RESEARCH ARTICLE Agricultural Science Digest, Volume 43 Issue 3: 408-413 (June 2023)

Immunological and Nutritional Characterization of Bovine Colostrum: Effect of Some Variation Factors

S. Kaouche, H. Regguem

10.18805/ag.DF-375

ABSTRACT

Background: The importance of colostrum is twofold: it plays a role in the metabolism and nutrition of the newborn, in addition to its immediate supply of functional immunoglobulins. The current paper aims to study the main factors of variation in the nutritional and immunological bovine colostrum values at the Centre National de l'Insémination Artificielle et d'Amélioration Génétique (CNIAAG) of Baba Ali (Algiers, Algeria).

Methods: The study was conducted on 23 colostrum samples from cows of different breeds (Prim-Holstein pie rouge, Prim-Holstein pie noire and Fleckvieh), from calving until the 11th day of milking. These females have calved during March 2020.

Result: The results obtained indicate that the chemical composition of colostrum changes during milkings. The average rates of dry matter, protein and mineral matter, at the 1st milking, respectively 20; 9.70 and 0.95 g/100 g tend to decrease to reach milk standards. Unlike lactose rate which gradually increase from milking to another. The average concentration of colostrum in immunoglobulins, evaluated at 34.3 g/L at birth, decreases during the milkings that follow. The fall is considerable (89%) from the 2nd post-partum day.

Key words: Colostrum, Dairy cows, Immunological quality, Nutritional value, Variation factors.

INTRODUCTION

At birth, mammalian survival is promoted by ingestion of maternal colostrum. This provides the nutrients and antibodies necessary for transient protection against external physical and biological aggressors as well as physiological effectors such as growth factors and hormones (Boudry *et al*., 2008). The importance of colostrum is twofold: it plays a role in the metabolism and nutrition of the newborn, in addition to its immediate supply of functional immunoglobulins. These constitute more than 50% of the total amount of colostrum proteins (Nazir *et al*., 2018a).

The richness of colostrum suggests many other functions of this product for the adaptation of the calf to its new environment. According to Devillers *et al*. (2006), colostrum can be extracted 12 to 48 hours after parturition through newborn breastfeeding or milkings. Whereas Gartioux (2003), defines colostrum as being the product of the milking of the first six days following the part. For other authors (Socie-Jacob *et al*., 2008; Scammell, 2007), colostrum is secreted between 3 or 4 days after parturition. Levieux (1999), indicates that on the third day of lactation, the milk still contains 5 to 10% colostrum and 1 to 2% on the 7th day. Colostrum must be provided to the new calf born immediately after birth (maximum 1 hour) because the immunoglobulins it contains are absorbed during the first 16 to 27 hours after birth (Puppel *et al*., 2019). This work aims to study the main factors of variation in nutritional and immunological values of bovine colostrum while focusing on breed, lactation rank and milking number.

MATERIALS AND METHODS

Description of the study conditions

The study was carried out at the farm of the Centre National de l'Insémination Artificielle et d'Amélioration Génétique (CNIAAG) located in Baba Ali (Algiers, Algeria). The cows studied were subjected to a two-month dry period, during which they received straw and, at the end of the dry period, straw and concentrate. The postpartum ration is composed of 8 kg of concentrate for milk production, 25 kg of complete TMR (Mash) and 2 kg of straw.

Dairy females that were the subject of this study were declared healthy for all diseases (mastitis, ketosis, …). The Table 1 summarizes all the data on these cows.

Sampling protocol

The collection of samples began in March 2020 for the determination of the chemical and immunological quality of colostrum. The samples were collected over a period from parturition to the eleventh postpartum day. The colostrum (n=23) was carried out manually in sterile bottles after cleaning the udder. The first stream of colostrum is discarded. The samples were stored at 4°C and sent to the laboratory for immediate analysis.

[1]Department of Agronomy, Faculty of Sciences, M'hamed Bougara University, Boumerdes, Algeria.

