBqUaQtId7aE3R_2013-6-21-15-54-36.pdf)
12. Larson LL, Owen FG, Albright JL, Appleman RD, Lamb RC, Muller LD 1977: Guidelines toward more uniformity in measuring and reporting calf experimental data. *J Dairy Sci.* 1977; 60(5): 989-991. DOI: [https://doi.org/10.3168/jds.S0022-0302\(77\)83975-1](https://doi.org/10.3168/jds.S0022-0302(77)83975-1)
13. Watson DL. Immunological functions of the mammary gland and its secretion –comparative review. *Aust J Biol Sci* 1980; 33(4):403-422. DOI: <https://doi.org/10.1071/bi9800403>
14. Arsenopoulos K, Theodoridis A, Papadopoulos E. Effect of colostrum quantity and quality on neonatal calf diarrhoea due to *Cryptosporidium* spp. infection, *Comparative Immunology. Comp Immunol Microbiol Infect Dis.* 2017; 53(1):50-55. DOI: <http://dx.doi.org/10.1016/j.cimid.2017.07.005>
15. Ganz Z, Bülte M, Gajewski Z, Wehrend A. Inhaltsstoffe des bovinen Kolostrums-eine Übersicht. *Tierarztl Prax Ausg G.* 2018; 46(3):178-189. DOI: <http://dx.doi.org/10.15653/TPG-180144>
16. Meganck V, Hoflack G, Opsomer G. Advances in prevention and therapy of neonatal dairy calf diarrhoea: a systematical review with emphasis on colostrum management and fluid therapy. *Acta Vet Scand.* 2014; 25(1):56-75. DOI: <http://dx.doi.org/10.1186/s13028-014-0075-x>
17. Windeyer MC, Leslie KE, Godden SM, Hodgins DC, Lissemore KD, Leblanc SJ. Factors associated with morbidity, mortality, and growth of dairy heifer calves up to 3 months of age. *Prev Vet Med* 2014; 113(1):231-240. DOI: <http://dx.doi.org/10.1016/j.prevetmed.2013.10.019>
18. Stieler A, Bernardo BS, Donovan GA. Neutrophil and monocyte function in neonatal dairy calves fed fresh or frozen colostrum. *Intern J Appl Res Vet Med* 2012; 10(4):328-334. <https://www.jarvm.com/articles/Vol10Iss4/Vol10%20Iss3%20Stieler.pdf>
19. Borad SG, SINGH AK. Colostrum immunoglobulins: Processing, preservation and application aspects. *Int Dairy J.* 2018; 85: 201-210. DOI: <http://dx.doi.org/10.1016/j.idairyj.2018.05.016>
20. Johnson JL, Godden SM, Molitor T, Ames T, Hagman D. Effects of feeding heat-treated colostrum on passive transfer of immune and nutritional parameters in neonatal dairy calves. *J Dairy Sci.* 2008; 90(11): 5189-5198. DOI: <http://dx.doi.org/10.3168/jds.2007-0219>
21. McMartin S, Godden S, Metzger L, Feirtag J, Bey R, Stabel J. Heat treatment of bovine colostrum. *J Dairy Sci.* 2016; 89(6):2110-2118. DOI: [https://doi.org/10.3168/jds.S0022-0302\(06\)72281-0](https://doi.org/10.3168/jds.S0022-0302(06)72281-0)
22. Stewart S, Godden S, Bey R, Rapnicki P, Fetrow J, Farnsworth R. Preventing bacterial contamination and proliferation during the harvest, storage, and feeding of fresh bovine colostrum. *J Dairy Sci.* 2005; 88(7):2571-2578. DOI: [https://doi.org/10.3168/jds.S0022-0302\(05\)72933-7](https://doi.org/10.3168/jds.S0022-0302(05)72933-7)
23. Sobczuk-Szul M, Wielgosz-Groth Z, Wroski M, Rzemieniewski A. Changes in the bioactive protein concentrations in the bovine colostrum of Jersey and Polish Holstein-Friesian cows. *Turk J Vet Anim Sci.* 2012; 37(1):43-49. doi: <https://doi.org/10.3906/vet-1107-42>
24. Morrill KM, Conrad EM, Lago A, Campbell J, Quigley J, Tyler H. Nation-wide evaluation of quality and composition of colostrum on dairy farms in the United States. *J Dairy Sci.* 2012; 95(7):3997-4005. DOI: <https://doi.org/10.3168/jds.2011-5174>

25. Chang Y, Chen C, Lin M. The macronutrients in human milk change after storage in various containers. *Pediatr neonatol.* 2012; 53:205-209. DOI: <https://doi.org/10.1016/j.pedneo.2012.04.009>
26. Cavalcante JL, Telles FJ, Peixoto MM, Rodrigues RC. Uso de acidez titulável no controle de qualidade do leite humano ordenhado. *Cienc Tecnol Aliment.* 2005; 25: 103-108. DOI: <http://dx.doi.org/10.1590/S0101-20612005000100017>
27. Wardell JM, Hill CM, D'Souza SW. Effect of pasteurization and of freezing and thawing human milk on its triglyceride content. *Acta Pediatr Scand.* 1981; 70: 467-471. DOI: <https://doi.org/10.1111/j.1651-2227.1981.tb05724.x>
28. Foley JA, Otterby DE. Availability, Storage, Treatment, Composition, and Feeding Value of Surplus Colostrum: A Review. *J Dairy Sci.* 1978; 61(8):1033-1060. DOI: [https://doi.org/10.3168/jds.S0022-0302\(78\)83686-8](https://doi.org/10.3168/jds.S0022-0302(78)83686-8)