Corresponding Author: S. Kaouche, Department of Agronomy, Faculty of Sciences, M'hamed Bougara University, Boumerdes, Algeria. Email: s.kaouche@univ-boumerdes.dz

How to cite this article: Kaouche, S. and Regguem, H. (2023). Immunological and Nutritional Characterization of Bovine Colostrum: Effect of Some Variation Factors. Agricultural Science Digest. 43(3): 408-413. doi: 10.18805/ag.DF-375.

Submitted: 08-07-2021 **Accepted:** 19-05-2022 **Online:** 27-06-2022

Colostrum samples not taken on day 2 from the Fleckvieh cow, as well as those on days 7, 9 and 10 of lactation from all cows are mainly due to the health situation linked to the COVID19 pandemic where movement was impossible on the farm.

Analysis protocol for colostrum samples collected

All chemical and immunological quality analyzes of colostrum were carried out at the SAIDAL Group (Groupe Pharmaceutique Généraliste Algérien) and ONAB (Office National des Aliments de Bétail) laboratories.

Chemical analysis of colostrum

The analyzes were carried out according to the conventional protocols.

1. Determination of water content (NA 1291-1994).
2. Determination of nitrogen content for the calculation of crude protein content (Kjeldahl method).
3. Determination of fat content (NA654-1992).
4. Determination of crude ash (NA650-1994).
5. Determination of lactose rate (Bertrand).

Determination of the immunological quality of colostrum

After analysis of the colostrum samples by refractometry (Refractometer ATAGO NAR, model 1T, reference 944511), the immunoglobulin concentration is calculated according to the brix table Calf Note 214 which allows the conversion of the brix value to immunoglobulin concentrations.

Statistical analysis of the data

Data analysis was performed by XLSTAT version 2020 software. Principale Component Analysis (PCA) and correlation test were used to highlight the existing correlations between the various chemical and immunological parameters of colostrum. The significance level is evaluated at $p<0.05$.

RESULTS AND DISCUSSION

Chemical quality of the colostrums collected (Table 2)

Determination of the dry matter content

Analysis of the 23 colostrum samples revealed a variable dry matter rate between 18 and 21% for the first milking and rates ranging from 10 to 16 g/100 g for subsequent milkings. The average dry matter content in the colostrum from the 1st milking for all the cows is 20%. It does not exceed 15% during the subsequent milkings. So there is a tendency to decrease the rate of dry matter during milkings. This was confirmed in the work of Meyer and Denis (1999); Boubée (1978), who report a dry matter content in colostrum of about 27% at the first milking. This rate decreases to reach 13% which is the standard for milk. The average dry matter content in the 23 colostrum samples of the Prim-Holstein pie noire cow (14.31 g), followed by the Fleckvieh with an average of (13.81 g). The female of the Prim-Holstein pie rouge has the lowest average (11.53 g) but with the highest maximum content (21.47 g).

Analysis of the dry matter content according to the lactation rank shows a slight difference between the females studied. Cows that are in the 3rd lactation have a dry matter content in the colostrum of approximately 11.53%, while the rate is approximately 14.06% for cows in the 4th lactation.

Determination of protein level

The average protein levels in the colostrums collected vary between 10 and 15 g/ 100 g for the first milking for the Prim-Holstein pie rouge and the Prim-Holstein pie noire respectively and a rate of 4 g/100 g for the Fleckvieh. The average protein level in colostrum is around 10% for the first milking. It decreases to reach approximately between 5 and 3% for the following milkings.

According to the study of Mahieu (1985), the protein level in colostrum at the first milking is 16 g/100 g, then it decreases to reach 3.5 g/100 g on the 10th day of milking. This decrease corresponds to the decrease recorded in the present study on the 11th day of milking (3.3 g/100 g). Protein levels first decrease rapidly and then gradually to reach normal milk content within 30 days (Tsioulpas *et al*., 2007; Foley and Otterby, 1978).

The average protein level in the 8 colostrums of Prim-Holstein pie noire is 5.56 g, followed by Prim- Holstein pie rouge with an average of 4.7 g. While for the Fleckvieh, the average is around 4%.

The protein content undergoes great individual variations with values ranging from 2.6 to 20.5% (Morill *et al*., 2012). This differs from the results obtained in our study with maximum values ranging from almost 5% for the Fleckvieh to 15% for the Prim-Holstein pie noire.

Cows which are in the 3rd lactation have a protein level of around 4.7% against almost 5.6% for the cow in the 4th lactation. According to Marzo (2007), the protein content in colostrum becomes increasingly important with increasing lactation rank.

Determination of the fat content in colostrum

The average fat content is different from one milking to another. It fluctuates between 3 and 6 g/100 g. This average content evaluated on the 1st day is 3.5 g/100 g. Tsioulpas *et al*. (2007), report that the fat content in colostrum gradually decreases during milkings. This is probably due to the individual capacities of each breed to produce a colostrum which is more or less rich in fat. The high body condition score after calving of Prim- Holstein pie rouge and Fleckvieh cows may also be a cause because a high level of long chain fatty acids resulting from the intense mobilization of body lipids can be detected in the colostrum.

The highest average fat content in colostrum was observed in the Fleckvieh cow colostrum (4.09%). It is followed by an average of about 3% for the other cows. The maximum value was recorded in the colostrum samples of the Prim- Holstein pie rouge cow ≈8%.

The analysis of the fat content according to the lactation rank reveals that the females in the 4th lactation have a higher fat content (3.31 g) in comparison with those in the 3rd lactation (2.67 g). These results are consistent with the results obtained

by Marzo (2007) who states that the level of colostral lipids increases from one lactation to another.

Determination of the mineral content in colostrum

In general, the mineral content fluctuated from 0.3 to 1.2 g/ 100g in the 23 colostrum samples analyzed. There are on average the mineral rate for each day of milking of the different cows studied varies between 0.55 and 0.95 g/100 g. This indicates that colostrum is very poor in mineral matter and the evolution during milkings is negligible. The cows in 3rd lactation experienced an average mineral content of 0.73 g/ 100 g while the rate is 0.83 g/ 100 g for cows in the 4th lactation.

Results of the lactose level in colostrum

The results indicate that the lactose level vary from 1.6 to 3.4 g/100 g during the 11 days postpartum. The lactose concentration according to Tsioulpas (2007) increases to reach its normal level in milk, 60 days after calving. On the other hand, Boubée (1978), reports a lactose level of 2.2 g/ 100 g in colostrum on the day of calving. This rate tends to increase according to this same author from the 2nd day to reach a value of 3.7 g/100 g.

The average lactose level in colostrum for all the breeds studied varied between 2.56 and 2.9 g/100 g. All peak values were slightly variable between 3.2 and 3.8%. Even the recorded minima did not exceed 2%.

The lactose level has a minimum value of 2.49 g in the works of Kehoe *et al*. (2007); Morill *et al*. (2012) and as a maximum value 2.9 g. The evaluation of the lactose rate in the colostrum according to the lactation rank does not show any considerable difference between that of cows in 3rd lactation (2.70%) and the other which concerns cows in 4th lactation rank with 2.75%. Lactose level increased significantly ($p \leq 0.05$) in colostrum samples from day 1 to day 3 postpartum (Nazir *et al*., 2018a).

Table 1: Descriptive data on cows.

Breed	Age (years)	Calving date /calf sexe	Lactation rank
Prim-Holstein pie noire	7	12/03/2020 (male)	4th
Prim-Holstein pie rouge	5	16/03/2020 (female)	3rd
Fleckvieh	7	24/03/2020 (female)	4th

Immunological quality of the colostrums collected (Table 2)

The average concentration of immunoglobulins during the 1st day of milking in the colostrum of the Prim-Holstein pie noire cow is 68.42 g/L. It is 2 times greater than that found in the colostrum of the Prim- Holstein pie rouge cow (34.43

Table 2: Results of the various parameters studied.

Results	Prim-holstein pie noire	Prim-holstein pie rouge	Fleckvieh
Samples number	08	08	07
	Dry matter		
Minimum (g/100 g)	11.37	9.70	9.98
Maximum (g/100 g)	21.40	18.32	21.47
Average ± SD (g/100 g)	14.31±0.031	11.53±0.028	13.81±0.036
	Protein		
Minimum (g/100 g)	3.65	2.85	3.2
Maximum (g/100 g)	15.00	10.29	4.82
Average ± SD (g/100 g)	5.56±0.036	4.70±0.023	3.95±0.005
	Fat		
Minimum (g/100 g)	1.08	0.6	1.4
Maximum (g/100 g)	3.92	7.62	6.2
Average ± SD (g/100 g)	2.54±0.01	2.67±0.023	4.09±0.014
	Mineral		
Minimum (g/100 g)	0.64	0.32	0.66
Maximum (g/100 g)	1.20	1.10	0.99
Average ± SD (g/100 g)	0.86±0.002	0.72±0.002	0.80±0.001
	Lactose		
Minimum (g/100 g)	1.17	1.36	1.98
Maximum (g/100 g)	3.8	3.6	3.21
Average ± SD (g/100 g)	2.90±0.008	2.73±0.006	2.56±0.004
	Immunoglobulin rates		
Minimum (g/100 g)	0	0	0
Maximum (g/100 g)	68.42	34.42	0.43
Average ± SD (g/100 g)	12.41±0.22	4.35±0.12	0.054±0.015

SD: Standard deviation.

g/L). The Fleckvieh cow is characterized by a concentration of 0 g/L.

According to Puppel *et al*. (2019) and Godden (2008), a colostrum can only be of sufficient quality when it has an IgG concentration greater than 50 g/ L. So that a colostrum with a concentration of 80 or even 100 g/L, it is considered to be an excellent quality colostrum.

Osaka *et al*. (2014) concluded that the failure of the passive immunity transfer can be avoided if the newborn calf consumes more than 3 L of colostrum with an immunoglobulin level that exceeds 40 g/L within 6 hours of birth.

The results of our study show that colostrum from the pie noire cow is the only one with good immunological quality. The relationship between the sex of the newborn and the concentration of immunoglobulins in colostrum was demonstrated in the study conducted by Odde (1988), where it was found that the average IgG concentration is high in cows having given birth to a male calf compared to those who have given birth to female calves. This explains the high IgG concentration of the pie noire cow which gave birth to a male calf compared to the Prim-Holstein pie rouge cow and the Fleckvieh cow which gave birth to female calves.

The contents of chemical constituents (fat, proteins and lactose) of colostrum samples taken from cows that had calved a male were significantly ($p \leq 0.05$) higher than those obtained in colostrums from cows that had calved a female newborn (Nazir *et al*., 2018b). According to Mushtaq *et al*. (2013), this may be due to the need to provide more nutrients to male newborns whose weight is sometimes higher than that of the female.

The average of the immunoglobulin levels in all the colostrums collected from the cows of the Prim-Holstein breed is the highest (around 34.3 g/L) at the 1st milking. This rate experiences a considerable drop of 89% from the 2nd milking until reaching 0 g/L at the 7th milking which corresponds to the 8th day of calving. This is explained by the gradual transition from colostrum to milk.

The IgG concentration decreases rapidly with the advance of milkings. Indeed, the most severe fall, ranging from 20 to 70%, occurs between the first and the second milking (Maillard and Guin, 2013). During the sixth milking, we can hope to obtain a concentration corresponding to 8% of the initial concentration according to these same authors. This explains why only the product of the first postpartum milking is called colostrum and is immunologically interesting for the transfer of passive immunity. The negative influence of the time to collection on the immunological quality of the colostrum is confirmed since a decrease of approximately 89% of the initial concentration at the second milking is observed in our study (Table 3).

The correlation coefficient $R^2=0.32$ (Fig 1), means that the equation of the regression line is able to determine 32% of the distribution of points. This decrease in IgG concentration with delay in colostrum collection appears to be the result of a dilution effect. In fact, the high circulating prolactin concentration after calving induces an end to the transfer of IgG to the udder and the start of milk production (Baumrucker *et al*., 2010; Guy *et al*., 1994).

The average level of immunoglobulins in the colostrum of Prim-Holstein pie noire is the highest (12.41 g/L). It is followed by the pie rouge with an average of 4.35 g/L. The differences that exist between dairy breeds seem to be due

Table 3: Effect of delayed colostrum collection.

Calving time - collection (days)	IgG concentration (g/L)	Change compared to the 1st day postpartum (%)
1	34.28	-
2	3.92	88.56
3	2.03	94.07
4	2.03	94.07
5	2.03	94.07
6	0.14	99.59
8	0	100.00
11	0.29	99.15

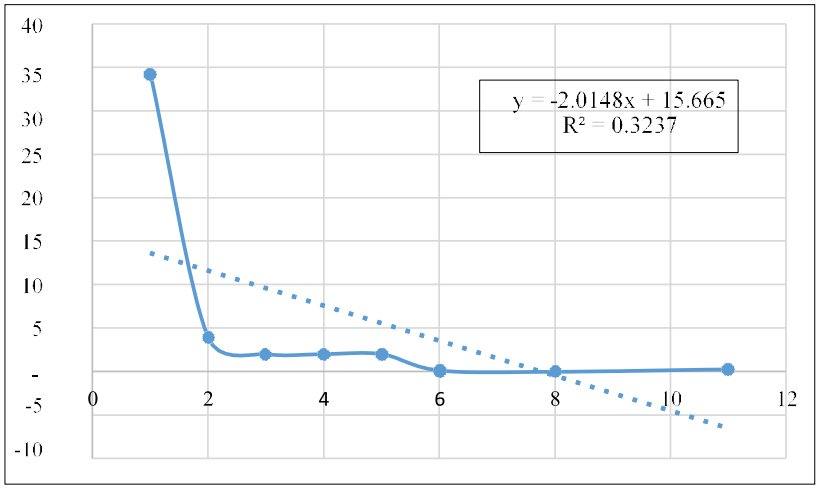

Fig 1: Average IgG concentration in colostrum of the Prim-Holstein breed according to the milking numbers (g/L).

to genetic differences and to the different amounts of colostrum produced.

Colostrum characteristics are linked to genetic variation according to the study conducted by Nazir *et al*. (2020) in Kashmir on the cows colostrums of different breeds. It was found that the physicochemical properties were lower in local breed cows in comparison with Jersey and Jersey crossed. On the other hand, the level of immunoglobulin concentration heritability in the Holstein-Frisesian cows colostrum is h^2=0.50 (Szulc and Zachwieja (1998) cited by Puppel *et al*. (2019). However, Gilbert *et al*., (1988) reported lower levels in the colostrum of Hereford, Angus and Simmental cows (h^2 = 0.41).

It is noted for the average level of immunoglobulins in the colostrum according to the lactation rank, that the cows in 4th lactation are characterized by a rate 3 times higher in immunoglobulins (12.42 g/L) compared to the cows in the 3rd rank of lactation (4.30 g/L). The maximum IgG value recorded goes to the female pie noire who is in her 4th lactation with almost 70 g/L.

Maillard and Guin (2013), had observed that the level of colostral IgG increased up to the 5th lactation rank, followed by a plateau for lactation ranks ranging from 5 to 8. Several authors (Bartier *et al*., 2015; Maillard and Guin, 2013; Le Cozler *et al*., 2012; Kehoe *et al*., 2011; Godden, 2008; Moore *et al*., 2005; Tyler *et al*., 1999; Pritchett *et al*., 1991), agree that cows in 1st or 2nd lactation generally produce colostrums of poorer immunological quality than cows with a higher lactation rank. In the study of Puppel *et al*. (2019), it was found that the highest immunoglobulin levels characterized cows in 3rd to 5th lactation.

Results of statistical analyzes of the various parameters studied

The results of the correlation between chemical and immunological parameters of colostrum show that there are non significant positive correlations (p>0.05) between immunoglobulins and protein content (r=0.991) on the one hand and with the lactose level (r=0.985) on the other hand. In addition, fat is negatively correlated (p>0.05) the IGg content (r=-0.813).

CONCLUSION

The study showed the influence of some factors on the variation in the immunological and nutritional quality of colostrum. Thus, with regard to the milking number, it has been observed that all the components of colostrum experience a decrease in their levels during the milkings to reach the milk standards, except for lactose. Lactation rank also has an influence on the variation of the chemical and immunological composition of colostrum, through the considerable increases in immunoglobulins and dry matter with increasing lactation rank. Race can also impact the immunological and chemical values of colostrum through its contribution in genetic factors.

Conflict of interest: None.

REFERENCES

Bartier, A.L., Windeyer, M.C., Doepel, L. (2015). Evaluation of on-farm tools for colostrum quality measurement. Journal of Dairy Science. 98(3): 1878-1884.

Baumrucker, C.R., Burkett, A.M., Magliaro-Macrina, A.L., Dechow, C.D. (2010). Colostrogenesis: mass transfer of IgG1 into colostrum. Journal of Dairy Science. 93(7): 3031-3038.

Boubée, T. (1978).Contribution à l'étude de l'immunité d'origine colostrale dans l'espèce bovine. Concentration en immunoglobulines de colostrums de vaches et de leur descendance. Thèse de Doctorat en sciences vétérinaires. Ecole Nationale Vétérinaire de Lyon. 90p.

Boudry, C., Dehoux, J.P., Portetelle, D., Buldgen, A. (2008). Bovine colostrum as a natural growth promoter for new lyweaned piglets. Biotechnology, Agronomy, Sociology and Environment. 12: 157-170.

Devillers, N., Le Dividich, J., Prunier, A. (2006). Physiologie de la production de colostrum chez la truie. INRA Productions Animales. 19: 29-38.

Foley, J.A., Otterby, D.E. (1978). Availability, storage, treatment, composition and feeding value of surplus colostrum: A Review. Journal of Dairy Science. 61(8): 1033-1060.

Gilbert, R., Gaskins, C., Hillers, J., Brinks, J., Denham, A. (1988). Inbreeding and immunoglobulin G1 concentrations in cattle. Journal of Animal Sciences. 66: 2490-2497.

Godden, S. (2008). Colostrum management for dairy calves. Veterinary Clinics. 24: 19-39.

Guy, M.A., Mc Fadden, T.B., Cockrell, D.C., Besser, T.E. (1994). Regulation of colostrum formation in beef and dairy cows. Journal of Dairy Science. 77: 3002-3007.

Gartioux, J.P. (2003). La transmission de l'immunité colostrale. Etude au sein d'une ferme expérimentale de Saône et Loire. (Thèse de Doctorat en sciences vétérinaires). Ecole Nationale vétérinaire de Lyon. 146 p.

Kehoe, S.I., Jayarao, B.M., Heinrichs, A.J. (2007). A survey of bovine colostrum composition and colostrum management practices on Pennsylvania dairy farms. Journal of Dairy Science. 90 (9): 4108- 4116.

Kehoe, S.I., Heinrichs, A.J., Moody, M.L., Jones, C.M., Long, M.R. (2011). Comparison of immunoglobulin G concentrations in primiparous and multiparous bovine colostrum. The Professional Animal Scientist. 27: 176-180.

Le Cozler, Y., Guatteo, R., Le Drean, E., Turban , H., Leboeuf, F ., Pecceu K., Guinard-Flament, J. (2012). Teneurs en IgG1 dans le colostrum des vaches et le plasma de leurs veaux. Rencontre, Recherches sur les Ruminants. 19: 135.

Levieux, D. (1999). Le colostrum, un lait particulièrement riche en de nombreux composants. Peut-on en déceler la présence dans les livraisons de lait de vache ? Le lait. 79: 465-488.

Mahieu, H. (1985). Facteurs de variation de la composition du lait. In: Laits et produits laitiers. 1. Les laits de la mamelle à la laiterie, Luquet F.M. (éd.), Technique et Documentation, Lavoisier, Paris., 127p.

Maillard, R., Guin, B. (2013). Immunité colostrale chez les bovins. Bulletin GTV. 71: 17-24.

Marzo, G. (2007). Etude de la composition du colostrum et du lait de brebis et de leurs effets sur la croissance des agneaux (Mémoire de bachelier en agronomie). Faculté des sciences agronomiques de Gembloux. 79p.

Meyer, M., Dennis, J. (1999). Elevage de la vache laitière en zone tropicale. Edition Cirad. 64 p.

Moore, M., Tyler, J.W., Chigerwe, M., Dawes, M.E., Middleton, J.R. (2005). Effect of delayed colostrum collection on colostral IgG concentration in dairy cows. Journal of Animals, Veterinary Medecine Association. 226(8): 1375-1377.

Morill, K.M., Conrad, E., Lago, A., Campbell, J., Quigley, J., Tyler, H. (2012). Nationwide evaluation of quality and composition of colostrum on dairy farms in the United States. Journal of Dairy Science. 95: 3997-4005.

Mushtaq, M.H., Saleem, M.N., Ayyub, R.M., Khattak, I. (2013). Challenges due to early calf mortality in dairy industry of Pakistan and strategies for improvement. Veterinaria. 1: 13-17.

Nazir, T., Pal, M.A., Sheikh, F.A., Khaliq, T., Sofi, A.H., Ahmad, S.R. (2018a). Effect of the age of cow through the transition period on various physico-chemical, compositional and microbiological characteristics of bovine colostrum. Journal of Entomology and Zoology Studies. 6(3): 1002-1009.

Nazir, T., Pal, M. A., Baba, F.A., Manzoor, A., Sofi, A.S., Ahmad, S.R. (2018b). Effect of the sex of newborn during various days of transition period on various physico-chemical, compositional and microbiological characteristics of bovine colostrum. International Journal of Livestock Research. 8(12): 233-246. doi: 10. 5455/ijlr.20180507014059.

Nazir, T., Pal, M.A., Manzoor, A., Padder, T., Sofi, A.H. Malik, A.H., Wani, S.A., Ahmad, S.R. (2020). Study on the effect of the breed during post-partum transition period on various physico-chemical, compositional and microbiological characteristics of bovine colostrum. Asian Journal of Dairy and Food Research. 39(1): 17-23.

Odde, K.G. (1988). Survival of the neonatal calf. Veterinary Clinics of North America: Food Animal Practices. 4(3): 501-508.

Osaka, I., Matsui, Y., Terada, F. (2014). Eûect of the mass of immunoglobulin (Ig)G intake and age at first colostrum feeding on serum IgG concentration in Holstein calves. Journal of Dairy Science. 97: 6608- 6612.

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(7): 2336-2341.

Puppel, K., Gołebiewski, M., Grodkowski, G., Slósarz, J., Kunowska-Slósarz, M., Solarczyk, P., Łukasiewicz, M., Balcerak, M., Przysucha, T. (2019). Composition and factors affecting quality of bovine colostrum: A review. Animals. 9: 1070-1084. doi: 10. 3390/ani9121070.

Scammell, A.W. (2007). Production and uses of colostrum. Australian Journal of Dairy Technology. 56: 74-82.

Socie-Jacob, M., Bolkaert, B., Wiggers, L., Van DeVen, J., Kirschvink, N. (2008). Effect of Vaccination against Enterotoxaemia of Pregnant Ewes on Antitoxin Alpha and Epsilon Antibodies in Colostrum, Milk and Lambs after Colostrum Intake. In: Proceedings of the XXV Jubilee World Buiatrics Congress, Budapest, Hungary. July 6-11/2008.

Tsioulpas, A., Grandison, A.S., Lewis, M.J. (2007). Changes in physical properties of bovine milk from the colostrum period to early lactation. Journal of Dairy Science. 90(11): 5012-5017.

Tyler, J.W., Steevens, B.J., Hostetler, D.E., Holle, J.M, Denbigh, J.L. (1999). Colostral immunoglobulin concentrations in Holstein and Guernsey cows. American Journal of Veterinary Research. 60(9): 1136-1139.